2011

Rules for the Classification of Steel Ships

Part 1 Classification and Surveys

Rules

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 1 Classification and Surveys

Guidance

KOREAN REGISTER

2011

Rules for the Classification of Steel Ships

Part 1

Classification and Surveys

RA-01-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 1 "CLASSIFICATION AND SURVEYS"

1. Unless expressly specified otherwise, the requirements in the Rules apply to ships for which the application for Classification Survey is submitted to the Society on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date 1 July 2010

CHAPTER 1 CLASSIFICATION

Section 4 Classification Survey after Construction
- 403. has been amended.

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General
- 109. 1 and 4 have been amended.

CHAPTER 3 HULL SURVEYS OF SHIPS SUBJECT TO THE ENHANCED SURVEY PROGRAMME

Section 1 General
- 101. 2 (2) has been amended.

Effective Date 13 August 2010

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 4 Special Survey(Hull, Equipment and Fire–extinguishing Appliances)
- 403. has been deleted.

Effective Date 1 January 2011 (Regardless of the application date for Classification Survey)

CHAPTER 1 CLASSIFICATION

Section 15 Miscellaneous
- 1501. has been newly added.

Effective Date 1 January 2011

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General

- 107. 5 (1) and (2) have been amended.

Effective Date 1 May 2011

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 2 Annual Survey

- 202. 1 (8), (9), (18), (19) and (23) to (26) have been newly added.
- 202. 1 (17) and (20) have been amended.
- 203. 9 and 16 have been amended.
- 204. 1, 2 and 3 have been amended.

Section 3 Intermediate Survey

- Table 1.2.1 has been amended.

Effective Date 1 July 2011

CHAPTER 1 CLASSIFICATION

Section 3 Classification Survey during Construction

- 303. has been amended.
- 309. has been moved from Chapter 2, 101. and amended.

Section 7 Cooperation Duties of Owners

- 702. 5 has been newly added.

Section 8 Competence and Duties of Surveyors

- 803. has been amended.
- 805. has been amended.

Section 9 Suspension/Withdrawal of Class and Reclassification

- 901. 2 (6) has been newly added.

Section 14 External Audit

- 1401. 1 and 2 have been amended.

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General

- 110. 1 (6) and (7) have been newly added.

Section 4 Special Survey(Hull, Equipment and Fire-extinguishing Appliances)

- 401. 8 has been newly added.
- 403. 1 (1) has been amended.

Section 5-1 Special Survey(Machinery, Electrical Installations and Additional Installations)

- 502. 6 has been newly added.

Section 5-2 Special Survey(Additional Requirements to Ship Types)

- 3 (1) (C) has been amended.

Section 6 Docking Survey

- 603. 10 and 11 have been newly added.
- 604. 2 has been newly added and 3 has been amended.
- 605. has been newly added.

Section 14 Hull Surveys for General Dry Cargo Ships

- 1404. 1 (7) has been amended.

CONTENTS

CHAPTER 1 CLASSIFICATION

Section 1 General

101. Classification

1. Steel ships built and surveyed in accordance with the Rules of the Society(hereafter referred to as "the Rules") or with the alternatives equivalent to the Rules will be assigned a class designation by the Society and registered in the Registration Master.

2. All ships classed with the Society are, for continuation of the classification, to be subjected to the periodical and other surveys, and are to be maintained in good condition in accordance with the requirements of the Rules.

3. When a ship classed with the Society makes an alteration or modification of such an extent as to influence to the ship's original performances, the plans have to be submitted for the Society's approval before the work is commenced and the alteration work has to be supervised by the Surveyor.

102. Standard application of the Rules

1. The Rules are framed on the understanding that ships will be properly loaded and handled. But those do not provide special distributions and concentrations of loading unless stated in the class notation.

2. The plans of ships designed for specific condition of loading or particular features in respect of the hull, machinery or equipment are also to be submitted for approval.

103. Exclusion from the Rules

The Society cannot assume responsibility for trim, hull vibration or other technical characteristics not covered by the Rules. However, the Society may advise on such matters upon application by an Owner.

104. Equivalence

The Society may consider the acceptance of alternatives to the Rules, provided that they are deemed to be equivalent to the Rules to the satisfaction to the Society.

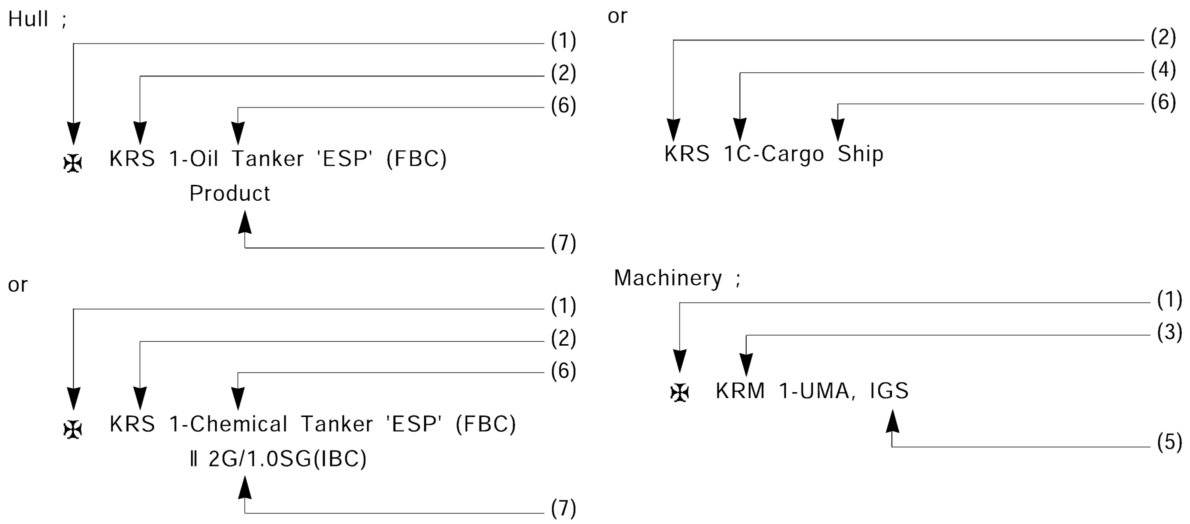
105. Novel features

The Society may consider the classification of ships based on or applying novel design principles or features, to which the Rules are not directly applicable, on the basis of experiments, calculations or other supporting information provided to the Society.

Section 2 Character of Classification

201. Class notations

The class notations assigned to the ships classed with the Society are to be in accordance with the followings:



(1) **Construction symbols**

The construction symbols assigned to the ships according to the distinction of Classification Survey are to be in accordance with the followings:

✠ ; For ships built under the supervision of the Society.
No symbol ; For ships considered to be fit as the result of surveys by the Surveyor after construction with the exception of the above mentioned construction symbols.

(2) **Service restriction notations of hull**

The following service restriction notations will be given for ships with hull construction and strength found to be in compliance with the Rules:

KRS1 ; For ships unrestricted in service area.
KRS0 ; For ships restricted in service area.

(3) **Service restriction notations of machinery**

The following service restriction notations will be given for ships with machinery and electrical installations found to be in compliance with the Rules:

KRM1 ; For ships unrestricted in service area.
KRM0 ; For ships restricted in service area.

(4) **Service restriction notations of equipment**

The following service restriction notations will be given for ships with equipment found to be in compliance with the Rules:

No symbol ; For ships unrestricted in service area.
C ; For ships approved with the condition of coastal service.
S ; For ships approved with the condition of smooth water service.

(5) **Additional installations notations**
Ships designed for the application of additional installations on hull items will be distinguished after the character of hull by the class notation such as "LI", "CHA", "HMS" or "HMS1", etc. and on machinery items will be distinguished after the character of machinery by the class notation such as "CMA", "UMA", "DPS", "NBS", "IGS", "COW", "STCM" or "RMC", etc.

(6) **Ship type notations**
Ships designed in compliance with particular Rules intended to apply to that type of ship will be indicated by the appropriate designations such as Oil Tanker 'ESP'(FBC), Bulk Carrier 'ESP', Cargo Ship, Passenger Ship, Tug Boat, Barge, etc. affixed to the character of hull.

(7) **Special feature notations**
When considered necessary by the Society, the special feature notations may be appended to the character of the ship type notations. These special feature notations could consist of the hull structure and the cargo tank type fitted for the kind and nature of cargoes, ice strengthening, in-water survey, cargo loading condition, design temperature, design pressure, the apparent specific gravity of cargoes, corrosion control, direct strength assessment, direct fatigue assessment, hull construction monitoring, and/or longitudinal strength of hull girder in flooded condition for bulk carriers, etc. Also, the restriction of navigation area and condition may be remarked additionally.

202. Class notations of yachts

The class notations of yachts classed with the Society are to be in accordance with the requirements specified in **Pt 8, Ch 1, 102.** of the **Guidance Relating to the Rules for the Classification of High Speed and Light Crafts** irrespective of the requirements in **201.**

Section 3 Classification Survey during Construction

301. Classification Survey during Construction

For a ship requiring Classification Survey during Construction, the construction, materials, scantlings and workmanship of the hull, equipment and machinery are to be examined in detail in order to ascertain that they meet the appropriate requirements of the Rules.

302. Approval of plans

For a ship requiring Classification Survey during Construction, the plans and documents showing the details of the construction, materials, scantlings and particulars of the hull, equipment and machinery are to be submitted in triplicate and approved before the work is commenced. The same applies also to the cases of any subsequent modifications to the approved drawings or documents.

303. Materials and equipments

All materials used for a ship requiring Classification Survey during Construction are to be manufactured under approved method or under alternative process considered equivalent to the approved method and are to be adequate to the relevant requirements of the Rules. The Society may request the relevant documents such as certificate of materials or equipment, etc. for the confirmation of the materials or equipment which are used.

304. Machinery installation

Main engines, shafting arrangement, boilers, pressure vessels, electrical equipment, essential auxiliary machinery, and piping arrangements to be installed on a ship intended for classification are to be surveyed during construction. Shop trials are to be carried out on completion under a same condition as installed on-board ship or a similar condition as far as practicable. Various tests on any special part amongst the automatic or remote control systems and measuring devices considered necessary by the Society may be requested at the manufacturing sites.

305. Workmanship

For Classification Survey of a ship, the materials, workmanship and arrangements are to be surveyed under the supervision of the Surveyor from the commencement of the work until the completion of the ship. When the machinery is constructed under Classification Survey, this survey is to be related to the period from the commencement of the work until the final test under working conditions. Any item found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

306. Tests

In the Classification Survey during Construction, hydrostatic, watertight and performance tests are to be carried out in accordance with the relevant part of the Rules. Also the control systems and measuring device after installation are to receive the necessary tests, as deemed necessary by the Society.

307. Stability experiments

1. In the Classification Survey during Construction for passenger ships and ships of 24 m and above in length other than passenger ships, stability experiments are to be carried out upon completion of the ship. A final stability information booklet adequate for the service intended and prepared on the basis of the stability particulars determined by the results of stability experiments, is to be approved by the Society and supplied to the master. However, a preliminary stability information booklet approved by the Society in lieu of a final stability information booklet may be provided on-board for a specific period.

2. Where an loading instrument having a stability computation capability as supplemental use of stability information booklet specified in **Par 1** is provided, the test report of representative operational conditions is to be submitted to the Society, and the loading instrument shall cover all stability requirements applicable to the ship such as intact, damage and grain stability, etc. When the stability information include sufficient loading conditions of the ship, some part of the function may be omitted. The instrument is to be confirmed by the Surveyor upon installation in accordance with the test report approved by the Society.

308. Trials

Trials are to be carried out for all equipment, machinery and electrical equipment under working conditions after completion of the ship in order to ascertain their performances. In the sea trials, speed test, astern test, steering test, emergency steering test and turning test are to be carried out. In addition, the operating conditions of machinery and other behaviors of the ship during the trial are to be examined.

309. Date of contract for construction

1. The date of contract for construction of a vessel is the date on which the contract to build the vessel is signed between the prospective Owner and the shipbuilder. This date and the construction numbers(i.e. hull numbers) of all the vessels included in the contract are to be declared to the Society by the party applying for the assignment of class to a newbuilding.

2. The date of contract for construction of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective Owner and the shipbuilder.

3. In application to **Par 2**, vessels built under a single contract for construction are considered a series of vessels if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided;

(1) Such alterations do not affect matters related to classification, or

(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.

The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

4. If a contract for construction is later amended to include additional vessels or additional options, the date of contract for construction for such vessels is the date on which the amendment to the contract, is signed between the prospective Owner and the shipbuilder. The amendment to the contract is to be considered as a new contract to which **Par 1** to **Par 3** above apply.

5. If a contract for construction is amended to change the ship type, the date of contract for construction of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Section 4 Classification Survey after Construction

401. Classification Survey after Construction

In the Classification Survey after Construction, the actual scantlings of main parts of the ship are to be measured in addition to such examinations of the construction, materials, workmanship and actual conditions of hull, machinery, outfittings, and equipment as required for the Special Survey corresponding to the ship's age in order to ascertain that they meet the relevant requirements in the Rules.

402. Submission of plans

In the Classification Survey after Construction, plans and documents as may be required for Classification Survey during Construction are to be submitted. If plans cannot be obtained, facilities are to be given for the Surveyor to take the necessary informations from the ship.

403. Classification Survey of ships classed by other Societies

When a ship holding class with any Society which is subject to verification of compliance with QSCS(Quality System Certification Scheme) of IACS is intended for classification, plans and documents to be submitted and survey items, etc. are to be in accordance with the Guidance relating to the Rules.

404. Tests

In the Classification Survey after Construction, the hydraulic pressure tests, watertight tests, performance tests and sea trials are to be carried out in accordance with the requirements of the Rules. However, sea trials may be dispensed with provided that sufficient data on the previous tests are available and neither alteration nor repair affecting the previous data has been made since the previous trials.

405. Stability experiments

In the Classification Survey after Construction for passenger ships and ships of 24 m and above in length other than passenger ships, stability experiments are to be carried out. A final stability information booklet adequate for the service intended and prepared on the basis of the stability particulars determined by the results of stability experiments, is to be approved by the Society and supplied to the master. However, a preliminary stability information booklet approved by the Society in lieu of a final stability information booklet may be provided on-board for a specific period. Stability experiments may be dispensed with provided that sufficient information based on previous stability experiments is available and neither alteration nor repair affecting the stability has been made since the previous experiments.

Section 5 Certificates and Reports

501. Certificate of Classification

1. Where ships have undergone the Classification Survey during or after Construction to the satisfaction of the Surveyor and approved by the Classification Committee, the ships will be classed and entered in the Registration Master with the issue of the Certificate of Classification.

2. Where ships have undergone the Special Survey to the satisfaction of the Surveyor, the Certificate of Classification is issued newly.

502. Interim Certificate of Classification

Where ships have undergone a Classification Survey during or after Construction to the satisfaction of the Surveyor, the Interim Certificate of Classification will be issued.

503. Certificate for construction survey

Where ships not intending to be classed have undergone the survey during construction, or marine engines, boilers, auxiliary machinery and outfittings have undergone the surveys during construction to the satisfaction of the Surveyor, the Certificate for Construction Survey will be issued.

504. Survey reports

On completion of the Classification Survey and the surveys assigned to maintain the classification, the Survey Reports will be issued. Ship's particulars, survey results, the date and description of the next surveys, etc. are to be stated in the Survey Reports. The Survey Reports will be used as notice to the Owners.

505. Keeping of the certificates and survey reports

The Certificate of Classification, the Interim Certificate of Classification, Particular Sheets and Survey Reports, etc. are always to be kept on board by the master of the ship and are to be produced when requested by the Surveyor.

506. Mention on certificate

1. Where ships classed with the Society have satisfactorily undergone the periodical survey, or where the period of validity of the Certificate of Classification is extended, or where the anniversary date is amended, the periodical survey or the case will be endorsed on the Appendix of Certificate of Classification or Interim Certificate of Classification.

2. Assigning of date of build

(1) The year, month and date at which the Classification Survey during Construction is completed shall be specified as the "Date of Build". Where there is substantial delay between completion of the Classification Survey during Construction and the ship commencing active service, the date of commissioning may be also specified.

(2) Where the ship is altered, the Date of Build shall be remain assigned to the ship and the altered parts are to be complied with **Ch 2, Sec 11.**

507. Re-issue and return of certificate

1. When the Certificate of Classification, the Interim Certificate of Classification, Particular Sheets, or Survey Reports are lost or impaired, or when the items stated in them require alteration, the application for re-issue must be made without delay.

2. When a ship holding the Interim Certificate of Classification is furnished with the Certificate of Classification, when the certificate is re-issued except in the case of its loss, or when the classification is cancelled, the old certificate is to be returned to the Society without delay.

508. Certificates of related equipment

The Society may, upon application, survey such equipment relating to ships as prime movers, shaftings, boilers, pressure vessels, auxiliary machinery, electrical equipment and other machinery installations and issue certificates where they are to the satisfaction of the Surveyor.

509. Class Maintenance Certificate

The Society will issue, upon request, a Class Maintenance Certificate to the Owner of a ship or the person having obtained his consent.

Section 6 Application for Survey

601. Classification Survey

The application for Classification Survey is to be made by the Builder for a ship during construction and by the Owner for a ship after construction.

602. Periodical and other surveys

The application for surveys of ship for the continuation of her classification is to be made by the Owner(including Charterer, Representatives of Owner, Representatives of Charterer and Master of the ship, hereafter referred to as "the Owner").

603. Re-issue of certificate

The application for re-issue and return of the Classification Certificate, the Interim Classification Certificate, Particular Sheets and Survey Reports are to be made by the Owner.

Section 7 Cooperation Duties of Owners

701. Report items

When any of the following cases occurs, the Owner is to report to the Society without delay:
(1) When the ship is sustained with a sea casualty by which her present class is deemed affected.
(2) When the ship is placed in drydock or on a slipway.
(3) When the ship is laid up or dismantled.
(4) When the Owner is changed.
(5) When the ship is withdrawn.
(6) When any items which may affect her class are changed.

702. Cooperation of survey

1. All such preparations as required for Classification Survey and periodical surveys necessary for the maintenance of class are to be made by the applicant of the survey in accordance with the requirements of the Rules. To permit safe and effective survey, such preparations are to include the provision of the work environment and safety measures in the way of suitable lighting, ventilation and access condition.

2. The Owner, master, chief engineer or their representatives are to attend the survey according to the items to be examined and are to give necessary assistances.

3. When a ship is to be surveyed, it is the duty of the Owner to inform the Surveyor of the correct place and items of survey.

4. Where it is intended to use service suppliers for the survey of ship, the service suppliers approved by the Society are used as a general rule, and the approval procedure and items are to be in accordance with the Guidance relating to the Rules.

5. The applicant of the survey is to ensure that there is no falsehood in the description on the application form, the notice and the presented data, etc. to the Society.

703. Cooperation Duties

Notwithstanding the general duty of confidentiality owed by the Society to its clients as specified in **805.**, the Society's clients hereby accept that the Society will participate in Early Warning Scheme which requires each Society to provide the involved Societies(the Classification Societies classing a sister or a similar ship to the one involved in the incident) with relevant technical information(but not including any drawings relating to the ship which may be the specific property of another party) on serious hull structural and engineering systems failures, as defined in the Early Warning Scheme(Refer to IACS PR No.2 Procedure for Failure Incident Reporting and Early Warning of Serious Failure Incidents - Early Warning Scheme - EWS) to enable such useful information to be shared and utilised to facilitate the proper working of Early Warning Scheme. The Society will provide its client with written details of such information upon sending the same to the involved Societies.

Section 8 Competence and Duties of Surveyors

801. Competence of Surveyors

1. The Surveyor can attend the classed ships at all reasonable times.

2. The Surveyor may suspend surveys when the necessary preparations required in the Rules have not been made or any appropriate attendant is not present.

3. The Surveyor may, if deemed necessary by the condition of a classed ship, request additional surveys of a part though such part may not fall under the survey items.

4. The Surveyor will notify the survey applicant of his recommendations for repairs or renewals when the hull, machinery or other equipments are in conflict with the requirements of the Rules, damaged, or worn out. Upon this notification the applicant is to carry out the repairs to the satisfaction of the Surveyor.

802. Duties of Surveyors

1. The Surveyor is to undertake all the surveys on a classed ship for which the application is made and is to report to the Head Office without delay.

2. For the convenience of the Owner, the Surveyor is to avoid any unnecessary duplication of surveys or repair works in carrying out his surveys.

803. Liability of Classification Society

1. (Liability) The Society shall be responsible for damage or loss incurred by the shipowner arising from a negligence of the Society. The liability will be limited to the greater of an amount equal to 10 times the sum actually paid for services alleged to be deficient, or USD 1,000,000.

2. The limitation on liability specified in **Par 1** does not apply in case of a willful act or imprudent feasance despite being cognizant of the fact that there is a concern for damage, or nonfeasance.

3. (Time bar) Rights of claims against the survey and other contracted services provided by the Society shall become nullified after 6 months from the date when the Owner had notice of the damage.

4. (Jurisdiction and Governing laws) All disputes which may arise from the services by the Society shall be subject to the exclusive jurisdiction of Korean court and be governed by the Laws of Korea.

804. Independence of Classification Society

The Society and its staff shall not be affected by designer, manufacturer, supplier, installer, purchaser, owner, user, maintainer and any other individuals of the item subject to the service and shall perform its works for the customers fairly from independent position.

805. Confidentiality

The Society and its staff shall not be perused, transferred or disclosed the confidential information obtained through the handling of records to the third party without the consent of the relevant customer, unless otherwise requested by the national Administration, investigative agency or a law court.

Section 9 Suspension/Withdrawal of Class and Reclassification

901. Suspension/Reinstatement of class

1. The classification is automatically suspended.

(1) when the Special Survey has not been completed by the due date unless the vessel is under attendance for completion of the Special Survey prior to resuming trading by the due date.
(2) when the Annual Survey or Intermediate Survey has not been completed by the end of the corresponding survey time window unless the vessel is under attendance for completion of the Annual Survey or Intermediate Survey by the end of the corresponding survey time window.

Classification will be reinstated upon satisfactory completion of the surveys due. Such surveys are to be credited from the date originally due. However, the vessel is disclassed from the date of suspension until the date class is reinstated.

2. The classification may be suspended in accordance with the Society's suspension procedure.

(1) when a vessel is not operated in compliance with the rule requirements, such as in cases of services or conditions not covered by the class notation, or trade outside the navigation restrictions for which the class was assigned.
(2) When the Society considers that a ship has not complied with the Rules.
(3) When any damage to the ship is to such an extent as affecting her class and is not repaired in accordance with the Rules of the Society, or when alterations or conversions affecting her class are carried out without the approval of the Society.
(4) When a ship proceeds to sea with less freeboard than that assigned, or when the freeboard marks are placed higher on the sides of the ship than the position assigned.
(5) when the assigned surveys to maintain the classification, except Annual Survey, Intermediate Survey and Special Survey, is not dealt with, or postponed by agreement, by the due date.
(6) When the Continuous Survey item(s) due or overdue at the time of Annual Survey is not surveyed, or postponed by agreement.
(7) in the event of non-payment of fees

Classification will be reinstated if the cause of such suspension are removed, or upon verification that the overdue survey has been satisfactorily dealt with. Suspension of class decided by the Society takes effect from the date when the condition for suspension of class are met and will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

3. Vessels laid-up in accordance with the Society's Rules prior to surveys becoming overdue need not be suspended when surveys addressed above become overdue. However, vessels which are laid-up after being suspended as a result of surveys going overdue, remain suspended until the overdue surveys are completed.

4. When a vessel is dual classed and in the event that the other Society involved takes action to suspend the class of the vessel for technical reasons, the Society will, upon receipt of this advice, also suspend the class of the vessel in accordance with the Society's suspension procedure, unless it can otherwise document that such suspension is incorrect.

5. When a vessel is intended for a demolition voyage with any periodical survey overdue, the vessel's class suspension may be held in abeyance and consideration may be given to allow the vessel to proceed on a single direct ballast voyage from the lay up or final discharge port to the demolition yard. In such cases a Interim Certificate of Classification with conditions for the voyage noted may be issued provided the attending Surveyor finds the vessel in satisfactory condition to proceed for the intended voyage.

6. If, due to circumstances reasonably beyond the owner's or the Society's control, the vessel is not in a port where the overdue surveys can be completed at the expiry of the periods allowed, the Society may allow the vessel to sail, in class, directly to an agreed discharge port, and if necessary, hence, in ballast, to an agreed port at which the survey will be completed, provided the Society:

(1) exams the ship's records;
(2) carries out the due and/or overdue surveys and examination of Recommendations/Conditions of Class at the first port of call when there is an unforeseen inability of the Society to attend the vessel in the present port, and
(3) has satisfied itself that the vessel is in condition to sail for one trip to a discharge port and subsequent ballast voyage to a repair facility if necessary.(Where there is unforeseen inability of the Society to attend the vessel in the present port, the master is to confirm that his ship is in condition to sail to the nearest port of call.)

If class has already been automatically suspended in such cases, it may be reinstated subject to the conditions prescribed in this paragraph.
Where 'force majeure' means damage to the ship; unforeseen inability of the Society to attend the vessel due to the governmental restrictions on right of access or movement of personnel; unforeseeable delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes or civil strife; acts of war; or other force majeure.

902. Withdrawal of class

1. The classification may be withdrawn under the approval of the Classification Committee.

(1) when class of a vessel has been suspended for a period of six(6) months. A longer suspension period may be granted when the vessel is not trading as in cases of lay-up, awaiting disposition in case of a casualty or attendance for reinstatement.
(2) when the vessel is reported as a constructive total loss.
(3) when the vessel is lost.
(4) when the vessel is reported scrapped.
(5) when the Surveyor reports that the vessel has not complied with the Rules of the Society as regards surveys to maintain the classification specified in **Ch 2, 102.**

2. Notwithstanding **Par 1**, the class may be withdrawn from the Society in consequence of a request from the Owner.

903. Reclassification

When reclassification is desired for a ship for which the class previously assigned has been withdrawn, the Society will carry out a survey for reclassification, appropriate to the age of the ship and condition of the ship and the circumstances of the case. If, at such survey, the ship be found in good and efficient condition in accordance with the requirements of the Rules, the Society will be prepared to reinstate her classification.

Section 10 Fees

1001. Survey fees

1. When the surveys or testing of materials are carried out by the Surveyor, fees will be charged for the surveys, testing of materials, and the certificates issued in accordance with separately established Tariff of Fees.

2. When travelling is required on account of a survey, the travelling expenses, communication expenses, and other expenses incurred by such travel will be charged.

3. When the attendance of a survey is required to suit the convenience of the Owners, outside of normal working hours or on holidays, an extra fee will be charged.

1002. Fees for plan approval

In the case of plans and other documents approval by the Society, fees will be charged in accordance with separately established Tariff of Fees.

Section 11 Appeal on Disagreement

1101. Appeal on disagreement

In case of disagreement between the Owners or Builders and the Surveyor regarding the application of the Rules, materials, workmanship and extent of repairs, etc. relating to any survey carried out by the Society, an appeal may be made to the Society.

1102. Re-survey

The Society will carry out re-survey when an appeal on disagreement is made.

1103. Fees for re-survey

The fees and expenses of re-survey are to be paid by the party appealing.

Section 12 Related Regulations and Surveys

1201. Governmental regulations

The Society may require to apply governmental regulations for items not specified in the Rules.

1202. International conventions

1. Following ships classed or intended to be classed with the Society are to meet the *International Convention for Load Lines, Safety of Life at Sea* and other related conventions,

(1) Ships flying Korean flag to which the conventions apply.

(2) Ships flying foreign flags, to which the conventions apply, where the Society is authorized by the concerned Governments to issue certificates and requested by the Owner.

2. Unless explicitly stipulated otherwise in the text of the regulations in the *International Convention for the Safety of Life at Sea, Load Lines* and *the Prevention of Pollution from Ships* and any of their mandatory Codes, distances are to be measured by using moulded dimensions.

1203. IACS Unified Interpretations

1. Ships classed with the Society are to be complied with the International Association of Classification Societies(IACS) Unified Interpretations applicable to a ship, its machinery and equipment, in accordance with the implementation dates and provisions stated in the UI, when the Society is acting as a recognized organization, authorized by a flag State Administration to act on its behalf, unless the flag Administration provides its own interpretation.

2. The requirements specified in **Par 1** above does not require the application of IACS UIs to ships retroactively, except for those UIs which explicitly require retroactive application.

Section 13 Classification of Other Installations or Equipment

1301. Classification

The Society may, upon application, survey such installations or equipment other than those relating to ship as offshore drilling unit, mobile/fixed offshore structures, dredgers, floating docks, cargo handling appliances, prime movers, boilers, pressure vessels, and other machinery installations for land service, and they will be registered to the Society with the issue of certificates where they are in satisfaction of the Surveyor. In this case, class notation shall be given to them at the discretion of the Society.

1302. Certificate

Where the installations or equipments have undergone the Classification Survey during or after Construction to the satisfaction of the Surveyor in accordance with the requirement in **1301.** the Certificate will be issued according to the requirements of **Sec 5.**

1303. Construction and survey

Constructions and surveys of installations or equipment intending to be registered are to be in accordance with the Guidance relating to the Rules.

1304. Maintenance of classification

Installations or equipment classed to the Society are to be upon the examination at the surveys assigned to maintain the classification in accordance with the requirements specified by the Society. The application for survey is to be made by the Owners or managers in substitute for the Owners.

1305. Related requirements

The requirements specified in **Sec 6** to **Sec 11** are applicable to the installations or equipment stated in this Section.

Section 14 External Audit

1401. External Audit

1. The auditors of external body such as flag state administration, etc. may conducts audits of processes followed by the Society to assess the degree of compliance with the relevant audit requirements.

2. Auditors of **Par 1** may accompany KR personnel at any stage of work which may necessitate the auditors having access to a vessel or access to the premises of a manufacturer or shipbuilder. In such instances, prior authorization for the auditor's access and any necessary assistances will be sought by the Society.

Section 15 Miscellaneous

1501. New installation of materials containing asbestos

1. This requirement is to apply to materials used for the structure, machinery, electrical installations and equipment.

2. For all ships, new installation of materials which contain asbestos is to be prohibited. ⚓

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General

101. Definitions

The definitions of terms used in **Ch 2** and **Ch 3** are to be as specified in the followings, unless otherwise specified elsewhere.

1. **Anniversary date** means the day and the month of each year which will correspond to the due date of the next Special Survey from the completion date of the initial Classification Survey or of the Special Survey.

2. A **bulk carrier** means a ship which is constructed generally with single deck, topside tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk. Combination carriers are included. For single skin combination carriers additional requirements are specified in **Ch 3, Sec 3.**

3. An **oil tanker** means a ship which is constructed primarily to carry oil in bulk and includes ship types such as combination carrier(Ore/Oil ship, etc.).

4. A **chemical tanker** means a ship constructed or adapted and used for the carriage in bulk of any liquid product listed in **Pt 7, Ch 6, Sec 17.**

5. A **tanker** means a ship constructed or adapted for the carriage in bulk of liquid cargoes of an inflammable nature.

6. A **liquefied gas carrier** means a ship constructed or adapted and used for the carriage in bulk of any liquid product listed in **Pt 7, Ch 5, Sec 19.**

7. A **ballast tank** is a tank that is being used primarily for salt water ballast.

8. A **space** is a separate compartment including holds and tanks.

9. A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom and longitudinal bulkhead. For transversely framed vessels, a transverse section includes adjacent frames and their end construction in way of transverse sections.

10. A **representative space/tank** is a space/tank which is expected to reflect the conditions of other spaces/tanks of similar type and service and with similar corrosion prevention systems. When selecting representative spaces/tanks, account is to be taken of the service and repair history on board and identifiable critical structural areas and/or suspect areas.

11. A **suspect area** is a location showing substantial corrosion and/or is considered by the Surveyor to be prone to rapid wastage.

12. **Substantial corrosion** is an extent of corrosion such that assessment of corrosion pattern indicates a wastage in excess of 75 % of allowable margins, but within acceptable limits. For vessels built under the IACS Common Structural Rules, substantial corrosion is an extent of corrosion such that the assessment of the corrosion pattern indicates a gauged(or measured) thickness between t_{net} + 0.5 mm and t_{net}.

13. An **Overall Survey** means a survey intended to report on the overall condition of the hull structure and determine the extent of additional Close-up Surveys.

14. A **Close-up Survey** means a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e. normally within reach of hand.

15. Corrosion prevention system

A corrosion prevention system is normally considered a full hard protective coating. Hard protective coating is usually to be epoxy coating or equivalent. Other coating systems, which are neither soft nor semi-hard coatings, may be considered acceptable as alternatives provided that they are applied and maintained in compliance with the manufacturer's specifications.

Where soft coating means a coating that remains soft so that is wears off at low mechanical impact or when touched; often based on oil(vegetable or petroleum) or lanolin(sheep wool grease) and semi-hard coating means a coating that dries or converts in such a way that it stays flexible although hard enough to touch and walk upon.

16. Coating condition is defined as follows:

(1) **GOOD** condition with only minor spot rusting
(2) **FAIR** condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20 % or more of areas under consideration, but less than as defined for POOR condition
(3) **POOR** condition with general breakdown of coating over 20 % or more, or hard scale at 10 % or more, of areas under consideration

17. A **prompt and thorough repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of classification, or recommendation.

18. Enhanced survey programme means, in addition to **Ch 2**, an enhanced survey method applied for hull structure and piping systems in way of cargo holds/tanks, pump rooms, cofferdams, pipe tunnels, void spaces within the cargo area and all ballast tanks in accordance with **Ch 3.**

19. Critical structural area is location which has been identified from calculations to require monitoring or from the service history of the subject ship or from similar ships or sister ships, if available, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship.

20. Special consideration or specially considered (in connection with Close-up Surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

21. Air pipe head

Air pipe heads installed on the exposed decks are those extending above the freeboard deck or superstructure decks.

22. Cargo length area is that part of the ship which contains all cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces.

102. Kinds of surveys

Periodical and other surveys to maintain the classification are divided as follows;
(1) Special Survey
(2) Intermediate Survey
(3) Annual Survey
(4) Docking Survey
(5) Propeller Shaft Survey
(6) Boiler Survey
(7) Continuous Survey
(8) Occasional Survey
(9) Alteration Survey

103. Duplication of surveys

When heavier kind of survey is carried out at the due range or in advance of a periodical survey, the periodical survey may be dispensed with.

104. Execution of heavier survey

At the periodical survey, any items as specially considered necessary by the Surveyor or specially requested by the Owner may be inspected to the standard of heavier periodical surveys.

105. Laid-up ships

No periodical surveys are to be carried out for classed ships when they are laid-up. In order to put the laid-up ship into service, the ship has to receive the heaviest kind of survey amongst all the due surveys during laid-up period.

106. Tests

At the periodical survey, when the repair to the ship is likely to affect the ship's speed or safety, the speed trials and inclining experiment may be required.

107. Repairs

1. When the Surveyor recommends the necessity of repairs in consequence of the surveys, he is to notify the applicant the reasons of his recommendations and the applicant after such notification must receive the supervision of the Surveyor during the repairs.

2. Any damage in association with wastage over the allowable limits(including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the vessel's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include;

(1) side shell frames, their end attachments and adjacent shell plating
(2) deck structure and deck plating
(3) bottom structure and bottom plating
(4) watertight or oiltight bulkheads
(5) hatch cover and hatch coamings
(6) items in **202. 1** (1) (f), (g) and (6)
(7) for bulk carriers and double skin bulk carriers;
- bottom structure and bottom plating
- side structure and side plating
- deck structure and deck plating
- inner bottom structure and inner bottom plating
- inner side structure and inner side plating
- watertight or oil tight bulkheads
- hatch covers and hatch coamings
- bunker and vent piping system, including ventilators

(8) for oil tankers, chemical tankers and double hull oil tankers;
- bottom structure and bottom plating
- side structure and side plating
- deck structure and deck plating
- watertight or oiltight bulkheads
- hatch covers or hatch coamings, where fitted

3. For location where adequate repair facilities are not available, consideration may be given to allow the vessel to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

4. Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the vessel's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

5. Voyage repairs and maintenance

(1) Where repairs to hull, machinery or equipment, which affect or may affect classification, are to be carried out by a riding crew during a voyage, they are to be planned in advance. A complete repair procedure including the extent of proposed repair and the need for Surveyor's attendance during the voyage is to be submitted to the Society in advance and the repair procedure is to be in accordance with the separate requirement specified by the Society. Where in any emergency circumstance, emergency repairs are to be effected immediately, the repairs should be documented in the ship's log and submitted thereafter to the Society for use in determining further survey requirements.

(2) The above is not intended to include maintenance and overhaul to hull, machinery and equipment in accordance with manufacturer's recommended procedures and established marine practice and which does not require the approval of the Society. However, any repairs as a result of such maintenance and overhauls which affects or may affect classification is to be noted in the ship's log and submitted to the attending Surveyor for use in determining further survey requirements.

108. Wear limit on structural members

When the thickness of hull structural members or the scantlings of equipment, etc. exceed the wear limit, they have to be renewed with those having the original scantlings or the scantlings considered suitable by the Society. As regards the scantlings of structural members which have been reduced by virtue of an approved system of corrosion control, the present scantlings are to be examined regarding them as having been corroded by the reduced amount since the time of construction. However, when the original scantlings were larger than the required ones, or when deemed appropriate by the Society, these requirements may be modified taking into account of the location, extent, kind of the wear.

109. Procedures for thickness measurements

1. Prior to commencement of the Intermediate or Special Survey, as required by **Sec 3, Sec 4, Sec 14, Sec 15** or **Ch 3**, a meeting is to be held between the attending Surveyor(s), the master of the ship or an appropriately qualified representative appointed by the master or company, the Owner's representative(s) in attendance and the thickness measurement firm's representative(s) so as to ensure the safe and efficient execution of the surveys and thickness measurements to be carried out onboard.

2. Thickness measurements are to be made by an appropriate ultrasonic equipment or other equivalent means and the results of the gaugings are to be reported.

3. Thickness measurements required in the context of hull structural classification surveys, if not carried out by the Society itself, shall be witnessed by a Surveyor. This requires the Surveyor to be on board, while the gaugings are taken, to the extent necessary to control the process.

4. Where the Surveyor is to attend to the thickness measurements in accordance with preceding **Par 3**, the control of the thickness measurement process, review, verification and record of attendance are to be in accordance with the separate requirement specified by the Society.

5. Thickness measurements and Close-up Surveys

In any kind of survey, i.e. Special, Intermediate, Annual or other Surveys having the scope of the foregoing ones, thickness measurements of structures in areas where Close-up Surveys are required shall be carried out simultaneously with Close-up Surveys.

110. Preparations for survey

1. Conditions for survey

(1) The Owner is to provide the necessary facilities for a safe execution of the survey.
(2) Tanks and spaces are to be safe for access, i.e. safe measured such as gas freed, ventilated, and illuminated.
(3) In preparation for survey and thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues etc. to reveal corrosion, deformation, fractures, damages, or other structural deterioration. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of the areas to be renewed.
(4) Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.
(5) Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.
(6) Casings, ceilings or linings, and loose insulation, where fitted, are to be removed, as required by the Surveyor, for examination of plating and framing. Compositions on plating are to be examined and sounded, but need not be disturbed if found adhering satisfactorily to the plating.
(7) In refrigerated cargo spaces the condition of the coating behind the insulation is to be examined at representative locations. The examination may be limited to verification that the protective coating remains effective and that there are no visible structural defects. Where POOR coating condition is found, the examination is to be extended as deemed necessary by the Surveyor. The condition of the coating is to be reported. If indents, scratches, etc., are detected during surveys of shell plating from the outside, insulations in way are to be removed as required by the Surveyor, for further examination of the plating and adjacent frames.

2. Access to structures

(1) For survey, means are to be provided to enable the Surveyor to examine the hull structure in a safe and practical way.
(2) For survey in cargo holds and ballast tank, one or more of the following means for access, acceptable to the Surveyor, is to be provided:
(A) permanent staging and passages through structures
(B) temporary staging and passages through structures
(C) lifts and movable platforms
(D) boats or rafts
(E) other equivalent means

3. Equipment for survey

(1) Thickness measurement is normally to be carried out by means of ultrasonic test equipment. The accuracy of the equipment is to be proven to the Surveyor as required. Thickness measurements are to be carried out by a firm approved by the Society in accordance with **Annex 1-11** of the Guidance, except that in respect of measurements on non-ESP ships less than 500 gross tonnage and all fishing vessels, the firm need not be so approved.
(2) One or more of the following fracture detection procedures may be required if deemed necessary by the Surveyor:
(A) radiographic equipment
(B) ultrasonic equipment
(C) magnetic particle equipment
(D) dye penetrant

4. Survey at sea or at anchorage

(1) Survey at sea or at anchorage may be accepted provided the Surveyor is given the necessary assistance from the personnel onboard. Necessary precautions and procedures for carrying out the survey are to be in accordance with **Par 1, Par 2** and **Par 3** above.
(2) A communication system is to be arranged between the survey party in the tank or space and the responsible officer on deck. This system is to also include the personnel in charge of ballast pump handling if boats or rafts are used.
(3) When boats or rafts are used, appropriate life jackets are to be available for all participants. Boats or rafts are to have satisfactory residual buoyancy and stability even if one chamber is ruptured. A safety check-list is to be provided.
(4) Surveys of tanks by means of boats or rafts may only be undertaken at the sole discretion of the Surveyor, who is to take into account the safety arrangements provided, including weather forecasting and ship response under foreseeable conditions.

111. Special consideration for military vessels

Special consideration may be given in application of relevant sections of this chapter to commercial vessels owned or chartered by Governments, which are utilized in support of military operations or service.

112. Internal examination for ballast tanks with semi-hard coating

As for the requirements regarding semi-hard coatings, these coatings, if already applied, will not be accepted form the next Special or Intermediate Survey commenced on or after 1 July 2010, which-ever comes first, with respect to waving the annual internal examination of the ballast tanks.

Section 2 Annual Survey

201. Due range

1. Annual Survey is to be carried out within 3 months before or after each anniversary date.

2. Annual Survey may be carried out in advance even if it is not due, upon application by the Owner. However, if Annual Survey is carried out more than 3 months earlier than the anniversary date, the anniversary date will be newly assigned to the date of 3 months later than the date on which the survey was completed. The subsequent Annual Survey shall be completed at the interval which will correspond to the new anniversary date.

202. Hull, equipment and fire-extinguishing appliances

1. The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull, hatch covers, hatch coamings, closing appliances, and equipment are maintained in a satisfactory condition.

(1) Examination of weather decks, ship side plating above waterline, hatch covers and coamings.
(a) Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.
(b) Where mechanically operated steel covers are fitted, checking the satisfactory condition, as applicable, of:
(i) hatch covers
(ii) tightness devices of longitudinal, transverse and intermediate cross junctions(gaskets, gaskets lips, compression bars, drainage channels)
(iii) clamping devices, retaining bars, cleating, chain or rope pulleys
(iv) guides, guide rails and track wheels, stoppers, etc.
(v) wires, chains, gypsies, tensioning devices
(vi) hydraulic system essential to closing and securing
(vii) safety locks and retaining devices
(c) Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition where applicable, of:
(i) wooden covers and portable beams, carriers or sockets for the portable beams, and their securing devices
(ii) steel pontoons, tarpaulins
(iii) cleats, battens and wedges
(iv) hatch securing bars and their securing devices
(v) loading pads/bars and the side plate edge
(vi) guide plates and chocks
(vii) compression bars, drainage channels and drain pipes(if any)
(d) Checking the satisfactory condition of hatch coamings plating and their stiffeners, where applicable.
(e) Random checking of the satisfactory operation of mechanically operated hatch covers is to be made including:
(i) stowage and securing in open condition
(ii) proper fit and efficiency of sealing in closed condition
(iii) operational testing of hydraulic and power components, wires, chains and link drives
(f) Examination of the weld connection between air pipes and deck plating.
(g) External examination of all air pipe heads installed on the exposed decks.
(h) Examination of flame screens on the open ends of air pipes to all bunker tanks.

(2) Checking that no alterations have been made to the hull or superstructures that would affect the calculations determining the position of the load lines.
(3) Checking of the positions of the deck line and load line which, if necessary, are to be re-marked and re-painted.
(4) Examining the means of securing the weathertightness of cargo hatchways, other hatchways and other openings on the freeboard and superstructure decks.
(5) Examining the watertight integrity of the closures to any openings in the ship's side below the freeboard deck.
(6) Examining the ventilators and air pipes, including their coamings and closing appliances.

(7) Examining the scuppers, inlets and discharges.
(8) Examining the garbage chutes
(9) Examining the means provided to minimize water ingress through the spurling pipes and chain lockers
(10) Examining the side scuttles and deadlights.
(11) Examining the bulwarks including the provision of freeing ports, special attention being given to any freeing ports fitted with shutters.
(12) Examining the guardrails, gangways, walkways and other means provided for the protection of the crew and for gaining access to and from crew's quarters and working spaces.
(13) Checking, when applicable, the fittings and appliances for timber cargoes on deck.
(14) Confirming that the drainage from enclosed cargo spaces situated on the freeboard deck is satisfactory.
(15) Examining engine room and boiler room including exposed engine casings and their openings, engine room skylights, ventilator openings and their closing appliances.
(16) Examining flush scuttles and manhole covers.
(17) General condition of outside of the hull above the water line including weather deck and the arrangement for drainage, mooring and anchoring(including the hull structures in the vicinity of the fittings) are to be examined so far as could be seen. For ships built after 1 January 2007 subject to the *International Convention for the Safety of Life at Sea(SOLAS)*, confirming that the towing and mooring equipment is clearly and properly marked with any restriction associated with its safe operation
(18) Examining the superstructure end bulkheads, and examining the collision and the other watertight bulkheads as far as can be seen
(19) Examining and testing(locally and remotely) all the watertight doors in watertight bulkheads
(20) Examining penetrations and stop valves on watertight bulkheads and closing appliances of openings on superstructure end bulkheads. If considered necessary by the Surveyor, performance test for closing appliances of openings on superstructure end bulkheads is to be carried out.
(21) Examining, when applicable, the special requirements for ships permitted to sail with reduced freeboard.
(22) Examining each bilge pump and confirming that the bilge pumping system for each watertight compartment is satisfactory.
(23) Confirming, when appropriate and as far as is practicable when examining internal spaces on oil tankers and bulk carriers, that the means of access to cargo and other spaces remain in good condition (SOLAS 74/00/02, Reg.II-1/3-6)
(24) Examining the functionality of bilge well alarms to all cargo holds and conveyor tunnels (SOLAS 74/97, Reg.XII/9)
(25) For bulk carriers, examining the hold, ballast and dry space water level detectors and their audible and visual alarms (SOLAS 74/02, Reg.XII/12)
(26) For bulk carriers, checking the arrangements for availability of draining and pumping systems forward of the collision bulkhead (SOLAS 74/02, Reg.XII/13)
(27) For container ships equipped with container securing arrangements in accordance with **Pt 7, Ch 4, 702.** of the Rules, the container securing arrangements are to be examined as follows:
(a) general examination for arrangements
(b) confirmation of on-board record book
(28) For ships provided with a loading instrument in accordance with the requirements of **Pt 3, Ch 3, 104.,** it is to be confirmed that a loading instrument having the performance and functions as deemed appropriate by the Society is installed on board. Where a stability instrument specified in **Ch 1, 307.** is provided on-board, then the system is to be tested.
(29) Documentations on board including the stability data, etc. approved by the Society are to be confirmed to be kept on board.
(30) Suspect areas
Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the Annual Survey is credited as completed.
Note : These requirements are not applicable to cargo tanks of oil tankers, chemical tankers and double hull oil tankers, surveyed in accordance with **Ch 3, Sec 3, Sec 4** and **Sec 5.**

(31) Examination of ballast tanks
Examination of ballast tank when required as a consequence of the results of the Special Survey and Intermediate Survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increase to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the Annual Survey is credited as completed.

(32) For ships provided with the equipment employed in the mooring of ships at single point mooring specified in **Pt 4, Ch 10, 101. 3** and assigned the additional class notation "EQ-SPM", the general function and deformation condition of this equipment employed in the mooring of ships at single point mooring and hull supporting structures are to be checked.

2. For fire-extinguishing appliances, the survey is to be in accordance with the Guidance relating to the Rules.

3. For ships subject to the enhanced survey programme such as **bulk carriers, oil tankers** and **chemical tankers**, etc., in addition to items of **Par 1** through **Par 2**, the additional requirements in accordance with **Ch 3** are to be taken. However, if the duplicated survey items are exist, these are not to be applied twice.

4. For additional requirements applicable to water level detectors fitted on single hold cargo ships, refer **Sec 14**.

5. In addition to **Par 1** through **Par 2, Ch 14** is also to be taken for general dry cargo ships and **Ch 15** is also to be taken for liquefied gas carriers. However, if the duplicated survey items are exist, these are not to be applied twice.

6. In addition to **Par 1** through **Par 2**, relevant requirements of **Ch 16** and/or **Ch 17** are also to be taken if applicable.

203. Machinery, electrical installations and additional installations

1. Confirming that the machinery, boilers and other pressure vessels, associated piping systems and fittings are installed and protected as to reduce to a minimum any danger to persons on board, due regard being given to moving parts, hot surfaces and other hazards.

2. Confirming that the normal operation of the propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative.

3. Confirming that means are provided so that the machinery can be brought into operation from the dead ship condition without external aid.

4. Carrying out a general examination of the machinery, the boilers, all steam, hydraulic, pneumatic and other systems and their associated fittings to see whether they are being properly maintained and with particular attention to the fire and explosion hazards.

5. Examining and testing the operation of main and auxiliary steering arrangements, including their associated equipment and control system.

6. Confirming that the means of communication between the navigating bridge and the steering gear compartment and the means of indicating the angular position of the rudder are operating satisfactorily.

7. Confirming that with ships having emergency steering positions there are means of relaying heading information and, when appropriate, supply visual compass reading to the emergency steering position.

8. Confirming that various alarms required for hydraulic power-operated, electric and electro-hydraulic steering gears are operating satisfactorily and that the re-charging arrangements for hydraulic power-operated steering gears are being maintained.

9. Examining the means for the operation of the main and auxiliary machinery essential for propulsion and the safety of the ship, including, when applicable, the means of remotely controlling the propulsion machinery from the navigating bridge(including the control, monitoring, reporting, alert and safety actions) and the arrangements to operate the main and other machinery from a machinery control room.

10. Confirming the operation of the ventilation for the machinery spaces.

11. Confirming that the engine room telegraph, the second means of communication between the navigating bridge and the machinery space and the means of communication with any other positions from which the engines are controlled are operating satisfactorily.

12. Confirming that the engineer's alarm is clearly audible in the engineer's accommodation.

13. Examining, as far as practicable, visually and in operation, the electrical installations, including the main source of power and the lighting systems.

14. Confirming, as far as practicable, the operation of the emergency sources of electrical power including their staring arrangements, the systems supplied and, when appropriate, their automatic operation.

15. Examining, in general, that the precautions provided against shock, fire and other hazards of electrical origin are being maintained.

16. Confirming, as far as practicable, that no changes have been made in the structural fire protection, examining any manual and automatic fir doors and proving their operation, testing the means of closing the main inlets and outlets of all ventilation systems and testing the means of stopping power ventilation systems from outside the space served.

17. Confirming that the means of escape from accommodation, machinery and other spaces are satisfactory.

18. Examining the arrangements for gaseous fuel for domestic purpose.

19. Examining visually the condition of any expansion joints in sea water systems.

20. External survey of boilers and thermal oil heaters including test of safety and protective devices, and test of safety valve using its relieving gear, is to be carried out. For exhaust gas economizers, the safety valves are to be tested by the Chief Engineer at sea within the Annual Survey. This test is to be recorded in the log book for review by the attending Surveyor prior to crediting the Annual Survey.

21. Examination for the pressure relief devices of the refrigerating machinery given in **Pt 5, Ch 6, Sec 12** is to be carried out. Where the test results done by ship's crew are considered satisfactory by the Surveyor, the test may be dispensed with.

22. The surveys for water jet propulsion systems and azimuth or rotatable thruster are to be carried out in accordance with the Guidance relating to the Rules.

23. The surveys for additional installations(cargo refrigerating installations, cargo handling appliances, centralized monitoring and control system for main propulsion and essential auxiliary machinery, operating systems for periodically unattended machinery spaces, automation equipment, dynamic positioning system, navigation bridge systems and hull monitoring systems, etc.) are to be carried out in accordance with the requirements specified in **Pt 9**, etc.

24. In case where ships with STCM(stern tube condition monitoring) notation, confirming that parameters in the stern tube condition monitoring records are within the permissible limit.

25. Where considered necessary by the Surveyor, opening up examination of the above items may be requested.

204. Additional requirements to ship types

1. Oil tankers(including tankers) :

The additional requirements are to be surveyed as follows, as far as practicable. Where considered necessary by the Surveyor, the performance test and overhauling may be required.

(1) Checking the deck foam system, including the supplies of foam concentrate and testing that the minimum required number of jets of water at the required pressure in the fire main is obtained when the system is in operation.
(2) Examining the inert gas system, and in particular:
  (A) Examining externally for any sign of gas or effluent leakage.
  (B) Confirming the proper operation of both inert gas blowers.
  (C) Observing the operation of the scrubber room ventilation system.
  (D) Checking the deck water seal for automatic filling and draining.
  (E) Examining the operation of all remotely operated or automatically controlled valves and, in-particular, the flue gas isolating valves.
  (F) Observing a test of the interlocking feature of soot blowers.
  (G) Observing that the gas pressure regulating valve automatically closes when the inert gas blowers are secured.
  (H) Checking, as far as practicable, the following alarms and safety devices of the inert gas system using simulated condition where necessary.
    (a) high oxygen content of gas in the inert gas main.
    (b) low gas pressure in the inert gas main.
    (c) low pressure in the supply to the deck water seal.
    (d) high temperature of gas in the inert gas main.
    (e) low water pressure or low water-flow rate.
    (f) accuracy of portable and fixed oxygen-measuring equipment by means of calibration gas.
    (g) high water level in the scrubber.
    (h) failure of the inert gas blower.
    (i) failure of the power supply to the automatic control system for the gas regulating valve and to the instrumentation for continuous indication and permanent recording of pressure and oxygen content in the inert gas main.
    (j) high pressure of gas in the inert gas main.
(3) Checking, when practicable, the proper operation of the inert gas system on completion of the checks listed above. And then the inert gas systems using stored carbon dioxide, oil fuel combustion type systems, etc. except those using flue gases, are to be tested to ascertain that they are in good working order.
(4) Examining the fixed fire-fighting system for cargo pump rooms, and confirming, as far as practicable, the operation of the remote means for closing the various openings.
(5) Checking protection of cargo pump room and in particular:
  (A) Checking temperature sensing devices for bulkhead gland and alarms.
  (B) Checking interlock between lighting and ventilation.
  (C) Checking gas detection system.
  (D) Checking bilge level monitoring devices and alarms.
(6) Confirming, when appropriate, that the requisite arrangements to regain steering capability in the event of the prescribed single failure are being maintained.
(7) Examining the cargo tank openings, including gaskets, covers, coamings and screens.
(8) Examining the cargo tank pressure/vacuum valves and devices to prevent the passage of flame.
(9) Examining flame screens on the open ends of air pipes to all bunker tanks, ballast tanks adjacent to cargo oil tanks, slop tanks and void spaces adjacent to cargo oil tanks.
(10) Examining the cargo tank venting, cargo tank purging and gas-freeing and other ventilation systems.
(11) Examining the cargo, crude oil washing, ballast and stripping systems both on deck and in the cargo pump-rooms and the bunker system on deck.
(12) Confirming that all electrical equipment in dangerous zones is suitable for such locations, is in good condition and is being properly maintained.
(13) Confirming that potential sources of ignition in or near the cargo pump-room are eliminated, such as loose gear, combustible materials, etc., that there are no signs of undue leakage and that access ladders are in good condition.

(14) Examining all pump-room bulkheads for signs of oil leakage or fractures and, in particular, the sealing arrangements of all penetrations of cargo pump-room bulkheads.
(15) Examining, as far as practicable, the cargo, bilge, ballast and stripping pumps for undue gland seal leakage. Verifying the proper operation of electrical and mechanical remote operating and shutdown devices and operation of cargo pump-room bilge system, and checking that pump foundations are intact.
(16) Confirming that the pump-room ventilation system is operational, ducting is intact, dampers are operational and screens are clean.
(17) Verifying that installed pressure gauges on cargo discharge lines and level indicator systems are operational.
(18) Examining access to bow arrangement.
(19) Examining the towing arrangement for tankers of not less than 20,000 tonnes deadweight.
(20) Examining the emergency lighting in all cargo pump rooms of tanker constructed after 1 July 2002.

2. Chemical tankers :

The additional requirements are to be surveyed as follows, as far as practicable. Where considered necessary by the Surveyor, the performance test and overhauling may be required.

(1) Confirming, when appropriate, that the requisite arrangements to regain steering capability in the event of the prescribed single failure are being maintained.
(2) Examining the cargo tank openings, including gaskets, covers, coamings and screens.
(3) Examining the cargo tank pressure/vacuum valves and devices to prevent the passage of flame.
(4) Examining flame screens on the open ends of air pipes to all bunker tanks, ballast tanks adjacent to cargo tanks, slop tanks and void spaces adjacent to cargo tanks.
(5) Examining the cargo tank venting, cargo tank purging and gas-freeing and other ventilation systems.
(6) Examining the cargo, tank cleaning, ballast and stripping systems both on deck and in the cargo pump-rooms and the bunker system on deck.
(7) Examining, as far as practicable, the cargo, bilge, ballast and stripping pumps for undue gland seal leakage. Verification of the proper operation of electrical and mechanical remote operating and shutdown devices and operation of cargo pump-room bilge system, and checking that pump foundations are intact.
(8) Confirming that the pump-room ventilation system is operational, ducting is intact, dampers are operational and screens are clean.
(9) Verifying that installed pressure gauges on cargo discharge lines and level indicator systems are operational.
(10) Confirming that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends facing the cargo area are in a satisfactory condition.
(11) Confirming that potential sources of ignition in or near the cargo pump-room are eliminated, such as loose gear, combustible materials, etc., that there are no signs of undue leakage and that access ladders are in good condition.
(12) Confirming that removable pipe lengths or other approved equipment necessary for cargo separation are available in the pump room and are in a satisfactory condition.
(13) Examining all pump room bulkhead for signs of cargo leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room bulkheads.
(14) Confirming that the remote operation of cargo pump bilge system is satisfactory.
(15) Examining the bilge and ballast arrangements and confirming that pumps and pipelines are identified.
(16) Confirming, when applicable, that the bow or stern loading and unloading arrangements are in order and testing the means of communication and the remote shut down for the cargo pumps.
(17) Examining the cargo transfer arrangements and confirming that any hoses are suitable for their intended purpose and, where appropriate, type-approved or marked with date of testing.
(18) Examining, as far as practicable, the cargo heating or cooling systems, including any sampling arrangements, and confirming that the means for measuring the temperature and associated alarms are operating satisfactorily.
(19) Examining, as far as practicable, the cargo tank vent systems, including the pressure/vacuum valves and secondary means to prevent over or under pressure and flame screens.
(20) Examining the gauging devices, high-level alarms and valves associated with overflow control.

(21) Confirming that arrangements for sufficient gas to be carried or generated to compensate for normal losses and that the means provided for monitoring ullage spaces are satisfactory.
(22) Confirming that arrangements are made for sufficient medium to be carried where drying agents are used on air inlets to cargo tanks.
(23) Confirming that all electrical equipments in dangerous zones is suitable for such locations, is in satisfactory condition and has been properly maintained.
(24) Examining the fixed fire-fighting system for the cargo pump room and the deck foam system for the cargo area and confirming that their means of operation are clearly marked.
(25) Confirming that the condition of the portable fire extinguishing equipment for the cargoes to be carried in the cargo area is satisfactory.
(26) Examining, as far as practicable, and confirming the satisfactory operation of, the arrangements for the ventilation of spaces normally entered during cargo handling operations and other spaces in the cargo area.
(27) Examining, as far as practicable, that the intrinsically safe systems and circuits used for measurement, monitoring, control and communication purposes in all hazardous locations are being properly maintained.
(28) Examining the equipment for personal protection and in particular that:
(A) the protective clothing for crew engaged in loading and discharging operation and its stowage is in a satisfactory condition;
(B) the required safety equipment and associated breathing apparatus and associated air supplies and, when appropriate, emergency-escape respiratory and eye protection are in a satisfactory condition and are properly stowed;
(C) medical first-aid equipment, including stretchers and oxygen resuscitation equipment are in a satisfactory condition;
(D) arrangements have been made for the antidotes for the cargoes actually carried to be on board;
(E) decontamination arrangements and eyewashes are operational;
(F) the required gas detection instruction are on board and that arrangements have been made for the supply of the appropriate vapour detection tubes;
(G) the arrangements for the stowage of cargo samples are satisfactory;
(29) Confirming that the system for continuous monitoring of the concentration of flammable vapours which is installed in cargo pump room is satisfactory. And, confirming that sampling points or detector heads are located in suitable positions in order that potentially dangerous leakages are readily detected.
(30) Examining externally and confirming that the pumping and piping systems, including a stripping system if fitted, and associated equipment remain as approved.
(31) Examining externally the tank washing piping and confirming that the type, capacity, number, and arrangement of the tank washing machine are as approved.
(32) Examining externally the wash water heating system.
(33) Examining externally, as far as practicable, the underwater discharge arrangements.
(34) Confirming that the means of controlling the rate of discharge of the residue is as approved.
(35) Confirming that the flow rate indicating device is operable.
(36) Confirming that the ventilation equipment for residue removal is as approved.
(37) Examining externally, as far as it is accessible, the heating system required for solidifying and high viscosity substances.
(38) Confirming that any cargo tank high-level alarms are operable.
(39) Examining any additional requirements for the carriage of cargoes listed on the relevant Certificate.
(40) Examining access to bow arrangement.
(41) Examining the towing arrangement for tankers of not less than 20,000 tonnes deadweight.
(42) Examining the emergency lighting in all cargo pump rooms of tanker constructed after 1 July 2002.

3. Liquefied gas carriers :

The additional requirements are to be surveyed as follows, as far as practicable, during a loading or discharging operation. Access for cargo tanks or inerted hold spaces, however, need not be surveyed unless otherwise specially required by the Surveyor. Where considered necessary by the Surveyor, the performance test and overhauling may be required.

(1) Confirming, when appropriate, that the requisite arrangements to regain steering capability in the event of the prescribed single failure are being maintained.
(2) Examining the cargo tank openings, including gaskets, covers, coamings and screens.
(3) Examining flame screens on the open ends of air pipes to all bunker tanks, ballast tanks adjacent to cargo tanks and spaces adjacent to cargo tanks.
(4) Examining the cargo tank venting, cargo tank purging and gas-freeing and other ventilation systems.
(5) Examining the cargo piping systems both on deck and in the cargo compressor-rooms and the bunker system on deck.
(6) Confirming that all electrical equipment in dangerous zones is suitable for such locations, is in good condition and has been properly maintained.
(7) Confirming that potential sources of ignition in or near the cargo compressor-room are eliminated, such as loose gear, combustible materials, etc., that there are no signs of undue leakage and that access ladders are in good condition.
(8) Examining all cargo compressor-room bulkheads for signs of oil leakage or fractures and, in particular, the sealing arrangements of all penetrations of cargo compressor-room bulkheads.
(9) Confirming that the compressor-room ventilation system is operational, ducting is intact, dampers are operational and screens are clean.
(10) Verifying that installed pressure gauges on cargo discharge lines and level indicator systems are operational.
(11) Confirming that special arrangements to survive conditions of damage are in order.
(12) Confirming that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends in the cargo area are in a satisfactory condition.
(13) Examining the cargo pump rooms and cargo compressor rooms
(14) Confirming the manually operated emergency shutdown system together with the automatic shutdown of the cargo pumps and compressors are satisfactory.
(15) Examining the cargo control room.
(16) Examining the gas detection arrangements for cargo control rooms and measures taken to exclude ignition sources where such spaces are not gas-safe.
(17) Confirming the arrangements for the air locks are being properly maintained.
(18) Examining, as far as practicable, the bilge, ballast and oil fuel arrangements.
(19) Examining, when applicable, the bow or stern loading and unloading arrangements with particular reference to the electrical equipment, fire-fighting arrangements and means of communication between cargo control room and the shore location.
(20) Confirming that the sealing arrangements at gas domes are satisfactory
(21) Confirming that portable or fixed drip tray of deck insulation for cargo leakage is in order.
(22) Examining the cargo and process piping, including the expansion arrangements, insulation from the hull structure, pressure relief and drainage arrangements.
(23) Confirming that the cargo tank and interbarrier space pressure and relief valves, including safety systems and alarms, are satisfactory.
(24) Confirming that the any liquid and vapour hoses are suitable for their intended purpose and, where appropriate, type-approved or marked with date of testing.
(25) Examining the arrangements for the cargo pressure/temperature control including, when fitted, any refrigeration system and confirming that any associated alarms are satisfactory.
(26) Examining the cargo, bunker, ballast and vent piping systems, including vent masters and flame screens, as far as practicable.
(27) Confirming that arrangements are made for sufficient inert gas to be carried to compensate for normal losses and that means are provided for monitoring the spaces.
(28) Confirming that the use of inert gas has not increased beyond that needed to compensate for normal losses by examining records of inert gas usage.
(29) Confirming that any air-drying system and any interbarrier and hold space purging inert gas system are satisfactory.

(30) Confirming that electrical equipments in gas-dangerous spaces and zones is in a satisfactory condition and is being properly maintained.
(31) Examining the arrangements for the fire protection and fire extinction and testing the remote means of starting one main fire pump.
(32) Examining the fixed fire-fighting system for the cargo pump room and confirming that its means of operation is clearly marked.
(33) Examining the water spray system for cooling, fire protection and crew protection and confirming that its means of operation is clearly marked.
(34) Examining the dry chemical powder fire-extinguishing system for the cargo area and confirming that its means of operation is clearly marked.
(35) Examining the fixed installation for the gas-dangerous spaces and confirming its means of operation is clearly marked.
(36) Examining, as far as practicable, and confirming the satisfactory operation of , the arrangements for the mechanical ventilation of spaces in the cargo area normally entered during cargo handling operations.
(37) Examining, and confirming the satisfactory operation of, the arrangements for the mechanical ventilation of spaces normally entered other than those covered by (36) above.
(38) Examining, and testing as appropriate and as far as practicable, the liquid level indicators, overflow control, pressure gauges, high pressure and, when applicable, low pressure alarms, and temperature indicating devices for the cargo tanks.
(39) Examining, and testing as appropriate, the gas detection equipment.
(40) Confirming that two sets of portable gas detection equipment suitable for the cargoes to be carried and a suitable instrument for measuring oxygen levels have been provided.
(41) checking the provision of equipment for personal protection and in particular that:
(A) two complete sets of safety equipment each permitting personnel to enter and work in a gas-filled space are provided and are properly stowed;
(B) the requisite supply of compressed air is provided and examining, when applicable, the arrangements for any special air compressor and low-pressure air line system.
(C) medical first-aid equipment, including stretchers and oxygen resusciation equipment and antidotes, when available, for the products to be carried are provided.
(D) respiratory and eye protection suitable for emergency escape purposes are provided.
(E) examining when applicable, the arrangements to protect personnel against the effects of major cargo release by a special suitably designed and equipped space within the accommodation area;
(F) examining, when applicable, the arrangements for the use of cargo as fuel and testing, as far as practicable, that the gas supply to the machinery space is cut off should the exhaust ventilation not be functioning correctly and that master gas fuel valve may be remotely closed from within the machinery space.
(42) The log books are to examined with regard to correct functioning of the cargo containment and cargo handling systems. The hours per day of the reliquefaction plants or the boil-off rate is to be considered.
(43) All accessible gas-tight bulkhead penetrations including gas-tight shaft sealings are to be visually examined.
(44) The means for accomplishing gas tightness of the wheelhouse doors and windows is to be examined. All windows and side scuttles within the area required to be of the fixed type (non-opening) are to be examined for gas tightness. the closing devices for all air intakes and openings into accommodation spaces, service spaces, machinery spaces, control stations and approved openings in superstructures and deckhouses facing the cargo area or bow and stern loading/unloading arrangements, are to be examined.
(45) Cargo handing systems
The cargo handling piping and machinery, e.g. cargo and process piping, cargo heat exchangers, vaporizers, pumps, compressors and cargo hoses are in general to be visually examined, as far as possible, during operation.
(46) Cargo containment venting systems
Venting systems, including protection screens if provided, for the cargo tanks, interbarrier spaces and hold spaces are to be visually examined externally. It is to be verified that the cargo tank relief valves are sealed and that the certificate for the relief valves opening/closing pressure is onboard.

(47) Instrumentation and safety systems
(A) The instrumentation of the cargo installations with regard to pressure, temperature and liquid level is to be verified in good working order by one or more of the following methods:
- Visual external examination
- Comparing of read outs from different indicators
- Consideration of read outs with regard to the actual cargo and/or actual condition
- Examination of maintenance records with reference to cargo plant instrumentation maintenance manual
- Verification of calibration status of the measuring instruments

(B) The logbooks are to be examined for confirmation that the emergency shutdown system has been tested.

(48) Environmental control for cargo containment systems
(A) Inert gas/ dry air installations including the means for prevention of backflow of cargo vapour to gas-safe spaces are to be verified as being in satisfactory operating condition.
(B) For membrane containment systems normal operation of the nitrogen control system for insulation and interbarrier spaces shall be confirmed to the Surveyor by the Master.

(49) Miscellaneous
(A) It is to be verified that all accessible cargo piping systems are electrically bonded to the hull.
(B) Arrangements for burning methane boil-off are to be visually examined as far as practicable. The instrumentation and safety systems are to be verified as being in good working order in accordance with (37) (A) above.
(C) The relevant instruction and information material such as cargo handling plans, filling limit information, cooling down procedures etc. are to be verified as being onboard.
(D) Mechanical ventilation fans in gas dangerous spaces are to be visually examined.

(50) Examining access to bow arrangement.
(51) Examining the towing arrangement for tankers of not less than 20,000 tonnes deadweight.
(52) Examining the emergency lighting in all cargo pump rooms of tanker constructed after 1 July 2002.

4. Pushers and integrated pusher barges :

The additional requirements for the connection system between pusher and integrated pusher barge are to be surveyed as follows.

(1) Confirmation of operating condition of connection system according to the operation procedure.
(2) Examination of connection condition including the supporting structures.
(3) Examination of hydraulic system for leak and operating condition, if fitted.
(4) Examination of hinge arm and joint pins, if fitted.
(5) Examination of mechanical locking/unlocking device including operating condition, if fitted.

Section 3 Intermediate Survey

301. Due range

1. Intermediate Survey is to be carried out within 3 months before or after the second or third anniversary date from the completion date of the initial Classification Survey or of the previous Special Survey. However, for passenger ships, submersibles, nuclear ships, hydrofoils, air cushion vehicles, high speed crafts, Intermediate Survey is to be carried out within 3 months before or after each anniversary date.

2. Intermediate Survey may be carried out in advance even if it is not due, upon application by an Owner. However, if Intermediate Survey is carried out more than 3 months earlier than the anniversary date, the anniversary date will be newly assigned to the date of 3 months later than the date on which the survey was completed. The subsequent Intermediate Survey shall be completed at the interval which will correspond to the new anniversary date.

3. A part of Intermediate Survey items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey, except those ships mentioned in **Par 1** of which Intermediate Survey is to be carried out every year.

4. A survey planning meeting is to be held prior to the commencement of the survey.

5. Concurrent crediting to both Intermediate Survey and Special Survey for surveys and thickness measurements of spaces are not acceptable.

302. Hull, equipment and fire-extinguishing appliances

At the Intermediate Survey, in addition to all the requirements for Annual Survey, the following items are to be surveyed:

1. Internal examination of ballast tanks and cargo spaces are given in **Table 1.2.1.**

Table 1.2.1 Internal examination of ballast tanks and cargo spaces

	5 years 〈 age ≤ 10 years	10 years 〈 age ≤ 15 years	15 years 〈 age
Ballast tanks	Representative ballast tanks[1), 2), 3), 4)]	All ballast tanks[2), 3), 4)]	All ballast tanks[2), 3), 4)]
Cargo holds	-	1. Ships carrying logs: each one of cargo hold at the forward and aft ends	1. Ships carrying logs: each one of cargo hold at the forward and aft ends 2. Ships carrying dry cargoes[5)]: selected cargo holds
Cargo tanks[6)]	-	Selected cargo tanks	Selected cargo tanks

(NOTES)
1) If there is no hard protective coating, soft or semi-hard coating, or POOR coating condition, the examination is to be extended to other ballast tanks of the same type.
2) If such examinations reveal no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains effective.
3) For ballast tanks, excluding double bottom ballast tanks, if there is no hard protective coating, soft or semi-hard coating, or POOR coating condition and it is not renewed, the spaces in question is are to be internally examined at annual intervals.
4) When such condition as above 3) are found in double bottom ballast tanks, the spaces in question may be internally examined at annual intervals.
5) General dry cargo ships subject to **Sec 14** or, bulk carriers or double skin bulk carriers subject to **Ch 3, Sec 2** or **Sec 6** are exempted and each relevant requirements are applied.
6) Liquefied gas carriers subject to **Sec 15** or, oil tankers, chemical tankers or double hull oil tankers subject to **Ch 3, Sec 3, Sec 4** or **Sec 5** are exempted and each relevant requirements are applied.

2. For fire-extinguishing appliances, the survey is to be in accordance with the Guidance relating to the Rules.

3. For ships subject to the enhanced survey programme such as **bulk carriers, oil tankers** and **chemical tankers**, etc., in addition to items of **Par 1** through **Par 2**, the additional requirements in accordance with **Ch 3** are to be taken. However, if the duplicated survey items are exist, these are not to be applied twice.

4. In addition to **Par 1** through **Par 2, Ch 14** is also to be taken for general dry cargo ships and **Ch 15** is also to be taken for liquefied gas carriers. However, if the duplicated survey items are exist, these are not to be applied twice.

5. In addition to **Par 1** through **Par 2**, relevant requirements of **Ch 16** and/or **Ch 17** are also to be taken if applicable.

303. Machinery, electrical installations and additional installations

At each Intermediate Survey, in addition to all the requirements of Annual Survey, the following requirements are to be complied with.

1. Steam turbines for main engines

(1) Examinations are to be carried out while rotating the rotor after removing the upper part of the turbine and rotor shaft bearings. The examinations on rotors may be dispensed with when deemed unnecessary by the Surveyor.
(2) The clutch coupling is to be examined.

2. Internal combustion engines for main engines

(1) Partial open-up survey for one cylinder is, in principle, to be carried out as follows, however, the extent may be extended when deemed necessary by the Surveyor.
  (A) Internal examinations of the cylinders and combustion side of the cylinder covers are to be carried out. Pistons may not have to be removed except when deemed necessary by the Surveyor.
  (B) Examinations are to be carried out while rotating the crank shaft after removing the upper parts of main bearings and crank-pin bearings. The deflection of crank webs are to be measured and where deemed necessary the alignment of the bearing are to be adjusted.
(2) Examination for high-rotating-speed internal combustion engines is to be done by the requirement specified in the above (1), but the measurement for crank web deflections may be dispensed with. However, where total running hours for an internal combustion engine is confirmed and found in satisfactory by the Surveyor, the survey may be extended until next overhauling hours recommended by the manufacturer since the previous overhauling survey.
(3) The survey for a passenger ship is to be in accordance with the Guidance relating to the Rules.

3. Auxiliary engines

Examinations on auxiliary engines driving generators(except emergency use) and other auxiliary machinery related with ship propulsion are to be carried out in accordance with the requirements for main engine.

4. Other essential auxiliaries

General examinations are to be carried out on other essential auxiliary machinery. Detailed examinations may, however, be required when deemed necessary by the Surveyor.

5. Electrical installations

Where deemed necessary by the Surveyor, insulation resistance test is to be made.

6. The surveys for water jet propulsion systems and azimuth or rotatable thruster are to be carried out in accordance with the Guidance relating to the Rules.

7. In addition to **Par 1** through **Par 6**, relevant requirements of **Ch 17** are also to be taken if applicable.

304. Additional requirements to ship types

At each Intermediate Survey, in addition to all the requirements of Annual Survey, the following requirements are to be complied with.

1. Oil tankers(including tankers) :

The additional requirements are to be surveyed as follows, as far as practicable.

(1) Should there by any doubt as to its condition when examining the various piping systems, the piping may be required to be pressure tested, gauged or both. Particular attention is to be paid to repairs such as welded doublers.
(2) For ships over ten years of age an internal examination of selected cargo spaces;
(3) Testing the insulation resistance of electrical circuits in dangerous zones such as cargo pump rooms and area adjacent to cargo tanks but in case where a proper record of testing is maintained consideration should be given to accepting recent readings.
(4) Checks are to be made on the resistance to earth for bonding straps described in **Pt 7, Ch 1, 1104.**, when deemed necessary by the Surveyor.

2. Chemical tankers :

The additional requirements are to be surveyed as follows, as far as practicable.

(1) Verifying from the cargo record book that the pumping and stripping arrangements have been emptying the tanks efficiently and are all in working order;
(2) Confirming, if possible, that the discharge outlets are in good condition;
(3) Confirming the satisfactory operation of the recording device, as fitted, and verifying by an actual flow test that it has an accuracy of ± 15 % or better;
(4) Confirming that the ventilation equipment for residue removal is satisfactory and that the pressure in the driving medium for portable fans for ventilation equipment for residue removal can be achieved to give the required fan capacity.
(5) Examination of vent line drainage arrangements.
(6) Confirmation, where applicable, that pipelines and independent cargo tanks are electrically bonded to the hull.
(7) Generally examining the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks to check for defective equipment, fixtures and wiring. The insulation resistance of the circuits should be tested and in cases where a proper record of testing is maintained, consideration should be given to accepting recent readings.
(8) Confirmation that spares are provided for cargo area mechanical ventilation fans.

3. Liquefied gas carriers :

The additional requirements are to be surveyed as follows, as far as practicable. This survey is preferably to be carried out with the ship in a gas-free conditions. The extent of the testing required for this survey will normally be such that the survey cannot be carried out during a loading or discharging operation, and then testing cargo handling installations with related automatic control, alarm and safety systems for correct functioning.

(1) Confirmation, where applicable, that pipelines and independent cargo tanks are electrically bonded to the hull.
(2) Generally examining the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks to check for defective equipment, fixtures and wiring. The insulation resistance of the circuits should be tested and in cases where a proper record of testing is maintained, consideration should be given to accepting recent readings.
(3) Confirmation that spares are provided for cargo area mechanical ventilation fans.
(4) Confirming that the heating arrangements, if any, for steel structures are satisfactory.
(5) The instrumentation of the cargo installation with regard to pressure, temperature and liquid level is to be visually examined and to be tested by changing the pressure, temperature and level as applicable and comparing with test instruments. Simulated testing may be accepted for sensors which are not accessible or for sensors located within cargo tanks or inerted hold spaces. The testing is to be include testing of alarm and safety function.
(6) The piping of the gas detection system is to be visually inspected for corrosion and damage as far as practicable. The integrity of the suction lines between suction points and analyzing units is to be verified as far as possible. Gas Detectors are to be calibrated or verified with sample gases.

(7) The emergency shutdown system is to be tested, without flow in the pipe lines, to verify that the system will cause the cargo pumps and compressors to stop.
(8) Electrical equipment in gas-dangerous spaces and zones is to be examined as far as practicable with particular respect to the following:
(A) Protective earthing(Spot check)
(B) Integrity of enclosures
(C) Damage of outer sheath of cable
(D) Function testing of pressurized equipment and of associated alarms
(E) Testing of systems for de-energizing non-certified safe electrical equipment located in spaces protected by air-locks, such as electrical motor-rooms, cargo control room, etc.
(F) Testing of insulation resistance of circuits. Such measurements are only to be made when the ship is in a gas-free or inerted condition. Where proper records of testing are maintained consideration may be given to accepting recent readings by the ship's crew.
(9) The instrumentation and safety systems for burning cargo as fuel are to be examined in accordance with (5). Inspection and maintenance of electrical equipment installed in hazardous area shall be complied with the requirements given in IEC60079-17, Part 17.
(10) Examination for non-metallic membranes of pressure relief valves for cargo tanks in accordance with the Guidance relating to the Rules.

Section 4 Special Survey (Hull, Equipment and Fire-extinguishing Appliances)

401. Due range

1. The first Special Survey is to be completed within 5 years from the date of the initial Classification Survey and thereafter within 5 years from the credited date of the previous Special Survey. Under 'exceptional circumstances', the Society may grant an extension not exceeding three(3) months to allow for completion of the Special Survey provided that the vessel is attended and the attending Surveyor(s) so recommend(s) after the following has been carried out: Where ‘exceptional circumstance' means unavailability of dry-docking facilities; unavailability of repair facilities; unavailability of essential materials, equipment or spare parts; or delays incurred by action taken to avoid severe weather conditions.

(1) Annual Survey;
(2) re-examination of Recommendations/Conditions of Class;
(3) progression of the Special Survey as far as practicable;
(4) in the case where dry docking is due prior to the end of the class extension, an underwater examination is to be carried out by an approved diving company. An underwater examination by an approved company may be dispensed with in the case of extension of dry-docking survey not exceeding 36 months interval provided the ship is without outstanding Recommendation/Condition of Class regarding underwater parts.

In this case, the next period of class will start from the expiry date of the Special Survey before the extension was granted.

2. In the case that the Certificate of Classification will expire when the vessel in expected to be at sea, an extension to allow for completion of the Special Survey may be granted provided there is documented agreement to such an extension prior to the expiry date of the certificate, and provided that positive arrangements have been made for attendance of the Surveyor at the first port of call, and provided that the Society is satisfied that there is technical justification for such an extension. Such an extension is to be granted only until arrival at the first port of call after the expiry date of the certificate. However, if owing to 'exceptional circumstances' the Special Survey cannot be completed at the first port of call, above **Par 1** may be followed, but the total period of extension shall in no case be longer than three(3) months after the original due date of the Special Survey.

3. For surveys completed within 3 months before the expiry date of the Special Survey, the next period of class will start form the expiry date of the Special Survey. For surveys completed more than 3 months before the expiry date of the Special Survey, the next Special Survey shall be assigned at the date of 5 years after the completion date of the concerned Special Survey.

4. The Special Survey including docking survey, compartment survey and thickness measurement may be commenced at the 4th Annual Survey and be progressed with a view to completion by the 5th anniversary date.

5. When the Special Survey is commenced prior to the 4th Annual Survey, the entire survey is to be completed within 15 months if such work is to be credited to the Special Survey.

6. A survey planning meeting is to be held prior to the commencement of the survey.

7. Concurrent crediting to both Intermediate Survey and Special Survey for surveys and thickness measurements of spaces are not acceptable.

8. Continuous Survey of Hull

For ships other than those subject to **Ch 3 Hull Surveys of Ships subject to the Enhanced Survey Programme** and **Sec 14 Hull Surveys for General Dry Cargo Ships,**

(1) A part of hull items of the Special Survey can be carried out on the Continuous Survey System basis, at the request of an Owner if has been approved by the Society. A part of hull items of the Special Survey(i.e. hull continuous survey items) means the internal examination, thickness measurements, survey in dry-dock, survey for anchor/chain cables, tank pressure test and survey for hatch covers/coamings. Ships on the Continuous Survey System are not exempt from other periodical surveys.

(2) When such a system is adopted all the hull continuous survey items of the particular Special Survey must be completed at the end of the five-year Special Survey period.

(3) During each survey cycle, all the hull continuous survey items are to be surveyed (and tested, where required) in regular rotation, as far as practicable, with uniform annual share within the five-year Special Survey period. In general, approximately 20 % of the total number of the hull continuous survey items of the Special Survey is to be completed each year.

(4) At the end of the five-year Special Survey period, for the purpose of completion of Special Survey, a survey at least in the scope of an Annual Survey is be carried out during which the Surveyor will satisfy himself/herself as to whether all items required to be surveyed have been surveyed throughout, and with satisfactory results. The Surveyor may inspect individual parts again if deemed necessary by the Surveyor.

(5) The Owner is entitled to fix the sequence in which the individual hull continuous survey items are intended to be surveyed. However, the sequence in each survey cycle shall be linked with that of the previous one in such a way that the interval between consecutive (in two cycles) examinations of each hull continuous survey items should not generally exceed five years. The survey in dry-dock may be held at any time within the five-year Special Survey period, provided all the requirements of **Sec 6** are also complied with. For ships more than 10 years of age, the ballast tanks are to be internally examined twice in each five-year Special Survey period, i.e. once within the scope of the Intermediate Survey and once within the scope of the Continuous Survey of Hull for the Special Survey.

(6) The Surveyor may extend the inspection at his/her discretion, to other items if the inspections carried out revealed any defects.

(7) The approval for surveys to be carried out on a Continuous Survey System basis may be withdrawn at discretion of the Society.

402. Kinds of Special Surveys

The first Special Survey on a ship after the Classification Survey during Construction is designated as Special Survey No. 1 and subsequent Special Surveys are designated as Special Survey No. 2, No. 3, etc. The kinds of Special Surveys on a ship for the Classification Survey after Construction are to be determined based upon the Special Surveys applied to the Classification Survey according to the ship's age.

403. Requirements of survey

1. The Special Survey is to include, in addition to the requirements of the Annual Survey, examination, tests and checks of sufficient extent to ensure that the hull, equipment and related piping, as required in (9), are in satisfactory condition and is fit for the intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and the periodical surveys being carried out at the due dates. The examinations of the hull are to be supplemented by thickness measurements and testing as required in (9) and (13), to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages, or other structural deterioration, that may be present.

(1) The vessel is to be placed in a drydock or upon a slipway and all items of **603.** are to be examined. However ships subject to the "Extended Dry-docking Interval System" specified in **605.**, this examination can be carried out in accordance with **605.**

(2) Hatch covers and coamings
The hatch covers and coamings are to be surveyed as follows:
  (a) A thorough inspection of the items listed in **202. 1** (1) and (6), including Close-up Survey of hatch cover plating and hatch coaming plating, is to be carried out.
  (b) Checking of the satisfactory operation of all mechanically operated hatch covers is to made, including:
    (i) stowage and securing in open condition
    (ii) proper fit and efficiency of sealing in closed condition
    (iii) operational testing of hydraulic and power components, wires, chains and link drives
  (c) Checking of the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent as necessary.

(3) The anchors and chain cables are to be ranged, examined and the required complement and condition verified. The chain locker, holdfasts, hawse pipes and chain stoppers are to be examined and pumping arrangements of the chain locker tested. At Special Survey No. 2 and subsequent Special Surveys, chain cables are to be gauged and renewed in cases where their mean diameter is 12 % or more below the original required nominal size.

(4) Inside of the hull is to be examined after articles not permanently attached to the hull are removed as far as possible and after all limber boards, mud boxes, strainers of bilge suction pipes, etc. are opened and interior of the hull is cleaned.

(5) All decks are to be examined, attention being paid to the welded parts of the strength deck, structures in way of discontinuities and corners of hatchway openings, etc. It is also to be ascertained whether the deck composition satisfactorily adheres to the plating.

(6) The protected structures are to be examined in accordance with **Table 1.2.2.**

Table 1.2.2 Examination of the protected structures at each Special Survey

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3 and Subsequent
	In addition to the requirements of Special Survey No. 1,	In addition to the requirements of Special Survey No. 2,
1) Single bottom construction is to be examined after removing at least one strake of bottom ceilings on each side of the centerline and the bilges and flooring plates in machinery space where deemed necessary. Special attention is to be paid to ascertain that the cement of other composition laid on the inner surface of bottom plating is in satisfactory condition.	1) Throughout the ship, in way of single bottoms one strake of ceilings on each side near to the keelson and in way of double bottoms and deep water or oil tanks ceilings at bilge (including limber hole) and centre line part, lower parts of pillars and bulkheads, shaft tunnels and any other parts deemed necessary by the Surveyor are to be removed and the internal structures are to be examined.	1) All ceilings, sparrings, wood linings, casings in the holds, and floor plates in the machinery spaces are to be removed in sufficient quantities to enable the Surveyor to examine the conditions of structure under them. The ship is to be made free from rust inside and outside in order to expose for examination the framing and plating together with discharges, scuppers, air and sounding pipes, and the steel-work is to be examined.
2) Where a double bottom is fitted, a sufficient amount of ceiling as deemed necessary by the Surveyor is to be removed and the condition of the top plating examined.	2) Shell plating in way of the side scuttles is to be examined with special attention, and where deemed necessary by the Surveyor, the thickness of the said parts and any other parts of the structure being excessively corroded is to be gauged.	2) Wood planks and other covering on steel decks are to be removed as required by the Surveyor and examined. Cement chocks on the ship's sides at bilges and decks are to be examined, portions of them are to be removed as deemed necessary by the Surveyor so that the condition of the shell plating and adjacent steel-work can be ascertained.
	3) The condition of steel deck plating under wooden deck is to be examined by drilling the worn parts of wooden deck.	3) Where deemed necessary by the Surveyor, the lining in way of the side scuttles is to be removed as required by the Surveyor, and the shell plating examined.
		4) Where the holds are insulated for carriage of refrigerated cargoes, the limbers and hatches are to be removed, and where considered necessary by the Surveyor, a sufficient amount of insulation is to be removed in each of the chambers to enable the Surveyor to ascertain the condition of the plating and framing.

(7) Internal examination of tanks and spaces
(a) All spaces including tanks and spaces in accordance with **Table 1.2.3** are to be internally examined.
(b) When tanks are examined internally, the plating and framing, bilges and drain wells, sounding, venting, pumping and drainage arrangements within the tanks and spaces are to be examined.
(c) Where provided, the condition of corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom ballast tanks, where a hard protective coating is found in POOR condition and it is not renewed, where soft or semi-hard coating has been applied, of where a hard protective coating was not applied from time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.
(d) When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary be the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

Table 1.2.3 Minimum requirements for Internal examination of tanks and spaces at each Special Survey

Tanks or Spaces \ No. of Special Survey		Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
Cargo holds(and their 'tween decks where fitted), cargo tanks		○	○	○	○
Double bottom tanks, deep tanks, ballast tanks, peak tanks		○	○	○	○
Pump room, pipe tunnel, duct keel, machinery spaces, dry spaces, cofferdams, void spaces		○	○	○	○
Fuel oil tanks△	Engine room	-	-	1	1
	Cargo length area	-	1	2	Half, minimum 2
Lubrication oil tanks△		-	-	-	1
Fresh water tanks△		-	1	○	○

(NOTES)
Purpose of tank has a priority in application.
○ : All tanks and spaces are to be internally examined.
△ : As follows:
1) These requirements apply to tanks of integral (structural) type.
2) If a selection of tanks is accepted to be examined, then different tanks are to be examined at each Special Survey, on a rotational basis.
3) Peak tanks (all uses) are subject to internal examination at each Special Survey.
4) At Special Survey No. 3 and subsequent surveys, one deep tank for fuel oil adjacent to side shell plate in the cargo length area is to be included, if fitted.

(8) The arrangements for mooring and anchoring are to be examined and their performances are to be tested. However, the performance tests may be dispensed with at the discretion of the Surveyor.
(9) The performance of hand bilge pumps is to be tested. All bilge and ballast piping systems are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.
(10) Fire protection, fire equipments and its operation tests.
(11) In tanks to which an approved measure of corrosion control in accordance with **Pt 3, Ch 1, Sec 8** is applied, the condition of coating or corrosion protection is to be examined.
(12) For **container ships,** equipped with container securing arrangements in accordance with **Pt 7, Ch 4, 702.** of the Rules, the container securing arrangements are to be examined as follows:
(a) Visual inspection for cell guides and securing devices(cracks, fractures, etc. of welds).
(b) Confirmation of comparison between on-board record book and securing devices.
(13) Thickness measurement
(a) Thickness measurements are to be carried out in accordance with **Table 1.2.4.** The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the survey is credited as completed.
(b) For the ships specified by the Society, the longitudinal strength is to be evaluated after carrying out the thickness measurements in accordance with the requirement specified in (a) above. However, the only thickness measurement records which have been measured within one(1) year period from the date of the longitudinal strength evaluation shall be considered valid.

Table 1.2.4 Minimum requirements for Thickness Measurements at Special Survey

1. General Ships

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas throughout the vessel	1. Suspect areas throughout the vessel 2. One transverse section of deck plating in way of a cargo space within the amidships 0.5 L	1. Suspect areas throughout the vessel 2. Two transverse sections within the amidships 0.5 L in way of two different cargo spaces4), 5), 6), 7) 3. All cargo hold hatch covers and coamings(plating and stiffeners) 4. Internals in forepeak and afterpeak tanks 5. All transverse bulkheads in all cargo tanks8) 6. All transverse bulkheads in all ballast tanks8)	1. Suspect areas throughout the vessel 2. A minimum of three transverse sections in way of cargo spaces within the amidships 0.5 L5), 6), 7) 3. All cargo hold hatch covers and coamings (plating and stiffeners) 4. Internals in forepeak and aftpeak tanks 5. All exposed main deck plating full length 6. Representative exposed deck plating (poop, bridge and forecastle deck) 7. Lowest strake and strakes in way of 'tween decks of all transverse bulkheads in cargo spaces together with internals in way 8. All wind and water strakes, port and starboard, full length 9. All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space and aft end of tanks 10. Plating of seachests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor 11. All transverse bulkheads and one web frame ring in all cargo tanks8) 12. All transverse bulkheads and all web frame ring in all ballast tanks8)

(NOTES)

1) In application to this table, General Ships means ships except Other Ships in **Table 1.2.4, 2.**
2) Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.
3) Thickness measurements of internals may be specially considered by the Surveyor if the hard protective coating is in GOOD condition.
4) For ships more than 100 meters in length, at Special Survey No. 3, thickness measurements of exposed deck plating within amidship 0.5 L may be required.
5) For ships less than 100 meters in length, the number of transverse sections required at Special Survey No. 3 may be reduced to one (1), and the number of transverse sections required at Special Survey No. 4 and subsequent may be reduced to two (2).
6) For the pure car carrier, the extent of thickness measurement for transverse sections may be considered as follows:
   - Exposed deck plate, side shell plate, bottom shell plate, inner bottom plate and longitudinal members in double bottom spaces.
7) Where the evaluation of longitudinal strength is required, all longitudinal structural members at the corresponding sections are to be gauged.
8) This requirement is to be applied only for tankers(including barges) carrying liquid cargo.

Table 1.2.4 Minimum requirements for Thickness Measurements at Special Survey (Continued)

2. Other Ships

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas throughout the vessel	1. Suspect areas throughout the vessel 2. One transverse section of deck plating[5], side shell plating and bottom plating within the amidships 0.5 L	1. Suspect areas throughout the vessel 2. Two transverse sections of deck plating[5], side shell plating and bottom plating within the amidships 0.5 L 3. Internals in forepeak and afterpeak tanks	1. Suspect areas throughout the vessel 2. Two transverse sections of side shell plating within the amidships 0.5L 3. Full length, 1) All exposed main deck plating[5] 2) Representative exposed superstructure deck plating(poop, bridge and forecastle deck) 3) Selected wind and water strakes 4) Bottom plating 5) Flat keel plating 4. Internals in forepeak and aftpeak tanks

(NOTES)
1) In application to this table, Other Ships means the ship specified as follows except Special Purpose Ship - Waste in **Annex 1-1, 1.1** of the Guidance relating to the Rules.
   - the ship type **12, 13**
   - the ship less than 500 GT and not engaged on international voyages among ship type **15, 16, 17** and **19** to **29**
2) Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion.
3) Thickness measurements of internals may be specially considered by the Surveyor if the hard protective coating is in GOOD condition.
4) When the evaluation of longitudinal strength is required, all longitudinal members at the corresponding sections are to be gauged.
5) For fishing vessel, thickness measurement requirements in way of deck(gutter water way part and hatch coaming part) may be modified at the discretion of the Surveyor if the structure remains effectively protected against corrosion by a permanent type special coating.

Table 1.2.5 Requirements for extent of thickness measurement at those areas of substantial corrosion

Structural Member	Extent of Measurement	Pattern of Measurement
Plating	Suspect area and adjacent plates	5 point pattern over 1 m^2
Stiffeners	Suspect area	3 measurements each in line across web and flange

(14) Tank testing
  (a) Tank testings are to be carried out in accordance with **Table 1.2.6.**
  (b) Tanks may be tested afloat at the discretion of the Surveyor, provided that the internal examination of the bottom is also carried out afloat.

Table 1.2.6 Minimum requirements for tank testing

Tanks \ No. of Special Survey	Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
Double bottom tank, deep tank, ballast tank, peak tank and other tank (including holds adopted for the carriage of salt water ballast)	○	○	○	○
Fuel oil tank, lubrication oil tank, fresh water tank	△	△	△	△

(NOTES)
1. Purpose of tank has a priority in application.
2. Boundaries of tanks are to be tested with a head of liquid to the top of air pipes or to near the top of hatches for ballast/cargo holds. Boundaries of fuel oil, lube oil and fresh water tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions.
3. ○ : All tanks are to be tested.
   △ : Tank testing of fuel oil, lube oil and fresh water tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.
4. For the cargo tanks(except cargo tanks for the liquefied natural gas), tests may be dispensed with, provided after an external and internal examination of the tanks, the Surveyor is satisfied with the condition of the tanks.
5. The Surveyor may extend the testing as deemed necessary.

(15) Where considered necessary by the Surveyor, the effectiveness of shell plating, watertight bulkheads, shaft tunnels, watertight doors and the closing appliances of openings on superstructure end bulkheads is to be confirmed.
(16) Engine room structure is to be examined. Particular attention is to be given to tank tops, shell plating in way of tank tops, brackets connecting side shell frames and tank tops, and engine room bulkheads in way of tank top and bilge wells. Particular attention is to be given to the sea suctions, sea water cooling pipes and overboard discharge valves and their connections to the shell plating. Where wastage is evident or suspect, thickness measurements are to be carried out, and renewals or repairs made when wastage exceeds allowable limits.

(17) For all ships except for passenger ships, automatic air pipe heads are to be completely examined(both externally and internally) as indicated in **Table 1.2.7.** For designs where the inner parts cannot be properly inspected from outside, this is to include removal of the head from air pipe. Particular attention is to be paid to the condition of the zinc coating in heads constructed from galvanized steel.

Table 1.2.7 Survey requirements for automatic air pipe heads at Special Survey

Special Survey No. 1 1), 2)	Special Survey No. 2 1), 2)	Special Survey No. 3 and Subsequent
· Two air pipe heads, one port and one starboard, located on the exposed decks in the forward 0.25 L, preferably air pipes serving ballast tanks	· All air pipe heads located on the exposed decks in the forward 0.25 L	· All air pipe heads located on the exposed decks
· Two air pipe heads, one port and one starboard, on the exposed decks, serving spaces aft of 0.25 L, preferably air pipes serving ballast tanks	· At least 20% of air pipe heads on the exposed decks serving spaces aft of 0.25 L, preferably air pipes serving ballast tanks	

(NOTES)
1) The selection of air pipe heads to be examined is left to the attending Surveyor.
2) According to the results of this examination, the Surveyor may require the examination of other heads located on the exposed deck.

(18) Where a stability instrument is provided on-board, all approved test loading conditions are to be examined.

(19) For ships provided with the equipment employed in the mooring of ships at single point mooring specified in **Pt 4, Ch 10, 101. 3** and assigned the additional class notation "EQ-SPM", the function and deformation condition of this equipment employed in the mooring of ships at single point mooring and hull supporting structures are to be closely checked and confirmed its satisfactory conditions. Where deemed necessary, non-destructive examinations may be required.

2. For ships subject to the enhanced survey programme such as **bulk carriers, oil tankers** and **chemical tankers**, etc., in addition to items of **Par 1** the additional requirements in accordance with **Ch 3** are to be taken. However, if the duplicated survey items are exist, these are not need to be applied twice.

3. For additional requirements applicable to water level detectors fitted on single hold cargo ships, refer **Sec 14.**

4. In addition to **Par 1, Ch 14** is also to be taken for general dry cargo ships and **Ch 15** is also to be taken for liquefied gas carriers. However, if the duplicated survey items are exist, these are not need to be applied twice.

5. In addition to **Par 1**, relevant requirements of **Ch 16** and/or **Ch 17** are also to be taken if applicable.

404. Fire-extinguishing appliances

For fire-extinguishing appliances, the survey is to be in accordance with the Guidance relating to the Rules.

Section 5-1 Special Survey (Machinery, Electrical Installations and Additional Installations)

501. Due range

The due range of Special Survey(Machinery, electrical installations and additional installations) is to be complied with the requirements specified in **401.**

502. Requirements of survey

At the Special Survey(Machinery, electrical installations and additional installations), in addition to the requirements for Intermediate Survey, the following requirements specified in **Par 1** to **Par 6** are to be complied with.

1. Requirements of main engines and auxiliary engines

(1) At the Special Survey for main engines, the following requirements are to be conformed to with respect to the type of engine, where deemed necessary by the Surveyor, control devices, governing devices and safety devices are to be tested.

(a) For internal combustion engines, cylinders, cylinder covers, pistons, piston rods and connecting rods, crosshead(including pins, bearings and guides), crank shafts and all bearings, elasticity couplings, cam shafts and their driving gears, essential valves and valve arrangements, fuel oil pumps and fittings, scavenging pumps, scavenging blowers, superchargers, intercoolers, filter or oil separators and safety devices, clutches, reverse gears, attached pumps and coolers, crank cases and explosion relief devices are to be opened up and examined, and the deflections of crank arms are to be measured. And, effectiveness of vibration damper is to be confirmed and balancers are to be examined.
However, those total running hours not more than the overhauling time recommended by the manufacturer since the previous overhauling survey, the survey is to be in accordance with the Guidance relating to the Rules.

(b) Examinations for high-rotating-speed internal combustion engines of specific construction such that complete engine overhaul is required for surveys may be in accordance with the Guidance relating to the Rules.

(c) Where the propulsion steam turbines are of a well known type, and fitted with rotor position indicators and vibration indicators of an approved type, as well as measuring equipment of steam pressure at proper locations along the steam flow, and the arrangements for change over in case of emergency operation of the plant are readily operable, the first Special Survey may be limited to be examination of rotor bearings, thrust bearings and flexible couplings, provided the Surveyor has been satisfied from operation service records and power trials subsequent to the survey, that the turbine plant is in good working condition. Turbine casings should be opened at the next second Special Survey and subsequent Special Surveys.

(2) For auxiliary engines, the requirements corresponding to those of the main engine are to be conformed to.

2. Requirements of machinery except for main engines and auxiliary engines

(1) All shafts(except the propeller and stern tube shafts), thrust blocks and line shaft bearings are to be examined. The lower halves of bearings need not be exposed, if alignment and wear are found satisfactory.

(2) Reduction gears are to be examined. Where deemed necessary by the Surveyor, reduction gears are to be opened up and the gear wheels, pinions, gear shafts and bearings are to be examined.

(3) Air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services are to be opened up as considered necessary by the Surveyor and examined.

(4) Operational conditions of steering gear are to be examined. Where deemed necessary by the Surveyor, main parts are to be opened up and examined.

(5) Operational conditions of windlass, mooring winches and cargo winches are to be examined. Where deemed necessary by the Surveyor, main parts of them are to be opened up and examined.

(6) Evaporators are to be opened up and examined. Their safety valves are also to be checked under working condition.

(7) The foundation bolts and chocks of main and auxiliary engines, gear casings, thrust blocks and line shaft bearings are to be examined.

(8) All air receivers and other pressure vessels for essential services together with their mountings and safety devices are to be opened up and examined internally and externally. If internal examination of them is not practicable, they are to be tested hydraulically to 1.5 times the working pressure, and if considered necessary by the Surveyor, performance test of safety valves for the above mentioned devices is to be carried out.

(9) Pumping and piping arrangements

(a) Valves, cocks and strainers of the bilge system including the emergency bilge suction valves are to be examined. And where deemed necessary by the Surveyor, opening up examination of above items or effectiveness test of the bilge system is to be carried out.

(b) The fuel oil, feed and lubricating oil systems, the ballast pipe connections and blanking arrangement to the ballast holds and all filters, heaters, coolers and condensers for essential services are to be opened up and examined. The pressure tests may be carried out, including safety devices, where deemed necessary by the Surveyor.

(c) Fuel oil tanks which do not form part of the ship's structure are to be examined internally and externally and, if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. At the Special Survey No. 1, internal examination of the tanks may be dispensed with, provided they are found satisfactory in external examination. All mountings, fittings and remote controls are to be examined as far as practicable.

(10) Where deemed necessary by the Surveyor, the performance tests of pressure gauges, revolutions and thermometers are to be made.

(11) Where automatic and remote controls are fitted up for essential machinery, they are to be tested to demonstrate that they are in good working order.

(12) Main steam pipes, where considered necessary by the Surveyor are to be examined after removing the lagging indicated by the Surveyor. The thickness of pipes is also to be checked as necessary.

(13) The following safety inspections are to be carried out for the cargo refrigerating machinery given in **Pt 5, Ch 6, 1201. 1.**

(a) Leaks of the refrigerants are to be tested while the machinery is examined in running condition.

(b) Coils of coil type condensers and evaporators, shell tube type condensers and shells of receivers are to be tested at a pressure of at least 90 percent of the design pressure. Where, however, relief valves attached to them are adjusted to a pressure less than the design pressure, the test pressure may be reduced to a pressure of 90 percent of the pressure to which the relief valves are adjusted. The above pressure test may be dispensed with except for those using NH_3 or CH_3Cl as refrigerants.

(14) Essential parts of incinerators are to be opened up and internally examined.

3. Electrical equipment

In the Special Survey for electrical equipment, the following requirements are to be conformed to.

(1) Main and emergency switchboards, section panels, and sub-distribution fuse panels are to be examined and overcurrent protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

(2) The generators are to be running under the loaded condition, either separately or in parallel and the performances of speed governors, switches and circuit breakers are to be tested.

(3) The insulation resistances of generators, switchboards, motors, cables and other electrical equipment are to be tested and adjusted if it is found not to comply with the requirements given in **Pt 6, Ch 1, 1801. 1.** However, this test may be dispensed with, where it is found that the measured records remain efficient and they comply with the requirements specified in **Pt 6, Ch 1, 1801. 1.**

(4) Where deemed necessary by the Surveyor, the lighting arrangements, internal communication and signalling systems, mechanical ventilation systems, and other electrical equipment are to be tested for effectiveness.

4. The surveys for water jet propulsion systems and azimuth or rotatable thruster are to be carried out in accordance with the Guidance relating to the Rules.

5. Where CMS specified in **Sec 9** is applied, the performance test for safety devices including the items other than CMS. are to be surveyed.

6. In addition to **Par 1** through **Par 5**, relevant requirements of **Ch 17** are also to be taken if applicable.

Section 5-2 Special Survey (Additional Requirements to Ship Types)

The Special Survey(Additional requirements to ship types), in addition to the requirements for Intermediate Survey, shall be carried out as follows.

1. Oil tankers(including tankers) :

The additional requirements are to be surveyed as follows,

(1) For pump room, in particular, the foundations and gland seals of pumps, stuffing box, sealing arrangements of all penetrations of bulkheads and ventilating arrangements are to be examined.
(2) Condition of the inner surface of the bottom plating in cargo tanks is to be examined in order to ascertain that there is no excessive pitting of the plating.
(3) Bell mouths of the cargo suction pipes in cargo tanks are to be removed to enable examination of the shell plating and bulkheads in that vicinity.
(4) All piping systems in the tanks and spaces, cargo oil pipes on weather deck, breather valves, flame screens on vents, purge systems, gas free systems, inert gas systems and other piping systems are to be examined. When considered necessary by the Surveyor, pressure tests and/or gaugings for pipings are to be carried out.
(5) For inert gas system, the following items are to be examined, when appropriate, opened-up.
    (A) Major parts of inert gas scrubbers.
    (B) Major parts of inert gas blowers.
    (C) Major parts of non-return devices(e.g., deck water seal).
    (D) Major parts of flue gas isolating valves.
    (E) Major parts of P/V breakers.

2. Chemical tankers :

The additional requirements are to be surveyed as follows,

(1) Foundation of cargo containments, including supports, keys and anti-rolling/anti-pitching devices are to be examined.
(2) Closing and sealing devices of the domes of cargo containments, where they penetrate decks are to be examined.
(3) The pumps are to be opened and examined.

3. Lliquefied gas carriers :

The additional requirements are to be surveyed as follows,

(1) Cargo containment survey
    (A) All cargo tanks are to be examined internally.
    (B) Special attention is to be paid to the cargo tank and insulation in way of chocks, supports, keys and other parts which consist of the foundation of tanks. Removal of insulation may be required in order to verify the condition of the tank or the insulation itself if found necessary by the Surveyor. Where the arrangement is such that the insulation cannot be examined, the surrounding structure of the wing tanks, double bottom tanks and cofferdams are to be examined for cold spots when the cargo tanks are in the cold condition unless voyage record together with the instrumentation give sufficient evidence of the integrity of the insulation system.

(C) Non-destructive test
Non-destructive testing is to supplement cargo tank inspection with special attention to be given to the integrity of the main structural members, tank shell and highly stressed parts, including welded connection as deemed necessary by the surveyor. However, this does not mean that non-destructive testing can be dispensed with totally. The following items are, inter alia, considered as highly stressed parts:
- cargo tank supports and anti-rolling/anti-pitching devices
- web frames or stiffening rings
- swash bulkhead boundaries
- dome and stump connections to tank shell
- foundations for pumps, towers, ladders, etc.
- pipe connections

For the independent tank type B, the extent of non-destructive testing shall be given in a programme specially prepared for the cargo tank design.

(D) The tightness of all cargo tanks is to be verified by an appropriate procedure. Provided that the effectiveness of the ships's gas detection equipment has been confirmed, it will be acceptable to utilize this equipment for the tightness test of independent tanks below deck.

(E) Where findings of (A) to (D) or an examination of the voyage records raises doubts as to the structure integrity of a cargo tank, a hydraulic or hydro-pneumatic test is to be carried out. For integral tanks and for independent tank type A and B, the test pressure is to be carried out in accordance with proper pressure based on design of each tank. For independent tank type C, the test pressure is not to be less than 1.25 times the MARVS.

(F) At every other special survey(i.e., 2nd, 4th, 6th, etc) all independent cargo tank type C are to be either:
(a) Hydraulically or hydro-pneumatically tested to 1.25 times MARVS, followed by non-destructive testing in accordance with (C), or
(b) Subjected to a thorough, planned non-destructive testing. This testing is to be carried out in accordance with a programme specially prepared for the tank design. If a special program does not exist, the following applies:
- cargo tank supports and anti-rolling/anti-pitching devices
- stiffening rings
- Y-connections between tank shell and a longitudinal bulkhead of tanks
- swash bulkhead boundaries
- dome and stump connections to the tank shell
- foundations for pumps, towers, ladders etc.
- pipe connections

At least 10 % of the length of the welded connections in each of the above mentioned areas is to be tested. This testing is to be carried out internally and externally as applicable. Insulation is to be removed as necessary for the required non-destructive test.

(2) As far as practicable all hold spaces and hull insulation(if provided), secondary barriers and tank supporting structures are to be visually examined. The secondary barriers is to be checked for their effectiveness by means of a pressure/ vacuum test, a visual inspection or another acceptable method.

(3) Membrane and semi-membrane tank
(A) For membrane and semi-membrane tank system, inspection and testing are to be carried out in accordance with programmes specially prepared in accordance with an approved method for the actual tank system.
(B) For membrane containment systems a tightness test of the secondary barrier shall be carried out in accordance with the system designers’ procedures as approved by the Society.
(C) For membrane containment systems with glued secondary barriers the values obtained shall be compared with previous results or results obtained at newbuilding stage. If significant differences are observed for each tank or between tanks, the Surveyor is to require an evaluation and additional testing as necessary.

(4) The pressure/vacuum relief valve, rupture disc and other pressure relief devices for interbarrier spaces and hold spaces are to be opened, tested and readjusted as necessary, depending on their design.

(5) The pressure relief valves for the cargo tanks are to be opened for examination, adjusted, function tested, and sealed. If the cargo tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are be replaced. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves, including each size and type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since crediting of the previous Special Survey.

(6) Piping systems

(A) The cargo, liquid nitrogen and process piping systems, including valves, actuators, compensators etc. are to be opened for examination as deemed necessary. Insulation is to be removed as deemed necessary to ascertain the condition of the pipes. If the visual examination raises doubt as to the integrity of the pipelines, a pressure test at 1.25 times the MARVS for the pipeline is to be carried out. After reassembly the complete piping systems are to be tested for leaks.

(B) The pressure relief valves are to be function-tested. A random selection of valve is to be opened for examination and adjusted.

(7) Components

Cargo pumps, compressors, process pressure vessels, liquid nitrogen tanks, heat exchangers and other components, including prime movers, used in connection with cargo handling and methane boil-off burning are to be examined.

(8) Miscellaneous

(A) Systems for removal of water or cargo from interbarrier spaces and holds are to be examined and tested as deemed necessary.

(B) All gas-tight bulkhead are to be inspected. The effectiveness of gas-tight shaft sealing is to be verified.

(C) Hose and spool pieces used for segregation of piping systems for cargo, inert gas and bilging are to be examined.

(D) It is to be verified that all cargo piping system are electrically bonded to the hull.

Section 6 Docking Survey

601. Due range

1. There is to be a minimum of two examinations of the outside of the ship's bottom and related items during each five-year Special Survey period. One such examination is to be carried out in conjunction with the Special Survey. In all cases the interval between any two such examinations is not to exceed 36 months.

2. Notwithstanding the requirements specified in **Par 1** above, for passenger ships, submersibles, nuclear ships, hydrofoils, air cushion vehicles, high speed crafts, the docking survey is to be a part of the Special, Intermediate or Annual Survey. But the Docking Survey may be subject to the requirements as provided separately by the Society.

3. In addition to **Par 1** through **Par 2**, relevant requirements of **Ch 17** are also to be taken if applicable.

602. Extension of survey

The Docking Survey may be extended upon the request of the Owner as follows:

1. Where the Special Survey is extended in accordance with **401. 1** and **2**, an extension of Docking Survey can be granted in accordance with the requirements specified in **401. 1** (4).

2. An extension of Docking Survey of 3 months beyond the due date can be granted upon the approval of the Society in exceptional circumstances defined in **401. 1.**

603. Requirements of survey

1. The ship is to be placed in a drydock or on a slipway, and it is to be placed on blocks of sufficient height and with the necessary staging to permit the examination of elements such as shell plating including bottom and bow plating, stern frame and rudder, sea chests and valves, propeller, etc.

2. The shell plating is to be examined for excessive corrosion, or deterioration due to chafing or contact with the ground and for any undue unfairness or buckling. Special attention is to be paid to bilge keels.

3. Rudder, rudder pintles, rudder shafts and couplings and stern frame are to be examined. If considered necessary by the Surveyor, the rudder is to be lifted or the inspection plates removed for the examination of pintles. The clearance in the rudder bearings is to be ascertained and recorded. If it exceeds the values given below, the bush is to be adjusted. Where applicable, pressure test of the rudder may be required as deemed necessary by the Surveyor.

Pintle (Diameter of Pintle : d_p)	Allowable clearance
$d_p \leq$ 50 mm	3.0 mm
50 mm < $d_p \leq$ 100 mm	5.0 mm
100 mm < d_p	0.01 d_p + 4.0 mm
Neck bearing (Diameter of rudder stock : d_s)	0.01 d_s + 2.0 mm

4. Sea chests and their gratings, sea connections and overboard discharge valves and cocks and their fastenings to the hull or sea chests are to be examined. Valves and cocks could be opened up at Docking Survey as a part of Special Survey unless considered necessary by the Surveyor.

5. The propeller is to be examined. The efficiency of the oil gland, if fitted, is to be ascertained and clearance or weardown in the stern bush are to be measured. For controllable pitch propellers and special type propellers, the sealing and tightness conditions are to be ascertained and recorded. In the case where the pitch control device is fitted, it is to be ascertained that the device is in good working order. However, if considered necessary by the Surveyor, the device is to be opened up for further examination.

6. Visible parts of side thrusters and anti-rolling devices are to be examined.

7. The clearance between the propeller shaft and the after bearing of stern tube or the shaft bracket bearing is to be measured for water-lubricated stern tube bearings, and if it exceeds the values given below, the lignumvitae bush is to be adjusted. Stern tube shafts are also to be comply with these requirements.

Diameter of propeller shaft D_p	Allowable clearance
$D_p \leq$ 230 mm	6.0 mm
230 mm $< D_p \leq$ 305 mm	8.0 mm
305 mm $< D_p$	9.5 mm

8. The surveys for water jet propulsion systems and azimuth or rotatable thruster are to be carried out in accordance with the Guidance relating to the Rules.

9. A mooring trial is to be carried out to attending Surveyor's satisfaction to confirm satisfactory operation of main and auxiliary machinery. If significant repairs are carried out to main or auxiliary machinery or steering gear, consideration is to be given to a sea trial to attending Surveyor's satisfaction.

10. For ships with IWS notation, the requirements to assign the IWS notation specified in **604. 3.** (8) are to be confirmed for continuing compliance.

11. For ships with EDD notation, the requirements to assign the EDD notation specified in **605. 2.** are to be confirmed for continuing compliance.

604. In-water survey

1. The Society may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on ships less than 15 years of age. Special consideration of the Society is to be given to ships of 15 years of age or over before being permitted to have such In-water Survey. For ships with ESP notation exceeding 15 years of age, such In-water Surveys are not to be allowed.

2. In-water Survey in lieu of the Docking Survey may be restricted at the discretion of the Society if there are record or indication of abnormal deterioration, existing outstanding recommendation for repairs, or damage to underwater part of the shell plating, the rudder, the propeller, the propeller shaft, sea connections or overboard discharge valves.

3. Where an In-water Survey in lieu of the intermediate docking between Special Surveys is desired, the survey procedures are as follows:

(1) Plans and documents
The following plans and documents are to be submitted to the Surveyor and the divers.
(a) Plans of shell plating below waterline showing the location and sizes of shell openings, location of bottom plugs, location of appendages, location of measuring position of navigation instruments, location of bilge keels, location of water-tight and oil-tight bulkheads, and location of welded seams and butts including any doublers and straps.
(b) Detailed information or drawing of constructions and arrangements indicated in (2) below.

(2) Constructions, arrangements, etc.
Where an In-water Survey in lieu of the docking survey is desired, the following construction and arrangements are to be made.
(a) Rudder arrangements are to be such that rudder pintle clearances can be checked.
(b) Rope-guard ring plates are to be of such construction as to facilitate the inspection of shaftings between propeller hubs and stern frame boss.
(c) In case of water lubricated stern tube bearings, the construction is to be suitable for confirmation and measurement of the clearance between the propeller shafts and these bearings.
(d) In case of oil lubricated stern tube bearings, suitable means of ascertaining the performances of stern tube bearings including oil sealing devices are to be provided.

(3) Condition of survey
(a) In the lightest draught condition as possible.
(b) The condition of hull below waterline and hull bottom is can be ascertained.
(c) The sea state conditions such as current, visibility, swell, etc., at the location of the survey are to be calm and peaceful.
(d) The distance between hull bottom and sea bottom is to be enough.
(e) In-water Survey are to be carried out by a company approved by the Society.

(4) Survey extent
(a) The In-water Survey is to provide the information normally obtained from a Docking Survey. Special consideration shall be given to ascertaining rudder bearing clearances and stern bush clearances of oil stern bearings based on a review of the operating history, on board testing and stern oil sample reports. These considerations are to be included in the proposals for In-water Survey which are to be submitted in advance of the survey so that satisfactory arrangements can be agreed with the Society.
(b) General inspection for sea connections and overboard discharge valves, at inside of the ship

(5) Practice of In-water Survey
(a) In-water Survey is to be carried out in the presences of the Surveyor and the Owner.
(b) All preparations required for an In-water Survey are to be made by the Owner.
(c) The Surveyor shall confirm the preparation for survey and the operational condition of In-water Survey equipment.
(d) The Surveyor shall know the status of the ship in advance, and inform the diver before diving of survey items and measurement.
(e) The means are to be provided to maintain good communication between the Surveyor and the underwater diver at all times.
(f) The Surveyor may confirm the status of survey by in-water photographs, cameras, television monitors and other means.
(g) In a job site, the results of In-water Survey shall be immediately reported to the Owner, and the Owner and diver sign their names on the Diving Report, confirming the result.

(6) Diving report
The following items are to be stated in the diving report.
(a) Name of diving company
(b) Name of diver and licence No.
(c) Date and place of survey
(d) Name of equipment used in In-water Survey
(e) Name of ship, classification character and notations, gross tonnage, port of registry, owner of ship
(f) Drafts(forward and aft)
(g) Contents and results of survey(damage configuration and status, etc.)
(7) Further surveys
(a) The Surveyor may require the further examination such as internal examinations, thickness measurement, etc. where deemed necessary by the Surveyor as a result of the In-water Survey
(b) If the result of In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the ship be dry-docked in order that a detailed survey can be undertaken and the necessary repairs carried out.
(8) For a ship with IWS of additional special feature notation, the following requirements are to be complied with, in addition to the requirements specified in preceding (1) to (7).
(a) The plans and documents specified in (1) and (b) to (d) below are to be submitted to the Society for approval, and are to be kept on board.
(b) Anodes are to be attached in such a manner as to be easily replaced when necessary.
(c) To the shell plating below load waterline, provision is to be made for ready identification of the position of bulkhead.
(d) Ships contracted for construction or intended to have IWS notation newly, on or after 1 July 2011, are to be complied with the following requirements additionally.
(i) A suitable means of ascertaining the position and identity of each blade of the propellers are to be provided.
(ii) Hinged gratings are to be installed on all sea chests and constructed so as to facilitate opening and closing by the diver.
(iii) Markings indicating the position of longitudinal and transverse bulkheads and the names of interior spaces, sea suction and overboard discharge openings on the shell plating below the load water line are to be provided so that the diver is able to orient his/her position relative to the ship. Such markings may be consist of a weld bead or center punch, and a contrasting color coating. Other suitable arrangements or means may be considered as equivalent where deemed appropriate by the Society.

605. Extended Dry-docking Interval System

1. General

(1) The "Extended Dry-docking Interval System" is in any case subject to approval by the relevant flag state. The approval or acceptance of this rule by the relevant flag state doesn't means the approval for the application of Extended Dry-docking Interval System on the relevant ship, and the separate approval by the each relevant flag state is required for the application of Extended Dry-docking Interval System.
(2) The "Extended Dry-docking Interval System" applies to ships with Container Ship notation or Cargo Ship notation and General Dry Cargo Ships specified in **Sec 14.**
(3) In application to **601. 1**, at the request of the Owners, where deemed appropriate by the Society considering survey history, damage history and coating conditions, etc. it is possible until the ship reaches 15 years of age to perform the first and second Docking Survey due from the completion date of the Classification Survey during Construction or the completion date of the previous Docking Survey as an In-water Survey, and the third Docking Survey has to be performed in dry-dock or on a slipway within 7.5 years from the completion date of the Classification Survey during Construction or the completion date of the previous Docking Survey.
(4) The Owner can apply to join the "Extended Dry-docking Interval System" before the date on which the ship reaches 10 years of age. When the Owner applied to join the "Extended Dry-docking Interval System" after the No.1 Special Survey and the Docking Survey assigned between 10 years to 15 years of age has carried out in dry-dock or on a slipway, the next Docking Surveys can be carried out as Docking Survey and In-water Survey alternately start with In-water Survey.
(5) In the case of a change in Owner or flag, the application of the "Extended Dry-docking Interval System" is to be reconsidered and a Docking Survey may be assigned or required immediately.
(6) The Society reserves the right to suspend the "Extended Dry-docking Interval System" at any time if it is determined that a dry-docking is necessary.
(7) The EDD notation shall be assigned as an additional special feature notation to ships carrying out the "Extended Dry-docking Interval System".

2. Necessary requirements

The necessary requirements for implementation of the "Extended Dry-docking Interval System" are as followings.

(1) To be applied the Owner's Hull Inspection and Maintenance Program according to **Annex 1-13** of the Guidance
(2) Ships contracted for construction on or after 1 July 2010 and classed through the Classification Survey during Construction are to have IWS notation according to **604. 3** (8), and the other ships can be carried out the In-water Survey according to **604. 2** and **3.**
(3) To have STCM(stern tube condition monitoring) notation according to **704.** Ships not assigned STCM notation are to be fitted with a shaft bearing and sealing system of approved design with implementation of regular monitoring procedures
(4) To be applied the Planned Maintenance System of machinery according to **903.**
(5) For ships contracted for construction on or after 1 July 2011, the dry film thickness(DFT) of the coating system for shell plating below the load water line excluding antifouling for the shell plating is to be more than 300 μm and for the other ships it is to be more than 250 μm. In addition, the anodes are to be fitted and/or the impressed cathodic current protection system are to be installed and maintained.
(6) In lieu of (5) above, the Society may accept the other coating system provided that the coating manufacturer proves with relevant documents that the coating system applied are designed to last for the 7.5 years.
(7) Ballast tanks shall have a corrosion prevention system and to be maintained in GOOD coating condition.
(8) The hull below load waterline is to be free of any recommendation.

3. Approval and survey

(1) Documents and approval

For implementation of the "Extended Dry-docking Interval System" the following documents shall be presented to the Society. The Society will issue an approval document for the "Extended Dry-docking Interval System" after review the presented documents. This approval document is to be placed on-board.

(A) Application for “Extended Dry-docking Interval System"

(B) Description of the system for the "Extended Dry-docking Interval System" with flow charts of the system organization within the company

(C) Plans and/or information showing the ship is satisfy to the necessary requirements for the "Extended Dry-docking Interval System" specified in **Par 2** above including the followings

(a) Manual for the Hull Inspection and Maintenance Program according to **Annex 1-13** of the Guidance

(b) Inspection procedures for In-water Survey

(c) Procedure for stern tube condition monitoring

(d) Certificate of planned maintenance system for machinery

(e) Coating system for shell plating below the load water line

(D) Other documents as deemed necessary by the Society

(2) Implementation survey

(A) Additional to the approval according to (1) above, the implementation survey is to be carried out within one year from the date of the approval of the "Extended Dry-docking Interval System" to verify that the "Extended Dry-docking Interval System"is implemented in accordance with the approval document.

(B) During the implementation survey, the attending Surveyor is to check the following items.

(a) An approval document for the "Extended Dry-docking Interval System"

(b) Documents specified in **Par 3** (1) (B) to (D)

(c) Whether the Master is familiar with the "Extended Dry-docking Interval System"

(d) A random check for compliance of the necessary requirements specified in **Par 2** above including the followings.

- Check whether the Owner's Hull Inspection and Maintenance Program specified in **Annex 1-13** of the Guidance is operated satisfactorily.
- Check the stern tube condition monitoring
- Check the planned maintenance system for machinery
- Check the impressed cathodic current protection system, if fitted

(3) Annual audit

(A) An annual audit is to be carried out to check the operation of the "Extended Dry-docking System" at Annual Survey

(B) At the annual audit the attending Surveyor is to check the following items.

(a) An approval document for the "Extended Dry-docking Interval System"

(b) Documents specified in **Par 3** (1) (B) to (D)

(c) Whether the Master is familiar with the "Extended Dry-docking Interval System"

(d) Check for compliance of the necessary requirements specified in **Par 2** above including the followings.

- Check whether the Owner's Hull Inspection and Maintenance Program specified in **Annex 1-13** of the Guidance is operated satisfactorily and confirmation of random compartments
- Check the stern tube condition monitoring
- Check the planned maintenance system for machinery
- Check the impressed cathodic current protection system, if fitted

Section 7 Surveys of Propeller Shaft and Stern Tube Shaft, Etc.

701. Due range

1. Propeller shafts Kind 1(including stern tube shafts, etc.) are to be surveyed with an interval of 5 years from the completion date of the previous survey.

2. Propeller shafts Kind 2(including stern tube shafts, etc.) are to be surveyed with an interval not exceeding 30 months from the completion date of the previous survey.

3. The surveys for water jet propulsion systems and azimuth or rotatable thruster are to be carried out in accordance with the Guidance relating to the Rules.

4. Upon the request of the Owner, the survey of propeller shaft(including stern tube shaft, etc.) may be postponed for a period not exceeding 6 months from the due date.

702. Ordinary survey items

1. After drawn out the propeller shaft from the stern tube bearings, parts of the propeller shaft, sleeves, fillets of coupling flange connected to the intermediate shaft and the coupling bolts are to be examined.

2. The stern tube bearings are to be examined and bearing weardown is to be measured.

3. Major parts of the stern tube sealing devices are to be opened and examined.

4. After the propeller is removed, the following examinations for the propeller shaft, in way of the propeller fitting area, is to be carried out:

(1) For shafts with keyed propeller, examination is to be carried out by an efficient crack detection method for the after end of the cylindrical part of the shaft(or from the after end of the liner, if any), and for about one-third of the length of the taper from the big end.

(2) For shafts with keyless propeller, examination is to be carried out by an efficient crack detection method for the forward part of the aft shaft taper. And when the propeller is force-fitted, the pull-up length is to be in accordance with the Guidance relating to the Rules.

(3) For shafts having coupling flanges at the after end, the flange fillet and coupling bolts are to be examined by an efficient crack detection method.

5. Propeller and propeller boss bore in way of the propeller shaft taper is to be examined. Pitch control gear and working parts for a controllable pitch propeller are to be examined and propeller blade fixing bolts are to be examined by an efficient crack detection method.

6. Where the water-lubricated stern tube bearings are adopted, the sea water piping for lubrication is to be examined.

7. Where the oil-lubricated stern tube bearings are adopted, low oil level alarms of lubricating oil tanks, oil temperature measuring devices and oil circulating pumps are to be confirmed in good operating condition, and lubricating oil records are to be examined.

703. Extension of Propeller Shaft Survey

1. Upon the request of the owner, where the propeller shaft is Kind 1 type fitted with oil-lubricated stern tube bearings and oil sealing gland and provided that new oil seals are able to be fitted without removal of the propeller(except in case of keyed propeller), instead of the survey specified in **702.**, after survey of the following items, the survey interval may be prolonged for not more than 5 years from the due date but not to be applied twice consecutively. However, where the results of the following surveys are not satisfactory, all the surveys required in **702.** with the drawn shaft are to be carried out.

(1) The shaft is to be drawn partially to expose the aft bearing contact area of the shaft for the examination. However, it may be exempted where stern tube bearing temperature and oil consumption are recorded and considered to be within permissible limits, and data of lubricating oil analysis in accordance with the Guidance relating to the Rules are satisfactory.
(2) The forward bearing is to be examined as far as possible and all accessible parts of the shaft including the propeller connection to the shaft is to be examined.
(3) Visual examination to confirm the good condition of oil sealing gland is to be carried out. And clearance or wear down of the aft bearing(or the after end of the strut bearing, if any) is to be measured.
(4) For shafts with keyed propeller, examination is to be carried out by an efficient crack detection method for about one-third of the length of the taper from the big end after removal of the propeller.

2. Upon the request of the owner, where the propeller shaft is Kind 1 type fitted with oil-lubricated stern tube bearings and oil sealing gland and provided that new oil seals are able to be fitted without removal of the propeller(except in case of keyed propeller), the following survey without drawing the propeller shaft may be carried out and after finding the good results, the survey interval may be prolonged for not more than 30 months from the due date but to be applied only once.

(1) Oil sealing devices of stern tube
(2) Measurement of clearance or wear down of the aft bearing(or the after end of the strut bearing, if any)
(3) For shafts with keyed propeller, examination is to be carried out by an efficient crack detection method for the forward part of the taper after removal of the propeller.

704. Survey for ships with STCM(Stern Tube Condition Monitoring) notation

Upon the request of the owner, an additional notation of STCM may be assigned provided that an approved oil-lubricated stern tube bearings comply with the following requirements. And if the Surveyor confirms at the periodical survey that parameters in the condition monitoring records are within permissible limits, the examination of this survey may be carried out without withdrawal of the shaft and omitted the requirements given in **702. 1** to **3** above. However, where the results of the surveys are not satisfactory, all the surveys required in **702.** with the drawn shaft are to be carried out.

(1) Regularly at intervals lubricating oil analysis specified separatedly is to be carried out.
(2) Lubricating oil consumption is to be recorded.
(3) At the aft stern tube bearing, two temperature sensors are to be provided, or if only one temperature senor is provided, a spare temperature sensor which can be replaced easily is to be provided when the using sensor is out of order.
(4) Aft stern tube bearing temperatures are to be recorded.
(5) Measurement of bearing weardown is to be provided.
(6) Oil seals devices are to be renewed without removal of propeller.

Section 8 Boiler Survey

801. Due range

1. The following boilers(including thermal oil heaters) are to be internally examined minimum twice during each 5 year Special Survey period. In all cases the interval between any two such examinations is not to exceed 36 months.

(1) Water tube boilers used for propulsion, including reheat boilers
(2) All other boilers of essential service
(3) Boilers of non-essential service having working pressure exceeding 3.5 bar and a heating surface exceeding 4.5 m^2

2. For main boilers with smoke tube type or single main boiler with water tube type which are over 7.5 years of age, the surveys are to be carried out within 3 months before or after every year.

802. Survey items

1. The surveys of boilers are to be carried out as follows, and where deemed necessary by the Surveyor, the parts of lagging are to be removed and inspected. Where deemed necessary by the Surveyor, further surveys may be required.

(1) At each survey, the boilers, superheaters and economizers are to be examined internally on water-steam side and fire side. Boiler mountings and safety valves are to be examined at each survey and opened out as considered necessary by the Surveyor.
(2) The adjustment of the safety valves is to be verified during each boiler internal survey. Boiler safety valve and relieving gear are to be examined and tested to verify satisfactory operation. However, for exhaust gas heated economizers, if steam cannot be raised at port, the safety valves may be set by the Chief Engineer at sea, and the results recorded in the log book for review by the Surveyor.
(3) Review of the following records since the last Boiler Survey is to be carried out as part of the survey:
(a) Operation
(b) Maintenance
(c) Repair history
(d) Feedwater chemistry

2. An extension of the internal examination of the boiler(including thermal oil heaters) up to 3 months beyond the due date can be granted in exceptional circumstance defined in **401. 1.** The extension may be granted by the Surveyor after the following is satisfactorily carried out:

(1) External examination of the boiler
(2) Boiler safety valve relieving gear is to be examined and operationally tested
(3) Boiler protective devices operationally tested
(4) Review of the following records since the last boiler Survey:
(a) Operation
(b) Maintenance
(c) Repair history
(d) Feedwater chemistry

3. In addition to the other requirements **Par 1** above(internal examination) in exhaust gas heated economizers of the shell type, all accessible welded joints are to be subjected to a visual examination for cracking. Non-destructive Testing may be required as deemed necessary by the Surveyor.

4. The surveys of thermal oil heaters are to be carried out as follows. Where deemed necessary by the Surveyor, further surveys may be required.

(1) The tightness of the installation to flange connections and valves and packings is to be examined.
(2) The coils in the oil fired furnace are to be externally examined.
(3) Plant instrumentation including regulation and safety systems is to be examined and tested.
(4) Liquid relief valves are to be examined, and the pressure is to adjusted.
(5) For thermal oil heater tubes heated by exhaust gas, hydraulic testing to the design pressure is to be carried out.
(6) Fuel oil equipment are to be examined.

Section 9 Continuous Survey of Machinery

901. Due range

1. At the request of the Owner, and upon approval of the proposed arrangements by the Society, continuous survey of machinery(hereafter referred to as "CMS") may be undertaken for all the items of machinery installations to be surveyed at the Special Survey in accordance with the Guidance relating to the Rules. When such a system is adopted, all the requirements of the Special Survey are to be surveyed in regular rotation, as far as practicable, with uniform annual share within 5 year period and to be completed.

2. CMS is to be carried out at the time of or during the periodical survey. However, at the request of the owner, CMS may be carried out as an Occasional Survey.

902. Survey items

1. The procedure of CMS is to be complied with the Guidance relating to the Rules.

2. Where any machinery installations were overhauled and inspected by the Chief Engineer the overhauled inspections may substitute for the CMS in accordance with the Guidance relating to the Rules. However, for each part of the main internal combustion engine and internal combustion engine to drive main generator among machinery permissible for the Chief Engineer's inspection, open-up survey by the Surveyor for at least one of two CMS cycles is to be carried.

3. If any defects of the CMS is found, further examinations of overhauling are to be carried out where deemed necessary by the Surveyor.

4. For passenger ships, the CMS is to be complied with the Guidance relating to the Rules.

5. The CMS is to be commenced after the classification of Ships to the Society in accordance with the Guidance relating to the Rules.

6. The withdrawal of CMS is to be complied with the requirements of the Guidance relating to the Rules.

903. Planned Maintenance System

1. At the request of the Owner, where deemed appropriate by the Society in accordance with the Guidance relating to the Rules, the Planned Maintenance System(hereinafter referred to as "PMS") may be applied by the maintenance procedures scheme as an alternative to the Continuous Machinery Survey(CMS). But passenger ships shall not apply to PMS and the Society may consider a special application for PMS on ships exceeding 15 years old based on their condition. However, where deemed necessary by the Surveyor, the overhaul inspection of the equipment may be required.

2. PMS certificate is to be issued and the inspection based on the PMS may be carried out by the chief engineer certified by this Society. The implementation survey and annual audit are to be in accordance with the requirements of the Guidance relating to the Rules.

3. In case the ship under PMS, the condition monitoring equipments(hereinafter referred to as "CM"). approved by the Society shall be in accordance with the Guidance relating to the Rules.

4. The damage and repairs for PMS are to be in accordance with the requirements of the Guidance relating to the Rules.

5. The withdrawal of PMS is to be in accordance with the requirements of the Guidance relating to the Rules.

6. Where there is change of ship management or shipowner, the approved PMS may be reconsidered.

Section 10 Occasional Survey

1001. Occasional Survey

All classed ships are to be subjected to Occasional Surveys when they fall under either of the following conditions at the periods other than those of Special, Intermediate, or Annual Survey:

(1) When main parts of hull or machinery, or important fittings or equipment which have been surveyed by the Society, have been damaged, or are about to be repaired or altered.
(2) When whole or a part of machinery are about to be shifted.
(3) When safety valves are opened up or when settings of safety valves is altered.
(4) When propeller shafts are drawn out and the survey of the shaft is requested by the Owner.
(5) When load lines are required to be changed or to be newly marked.
(6) Other cases where surveys are designated or whenever survey is deemed necessary by the Surveyor.
(7) When the due dates of surveys are to be postponed.

1002. Items of survey

1. In the Occasional Surveys, the necessary parts are to be examined in each case of **1001.**

2. When a ship is in drydock or on a slipway, the requirements specified in **603. 9** are applicable.

Section 11 Alteration Survey

1101. Alteration survey

All classed ships are to be subjected to survey when hull, machinery, or equipment are about to be altered.

1102. Approval of plans

When it is intended to obtain a surveys for alterations, plans and documents equivalent to the survey during construction are to be submitted to the Society for the approval before the work is commenced.

1103. Items of survey

1. In the surveys for alterations, the altered parts are to be examined in accordance with the survey items equivalent to the survey during construction.

2. Where a complete replacement or addition of a major portion of the ship(e.g. forward section, after section, main cargo section) is involved at the alteration, the Date of Build(i.e. the year, month and date at which the alteration survey is completed) associated with each altered major portion of the ship shall be indicated in the Certificate of Classification in addition to the Date of Build assigned to the ship, and survey requirements for each altered major portion of the ship shall be based on this Date of Build. Such survey due dates may be aligned with ships survey due date at the discretion of the Society.

Section 12 Survey of Ships Carrying Dangerous Goods and Other Special Cargoes

1201. Surveys

For surveys of ships carrying dangerous goods and other special cargoes, the Society may request to apply, in addition to the Rules, *Korean Ship Safety Act*, related international conventions and other regulations as deemed appropriate.

Section 13 Additional Installations Survey

1301. Surveys

The surveys for additional installations(cargo refrigerating installations, cargo handling appliances, centralized monitoring and control system for main propulsion and essential auxiliary machinery, operating systems for periodically unattended machinery spaces, automation equipment, dynamic positioning system, navigation bridge systems and hull monitoring systems, etc.) are to be carried out in accordance with the requirements specified in **Pt 9**, etc.

Section 14 Hull Surveys for General Dry Cargo Ships

1401. General

1. Application

(1) In addition to the other requirements specified in **Ch 2**, the requirements apply to all self-propelled general dry cargo ships of 500 GT and above carrying solid cargoes other than:
- Bulk Carriers and Double Skin Bulk Carriers subjects to the enhanced survey programme(ESP)
- dedicated container carriers
- dedicated forest product carriers(not timber or log carriers)
- Ro-Ro cargo ships
- refrigerated cargo ships
- dedicated wood chip carriers
- dedicated cement carriers
- livestock carriers
- deck cargo ship(A ship that is designed to carry cargo exclusively above deck without any access for cargo below deck)

However, the requirements specified in **1402. 7** and **1404. 7** also apply to those cargo ships, which, although belonging to the ship types listed above that are excluded from the application of this requirements, are fitted with a single cargo hold.

(2) The requirements apply to surveys of hull structure and piping systems in way of the following spaces;
(A) cargo holds, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo area
(B) all ballast tanks

(3) The requirements contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional Close-up Survey when necessary.

2. Definitions

A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom and hopper side plating, longitudinal bulkheads and bottom plating in top wing tanks. For transversely framed vessels, a transverse section includes adjacent frames and their end connections in way of transverse sections.

3. Procedures for thickness measurements

(1) The required thickness measurements, if not carried out by the Society itself, are to be witnessed by a Surveyor. The Surveyor is to be on board to the extent necessary to control the process. In this case, the control of thickness measurement process is to be in accordance with the separate requirements specified by the Society.
(2) The thickness measurement company is to be part of the survey planning meeting to be held prior to commencing the survey.
(3) Thickness measurements of structures in areas where Close-up Surveys are required shall be carried out simultaneously with Close-up Surveys.
(4) The thickness measurements are to be carried out by a company certified by the Society.
(5) A thickness measurement report is to be prepared. The report is to give the location of measurements, the thickness measured as well as corresponding original thickness. Furthermore, the report is to give the date when the measurements were carried out, type of measurement equipment, names of personnel and their qualifications and has to be signed by the operator.
(6) The Surveyor is to review the final thickness measurement report and countersign the cover page.

1402. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull, hatch covers, coamings and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of weather deck, hatch covers and coamings

(1) Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.
(2) Where mechanically operated steel covers are fitted, checking the satisfactory condition of:
   (a) hatch covers; including Close-up Survey of hatch cover plating
   (b) tightness devices of longitudinal, transverse and intermediate cross joints(gaskets, gasket lips, compression bars, drainage channels)
   (c) clamping devices, retaining bars, cleating, chain or rope pulleys
   (d) guides, guide rails, track wheels and stoppers, etc.
   (e) wires, chains, gypsies, tensioning devices
   (f) hydraulic system essential to closing and securing
   (g) safety locks and retaining devices
(3) Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition where applicable of:
   (a) wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices
   (b) steel pontoons
   (c) tarpaulins
   (d) cleats, battens and wedges
   (e) hatch securing bars and their securing devices
   (f) loading pads/bars and the side plate edge
   (g) guide plates and chocks
   (h) compression bars, drainage channels and drain pipes(if any)
(4) Checking the satisfactory condition of hatch coaming plating and their stiffeners including Close-up Survey.
(5) Random checking of the satisfactory operating of mechanically operated hatch covers is to be made including:
   (a) stowage and securing in open condition
   (b) proper fit and efficiency of sealing in closed condition
   (c) operational testing of hydraulic and power components, wires, chains and link drives

Note : For survey of air pipes, flame screens on the open ends of air pipes and ventilations refer to **202. 1** (1) (f) to (h) and (6).

4. Suspect areas

Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the Annual Survey is credited as completed.

5. Examination of cargo holds

The examination of cargo holds in Annual Survey is to be in accordance with the follows.

	10 years < age ≤ 15 years[3]	15 years < age[1), 2), 3)]
Overall Survey	· One forward cargo hold (and their associated 'tween deck spaces, where fitted) · One after cargo hold (and their associated 'tween deck spaces, where fitted)	All cargo hold (and their associated 'tween deck spaces, where fitted)
Close-up Survey	-	1. Cargo holds: · one forward lower cargo hold · one other lower cargo hold 2. Extent: · Close-up examination of sufficient extent, minimum 25 % of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating
Others	-	All piping and penetrations in cargo holds, including overboard piping, are to be examined

(NOTES)
1) Where the protective coating in cargo holds, as applicable, is found to be in GOOD condition, the extent of Close-up Surveys may be specially considered.
2) Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a Close-up Survey of all of the shell frames and adjacent shell plating of those cargo holds and associated 'tween deck spaces(as applicable) as well as a Close-up Survey of sufficient extent of all remaining cargo holds and 'tween deck spaces(as applicable).
3) When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements is to be carried out before the Annual Survey is credited as completed.

6. Examination of ballast tanks

Examination of ballast tanks when required as a consequence of the results of the Special Survey and Intermediate Survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the Annual Survey is credited as completed.

7. Additional Annual Survey requirements for single hold cargo ships (See 1401. 1 (1)) after determining compliance with SOLAS II-1/23-3 and II-1/25

For ships complying with the requirements of SOLAS II-1/23-3 and II-1/25 for hold water level detectors, the Annual Survey is to include an examination and a test, at random, of the water ingress detection system and of their alarms.

1403. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **301.**
(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.
(3) A survey planning meeting is to be held prior to the commencement of the survey.
(4) Ships over 15 years of age, the following is to apply:
  (a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **1404.**, except for item 2. c) in column for Special Survey No. 4 and Subsequent of **Table 1.2.9**. (Caution : In this case, the requirements specified in **403.** are not need to be applied) However, tank testing specified in **1404. 6**, survey of automatic air pipe heads(See Notes in **1404. 1** (6) and **1404. 4** (4)) and internal examination of fuel oil, lube oil and fresh water tanks(See **1404. 4** (1)) are not required unless deemed necessary by the attending Surveyor.
  (b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application **401. 4** and **5**.
  (c) In lieu of the requirements of **1404. 1** (7), an under water survey may be considered as equivalent.

2. Examination of ballast tanks

The examination of ballast tanks in Intermediate Survey is to be in accordance with the follows.

5 years < age ≤ 10 years[1), 2), 3)]	10 years < age ≤ 15 years[1), 3)]	15 years < age
· Overall Survey of representative ballast tanks · Survey of suspect areas found at previous surveys in accordance with the requirements specified in **1402. 4.**	· Overall Survey of all ballast tanks · Survey of suspect areas found at previous surveys in accordance with the requirements specified in **1402. 4.**	**1403. 1** (4) to be applied

(NOTES)
1) If such Overall Survey reveals no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient.
2) Where POOR coating condition, soft or semi-hard coating, corrosion or other defects are found in ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type.
3) In ballast tanks other than double bottom ballast tanks, where a hard protective coating is found in POOR condition, and it is not renewed, where soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual intervals. When such breakdown of hard protective coating is found in double bottom ballast tanks, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied, the tanks in question may be examined at annual intervals. When considered necessary by the attending Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

3. Examination of cargo holds

The examination of cargo holds in Intermediate Survey is to be in accordance with the follows.

5 years < age ≤ 10 years	10 years < age ≤ 15 years[1]	15 years < age
· Overall Survey of one forward and one after cargo hold(and their associated 'tween deck spaces, where fitted) · Survey of suspect areas found at previous surveys in accordance with the requirements specified in **1402. 4.**	· Overall Survey of all cargo holds(and their associated 'tween deck spaces, where fitted) · Survey of suspect areas found at previous surveys in accordance with the requirements specified in **1402. 4.**	**1403. 1** (4) to be applied
(NOTES) 1) When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the survey is credited as completed.		

1404. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **401.**
(2) A survey planing meeting is to be held prior to the commencement of the survey.
(3) The Special Survey is to include, in addition to the requirements of the Annual Surveys, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in (5), are in a satisfactory condition and is fit for the intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(4) All cargo holds, ballast tanks, including double bottom tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in **Par 5** and **Par 6**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(5) All piping systems within the spaces specified in (4) above are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.
(6) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.
Note : For survey of automatic air pipe heads refer to **403. 1** (17).
(7) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.
Note : Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.
However, ships subject to the "Extended Dry-docking Interval System" specified in **605.**, this survey in dry dock can be carried out in accordance with **605.**

2. Tank protection

(1) Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom ballast tanks, where a hard protective coating is found in POOR condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary be the Surveyor.
(2) When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(3) Where the hard protective coating in spaces is found to be in a GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.

3. Hatch covers and coamings

In addition to the requirements in **1402. 3** of the Annual Survey, the following items are to be surveyed.

(1) Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:
(a) stowage and securing in open condition
(b) proper fit and efficiency of sealing in closed condition
(c) operational testing of hydraulic and power components, wires, chains and link drives
(2) Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent is to be carried out.
(3) Thickness measurement of the hatch cover and coaming plating and stiffeners is to be carried out as given in **Table 1.2.9.**

4. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces, excluding fuel oil, lube-oil and fresh water tanks, is to be carried out at each Special Survey.
Note : For fuel oil, lube oil and fresh water tanks, reference is to be made to **Table 1.2.3.**
(2) The minimum requirements for Close-up Surveys at Special Surveys are given in **Table 1.2.8.**
(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.
(4) For areas in spaces where hard protective coatings are found in a GOOD condition, the extent of Close-up Surveys according to **Table 1.2.8** may be specially considered.
Note : For examination of automatic air pipe heads, reference is to be made to **Table 1.2.7.**

5. Extent of thickness measurement

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.2.9.**
(2) Representative thickness measurement to determine both general and local levels of corrosion in the shell frames and their end attachments in all cargo holds and ballast tanks is to be carried out. Thickness measurement is also to be carried out to determine the corrosion levels on the transverse bulkhead plating. The thickness measurements may be dispensed with provided the Surveyor is satisfied by the Close-up Survey, that there is no structural diminution, and the hard protective coating where applied remains efficient.
(3) The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements.
(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to **Table 1.2.9** may be specially considered.
(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

6. Extent of tank testing

(1) All boundaries of ballast tanks and deep tanks used for water ballast within the cargo length area are to be pressure tested. For fuel oil tanks within the cargo length area, representative tanks are to be pressure tested.
(2) The Surveyor may extend the tank testing as deemed necessary.
(3) Tank testing of fuel oil tanks is to be carried out with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be spacially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

7. Additional Special Survey requirements for single hold cargo ships (See 1401. 1 (1)) after determining compliance with SOLAS II-1/23-3 and II-1/25

For ships complying with the requirements of SOLAS II-1/23-3 and II-1/25 for hold water level detectors, the Special Survey is to include an examination and a test of the all water ingress detection system and of their alarms.

Table 1.2.8 Minimum requirements for Close-up Survey at Special Survey of General Dry Cargo Ships

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Selected shell frames in one forward and one aft cargo hold and associated 'tween deck spaces (*1)	1. Selected shell frames in all cargo holds and 'tween deck spaces (*1)	1. All shell frames in the forward lower cargo hold and 25 % frames in each of the remaining cargo holds and 'tween deck spaces including upper and lower end attachments and adjacent shell plating (*1)	1. All shell frames in all cargo holds and 'tween deck spaces including upper and lower end attachments and adjacent shell plating (*1)
2. One selected cargo hold transverse bulkhead (*2)	2. One transverse bulkhead in each cargo hold (*2)	2. All cargo hold transverse bulkheads (*2)	2. All cargo hold transverse bulkheads (*2)
	3. Forward and aft transverse bulkhead in one side ballast tank, including stiffening system (*2)	3. All transverse bulkheads in ballast tanks, including stiffening system (*2)	3. All transverse bulkheads in ballast tanks, including stiffening system (*2)
	4. One transverse web with associated plating and framing in two representative ballast tanks of each type (i.e. topside, hopper side, side tank or double bottom tank) (*3)	4. All transverse webs with associated plating and framing in each ballast tank (*3)	4. All transverse webs with associated plating and framing in each ballast tank (*3)
3. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)	5. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)	5. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)	5. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)
	6. Selected areas of all deck plating and underdeck structure inside line of hatch openings between cargo hold hatches (*5)	6. All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches (*5)	6. All deck plating and underdeck structure inside line of hatch openings between cargo hold hatches (*5)
	7. Selected areas of inner bottom plating (*6)	7. All areas of inner bottom plating (*6)	7. All areas of inner bottom plating (*6)

(NOTES)
1) (*1) to (*6) means as follows and are illustrated in **Annex 1-6** of the Guidance:
(*1) Cargo hold transverse frames
(*2) Cargo hold transverse bulkhead plating, stiffeners and girders
(*3) Transverse web frame or watertight transverse bulkhead in ballast tanks
(*4) Cargo hold hatch covers and coamings
(*5) Deck plating and underdeck structure inside line of hatch openings between cargo hold hatches
(*6) Inner bottom plating
2) Close-up Survey of cargo hold transverse bulkheads is to be carried out at the following levels:
· Immediately above the inner bottom and immediately above the 'tween decks, as applicable
· Mid-height of the bulkheads for holds without 'tween decks
· Immediately below the main deck plating and 'tween deck plating

Table 1.2.9 Minimum requirements for thickness measurements at Special Survey of General Dry Cargo Ships

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas	1. Suspect areas	1. Suspect areas	1. Suspect areas
	2. One transverse section of deck plating in way of a cargo length area within the amidships 0.5 L	2. Two transverse sections within the amidships 0.5 L in way of two different cargo spaces	2. Within the cargo length area: 1) A minimum of three transverse sections within the amidships 0.5 L 2) Each deck plate outside line of cargo hatch openings 3) Each bottom plate, including lower turn of bilge 4) Duct keel or pipe tunnel plating and internals
	3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.8**	3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.8**	3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.8**
		4. Within the cargo length area, each deck plate outside line of cargo hatch openings	
		5. All wind and water strakes within the cargo length area	4. All wind and water strakes full length
		6. Selected wind and water strakes outside the cargo length area	

(NOTES)
1) Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.
2) For ships less than 100 meters in length, the number of transverse sections required at Special Survey No. 3 may be reduced to one and the number of transverse sections at Special Survey No. 4 and subsequent surveys may be reduced to two.

Section 15 Hull Surveys for Liquefied Gas Carriers

1501. General

1. Application

(1) In addition to the other requirements specified in **Ch 2**, the requirements apply to all self-propelled ships carrying liquefied gases in bulk.

(2) The requirements apply to surveys of hull structure and piping systems, except piping covered by **204. 3, 304. 3** and **Sec 5-2, 3**, in way of the following spaces;

(A) pump rooms, compressor rooms, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo area

(B) all ballast tanks

Refer to **204. 3, 304. 3** and **Sec 5-2, 3** for periodical surveys of cargo carriage and handling installations

(3) The requirements contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional Close-up Survey when necessary.

2. Definitions

(1) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom and longitudinal bulkheads.

(2) **Cargo area** is that part of the ship which contains cargo tanks, cargo/ballast pump-rooms, compressor rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.

3. Procedures for thickness measurements

(1) The required thickness measurements, if not carried out by the Society itself, are to be witnessed by a Surveyor. The Surveyor is to be on board to the extent necessary to control the process. In this case, the control of thickness measurement process is to be in accordance with the separate requirements specified by the Society.

(2) The thickness measurement company is to be part of the survey planning meeting to be held prior to commencing the survey.

(3) Thickness measurements of structures in areas where Close-up Surveys are required shall be carried out simultaneously with Close-up Surveys.

(4) The thickness measurements are to be carried out by a company certified by the Society.

(5) A thickness measurement report is to be prepared. The report is to give the location of measurements, the thickness measured as well as corresponding original thickness. Furthermore, the report is to give the date when the measurements were carried out, type of measurement equipment, names of personnel and their qualifications and has to be signed by the operator.

(6) The Surveyor is to review the final thickness measurement report and countersign the cover page.

1502. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of weather deck

(1) Examination of flame screens on the open ends of air pipes to all bunker tanks.
(2) Examination of bunker and vent piping systems.

4. Examination of cargo pump rooms and compressor rooms and, as far as practicable, pipe tunnels if fitted

(1) Examination of all pump room and compressor room bulkheads for signs of leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room and compressor room bulkheads.
(2) Examination of the condition of all piping systems, except those covered by **204. 3, 304. 3** and **Sec 5-2, 3.**

Note : For survey of air pipes, flame screens on the open ends of air pipes and ventilations refer to **202. 1** (1) (f) to (h) and (6).

5. Suspect areas

Suspect areas identified at previous surveys are to be examined. Thickness measurements are to be taken of the areas of substantial corrosion and the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the Annual Survey is credited as completed.

6. Examination of ballast tanks

Examination of ballast tanks when required as a consequence of the results of the Special Survey and Intermediate Survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, then the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements. These extended thickness measurements are to be carried out before the Annual Survey is credited as completed.

1503. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **301.**
(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.
(3) A survey planning meeting is to be held prior to the commencement of the survey.

2. Examination of ballast tanks

(1) The Overall Survey of ballast tanks in Intermediate Survey is to be in accordance with the follows.

5 years < age ≤ 10 years1), 2), 3)	10 years < age1), 3)
Overall Survey of representative ballast tanks	Overall Survey of all ballast tanks
(NOTES) 1) If such examinations reveals no visible structural defects, the examination may be limited to a verification that the corrosion prevention system remains efficient. 2) If there is no hard protective coating, soft or semi-hard coating or POOR coating condition, the examination is to be extended to other ballast tanks of the same type. 3) For ballast tanks, excluding double bottom ballast tanks, if there is no hard protective coating, soft or semi-hard coating, or POOR coating condition and it is not renewed, the tanks in question are to be internally examined at annual intervals. 4) When such conditions as above 3) are found in double bottom ballast tanks, the tanks in question may be internally examined at annual intervals.	

(2) The minimum requirements for Close-up Survey of ballast tanks in Intermediate Survey is to be in accordance with the follows.

10 years < age ≤ 15 years	15 years < age
Close-up Survey of: 1. all web frames and both transverse bulkheads in a representative ballast tank (*1) and (*2) 2. the upper part of one web frame in another representative ballast tank 3. one transverse bulkhead in another representative ballast tank (*2)	Close-up Survey of: 1. all web frames and both transverse bulkheads in two representative ballast tanks (*1) and (*2)
(NOTES) 1) (*1) and (*2) mean as follows; (*1) : Complete transverse web frame including adjacent structural members (*2) : Transverse bulkhead complete, including girder system and adjacent structural members, and adjacent longitudinal bulkhead structure 2) Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted. 3) For areas in tanks where protective coatings are found to be in GOOD condition, the extent of Close-up Surveys may be specially considered by the Society. 4) For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of Close-up Surveys may be specially considered by the Society. 5) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases: - in particular, in tanks having structural arrangements or details which have suffered defects in similar tanks, or on similar ships according to available information; - in tanks having structures approved with reduced scantlings.	

1504. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **401.**
(2) A survey planing meeting is to be held prior to the commencement of the survey.
(3) The Special Survey is to include, in addition to the requirements of the Annual Surveys, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in (5), are in a satisfactory condition and is fit for the intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(4) Ballast tanks, including double bottom tanks, pump rooms, compressor rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in **Par 4** and **Par 5**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(5) All piping systems within the spaces specified in (4) above, except those covered by **204. 3, 304. 3** and **Sec 5-2, 3**, are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.
(6) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.
Note : For survey of automatic air pipe heads refer to **403. 1** (17).
(7) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.
Note : Lower portions of the ballast tanks are considered to be the parts below light ballast water line.

2. Tank protection

(1) Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom ballast tanks, where a hard protective coating is found in POOR condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary be the Surveyor.
(2) When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(3) Where the hard protective coating in ballast tanks is found to be in a GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.

3. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces, excluding fuel oil, lube-oil and fresh water tanks, is to be carried out at each Special Survey.
Note : For fuel oil, lube oil and fresh water tanks, reference is to be made to **Table 1.2.3.**
(2) The minimum requirements for Close-up Surveys at Special Surveys are given in **Table 1.2.10.**
(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and where tanks have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.
(4) For areas in tanks where hard protective coatings are found in a GOOD condition, the extent of Close-up Surveys according to **Table 1.2.10** may be specially considered.
Note : For examination of automatic air pipe heads, reference is to be made to **Table 1.2.7.**

4. Extent of thickness measurement

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.2.11.**

(2) The Surveyor may extend the thickness measurements as deemed necessary. When thickness measurements indicate substantial corrosion, the extent of thickness measurements is to be increased to determine the extent of areas of substantial corrosion. **Table 1.2.5** may be used as guidance for these additional thickness measurements.

(3) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to **Table 1.2.11** may be specially considered.

(4) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

5. Extent of tank testing

(1) All boundaries of ballast tanks and deep tanks used for water ballast within the cargo area are to be pressure tested. For fuel oil tanks within the cargo length area, representative tanks are to be pressure tested.

(2) The Surveyor may extend the tank testing as deemed necessary.

(3) Tank testing of fuel oil tanks is to be carried out with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be spacially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

Table 1.2.10 Minimum requirements for Close-up Survey at Special Survey of Liquefied Gas Carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3 and Subsequent
1. One web frame in a representative ballast tank of the topside, hopper side and double hull side type (*1)	1. All web frame in a ballast tank, which is to be a double hull side tank or a topside tank. If such tanks are not fitted, another ballast tank is to be selected. (*1) 2. One web frame in each remaining ballast tank (*1)	1. All web frames in all ballast tanks (*1)
	3. One transverse bulkhead in each ballast tank (*2)	2. All transverse bulkheads in all ballast tanks (*2)
2. One transverse bulkhead in a ballast tank (*3)		

(NOTES)

1) (*1) to (*3) mean as follows and the typical midship sections of liquefied gas carriers are illustrated in **Annex 1-6** of the Guidance.
   (*1) : Complete transverse web frame including adjacent structural members
   (*2) : Transverse bulkhead complete, including girder system and adjacent structural members, and adjacent longitudinal bulkhead structure
   (*3) : Transverse bulkhead lower part including girder system and adjacent structural members
2) Ballast tanks include topside, double hull side, double bottom, hopper side, or any combined arrangement of the aforementioned, and peak tanks where fitted.
3) For areas in tanks where protective coatings are found to be in GOOD condition, the extent of Close-up Surveys may be specially considered by the Society.
4) For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of Close-up Surveys may be specially considered by the Society.
5) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:
   - in particular, in tanks having structural arrangements or details which have suffered defects in similar tanks, or on similar ships according to available information;
   - in tanks having structures approved with reduced scantlings.

Table 1.2.11 Minimum requirements for thickness measurements at Special Survey of Liquefied Gas Carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas	1. Suspect areas	1. Suspect areas	1. Suspect areas
2. One section of deck plating for the full beam of the ship within 0.5 L amidships in way of a ballast tank, if any	2. Within the cargo area: 1) Each deck plate 2) One transverse section within 0.5 L amidships in way of a ballast tank, if any	2. Within the cargo area: 1) Each deck plate 2) Two transverse sections[1)] 3) All wind and water strakes	2. Within the cargo area: 1) Each deck plate 2) Three transverse sections[1)] 3) Each bottom plate 4) Duct keel plating and internals
	3. Selected wind and water strakes outside the cargo area	3. Selected wind and water strakes outside the cargo area	3. All wind and water strakes, full length
3. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.10**	4. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.10**	4. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.10**	4. Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey according to **Table 1.2.10**

(NOTES)
1) At least one section is to include a ballast tank within 0.5 L amidships, if any.
2) For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of thickness measurements may be increased to include the tank top plating at the discretion of the Surveyor.
3) For areas in spaces where protective coatings are found to be in GOOD condition, the extent of thickness measurements may be specially considered by the Society.
4) The Surveyor may extend the thickness measurements as deemed necessary. Where substantial corrosion is found, the extent of thickness measurements is to be increased to the satisfaction of the Surveyor.

Section 16 Additional Requirements

1601. Strength and securing of small hatches, fittings and equipment on the fore deck

1. Ships that are described in **Pt 4, Ch 9, 101. 1** that are contracted for construction on or after 1 January 2004 are to comply with the requirements specified in **Pt 4, Ch 9** by the time of delivery.

2. Ships described in **Pt 4, Ch 9, 101. 2** that are contracted for construction prior to 1 January 2004 are to comply with the requirements specified in **Pt 4, Ch 9.**

(1) For ships which will be 15 years of age or more on 1 January 2004 by the due date of the first Intermediate or Special Survey after that date;
(2) For ships which will be 10 years of age or more on 1 January 2004 by the due date of the first Special Survey after that date;
(3) For ships which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.

3. Ships described in **Pt 4, Ch 9, 101.**, contracted for construction prior to 1 July 2007, are to comply with the requirements specified in **Pt 4, Ch 9, 201.** of the Guidance relating to the Rules by the relevant compliance date specified in **Par 1** or **Par 2** above, or by the due date of the first Special Survey after 1 July 2007, whichever is later. Completion prior to 1 July 2007 of a Special Survey with a due date after 1 July 2007 cannot be used to postpone compliance.

1602. Water level detectors on single hold cargo ships other than bulk carriers

Among the ships subject to the requirements specified in **Pt 7, Ch 3, 1402. 2,** ships constructed before 1 January 2007 shall comply with the requirements specified in **Pt 7, Ch 3, 1403. 3** not later than the date of the first Intermediate or Special Survey of the ship to be carried out after 1 January 2007, whichever comes first, but not later than 31 December 2009.

Section 17 Special Requirements for Ships Subject to Korean Ship Safety Act

1701. Special requirements

1. In application to **202. 2**(Fire-extinguishing appliances at Annual Survey), **302. 2**(Fire-extinguishing appliances at Intermediate Survey) and **404.**(Fire-extinguishing appliances at Special Survey), the survey for fire-extinguishing appliances is to be in accordance with the relevant requirements of *Korean Ship Safety Act*.

2. In application to **301.**(Intermediate Survey), Intermediate Surveys for Ships of 24 m in length and above and over 30 years after launching date(except fishing vessels) are to be carried out within 3 months before or after each anniversary date.

3. At the Intermediate Survey according to **Par 2** above, the following relevant requirements are applied only at the Intermediate Survey carried out within 3 months before or after the second or third anniversary date from the completion date of the previous Special Survey in accordance with **301.**

(1) **1403.**
(2) **1503.**
(3) **Ch 3, 201. 1** (3), (4), (6) and **203.**
(4) **Ch 3, 303.**
(5) **Ch 3, 403.**
(6) **Ch 3, 503.**
(7) **Ch 3, 603.**

4. At the Intermediate Survey according to **Par 2** above, the surveys in **303.**(Machinery, electrical installations and additional installations at Intermediate Survey) **Par 1** to **Par 4** are applied only at the Intermediate Survey carried out within 3 months before or after the second or third anniversary date from the completion date of the previous Special Survey in accordance with **301.**

5. In application to **303.**(Machinery, electrical installations and additional installations at Intermediate Survey), spare parts for ships are to be examined.

6. In application to **Pt 9, Ch 2**(Cargo handling appliances), the cargo handling appliances, except cargo ramps, of safe working load not less than 1 ton are to be included.

7. When a Korean flagged Deep-Sea Fishing Vessel(except for factory ship or carrier) approved for pelagic fishing by the Korean Government, at the time of Annual or Intermediate Survey, is not at the location where the survey can be taken due to the fishing operation in foreign waters, the relevant survey may be postponed within 12 months from the anniversary date through the approval of the Society. ⚓

CHAPTER 3 HULL SURVEYS OF SHIPS SUBJECT TO THE ENHANCED SURVEY PROGRAMME

Section 1 General

101. Application

1. In addition to the requirements specified in **Ch 2,** these requirements apply to hull surveys of ships subject to the enhanced survey programme such as **bulk carriers, oil tankers** and **chemical tankers,** etc.

2. Procedural requirements for certain ESP surveys

The objective of these requirements are to improve the quality of surveys. Taking into consideration, the size of vessels and scope of surveys for vessels noted below, it is more effective to have more than one Surveyor examine the required spaces, holds or tanks and to provide mutual support and consultation during the surveys in recommending repairs and actions required for conditions of class/recommendations.

(1) On ships 20,000 DWT and above, subject to ESP, starting with Special Survey No. 3, all special and intermediate hull classification surveys are to be carried out by at least two exclusive Surveyors. On bulk carriers 100,000 DWT and above of single side skin construction the intermediate hull classification survey between 10 and 15 years of age is to be performed by two exclusive Surveyors.

(2) This requires that at least two exclusive Surveyors attend on board at the same time to perform the required survey. Where compatible with relevant laws and regulations, on dual class vessels, the requirement for two Surveyors may be fulfilled by having one Surveyor attend from each Society.

(3) Though each attending Surveyor is not required to perform all aspects of the required survey, they are required to consult with each other and to do joint Overall and Close-up Surveys to the extent necessary to determine the condition of the vessel. The extent of these surveys should be sufficient for the Surveyors to agree on actions required to complete the survey with respect to renewals, repairs, and other recommendations or conditions of class. Each Surveyor is required to co-sign the survey report or indicate their concurrence in an equivalent manner.

(4) The following surveys may be witnessed by a single Surveyor;

- Thickness measurements in accordance with **Ch 2, 109**. of the Rules
- Tank testing in accordance with the applicable **Ch 3** of the Rules
- Repairs carried out in association with intermediate and special hull classification survey, the extent of which have been agreed upon by the required two Surveyors during the course of the surveys

(5) Surveyors used to fulfill this requirements are to be qualified in the survey processes involved.

(6) The onboard attendance of the Surveyors is to be documented according to the separate requirements specified by the Society.

102. Preparations for survey

1. Survey programme

(1) The Owner in cooperation with the Society is to work out a specific survey programme prior to the commencement of any part of:
- the Special Survey
- the Intermediate Survey for ships subject to the enhanced survey programme over 10 years of age.

The survey programme is to be in a written format, based on the information in **Annex 1-3, Table 1** of the Guidance. The survey is not to commence until the survey programme has been agreed.

The survey programme at Intermediate Survey may consist of the survey programme at the previous Special Survey supplemented by the executive hull summary of that Special Survey and later relevant survey reports. The survey programme is to be worked out taking into account any amendments to the survey requirements implemented after the last Special Survey carried out.

Prior to the development of the survey programme, the survey planning questionnaire is to be completed by the Owner based on the information set out in **Annex 1-3, Table 2** of the Guidance, and forwarded to the Society.

(2) In developing the survey programme, the following documentation is to be collected and consulted with a view to selecting cargo holds/tanks, tanks, areas, and structural elements to be examined:

(A) Bulk carriers and double skin bulk carriers
(a) Survey status and basic ship information
(b) Documentation on-board, as described in **103. 2** and **3**
(c) Main structural plans(scantling drawings), including information regarding use of high tensile steels(HTS)
(d) Relevant previous survey and inspection reports from both the Society and the Owner
(e) Information regarding the use of the ship's holds and tanks, typical cargoes and other relevant data
(f) Information regarding corrosion prevention level on the new building
(g) Information regarding the relevant maintenance level during operation

(B) Oil tankers, chemical tankers and double hull oil tankers
(a) Survey status and basic ship information
(b) Documentation on-board, as described in **103. 2** and **3**
(c) Main structural plans of cargo and ballast tanks(scantling drawings), including information regarding use of high tensile steels(HTS), clad steel and stainless steel(for chemical tankers)
(d) Executive hull summary
(e) Relevant previous damage and repair history
(f) Relevant previous survey and inspection reports from both the Society and the Owner
(g) For oil tankers and double hull oil tankers cargo and ballast history for the last 3 years, including carriage of cargo under heated conditions, for chemical tankers information regarding the use of the ship's tanks, typical cargoes and other relevant data
(h) Details of the inert gas plant and tank cleaning procedures
(i) Information and other relevant data regarding conversion or modification of the ship's cargo and ballast tanks since the time of construction
(j) Description and history of the coating and corrosion prevention system, if any
(k) Inspections by the Owner’s personnel during the last 3 years with reference to structural deterioration in general, leakages in tank boundaries and piping and condition of the coating and corrosion prevention system, if any
(l) Information regarding the relevant maintenance level during operation including port state control reports of inspection containing hull related deficiencies, Safety Management System non-conformities relating to hull maintenance, including the associated corrective action(s)
(m) Any other information that will help identify suspect areas and critical structural areas

(3) The submitted survey programme is to include relevant information including at least:
  (A) Bulk carriers and double skin bulk carriers
    (a) Basic ship information and particulars
    (b) Main structural plans(scantling drawings), including information regarding use of high tensile steels(HTS)
    (c) Plan of tanks and holds
    (d) List of tanks and holds with information on use, protection and condition of coating
    (e) Conditions for survey(e.g., information regarding hold and tank cleaning, gas freeing, ventilation, lighting, etc.)
    (f) Provisions and methods for access to structures
    (g) Equipment for surveys
    (h) Nomination of hold and tanks and areas for Close-up Survey
    (i) Nominations of sections and areas for thickness measurement
    (j) Nomination of tanks for tank pressure testing
    (k) Damage experience related to the ship in question
  (B) Oil tankers, chemical tankers and double hull oil tankers
    (a) Basic ship information and particulars
    (b) Main structural plans of cargo and ballast tanks(scantling drawings), including information regarding use of high tensile steels(HTS), clad steel and stainless steel(for chemical tankers)
    (c) Arrangement of tanks
    (d) List of tanks with information on their use, extent and condition of coatings and corrosion prevention systems
    (e) Conditions for survey(e.g., information regarding tank cleaning, gas freeing, ventilation, lighting, etc.)
    (f) Provisions and methods for access to structures
    (g) Equipment for surveys
    (h) Nomination of tanks and areas for Close-up Survey
    (i) Nomination of areas and sections for thickness measurement
    (j) Nomination of tanks for tank pressure testing and the pipes that are to undergo pipe pressure testing as per **404. 6** (for chemical tankers)
    (k) Identification of the thickness measurement company
    (l) Damage experience related to the ship in question
    (m) Critical structural areas and suspect areas, where relevant

(4) The Society will advise the Owner of the maximum acceptable structural corrosion diminution levels applicable to the vessel.

(5) Use may also be made of the process contained in **Annex 1-3, Par 1** of the Guidance in conjunction with the preparation of the required survey programme. This process is a recommended tool which may be invoked at the discretion of the Society, when considered necessary and appropriate.

2. Conditions for survey

(1) The Owner is to provide the necessary facilities for a safe execution of the survey.
   (A) In order to enable the attending Surveyors to carry out the survey, provisions for proper and safe access are to be agreed between the Owner and the Society.
   (B) Details of the means of access are to be provided in the survey planning questionnaire.
   (C) In cases where the provisions of safety and required access are judged by the attending Surveyor(s) not to be adequate, the survey of the spaces involved is not to proceed.

(2) Cargo holds, tanks and spaces are to be safe for access. Cargo holds, tanks and spaces are to be gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

(3) In preparation for survey and thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues etc. to reveal corrosion, deformation, fractures, damages, or other structural deterioration as well as the condition of the coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of the areas to be renewed.

(4) Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration as well as the condition of the coating.

(5) Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

(6) The Surveyor(s) are to always be accompanied by at least one responsible person, assigned by the Owner, experienced in tank and enclosed spaces inspection. In addition a backup team of at least two experienced persons is to be stationed at the hatch opening of the tank or space that is being surveyed. The back-up team is to continuously observe the work in the tank or space and is to keep lifesaving and evacuation equipment ready for use.

(7) A communication system is to be arranged between the survey party in the cargo hold, tank or space being examined, the responsible officer on deck and, as the case may be, the navigation bridge. The communication arrangements are to be maintained throughout the survey.

3. Access to structures

(1) For Overall Survey, means are to be provided to enable the Surveyor to examine the hull structure in a safe and practical way.

(2) For Close-up Survey(for bulk carriers(except double skin bulk carriers), Close-up Survey of the hull structure, other than cargo hold shell frames), one or more of the following means for access, acceptable to Surveyor, is to be provided:
   (A) permanent staging and passages through structures
   (B) temporary staging and passages through structures
   (C) lifts and movable platforms
   (D) boats or rafts
   (E) portable ladders
   (F) other equivalent means

(3) For Close-up Surveys of the cargo hold shell frames of bulk carriers(except double skin bulk carriers) less than 100,000 DWT, one or more of the following means for access, acceptable to the Surveyor, is to be provided:
   (A) permanent staging and passage through structures
   (B) temporary staging and passage through structures
   (C) portable ladder restricted to not more than 5 m in length may be accepted for surveys of lower section of a shell frame including bracket
   (D) hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
   (E) boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water
   (F) other equivalent means

(4) For Close-up Surveys of the cargo hold shell frames of bulk carriers(except double skin bulk carriers) 100,000 DWT and above, the use of portable ladders is not accepted, and one or more of the following means for access, acceptable to the Surveyor, is to be provided:
 (A) Annual Surveys, Intermediate Survey under 10 years of age and Special Survey No. 1
  (a) permanent staging and passage through structures
  (b) temporary staging and passage through structures
  (c) hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
  (d) boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water
  (e) other equivalent means
 (B) Subsequent Intermediate Surveys and Special Surveys
  (a) either permanent or temporary staging and passage through structures for Close-up Survey of at least the upper part of hold frames
  (b) hydraulic arm vehicles such as conventional cherry pickers for surveys of lower and middle part of shell frames as alternative to staging
  (c) lifts and movable platforms
  (d) boats or rafts provided the structural capacity of the hold is sufficient to withstand static loads at all levels of water
  (e) other equivalent means
 Notwithstanding the above requirements, the use of a portable ladder fitted with a mechanical device to secure the upper end of the ladder is acceptable for the "close-up examination of sufficient extent, minimum 25 % of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating of the forward cargo hold" at Annual Survey, required in **202. 4**(10 years < age ≤ 15 years, Close-up Survey), and the "one other selected cargo hold" required in **202. 4**(15 years ≤ age, Close-up Survey).

4. Equipment for survey

(1) Thickness measurement is normally to be carried out by means of ultrasonic test equipment. The accuracy of the equipment is to be proven to the Surveyor as required.
(2) One or more of the following fracture detection procedures may be required if deemed necessary by the Surveyor:
 (A) radiographic equipment
 (B) ultrasonic equipment
 (C) magnetic particle equipment
 (D) dye penetrant
(3) Explosimeter, oxygen-meter, breathing apparatus, lifelines, riding belts with rope and hook and whistles together with instructions and guidance on their use are to be made available during the survey. A safety check-list is to be provided.
(4) Adequate and safe lighting is to be provided for the safe and efficient conduct of the survey.
(5) Adequate protective clothing is to be made available and used during the survey(e.g. safety helmet, gloves, safety shoes, etc.).

5. Survey at sea or at anchorage

(1) Survey at sea or at anchorage may be accepted provided the Surveyor is given the necessary assistance from the personnel onboard. Necessary precautions and procedures for carrying out the survey are to be in accordance with **Par 1, Par 2, Par 3** and **Par 4** above.

(2) A communication system is to be arranged between the survey party in the tank or space under examination and the responsible officer on deck. This system is to also include the personnel in charge of ballast pump handling if boats or rafts are used.

(3) Surveys of tanks or applicable holds by means of boats or rafts may only be undertaken with the agreement of the Surveyor, who is to take into account the safety arrangements provided, including weather forecasting and ship response under foreseeable conditions and provided the expected rise of water within the tank or hold does not exceed 0.25 m.

(4) When rafts or boats are used for Close-up Survey the following conditions are to be observed.

(A) only rough duty, inflatable rafts or boats, having satisfactory residual buoyancy and stability even if one chamber is ruptured, are to be used.

(B) the boat or raft is to be tethered to the access ladder and an additional person is to be stationed down the access ladder with a clear view of the boat or raft.

(C) appropriate lifejackets are to be available for all participants.

(D) the surface of water in the tank or hold is to be calm(under all foreseeable conditions the expected rise of water within the tank or hold is not to exceed 0.25 m) and the water level stationary. On no account is to the level of the water be rising while the boat or raft is in use.

(E) the tank, hold or space must contain clean ballast water only. Even a thin sheen of oil or cargo on the water is not acceptable.

(F) at no time is the water level to be allowed to be within 1 m of the deepest under deck web face flat so that the survey team is not isolated from a direct escape route to the tank hatch. Filling to levels above the deck transverses is only to be contemplated if a deck access manhole is fitted and open in the bay being examined, so that an escape route for the survey party is available at all times. Other effective means of escape to the deck may be considered.

(G) if the tanks(or spaces) are connected by a common venting system, or inert gas system, the tank in which the boat or raft is to be used is to be isolated to prevent a transfer of gas from other tanks(or spaces).

(5) Rafts or boats alone may be allowed for inspection of the under deck areas for tanks or spaces, if the depth of the webs is 1.5 m or less.

(6) If the depth of the webs is more than 1.5 m, rafts or boats alone may be allowed only:

(A) when the coating of the under deck structure is in GOOD condition and there is no evidence of wastage; or

(B) if a permanent means of access is provided in each bay to allow safe entry and exit. This means:

(a) access direct from the deck via a vertical ladder and a small platform fitted approximately 2 m below the deck in each bay; or

(b) access to deck from a longitudinal permanent platform having ladders to deck in each end of the tank. The platform shall, for the full length of the tank, be arranged in level with, or above, the maximum water level needed for rafting of under deck structure. For this purpose, the ullage corresponding to the maximum water level is to be assumed not more than 3 m from the deck plate measured at the midspan of deck transverses and in the middle length of the tank. (For oil tankers, chemical tankers and double hull oil tankers, see **Fig 1.3.1**)

If neither of the above conditions are met, then staging or an "other equivalent means" is to be provided for the survey of the under deck areas.

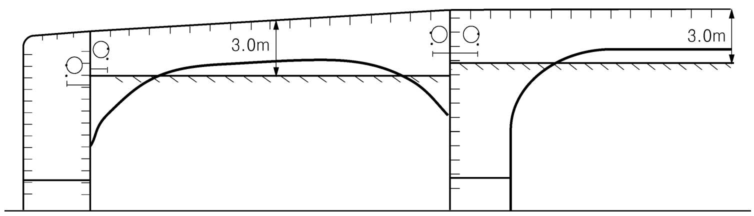


Fig 1.3.1

(7) The use of rafts or boats alone in (5) and (6) above does not preclude the use of boats or rafts to move about within a tank during a survey.

6. Survey planning meeting

(1) The establishment of proper preparation and close co-operation between the attending Surveyor(s) and the Owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board safety meetings are to be held regularly.

(2) Prior to the commencement of any part of the Special and Intermediate Survey, a survey planning meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company operator(as applicable) and the master of the ship or an appropriately qualified representative appointed by the master or company for the purpose to ascertain that all the arrangements envisaged in the survey programme are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out.

(3) The following is an indicative list of items that are to be addressed in the meeting.

(A) schedule of the vessel(i.e. the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations, etc.)

(B) provisions and arrangements for thickness measurements(i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety)

(C) extent of the thickness measurements

(D) acceptance criteria

(E) extent of Close-up Survey and thickness measurement considering the coating condition and suspect areas/areas of substantial corrosion

(F) execution of thickness measurements

(G) taking representative readings in general and where uneven corrosion/pitting is found

(H) mapping of areas of substantial corrosion

(I) communication between attending Surveyor(s) the thickness measurement company operator(s) and Owner representative(s) concerning findings

103. Documentation on board

1. General

(1) The Owner is to obtain, supply and maintain on board documentation as specified in **Par 2** and **Par 3** below, which is to be readily available for the Surveyor.
(2) The documentation is to be kept on board for the life time of the ship.

2. Survey report file

(1) A survey report file is to be a part of the documentation on board consisting of
   (A) Reports of structural surveys
   (B) Executive hull summary
   (C) Thickness measurement reports
(2) The survey report file is to be available also in the Owner's and the Society's management offices.

3. Supporting documents

The following additional documentation is to be available onboard.
(1) Main structural plans of cargo (holds) and ballast tanks
(2) Previous repair history
(3) Cargo and ballast history
(4) Extent of use of inert gas plant and tank cleaning procedures
(5) The Owners inspection report with reference to
   (A) structural deterioration in general
   (B) leakages in bulkheads and piping
   (C) condition of corrosion prevention system, if any
(6) Any other information that will help identify critical structural areas and/or suspect areas requiring inspection
(7) Survey programme as required in **102. 1** until such time as the Special Survey or Intermediate Survey, as applicable, has been completed

4. Review of documentation on board

Prior to survey, the Surveyor is to examine the completeness of the documentation onboard, and its contents as a basis for the survey.

104. Procedures for thickness measurements

1. General

(1) The required thickness measurements, if not carried out by the Society itself, are to be witnessed by a Surveyor. The Surveyor is to be on board to the extent necessary to control the process. In this case, the control of thickness measurement process, review, verification and record of attendance are to be in accordance with the separate requirements specified by the Society.
(2) The thickness measurement company is to be part of the survey planning meeting to be held prior to commencing the survey.
(3) Thickness measurements of structures in areas where Close-up Surveys are required shall be carried out simultaneously with Close-up Surveys.
(4) In all cases the extent of the thickness measurements is to be sufficient as to represent the actual average condition.
(5) The thickness measurements are to be carried out by a qualified company certified by the Society.

2. Reporting

(1) A thickness measurement report is to be prepared. The report is to give the location of measurements, the thickness measured as well as corresponding original thickness. Furthermore, the report is to give the date when the measurements were carried out, type of measurement equipment, names of personnel and their qualifications and has to be signed by the operator. The thickness measurement report is to follow the principles as specified in **Annex 1-5** of the Guidance.
(2) The Surveyor is to review the final thickness measurements report and countersign the cover page.

105. Reporting and evaluation of survey

1. Evaluation of survey report

(1) The data and information on the structural condition of the vessel collected during the survey is to be evaluated for acceptability and continued structural integrity of the vessel.
(2) In case of oil tankers(including double hull oil tankers) of 130 m in length and upwards(as defined in **Pt 3, Ch 1, 103.**), the ship's longitudinal strength is to be evaluated by using the thickness of structural members measured, renewed and reinforced, as appropriate, during the Special Survey carried out after the ship reached 10 years of age in accordance with the criteria for longitudinal strength of the ship's hull girder for oil tankers specified in the separate requirements specified by the Society. However, the only thickness measurement records which have been measured within one(1) year period from the date of the longitudinal strength evaluation shall be considered valid.
(3) The final result of evaluation of the ship's longitudinal strength required (2) above, after renewal or reinforcement work of structural members, if carried out as a result of initial evaluation, is to be reported as a part of the executive hull summary.

2. Reporting

An executive hull summary of the survey and results is to be issued to the Owner and placed on board the vessel for reference at future surveys. The executive hull summary is to be endorsed by the Society.

3. When a survey is split between different survey stations, a report is to be made for each portion of the survey. A list of items examined and/or tested(pressure testing, thickness measurements etc.) and an indication of whether the item has been credited, are to be made available to the next attending Surveyor(s), prior to continuing or completing the survey.

Section 2 Bulk Carriers

201. General

1. Application

(1) In addition to the requirements specified in **Ch 2**, the requirements apply to surveys of hull structure and piping systems in way of the following spaces for all bulk carriers with ESP notation other than double skin bulk carriers as defined in **601. 2** (1).

(a) cargo holds, cofferdams, pipe tunnels, void spaces and fuel oil tanks within the cargo length area

(b) all ballast tanks

(2) The requirements contain the minimum extent of examination, thickness measurement and tank testing. The survey is to be extended when Substantial Corrosion and/or structural defects are found and include additional Close-Up Survey when necessary.

(3) Ships, specified in **Pt 7, Annex 7-5, 1** of the Guidance, which are required to comply with IACS UR S19(Evaluation of Scantlings of the Transverse Watertight Corrugated Bulkhead between Cargo Holds Nos. 1 and 2, with Cargo Hold No.1 Flooded, for Existing Bulk Carriers) are subject to the additional thickness measurement guidance contained in **Annex 1-5, Table 9** of the Guidance with respect to the vertically corrugated transverse watertight bulkhead between cargo hold Nos.1 and 2 for purpose of determining compliance with UR S19 prior to the relevant compliance deadline stipulated in UR S23(Implementation of IACS UR S19 and S22 for Existing Single Side Skin Bulk Carriers) as following and at subsequent Intermediate Surveys(for ships over 10 years of age) and Special Surveys for purpose of verifying continuing compliance with UR S19.

(A) For ships which were 20 years of age or more on 1 July 1998, by the due date of the first Intermediate or the due date of the first Special Survey to be held after 1 July 1998, whichever comes first, the compliance with the requirements specified in **Pt 7, Annex 7-5** of the Guidance is to be confirmed.

(B) For ships which were 15 years of age or more but less than 20 years of age on 1 July 1998, by the due date of the first Special Survey to be held after 1 July 1998, but not later than 1 July 2002, the compliance with the requirements specified in **Pt 7, Annex 7-5** of the Guidance is to be confirmed.

(C) For ships which were 10 years of age or more but less than 15 years of age on 1 July 1998, by the due date of the first Intermediate, or the due date of the first Special Survey to be held after the date on which the ship reaches 15 years of age but not later than the date on which the ship reaches 17 years of age, the compliance with the requirements specified in **Pt 7, Annex 7-5** of the Guidance is to be confirmed.

(D) For ships which were 5 years of age or more but less than 10 years of age on 1 July 1998, by the due date, after 1 July 2003, of the first Intermediate or the first Special Survey after the date on which the ship reaches 10 years of age, whichever occurs first, the compliance with the requirements specified in **Pt 7, Annex 7-5** of the Guidance is to be confirmed.

(E) For ship which were less than 5 years of age on 1 July 1998, by the date on which the ship reaches 10 years of age, the compliance with the requirements specified in **Pt 7, Annex 7-5** of the Guidance is to be confirmed.

(F) Completion prior to 1 July 2003 of an Intermediate or Special Survey with a due date after 1 July 2003 cannot be used to postpone compliance. However, completion prior to 1 July 2003 of an Intermediate Survey the window for which straddles 1 July 2003 can be accepted.

(4) Ships, specified in **Pt 7, Ch 3, Sec 17** which required to comply with IACS UR S31(Renewal Criteria for Side Shell Frames and Brackets in Single Side Skin Bulk Carriers and Single Side Skin OBO Carriers not Built in accordance with UR S12 Rev.1 or subsequent revisions) are subject to the additional thickness measurement guidance contained in **Pt 7, Ch 3, Sec 17** and the separate requirements specified by the Society with respect to the side shell frames and brackets for the purpose of determining compliance with UR S31 prior to the relevant compliance deadline stipulated in UR S31 as following and at subsequent Intermediate and Special Surveys for purpose of verifying continuing compliance with UR S31.
   (A) Bulk Carriers subject to the requirements specified in **Pt 7, Ch 3, Sec 17** are to be assessed for compliance with the requirements of this rules and steel renewal, reinforcement or coating, where required in accordance with this rules, is to be carried out in accordance with the following schedule and at subsequent Intermediate and Special Surveys.
      (a) For bulk carriers which will be 15 years of age or more on 1 January 2004 by the due date of the first Intermediate or Special Survey after that date;
      (b) For bulk carriers which will be 10 years of age or more on 1 January 2004 by the due date of the first Special Survey after that date;
      (c) For bulk carriers which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.
      (d) Completion prior to 1 January 2004 of an Intermediate or Special Survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an Intermediate Survey the window for which straddles 1 January 2004 can be accepted.
   (B) OBO carriers subject to the requirements specified in **Pt 7, Ch 3, Sec 17** are to be assessed for compliance with the requirements of this rules and steel renewal, reinforcement or coating, where required in accordance with this rules, is to be carried out in accordance with the following schedule and at subsequent Intermediate and Special Surveys.
      (a) For OBO carriers which will be 15 years of age or more on 1 July 2005 by the due date of the first Intermediate or Special Survey after that date;
      (b) For OBO carriers which will be 10 years of age or more on 1 July 2005 by the due date of the first Special Survey after that date;
      (c) For OBO carriers which will be less than 10 years of age on 1 July 2005 by the date on which the ship reaches 10 years of age.
      (d) Completion prior to 1 July 2005 of an Intermediate or Special Survey with a due date after 1 July 2005 cannot be used to postpone compliance. However, completion prior to 1 July 2005 of an Intermediate Survey the window for which straddles 1 July 2005 can be accepted.

(5) For bulk carriers with hybrid cargo hold arrangements, e.g. with some cargo holds of single side skin and others of double side skin, the requirements of **Sec 6** are to apply to cargo hold of double side skin and associated wing spaces.

(6) All bulk carriers, which required to comply with IACS UR S30(Cargo Hatch Cover Securing Arrangements for Bulk Carriers not Built in accordance with UR S21(Rev.3)), not built in accordance with **Pt 7, Ch 3, Sec 9** are to comply with the requirements specified in **Pt 7, Ch 3, Sec 18** in accordance with the following schedule:
   (A) For ships which will be 15 years of age or more on 1 January 2004 by the due date of the first Intermediate or Special Survey after that date;
   (B) For ships which will be 10 years of age or more on 1 January 2004 by the due date of the first Special Survey after that date;
   (C) For ships which will be less than 10 years of age on 1 January 2004 by the date on which the ship reaches 10 years of age.
   (D) Completion prior to 1 January 2004 of an Intermediate or Special Survey with a due date after 1 January 2004 cannot be used to postpone compliance. However, completion prior to 1 January 2004 of an Intermediate Survey the window for which straddles 1 January 2004 can be accepted.

2. Definitions

(1) A **ballast tank** is a tank which is used solely for salt water ballast, or, where applicable, a space which is used for both cargo and slat water ballast will be treated as a ballast tank when substantial corrosion has been found in that space.

(2) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom hopper sides, longitudinal bulkheads and bottom in top wing tanks.

(3) **Spaces** are separate compartments including holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

202. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **Ch 2, 201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull, weather decks, hatch covers, coamings and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of weather decks, hatch covers and coamings

(1) Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.
(2) A thorough survey of cargo hatch covers and coamings is only possible by examination in the open as well as closed positions and is to include verification of proper opening and closing operation. As a result, the hatch cover sets within the forward 25 % of the ship's length and at least one additional set, such that all sets on the ship are assessed at least once in every 5-year period, are to be surveyed open, closed and in operation to the full extent on each direction at each Annual Survey, including:
(A) stowage and securing in open condition
(B) proper fit and efficiency of sealing in closed condition
(C) operational testing of hydraulic and power components, wires, chains, and link drives
The closing of the covers is to include the fastening of all peripheral and cross joint cleats or other securing devices. Particular attention is to be paid to the condition of the hatch covers in the forward 25 % of the ship's length, where sea loads are normally greatest.
(3) If there are indications of difficulty in operating and securing hatch covers, additional sets above those required by (2), at the discretion of the Surveyor, are to be tested in operation.
(4) Where the cargo hatch securing system does not function properly, repairs are to be carried out under the supervision of the Society.
(5) For each cargo hatch cover set, at each Annual Survey, the following items are to be surveyed:
(A) cover panels, including side plates, and stiffener attachments that may be accessible in the open position by Close-up Survey(for corrosion, cracks, deformation)
(B) sealing arrangements of perimeter and cross joints(gaskets for condition and permanent deformation, flexible seals on combination carriers, gasket lips, compression bars, drainage channels and non return valves)
(C) clamping devices, retaining bars, cleating(for wastage, adjustment, and condition of rubber components)
(D) closed cover locating devices(for distortion and attachment)
(E) chain or rope pulleys
(F) guides
(G) guide rails and track wheels
(H) stoppers
(I) wires, chains, tensioners, and gypsies
(J) hydraulic system, electrical safety devices and interlocks
(K) end and interpanel hinges, pins and stools where fitted
(6) At each hatchway, at each Annual Survey, the coamings, with panel stiffeners and brackets are to be checked for corrosion, cracks and deformation, especially of the coaming tops, including Close-up Survey.
(7) Where considered necessary, the effectiveness of sealing arrangements may be proved by hose or chalk testing supplemented by dimensional measurements of seal compressing components.

(8) Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition, where applicable, of:
  (A) wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices
  (B) steel pontoons, including Close-up Survey of hatch cover plating
  (C) tarpaulins
  (D) cleats, battens and wedges
  (E) hatch securing bars and their securing devices
  (F) loading pads/bars and the side plate edge
  (G) guide plates and chocks
  (H) compression bars, drainage channels and drain pipes(if any)
(9) Examination of flame screens on the open ends of air pipes to all bunker tanks.
(10) Examination of bunker and vent piping systems, including ventilators.

4. Examination of cargo holds

The examination of cargo holds in Annual Survey is to be in accordance with the follows.

	10 years 〈 age ≤ 15 years[2), 3)]	15 years 〈 age[2), 3)]
Overall Survey	All cargo holds	All cargo holds
Close-up Survey	1. Cargo Holds: - forward cargo hold 2. Extent: Close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating[1)]	1. Cargo Holds: - forward cargo hold - one other selected cargo hold 2. Extent: Close-up examination of sufficient extent, minimum 25% of frames, to establish the condition of the lower region of the shell frames including approx. lower one third length of side frame at side shell and side frame end attachment and the adjacent shell plating[1)]
Others	All piping and penetrations in cargo holds, including overboard piping, are to be examined.	All piping and penetrations in cargo holds, including overboard piping, are to be examined.

(NOTES)
1) Where this level of survey reveals the need for remedial measures, the survey is to be extended to include a Close-up Survey of all of the shell frames and adjacent shell plating of that cargo hold as well as a Close-up Survey of sufficient extent of all remaining cargo holds.
2) When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These increased thickness measurements are to be carried out before the Annual Survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurement taken.
3) Where a hard protective coating in cargo holds is found to be in GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.

5. Examination of ballast tanks

Examination of ballast tanks when required as a consequence of the results of the Special Survey and Intermediate Survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous survey are to have thickness measurements taken.

6. Additional Annual Survey requirements for the foremost cargo hold of ships subject to SOLAS XII/9.1

(1) Ships subject to SOLAS XII/9.1 are those meeting all the following conditions;
- Bulk Carriers of 150 m in length and upwards of single side skin construction,
- carrying solid bulk cargoes having a density of 1780 kg/m^3 and above,
- contracted for construction before 1 July 1999, and
- constructed with an insufficient number of transverse watertight bulkheads to enable them to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium as specified in SOLAS XII/4.3.

(2) In accordance with SOLAS XII/9.1, for the foremost cargo hold of such ships, the additional survey requirements listed in the Guidance relating to the Rules shall apply.

7. Additional Annual Survey requirements after determining compliance with SOLAS XII/12 and XII/13

(1) For ships complying with the requirements of SOLAS XII/12 for hold, ballast and dry space water level detectors, the Annual Survey is to include an examination and a test, at random, of the water ingress detection systems and of their alarms.

(2) For ships complying with the requirements of SOLAS XII/13 for the availability of pumping systems, the Annual Survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

203. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **Ch 2, 301.**
(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.
(3) Bulk carriers exceeding 10 years of age up to 15 years of age, the following is to apply:
(a) The requirements of the Intermediate Survey are to be to the same extent to the previous Special Survey as required in **204.** and **102. 1.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, internal examination of fuel tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.
(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**
(c) In application of (a) above, an under water survey may be considered in lieu of the requirements of **204. 1** (6).
(4) Bulk carriers over 15 years of age, the following is to apply:
(a) The requirements of the Intermediate Survey are to be to the same extent to the previous Special Survey as required in **204.** and **102. 1.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, internal examination of fuel tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.
(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**
(c) In application of (a) above, a survey in dry dock is to be part of the Intermediate Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for Intermediate Surveys, if not already performed.
Note : Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

2. Examination of ballast tanks

The examination of ballast tanks in Intermediate Survey is to be in accordance with the follows.

5 years 〈 age ≤ 10 years[1), 2), 3)]	10 years 〈 age ≤ 15 years	15 years 〈 age
1. Overall Survey of representative ballast tanks 2. Overall Survey and Close-up Survey of suspect areas identified at previous surveys	**203. 1** (3) to be applied.	**203. 1** (4) to be applied.

(NOTES)
1) The selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks. If such Overall Survey reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains efficient.
2) Where POOR coating condition, corrosion or other defects are found in ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type.
3) In ballast tanks other than double bottom ballast tanks, where a hard protective coating is found in POOR condition, and it is not renewed, or where soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual intervals. When such breakdown of hard protective coating is found in double bottom ballast tanks, of where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

3. Examination of cargo holds

The examination of cargo holds in Intermediate Survey is to be in accordance with the follows.

	5 years 〈 age ≤ 10 years[1)]	10 years 〈 age ≤ 15 years	15 years 〈 age
Overall Survey	All cargo holds	**203. 1** (3) to be applied.	**203. 1** (4) to be applied.
Close-up Survey	1. Cargo holds: - forward cargo hold - one other selected cargo hold. (extent : Survey of sufficient extent, minimum 25% of frames, is to be carried out to establish the condition of: shell frames including their upper and lower end attachments, adjacent shell plating, and transverse bulkheads) 2. Suspect areas found at previous surveys	**203. 1** (3) to be applied.	**203. 1** (4) to be applied.

(NOTES)
1) Where considered necessary by the Surveyor as a result of the Overall and Close-up Survey, the survey is to be extended to include a Close-up Survey of all of the shell frames and adjacent shell plating of that cargo hold as well as a Close-up Survey of sufficient extent of all remaining cargo holds.

4. Extent of thickness measurement

(1) Bulk carriers exceeding 5 years of age up to 10 years of age, the following is to apply:
(a) Thickness measurements are to be carried out to an extent sufficient to determine both general and local corrosion levels at areas subject to Close-up Survey, as described in **Par 3.** The minimum requirement for thickness measurements at the Intermediate Survey are areas found to be suspect areas at previous surveys.
(b) The thickness measurement may be specially considered provided the Surveyor is satisfied by the Close-up Survey, that there is no structural diminution and the hard protective coatings are found to be in a GOOD condition.
(c) Where substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
(d) Where the hard protective coating in cargo holds is found to be in GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.
Note : For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the Close-up Surveys and thickness measurement. Prior to the coating of cargo holds of existing ships, scantlings should be ascertained in the presence of a Surveyor.
(2) Bulk carriers exceeding 10 years of age up to 15 years of age, **Par 1** (3) above is to apply.
(3) Bulk carriers exceeding 15 years of age, **Par 1** (4) above is to apply.
(4) The side shell frames and brackets of cargo holds bounded by the single side shell of bulk carriers which were not built in accordance with **Pt 7, Ch 3, Sec 7** are to have thickness measurements taken for the extent of Close-up Survey according to the ship's age.

204. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **Ch 2, 401.**
(2) The Special Survey is to include, in addition to the requirements of the Annual Survey, examination, tests, and checks of sufficient extent to ensure that the hull and related piping, as required in (4), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(3) All cargo holds, ballast tanks, including double bottom tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in **Par 5** and **Par 6**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(4) All piping systems within the spaces specified in (3) above are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remains satisfactory.
(5) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.
(6) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.
Note : Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

2. Tank protection

(1) Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom ballast tanks, where a hard protective coating is found in POOR condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.
(2) When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(3) Where a hard protective coating is provided in cargo holds and is found in GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.

3. Hatch covers and coamings

In addition to the requirements in **202. 3** of the Annual Survey, the following items are to be surveyed.

(1) Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:
   (a) stowage and securing in open condition
   (b) proper fit and efficiency of sealing in closed condition
   (c) operational testing of hydraulic and power components, wires, chains, and link drives.
(2) Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent.
(3) Thickness measurement of the hatch cover and coaming plating and stiffeners is to be carried out as given in **Table 1.3.2.**

4. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces is to be carried out at each Special Survey. Fuel oil tanks in cargo length area are to be surveyed as follows:

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
-	One	Two	Half, minimum two

(NOTES)
1. These requirements apply to tanks of integral (structural) type.
2. If a selection of tanks is accepted to be examined, then different tanks are to be examined at each Special Survey, on a rotational basis.
3. Peak tanks (all uses) are subject to internal examination at each Special Survey.
4. At Special Survey No. 3 and subsequent Special Surveys, one deep tank adjacent to side shell plate for fuel oil in the cargo area is to be included, if fitted.

(2) The minimum requirements for Close-up Survey at Special Survey are given in **Table 1.3.1.**
(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.
(4) For areas in spaces where hard protective coatings are found to be in a GOOD condition, the extent of Close-up Surveys according to **Table 1.3.1** may be specially considered. (Refer also to **204. 2** (3))

5. Extent of thickness measurement

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.3.2.** For additional thickness measurement guidelines applicable to the vertically corrugated transverse watertight bulkhead between cargo hold Nos. 1 and 2 on ships subject to compliance with IACS URs S19 and S23, reference is to be made to **201. 1** (3) and **Annex 1-5**, **Table 9** of the Guidance. For additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31, reference is to be made to **201. 1** (4) and **Pt 7, Ch 3, Sec 17** of the Rules and the separate requirements specified by the Society.
(2) Provisions for extended measurements for areas with substantial corrosion are given in the Guidance relating to the Rules and as may be additionally specified in the survey programme as required in **102. 1.** These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
(3) The Surveyor may further extend the thickness measurements as deemed necessary.
(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to **Table 1.3.2** may be specially considered. (Refer also to **204. 2** (3))
(5) Transverse sections are to be chosen where largest reductions are suspected to occur or are revealed from deck plating measurements.
(6) Representative thickness measurement to determine both general and local levels of corrosion in the shell frames and their end attachments in all cargo holds and ballast tanks is to be carried out. Thickness measurement is also to be carried out to determine the corrosion levels on the transverse bulkhead plating. The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the Close-up Survey, that there is no structural diminution, and the hard protective coating where applied remains efficient.

6. Extent of tank testing

The minimum requirements for tank testing at Special Survey are given in **Table 1.3.3.**

7. Additional Special Survey requirements after determining compliance with SOLAS XII/12 and XII/13

(1) For ships complying with the requirements of SOLAS XII/12 for hold, ballast and dry space water level detectors, the Special Survey is to include an examination and a test of the all water ingress detection systems and of their alarms.

(2) For ships complying with the requirements of SOLAS XII/13 for the availability of pumping systems, the Special Survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

Table 1.3.1 Minimum requirements for Close-up Survey at Special Survey of Bulk Carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. 25% of shell frames in the forward cargo hold at representative positions, and selected frames in remaining cargo holds (*1)	1. All shell frames in the forward cargo hold and 25% of shell frames in each of the remaining cargo holds including upper and lower end attachments and adjacent shell plating. For bulk carriers 100,000 DWT and above, all shell frames in the forward cargo hold and 50% of shell frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating. (*1)	1. All shell frames in the forward and one other selected cargo hold and 50% of frames in each of the remaining cargo holds, including upper and lower end attachments and adjacent shell plating (*1)	1. All shell frames in all cargo holds, including upper and lower end attachments and adjacent shell plating (*1)
2. One transverse web with associated plating and longitudinals in two representative ballast tanks of each type (i.e. topside, or hopper side tank) (*2)	2. One transverse web with associated plating and longitudinals in each ballast tank (*2)	2. All transverse webs with associated plating and longitudinals in each ballast tank (*2)	2. All transverse webs with associated plating and longitudinals in each ballast tank (*2)
3. Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3)	3. Forward and aft transverse bulkhead in one ballast tank, including stiffening system (*2)	3. All transverse bulkheads in ballast tanks, including stiffening system (*2)	3. All transverse bulkheads in ballast tanks, including stiffening system (*2)
4. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)	4. All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3)	4. All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3)	4. All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3)
	5. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)	5. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)	5. All cargo hold hatch covers and coamings (plating and stiffeners) (*4)
	6. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches. (*5)	6. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches. (*5)	6. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches. (*5)

(NOTES)

1. (*1) to (*5) means as follows and are illustrated in **Annex 1-6** of the Guidance:
   (*1) : Cargo hold transverse frames
   (*2) : Transverse web frame or watertight transverse bulkhead in ballast tanks
   (*3) : Cargo hold transverse bulkheads stiffeners and girders
   (*4) : Cargo hold hatch covers and coamings
   (*5) : Deck plating and under deck structure inside line of hatch openings between cargo hold hatches
2. Close-up Survey of transverse bulkheads to be carried out at four levels:
   Level(a) : Immediately above the inner bottom and immediately above the line of gussets (if fitted) and shedders for ships without lower stool.
   Level(b) : Immediately above and below the lower stool shelf plate (for those ships fitted with lower stools), and immediately above the line of the shedder plates.
   Level(c) : About mid-height of the bulkhead.
   Level(d) : Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks.

Table 1.3.2 Minimum requirements for thickness measurements at Special Survey of Bulk Carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas	1. Suspect areas	1. Suspect areas	1. Suspect areas
	2. Within the cargo length: 1) Two transverse sections of deck plating outside line of cargo hatch openings	2. Within the cargo length: 1) Each deck plate outside line of cargo hatch openings 2) Two Transverse Sections, one in the amidship area, outside line of cargo hatch openings 3) All wind and water strakes	2. Within the cargo length: 1) Each deck plate outside line of cargo hatch openings 2) Three Transverse Sections, one in the amidship area, outside line of cargo hatch openings 3) Each bottom plate
	3. 1) Wind and water strakes in way of the transverse sections considered under **2** above 2) Selected wind and water strakes outside the cargo length area	3. Selected wind and water strakes outside the cargo length area	3. All wind and water strakes, full length
	4. Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.1**	4. Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.1**	4. Measurement, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.1**
		5. See **201. 1** (3) and **Annex 1-5, Table 9** of the Guidance for additional thickness measurement guidelines applicable to the vertically corrugated transverse watertight bulkhead between cargo hold Nos. 1 and 2 on ships subject to compliance with IACS URs S19 and S23	5. See **201. 1** (3) and **Annex 1-5, Table 9** of the Guidance for additional thickness measurement guidelines applicable to the vertically corrugated transverse watertight bulkhead between cargo hold Nos. 1 and 2 on ships subject to compliance with IACS URs S19 and S23
	5. See **201. 1** (4), **Pt 7, Ch 3, Sec 17** and the separate requirements specified by the Society for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31	6. See **201. 1** (4), **Pt 7, Ch 3, Sec 17** and the separate requirements specified by the Society for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31	6. See **201. 1** (4), **Pt 7, Ch 3, Sec 17** and the separate requirements specified by the Society for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31

Table 1.3.3 Minimum requirements for tank testing at Special Survey of Bulk Carriers

Tanks or spaces \ No. of Special Survey	Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
All boundaries of ballast tanks, deep tanks and cargo holds used for water ballast within the cargo length area	○	○	○	○

(NOTES)
1. For fuel oil tanks within the cargo length area, only representative tanks are to be pressure tested.
2. The Surveyor may extend the tank testing as deemed necessary.
3. Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.
4. Boundaries of ballast holds are to be tested with a head of liquid to near to the top of hatches.
5. Boundaries of fuel oil tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.
6. The testing of double bottom and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tanktop is carried out.

Section 3 Oil Tankers

301. General

1. Application

(1) In addition to the requirements specified in **Ch 2**, the requirements apply to surveys of hull structure and piping systems in way of the following spaces for all oil tankers with ESP notation other than Double Hull Oil Tankers as defined in **501. 2** (1).
  (a) cargo tanks, pump rooms, cofferdams, pipe tunnels, void spaces within the cargo area
  (b) all ballast tanks

(2) The requirements contain the minimum extent of examination, thickness measurements and tank testing. The survey should be extended when substantial corrosion and/or structural defects are found and include additional Close-up Survey when necessary.

2. Definitions

(1) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom and longitudinal bulkheads.

(2) **Cargo area** is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.

(3) A **ballast tank** is a tank which is used solely for the carriage of salt water ballast.

(4) A **combined cargo/ballast tank** is a tank which is used for the carriage of cargo or ballast water as a routine part of the vessel's operation and will be treated as a ballast tank. Cargo tanks in which water ballast might be carried only in exceptional cases per MARPOL Annex I, Ch 4, Reg. 18.3 are to be treated as cargo tanks.

302. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **Ch 2, 201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of weather decks

(1) Examination of cargo tank openings including gaskets, covers, coamings and flame screens.
(2) Examination of cargo tanks pressure/vacuum valves and flame screens.
(3) Examination of flame screens on the open ends of air pipes to all bunker tanks.
(4) Examination of cargo, crude oil washing, bunker and vent piping systems, including vent masts and headers.

4. Examination of cargo pump rooms and pipe tunnels(if fitted)

(1) Examination of all pump room bulkheads for signs of oil leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room bulkheads.
(2) Examination of the condition of all piping systems.

5. Examination of ballast tanks

Examination of ballast tanks where required as a consequence of the results of the Special Survey(See **304. 2**) and Intermediate Survey(See **303. 3**) is to be carried out. When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

303. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **Ch 2, 301.**

(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.

(3) Oil tankers exceeding 10 years of age up to 15 years of age, the following is to apply:

(a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **102. 1** and **304.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, pressure testing of cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girder as required in **105. 1** (2) are not required unless deemed necessary by the attending Surveyor.

(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**

(c) In application of (a) above, an under water survey may be considered in lieu of the requirements of **304. 1** (5).

(4) Oil tankers over 15 years of age, the following is to apply:

(a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **102. 1** and **304.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, pressure testing of cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girder as required in **105. 1** (2) are not required unless deemed necessary by the attending Surveyor.

(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**

(c) In application of (a) above, a survey in dry dock is to be a part of the Intermediate Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for Intermediate Surveys, if not already performed.

Note : Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

2. For weather decks, an examination as far as applicable of:

(1) Cargo, crude oil washing, bunker, ballast, steam and vent piping systems as well as vent masts and headers is to be carried out.

(2) If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both.

3. Extent of examination

The examination in Intermediate Survey is to be in accordance with the follows.

5 years 〈 age ≤ 10 years[1), 2)]	10 years 〈 age ≤ 15 years	15 years 〈 age
1. All ballast tanks 2. Suspect areas identified at previous surveys	**303. 1** (3) to be applied.	**303. 1** (4) to be applied.

(NOTES)

1) When considered necessary by the Surveyor, thickness measurement and testing are to be carried out to ensure that the structural integrity remains effective.

2) A ballast tank is to be examined at subsequent annual intervals where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

304. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **Ch 2, 401.**
(2) The Special Survey is to include, in addition to the requirements of the Annual Survey, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in (4), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(3) All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, this examination is to be supplemented by thickness measurement and testing as required in **Par 4** and **Par 5**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(4) Cargo piping on deck, including crude oil washing (COW) piping, cargo and ballast piping within the tanks and spaces specified in (3) above are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are opened during repair periods and can be examined internally.
(5) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.
Note : Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

2. Tank protection

Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual intervals where:
- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

3. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces is to be carried out at each Special Survey.
(2) The minimum requirements for Close-up Survey at Special Survey are given in **Table 1.3.4.**
(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:
(a) In particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information.
(b) In tanks which have structures approved with reduced scantlings due to an approved corrosion control system.
(4) For areas in tanks where hard protective coatings are found to be in GOOD condition, the extent of Close-up Surveys according to **Table 1.3.4** may be specially considered.

4. Extent of thickness measurement

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.3.5.**

(2) Provisions for extended measurements for areas with substantial corrosion are given in the Guidance relating to the Rules, and as may be additionally specified in the survey programme as required in **102. 1.** These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

(3) The Surveyor may further extend the thickness measurements as deemed necessary.

(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurements according to **Table 1.3.5** may be specially considered.

(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

(6) In case where two or three sections are to be measured, at least one is to include a ballast tank within 0.5 L amidships. In case of oil tankers of 130 m in length and upwards(as defined in **Pt 3, Ch 1, 103.**) and more than 10 years of age, for the evaluation of the ship's longitudinal strength as required in **105. 1** (2), the sampling method of thickness measurements is given in the Guidance relating to the Rules.

5. Extent of tank testing

The minimum requirements for tank testing at Special Survey are given in **Table 1.3.6.**

Table 1.3.4 Minimum requirements for Close-up Survey at Special Survey of Oil Tankers, Ore/Oil Ships and etc.[1)]

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. One web frame ring in a ballast wing tank, if any, or a cargo wing tank, used primarily for water ballast (*1)	1. All web frame rings in a ballast wing tank, if any, or a cargo wing tank, used primarily for water ballast (*1)	1. All web frame rings in all ballast tanks (*1) 2. All web frame rings in a cargo wing tank (*1) 3. A minimum of 30% of all web frame ring in each remaining cargo wing tank (*1)[2)]	1. All web frames rings in all ballast tanks (*1) 2. All web frame rings in a cargo wing tank (*1) 3. A minimum of 30% of all web frame ring in each remaining cargo wing tank (*1)[2)]
2. One deck transverse in a cargo oil tank (*2)	2. One deck transverse in each of the remaining ballast tanks, if any (*2) 3. One deck transverse in a cargo wing tank (*2) 4. One deck transverse in two cargo centre tanks (*2)		
	5. Both transverse bulkheads in a wing ballast tank, if any, or a cargo wing tank used primarily for water ballast (*3)	4. All transverse bulkheads in all cargo and ballast tanks (*3)	4. All transverse bulkheads in all cargo and ballast tanks (*3)
3. One transverse bulkhead in a ballast tank (*4)	6. One transverse bulkhead in each remaining ballast tank (*4)	5. A minimum of 30% of deck and bottom transverse including adjacent structural members in each cargo centre tank (*5)	5. A minimum of 30% of deck and bottom transverse including adjacent structural members in each cargo centre tank (*5)
4. One transverse bulkhead in a cargo oil wing tank (*4)	7. One transverse bulkhead in a cargo oil wing tank (*4)	6. As considered necessary by the Surveyor (*6)	6. As considered necessary by the Surveyor (*6)
5. One transverse bulkhead in a cargo oil centre tank (*4)	8. One transverse bulkhead in two cargo centre tanks (*4)		7. Additional transverses included as deemed necessary by the Society

(NOTES)

1) (*1) to (*6) mean as follows and are illustrated in **Annex 1-6** of the Guidance:
   - (*1) : Complete transverse web frame ring including adjacent structural members
   - (*2) : Deck transverse including adjacent deck structural members
   - (*3) : Transverse bulkhead complete including girder system and adjacent structural members
   - (*4) : Transverse bulkhead lower part including girder system and adjacent structural members
   - (*5) : Deck and bottom transverse including adjacent structural members
   - (*6) : Additional complete transverse web frame ring

2) The 30 % is to be rounded up to the next whole integer.

Table 1.3.5 Minimum requirements for thickness measurements at Special Survey of Oil Tankers, Ore/Oil Ships and etc.

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas 2. One transverse section of deck plating for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast) 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.4**	1. Suspect areas 2. Within the cargo area: 1) Each deck plate 2) One transverse section 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.4** 4. Selected wind and water strakes outside the cargo area	1. Suspect areas 2. Within the cargo area: 1) Each deck plate 2) Two transverse sections[1)] 3) All wind and water strakes 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.4** 4. Selected wind and water strakes outside the cargo area	1. Suspect areas 2. Within the cargo area: 1) Each deck plate 2) Three transverse sections[1)] 3) Each bottom plate 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.4** 4. All wind and water strakes, full length

(NOTES)
1) At least one section is to include a ballast tank within 0.5 L amidships.

Table 1.3.6 Minimum requirements for tank testing at Special Survey of Oil Tankers, Ore/Oil Ships and etc.

Special Survey No. 1	Special Survey No. 2 and Subsequent
1. All ballast tank boundaries 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump-rooms or cofferdams	1. All ballast tank boundaries 2. All cargo tank bulkheads

(NOTES)
1. The Surveyor may extend the tank testing as deemed necessary.
2. Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.
3. Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.

Section 4 Chemical Tankers

401. General

1. Application

(1) In addition to the requirements specified in **Ch 2**, the requirements apply to all Chemical Tankers, with ESP notation, with integral tanks. If a chemical tanker is constructed with both integral and independent tanks, these requirements are applicable only to that portion of the cargo length containing integral tanks. Combined gas carriers/chemical tankers with independent tanks within the hull, are to be surveyed as gas carriers.

(2) The requirements apply to surveys of hull structure and piping systems in way of following spaces. The requirements are not applicable for independent tanks on deck:
(a) cargo tanks, pump rooms, cofferdams, pipe tunnels, void spaces within the cargo area
(b) all ballast tanks

(3) These requirements contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional Close-up Survey when necessary.

2. Definitions

(1) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom and longitudinal bulkheads.

(2) **Cargo area** is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.

(3) A **ballast tank** is a tank which is used solely for the carriage of salt water ballast.

(4) A **combined cargo/ballast tank** is a tank which is used for the carriage of cargo or ballast water as a routine part of the vessel's operation and will be treated as a ballast tank. Cargo tanks in which water ballast might be carried only in exceptional cases per MARPOL Annex I, Ch 4, Reg. 18.3 are to be treated as cargo tanks.

402. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **Ch 2, 201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of weather decks

(1) Examination of cargo tank openings including gaskets, covers, coamings and flame screens.
(2) Examination of cargo tanks pressure/vacuum valves and flame screens.
(3) Examination of flame screens on the open ends of air pipes to all bunker tanks.
(4) Examination of cargo, bunker and vent piping systems, including vent masts and headers.

4. Examination of cargo pump rooms and pipe tunnels(if fitted)

(1) Examination of all pump room bulkheads for signs of chemical leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room bulkheads.
(2) Examination of the condition of all piping systems.

5. Examination of ballast tanks

Examination of ballast tanks where required as a consequence of the results of the Special Survey(See **404. 2**) and Intermediate Survey(See **403. 3**) is to carried out. When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

403. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **Ch 2, 301.**

(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.

(3) Chemical tankers exceeding 10 years of age up to 15 years of age, the following is to apply:

(a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **102. 1** and **404.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, pressure testing of cargo and ballast tanks is not required unless deemed necessary by the attending Surveyor.

(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**

(c) In application of (a) above, an under water survey may be considered in lieu of the requirements of **404. 1** (5).

(4) Chemical tankers over 15 years of age, the following is to apply:

(a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **102. 1** and **404.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, pressure testing of cargo and ballast tanks is not required unless deemed necessary by the attending Surveyor.

(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**

(c) In application of (a) above, a survey in dry dock is to be a part of the Intermediate Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for Intermediate Surveys, if not already performed.

Note : Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

2. For weather decks, an examination as far as applicable of:

(1) Cargo, bunker, ballast, steam and vent piping systems as well as vent masts and headers is to be carried out.

(2) If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both.

3. Extent of examination

The examination in Intermediate Survey is to be in accordance with the follows.

5 years 〈 age ≤ 10 years[1), 2)]	10 years 〈 age ≤ 15 years	15 years 〈 age
1. Overall Survey of representative ballast tanks 2. Examination of suspect areas identified at previous surveys	**403. 1** (3) to be applied.	**403. 1** (4) to be applied.

(NOTES)

1) If such inspections reveal no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in GOOD condition.

2) A ballast tank is to be examined at subsequent annual intervals where:
- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

404. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **Ch 2, 401.**
(2) The Special Survey is to include, in addition to the requirements of the Annual Survey, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in (4), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(3) All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, this examination is to be supplemented by thickness measurement and testing as required in **Par 4** and **Par 5**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(4) Cargo piping on deck and cargo and ballast piping within the tanks and spaces specified in (3) above are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are opened during repair periods and can be examined internally.
(5) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.
Note : Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

2. Tank protection

Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual intervals where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

3. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces is to be carried out at each Special Survey.
(2) The minimum requirements for Close-up Survey at Special Survey are given in **Table 1.3.7.** The survey of stainless steel tanks may be carried out as an Overall Survey supplemented by Close-up Survey as deemed necessary by the Surveyor.
(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:
(a) In particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information.
(b) In tanks which have structures approved with reduced scantlings due to an approved corrosion control system.
(4) For areas in tanks where hard protective coatings are found to be in GOOD condition, the extent of Close-up Surveys according to **Table 1.3.7** may be specially considered.

4. Extent of Thickness Measurement

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.3.8.** The thickness measurement of stainless steel hull structure and piping may be waived, except for clad steel plating.
(2) Provisions for extended measurements for areas with substantial corrosion are given in the Guidance relating to the Rules, and as may be additionally specified in the survey programme as required in **102. 1.** These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
(3) The Surveyor may further extend the thickness measurements as deemed necessary.
(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurements according to **Table 1.3.8** may be specially considered.
(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.
(6) In case where two or three sections are to be measured, at least one is to include a ballast tank within 0.5 L amidships.

5. Extent of tank testing

The minimum requirements for tank testing at Special Survey are given in **Table 1.3.9.** Pressure testing of cargo tanks may be specially considered based on a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with a satisfactory result.

6. Chemical tankers over 10 years of age

(1) Selected steel cargo pipes outside cargo tanks and ballast pipes passing through cargo tanks are to be:
  (a) thickness measured at random or selected pipe lengths to be opened for internal inspection.
  (b) pressure tested to the maximum working pressure.
(2) Special attention is to be given to cargo/slop discharge piping through ballast tanks and void spaces.

Table 1.3.7 Minimum requirements for Close-up Survey at Special Survey of Chemical Tankers[1)]

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. One web frame in a ballast wing tank(for S.H.) or ballast double hull tank(for D.H.)[2)] (*1)	1. All web frames in a ballast wing tank(for S.H.) or ballast double hull tank(for D.H.)[2)] (*1)	1. All web frames in all ballast tanks (*1)	1. All web frames in all ballast tanks (*1)
2. One deck transverse in a cargo tank or on deck (*2)	2. One deck transverse in each remaining ballast tank or on deck(for S.H.) (*2) 3. The knuckle area and the upper part(3 metres approx) of one web frame in each remaining ballast tank(for D.H.) (*2)	2. All web frames in a cargo wing tank (*1)	2. All web frames in a cargo wing tank (*1)
3. One transverse bulkhead(lower part for S.H., complete for D.H.) in a ballast tank (*3) (*4)	4. One deck transverse in a cargo wing tank or on deck(for S.H.) (*2)	3. One web frame in each remaining cargo tank (*1)	3. One web frame in each remaining cargo tank (*1)
4. One transverse bulkhead in a cargo wing tank (*4) 5. One transverse bulkhead in a cargo centre tank[3)] (*4)	5. One deck transverse in two cargo centre tanks or on deck(for S.H.) and one deck transverse in two cargo tanks(for D.H.) (*2) 6. Both transverse bulkhead in a ballast wing tank(for S.H.) (*3) 7. One transverse bulkhead in each ballast tank(for D.H.)[2)] (*3) 8. One transverse bulkhead in each remaining ballast tank(for S.H.) (*4) 9. One transverse bulkhead in a cargo wing tank (*4) 10. One transverse bulkhead in two cargo centre tanks[3)] (*4)	4. All transverse bulkhead in all cargo and ballast tanks (*3)	4. All transverse bulkhead in all cargo and ballast tanks (*3) 5. Additional transverse areas as deemed necessary by the Society

(NOTES)

1) (*1) to (*4) mean as follows and are illustrated in **Annex 1-6** of the Guidance:
   - (*1) : Complete transverse web frame ring including adjacent structural members
   - (*2) : Deck transverse including adjacent deck structural members
   - (*3) : Transverse bulkhead complete including girder system and adjacent structural members
   - (*4) : Transverse bulkhead lower part including girder system and adjacent structural members

2) Double hull tank - including double bottom and side tank even though these tanks are separate.

3) Where no centre cargo tanks are fitted(as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

Table 1.3.8 Minimum requirements for thickness measurements at Special Survey of Chemical Tankers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas 2. One transverse section of deck plating for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast) 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.7.**	1. Suspect areas 2. Within the cargo area: 1) Each deck plate 2) One transverse section 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.7.** 4. Selected wind and water strakes outside the cargo area	1. Suspect areas 2. Within the cargo area: 1) Each deck plate 2) Two transverse sections[1)] 3) All wind and water strakes 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.7.** 4. Selected wind and water strakes outside the cargo area	1. Suspect areas 2. Within the cargo area: 1) Each deck plate 2) Three transverse sections[1)] 3) Each bottom plate 3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.7.** 4. All wind and water strakes, full length
(NOTES) 1) At least one section is to include a ballast tank within 0.5 L amidships.			

Table 1.3.9 Minimum requirements for tank testing at Special Survey of Chemical Tankers

Special Survey No. 1	Special Survey No. 2 and Subsequent
1. All ballast tank boundaries 2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump-rooms or cofferdams	1. All ballast tank boundaries 2. All cargo tank bulkheads
(NOTES) 1. The Surveyor may extend the tank testing as deemed necessary. 2. Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes. 3. Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions. 4. The testing of double bottom and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tanktop is carried out.	

Section 5 Double Hull Oil Tankers

501. General

1. Application

(1) In addition to the requirements specified in **Ch 2**, the requirements apply to surveys of hull structure and piping systems in way of the following spaces for all double hull oil tankers with ESP notation.

(a) cargo tanks, pump rooms, cofferdams, pipe tunnels, void spaces within the cargo area

(b) all ballast tanks

(2) The requirements contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when substantial corrosion and/or structural defects are found and include additional Close-up Survey when necessary.

2. Definitions

(1) A **double hull oil tanker** is a ship which is constructed primarily for the carriage of oil in bulk, which have the cargo tanks protected by a double hull which extends for the entire length of the cargo area, consisting of double sides and double bottom spaces for the carriage of water ballast or void spaces.

(2) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom and longitudinal bulkheads.

(3) **Cargo area** is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over above mentioned spaces.

(4) A **ballast tank** is a tank which is used solely for the carriage of salt water ballast.

(5) A **combined cargo/ballast tank** is a tank which is used for the carriage of cargo or ballast water as a routine part of the vessel's operation and will be treated as a ballast tank. Cargo tanks in which water ballast might be carried only in exceptional cases per MARPOL Annex I, Ch 4, Reg. 18.3 are to be treated as cargo tanks.

502. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **Ch 2, 201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of the weather deck

(1) Examination of cargo tank openings including gaskets, covers, coamings and flame screens.
(2) Examination of cargo tanks pressure/vacuum valves and flame screens.
(3) Examination of flame screens on the open ends of air pipes to all bunker tanks.
(4) Examination of cargo, crude oil washing, bunker and vent piping systems, including vent masts and headers.

4. Examination of cargo pump rooms and pipe tunnels(if fitted)

(1) Examination of all pump rooms bulkheads for signs of oil leakage or fractures and, in particular, the sealing arrangements of all penetrations of pump room bulkheads.
(2) Examination of the condition of all piping systems.

5. Examination of ballast tanks

Examination of ballast tanks where required as a consequence of the results of the Special Survey(See **504. 2**) and Intermediate Survey(See **503. 3**) is to be carried out. When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

503. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **Ch 2, 301.**
(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.
(3) Double hull oil tankers exceeding 10 years of age up to 15 years of age, the following is to apply:
(a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **102. 1** and **504.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, pressure testing of cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girder as required in **105. 1** (2) are not required unless deemed necessary by the attending Surveyor.
(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**
(c) In application of (a) above, an under water survey may be considered in lieu of the requirements of **504. 1** (5).
(4) Double hull oil tankers over 15 years of age, the following is to apply:
(a) The requirements of the Intermediate Survey are to be to the same extent as the previous Special Survey as required in **102. 1** and **504.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, pressure testing of cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girder as required in **105. 1** (2) are not required unless deemed necessary by the attending Surveyor.
(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**
(c) In application of (a) above, a survey in dry dock is to be a part of the Intermediate Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for Intermediate Surveys, if not already performed.
Note : Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

2. For weather decks, an examination as far as applicable of:

(1) Cargo, crude oil washing, bunker, ballast, steam and vent piping systems as well as vent masts and headers is to be carried out.
(2) If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressures-tested, thickness measured or both.

3. Extent of examination

The examination in Intermediate Survey is to be in accordance with the follows.

5 years < age ≤ 10 years[1), 2)]	10 years < age ≤ 15 years	15 years < age
1. Overall Survey of representative ballast tanks 2. Examination of suspect areas identified at previous surveys	**503. 1** (3) to be applied.	**503. 1** (4) to be applied.

(NOTES)
1) If such inspections reveal no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in GOOD condition.
2) A ballast tank is to be examined at subsequent annual intervals where:
- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

504. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **Ch 2, 401.**

(2) The Special Survey is to include, in addition to the requirements of the Annual Survey, examination, tests and checks of sufficient extent to ensure that the hull and related piping, as required in (4), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

(3) All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, this examination is to be supplemented by thickness measurement and testing as required in **Par 4** and **Par 5**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

(4) Cargo piping on deck, including crude oil washing (COW) piping, cargo and ballast piping within the tanks and spaces specified in (3) above are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces, and Surveyors are to be advised on all occasions when this piping, including valves and fittings are opened during repair periods and can be examined internally.

(5) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.

Note : Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast water line.

2. Tank protection

Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined. A ballast tank is to be examined at subsequent annual intervals where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than GOOD condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurements are to be carried out as deemed necessary by the Surveyor.

3. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces is to be carried out at each Special Survey.

(2) The minimum requirements for Close-up Survey at Special Survey are given in **Table 1.3.10**.

(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the tanks under survey, the condition of the corrosion prevention system and also in the following cases:

(a) In particular, tanks having structural arrangements or details which have suffered defects in similar tanks or on similar ships according to available information.

(b) In tanks which have structures approved with reduced scantlings due to an approved corrosion control system.

(4) For areas in tanks where hard protective coatings are found to be in GOOD condition, the extent of Close-up Surveys according **Table 1.3.10** may be specially considered.

4. Extent of thickness measurement

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.3.11.**

(2) Provisions for extended measurements for areas with substantial corrosion are given in the Guidance relating to the Rules, and as may be additionally specified in the survey programme as required in **102. 1.** These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

(3) The Surveyor may further extend the thickness measurements as deemed necessary.

(4) For areas in tanks where hard protective coatings are found to be in GOOD condition, the extent of thickness measurements according to **Table 1.3.11** may be specially considered.

(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.

(6) In case where two or three sections are to be measured, at least one is to include a ballast tank within 0.5 L amidships. In case of oil tankers of 130 m in length and upwards(as defined in **Pt 3, Ch 1, 103.**) and more than 10 years of age, for the evaluation of the ship's longitudinal strength as required in **105. 1** (2), the sampling method of thickness measurements is given in the Guidance relating to the Rules.

5. Extent of tank testing

The minimum requirements for tank testing at Special Survey are given in **Table 1.3.12.**

Table 1.3.10 Minimum requirements for Close-up Survey at Special Survey of Double Hull Oil Tankers[1]

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. One web frame, in a ballast tank[2] (*1)	1. All web frames, in a ballast tank[2] (*1)	1. All web frames, in all ballast tanks (*1)	1. As for Special Survey No. 3
2. One deck transverse, in a cargo oil tank (*2)	2. The knuckle area and the upper part (5 meters approximately) of one web frame in each remaining ballast tank (*6)	2. All web frames, including deck transverse and cross ties, if fitted, in a cargo oil tank (*7)	2. Additional transverse areas as deemed necessary by the Society
3. One transverse bulkhead, in a ballast tank[2] (*4)	3. One deck transverse, in two cargo oil tanks (*2)	3. One web frame, including deck transverse and cross ties, if fitted, in each remaining cargo oil tank (*7)	
4. One transverse bulkhead, in a cargo oil centre tank[3] (*5)	4. One transverse bulkhead, in each ballast tank[2] (*4)	4. All transverse bulkheads, in all cargo oil (*3) and ballast (*4) tanks	
5. One transverse bulkhead, in a cargo oil wing tank (*5)	5. One transverse bulkhead, in two cargo oil centre tanks[3] (*5)		
	6. One transverse bulkhead, in a cargo oil wing tank (*5)		

(NOTES)

1) (*1) to (*7) mean as follows and are illustrated in **Annex 1-6** of the Guidance:
   - (*1) Web frame in a ballast tank means vertical web in side tank, hopper web in hopper tank, floor in double bottom tank and deck transverse in double deck tank(where fitted), including adjacent structural members. In fore and aft peak tanks web frame means a complete transverse web frame ring including adjacent structural members.
   - (*2) Deck transverse, including adjacent deck structural members(or external structure on deck in way of the tank, where applicable)
   - (*3) Transverse bulkhead complete in cargo tanks, including girder system, adjacent structural members(such as longitudinal bulkheads) and internal structure of lower and upper stools, where fitted.
   - (*4) Transverse bulkhead complete in ballast tanks, including girder system and adjacent structural members, such as longitudinal bulkheads, girders in double bottom tanks, inner bottom plating, hopper side, connecting brackets.
   - (*5) Transverse bulkhead lower part in cargo tank, including girder system, adjacent structural members(such as longitudinal bulkheads) and internal structure of lower stool, where fitted.
   - (*6) The knuckle area and the upper part(5 metres approximately), including adjacent structural members. Knuckle area is the area of the web frame around the connections of the slope hopper plating to the inner hull bulkhead and the inner bottom plating, up to 2 metres from the corners both on the bulkhead and the double bottom.
   - (*7) Web frame in a cargo oil tank means deck transverse, longitudinal bulkhead vertical girder and cross ties, where fitted, including adjacent structural members.

2) Ballast tank : means double bottom tank plus double side tank plus double deck tank, as applicable, even if these tanks are separate.

3) Where no centre cargo tanks are fitted(as in the case of centre longitudinal bulkhead), transverse bulkheads in wing tanks are to be surveyed.

Table 1.3.11 Minimum requirements for thickness measurements at Special Survey of Double Hull Oil Tankers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect areas	1. Suspect areas	1. Suspect areas	1. Suspect areas
2. One section of deck plating for the full beam of the ship within the cargo area	2. Within the cargo area : 1) Each deck plate 2) One transverse section	2. Within the cargo area: 1) Each deck plate 2) Two transverse sections 1) 3) All wind and water strakes	2. Within the cargo area: 1) Each deck plate 2) Three transverse sections 1) 3) Each bottom plate
3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.10**	3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.10**	3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.10**	3. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.10**
	4. Selected wind and water strakes outside the cargo area	4. Selected wind and water strakes outside the cargo area	4. All wind and water strakes, full length

(NOTES)
1) At least one section is to include a ballast tank within $0.5L$ amidships.

Table 1.3.12 Minimum requirements for tank testing at Special Survey of Double Hull Oil Tankers

Special Survey No. 1	Special Survey No. 2 and Subsequent
1. All ballast tank boundaries	1. All ballast tank boundaries
2. Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump-rooms or cofferdams	2. All cargo tank bulkheads

(NOTES)
1. The Surveyor may extend the tank testing as deemed necessary.
2. Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.
3. Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions.
4. The testing of double bottom and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tanktop is carried out.

Section 6 Double Skin Bulk Carriers

601. General

1. Application

(1) In addition to the requirements specified in **Ch 2**, the requirements apply to surveys of hull structure and piping systems in way of the following spaces for all double skin bulk carriers with ESP notation.

(A) cargo holds, cofferdams, pipe tunnels, void spaces, fuel oil tanks within the cargo length area

(B) all ballast tanks

(2) The requirements contain the minimum extent of examination, thickness measurements and tank testing. The survey is to be extended when Substantial Corrosion and/or structural defects are found and include additional Close-up Survey when necessary.

(3) For some cargo holds of single side skin, and where IACS UR S19 or S30 is required to be complied, the requirements of **Sec 2** are to apply as applicable.

2. Definitions

(1) A **Double Skin Bulk Carrier** is a ship which is constructed generally with single deck, topside tank and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers, in which all cargo holds are bounded by a double-side skin(regardless of the width of the wing space). For combination carriers with longitudinal bulkheads additional requirements are specified in **Sec 3** or **Sec 5,** as applicable.

(2) A **Ballast Tank** is a tank which is used solely for salt water ballast, or, where applicable, a space which is used for both cargo and salt water ballast will be treated as a ballast tank when substantial corrosion has been found in that space. A Double Side Tank is to be considered as a separate tank even if it is in connection to either the topside tank or the hopper side tank.

(3) A **transverse section** includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom, hopper sides top wing inner sides and longitudinal bulkheads.

(4) **Spaces** are separate compartments including holds, tanks, cofferdams and void spaces bounding cargo holds, decks and the outer hull.

602. Annual Survey

1. General

(1) The due range of Annual Survey is to be in accordance with the requirements of **Ch 2, 201.**
(2) The survey is to consist of an examination for the purpose of ensuring, as far as practicable, that the hull, weather decks, hatch covers, coamings and piping are maintained in a satisfactory condition.

2. Examination of the hull

(1) Examination of the hull plating and its closing appliances as far as can be seen.
(2) Examination of watertight penetrations as far as practicable.

3. Examination of weather deck, hatch covers and coamings

(1) Confirmation is to be obtained that no unapproved changes have been made to the hatch covers, hatch coamings and their securing and sealing devices since the last survey.
(2) A thorough survey of cargo hatch covers and coamings is only possible by examination in the open as well as closed positions and is to include verification of proper opening and closing operation. As a result, the hatch cover sets within the forward 25 % of the ship's length and at least one additional set, such that all sets on the ship are assessed at least once in every 5-year period, are to be surveyed open, closed and in operation to the full extent on each direction at each Annual Survey, including:
(A) stowage and securing in open condition
(B) proper fit and efficiency of sealing in closed condition
(C) operational testing of hydraulic and power components, wires, chains, and link drives
The closing of the covers is to include the fastening of all peripheral and cross joint cleats or other securing devices. Particular attention is to be paid to the condition of the hatch covers in the forward 25% of the ship's length, where sea loads are normally greatest.
(3) If there are indications of difficulty in operating and securing hatch covers, additional sets above those required by (2), at the discretion of the Surveyor, are to be tested in operation.
(4) Where the cargo hatch securing system does not function properly, repairs are to be carried out under the supervision of the Society.
(5) For each cargo hatch cover set, at each Annual Survey, the following items are to be surveyed:
(A) cover panels, including side plates, and stiffener attachments that may be accessible in the open position by Close-up Survey(for corrosion, cracks, deformation)
(B) sealing arrangements of perimeter and cross joints(gaskets for condition and permanent deformation, flexible seals on combination carriers, gasket lips, compression bars, drainage channels and non return valves)
(C) clamping devices, retaining bars, cleating(for wastage, adjustment, and condition of rubber components)
(D) closed cover locating devices(for distortion and attachment)
(E) chain or rope pulleys
(F) guides
(G) guide rails and track wheels
(H) stoppers
(I) wires, chains, tensioners, and gypsies
(J) hydraulic system, electrical safety devices and interlocks
(K) end and interpanel hinges, pins and stools where fitted
(6) At each hatchway, at each Annual Survey, the coamings, with panel stiffeners and brackets are to be checked for corrosion, cracks and deformation, especially of the coaming tops, including Close-up Survey.
(7) Where considered necessary, the effectiveness of sealing arrangements may be proved by hose or chalk testing supplemented by dimensional measurements of seal compressing components.

(8) Where portable covers, wooden or steel pontoons are fitted, checking the satisfactory condition, where applicable, of:
 (A) wooden covers and portable beams, carriers or sockets for the portable beam, and their securing devices
 (B) steel pontoons, including Close-up Survey of hatch cover plating
 (C) tarpaulins
 (D) cleats, battens and wedges
 (E) hatch securing bars and their securing devices
 (F) loading pads/bars and the side plate edge
 (G) guide plates and chocks
 (H) compression bars, drainage channels and drain pipes(if any)
(9) Examination of flame screens on the open ends of air pipes to all bunker tanks.
(10) Examination of bunker and vent piping systems, including ventilators.

4. Examination of cargo holds

The examination of cargo holds in Annual Survey is to be in accordance with the follows.

	10 years < age ≤ 15 years	15 years 〈 age
Overall Survey	Two selected cargo holds	All cargo holds
Others	All piping and penetrations in cargo holds, including overboard piping, are to be examined.	All piping and penetrations in cargo holds, including overboard piping, are to be examined.

(NOTES)
1. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurement is to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These increased thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

5. Examination of ballast tanks

Examination of ballast tanks when required as a consequence of the results of the Special Survey and Intermediate Survey is to be carried out. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that Substantial Corrosion is found, the extent of thickness measurements is to be increased in accordance with the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect Areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

6. Additional Annual Survey requirements after determining compliance with SOLAS XII/12 and XII/13

(1) For ships complying with the requirements of SOLAS XII/12 for hold, ballast and dry space water level detectors, the Annual Survey is to include an examination and a test, at random, of the water ingress detection systems and of their alarms.
(2) For ships complying with the requirements of SOLAS XII/13 for the availability of pumping systems, the Annual Survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

603. Intermediate Survey

1. General

(1) The due range of Intermediate Survey is to be in accordance with the requirements of **Ch 2, 301.**

(2) At each Intermediate Survey, in addition to the requirements of the Annual Survey, the following items are to be surveyed. Those items which are additional to the requirements of the Annual Survey may be surveyed either at or between the 2nd and 3rd Annual Survey.

(3) Double skin bulk carriers exceeding 10 years of age up to 15 years of age, the following is to apply:

(a) The requirements of the Intermediate Survey are to be to the same extent to the previous Special Survey as required in **604.** and **102. 1.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, internal examination of fuel oil tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.

(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**

(c) In application of (a) above, an under water survey may be considered in lieu of the requirements of **604. 1** (6).

(4) Double skin bulk carriers over 15 years of age, the following is to apply:

(a) The requirements of the Intermediate Survey are to be to the same extent to the previous Special Survey as required in **604.** and **102. 1.** (Caution : In this case, the requirements specified in **Ch 2, 403.** are not need to be applied) However, internal examination of fuel oil tanks and pressure testing of all tanks are not required unless deemed necessary by the attending Surveyor.

(b) In application of (a) above, the Intermediate Survey may be commenced at the second Annual Survey and be progressed during the succeeding year with a view to completion at the third Annual Survey in lieu of the application of **Ch 2, 401. 4** and **5.**

(c) In application of (a) above, a survey in dry dock is to be part of the Intermediate Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for Intermediate Surveys, if not already performed.

Note : Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

2. Examination of ballast tanks

The examination of ballast tanks in Intermediate Survey is to be in accordance with the follows.

5 years 〈 age ≤10 years 1), 2), 3)	10 years 〈 age ≤ 15 years	15 years 〈 age
1. Overall Survey of representative ballast tanks 2. Overall Survey and Close-up Survey of suspect areas identified at previous surveys	**603. 1** (3) to be applied.	**603. 1** (4) to be applied.
(NOTES) 1) The selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks. If such Overall Survey reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains efficient. 2) Where POOR coating condition, corrosion or other defects are found in ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tank of the same type. 3) In ballast tanks other than double bottom ballast tanks, where a hard protective coating is found in POOR condition, and it is not renewed, or where soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual intervals. When such breakdown of hard protective coating is found in double bottom ballast tanks, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied, the tanks in question may be examined at annual interval. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.		

3. Examination of cargo holds

The examination of cargo holds in Intermediate Survey is to be in accordance with the follow.

5 years 〈 age ≤10 years[1)]	10 years 〈 age ≤ 15 years	15 years 〈 age
Overall Survey of all cargo holds	**603. 1** (3) to be applied.	**603. 1** (4) to be applied.

(NOTES)
1) Where considered necessary by the Surveyor as a result of the Overall Survey, the survey is to be extended to include a Close-up Survey of those areas of structure in the cargo holds selected by the Surveyor.

4. Extent of thickness measurements

(1) Double skin bulk carriers exceeding 5 years of age up to 10 years of age, the following is to apply:
   (a) Thickness measurements are to be carried out to an extent sufficient to determine both general and local corrosion levels at areas subject to Close-up Survey, where required as per preceding **Par 2** and **Par 3**.
   (b) The extent of thickness measurement may be specially considered provided the Surveyor is satisfied by the Close-up Survey that there is no structural diminution and the hard protective coatings are found to be in a GOOD condition.
   (c) Where Substantial Corrosion is found, the extent of thickness measurements is to be increased in accordance with the requirements of the Guidance relating to the Rules. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
   (d) Where the hard protective coating in cargo holds is found to be in GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.
   Note : For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the Close-up Surveys and thickness measurement. Prior to the coating of cargo holds of existing ships, scantlings should be ascertained in the presence of a Surveyor.
(2) Double skin bulk carriers exceeding 10 years of age up to 15 years of age, **Par 1** (3) above is to apply.
(3) Double skin bulk carriers exceeding 15 years of age, **Par 1** (4) above is to apply.

604. Special Survey

1. General

(1) The due range of Special Survey is to be in accordance with the requirements of **Ch 2, 401.**
(2) The Special Survey is to include, in addition to the requirements of the Annual Survey, examination, tests, and checks of sufficient extent to ensure that the hull and related piping, as required in (4), is in a satisfactory condition and is fit for its intended purpose for the new period of class of 5 years to be assigned subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.
(3) All cargo holds, ballast tanks, including double bottom and double side tanks, pipe tunnels, cofferdams and void spaces bounding cargo holds, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in **Par 5** and **Par 6**, to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.
(4) All piping systems within the spaces specified in (3) above are to be examined and operationally tested to working pressure to attending Surveyor's satisfaction to ensure that tightness and condition remain satisfactory.
(5) The survey extent of ballast tanks converted to void spaces is to be specially considered in relation to the requirements for ballast tanks.
(6) A survey in dry dock is to be a part of the Special Survey. The Overall and Close-up Surveys and thickness measurements, as applicable, of the lower portions of the cargo holds and ballast tanks are to be carried out in accordance with the applicable requirements for Special Surveys, if not already performed.
Note : Lower portions of the cargo holds and ballast tanks are considered to be the parts below light ballast water line.

2. Tank protection

(1) Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom ballast tanks, where a hard protective coating is found in POOR condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.
(2) When such breakdown of hard protective coating is found in double bottom ballast tanks and it is not renewed, where a soft or semi-hard coating is applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(3) Where a hard protective coating is provided in cargo holds, and is found in GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.

3. Hatch covers and coamings

In addition to the requirements in **602. 3** of the Annual Survey, the following items are to be surveyed.
(1) Checking of the satisfactory operation of all mechanically operated hatch covers is to be made, including:
  (A) stowage and securing in open condition;
  (B) proper fit and efficiency of sealing in closed condition;
  (C) operational testing of hydraulic and power components, wires, chains, and link drives.
(2) Checking the effectiveness of sealing arrangements of all hatch covers by hose testing or equivalent.
(3) Thickness measurement of the hatch cover and coaming plating and stiffeners is to be carried out as given in **Table 1.3.14.**

4. Extent of Overall and Close-up Survey

(1) An Overall Survey of all tanks and spaces is to be carried out at each Special Survey. Fuel oil tanks in the cargo length area are to be surveyed as follows:

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
-	One	Two	Half, minimum two

(NOTES)
1. These requirements apply to tanks of integral (structural) type.
2. If a selection of tanks is accepted to be examined, then different tanks are to be examined at each Special Survey, on a rotational basis.
3. Peak tanks (all uses) are subject to internal examination at each Special Survey.
4. At Special Survey No. 3 and subsequent Special Surveys, one deep tank adjacent to side shell plate for fuel oil in the cargo area is to be included, if fitted.

(2) The minimum requirements for Close-up Survey at Special Survey are given in **Table 1.3.13.** 1) for double skin bulk carriers, excluding ore carriers and in **Table 1.3.13**, 2) for ore carriers, respectively.
(3) The Surveyor may extend the Close-up Survey as deemed necessary taking into account the maintenance of the spaces under survey, the condition of the corrosion prevention system and where spaces have structural arrangements or details which have suffered defects in similar spaces or on similar ships according to available information.
(4) For areas in spaces where hard protective coatings are found to be in a GOOD condition, the extent of Close-up Survey according to **Table 1.3.13** may be specially considered. (Refer also to **604. 2** (3))

5. Extent of thickness measurements

(1) The minimum requirements for thickness measurements at Special Survey are given in **Table 1.3.14.**
(2) Provisions for extended measurements for areas with substantial corrosion are given in the Guidance relating to the Rules and as may be additionally specified in the survey programme as required in **102. 1.** These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.
(3) The Surveyor may further extend the thickness measurements as deemed necessary.
(4) For areas in tanks where hard protective coatings are found to be in a GOOD condition, the extent of thickness measurement according to **Table 1.3.14** may be specially considered. (Refer also to **604. 2** (3))
(5) Transverse sections are to be chosen where the largest reductions are suspected to occur or are revealed from deck plating measurements.
(6) Representative thickness measurement to determine both general and local levels of corrosion in the transverse web frames in ballast tanks is to be carried out. Thickness measurement is also to be carried out to determine the corrosion levels on the transverse bulkhead plating. The extent of thickness measurements may be specially considered provided the Surveyor is satisfied by the Close-up Survey, that there is no structural diminution, and the hard protective coating where applied remains efficient.

6. Extent of tank testing

The minimum requirements for tank testing at Special Survey are given in **Table 1.3.15.**

7. Additional Special Survey requirements after determining compliance with SOLAS XII/12 and XII/13

(1) For ships complying with the requirements of SOLAS XII/12 for hold, ballast and dry space water level detectors, the Special Survey is to include an examination and a test of the all water ingress detection systems and of their alarms.
(2) For ships complying with the requirements of SOLAS XII/13 for the availability of pumping systems, the Special Survey is to include an examination and a test of the means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold, and of their controls.

Table 1.3.13 Minimum requirements for Close-up Survey at Special Survey for Double Skin Bulk Carriers

1) Excluding ore carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. One transverse web with associated plating and longitudinals in two representative ballast tanks of each type(This is to include the foremost topside and double side ballast tanks on either side) (*1)	1. One transverse web with associated plating and longitudinals as applicable in each ballast tank (*1) 2. Forward and aft transverse bulkheads including stiffening system in a transverse section including topside, hopper side and double side ballast tanks (*1) 3. 25% of ordinary transverse web frames in the foremost double side tanks (*2)	1. All transverse webs with associated plating and longitudinals as applicable in each ballast tank (*1) 2. All transverse bulkheads including stiffening system in each ballast tanks (*1) 3. 25% of ordinary transverse web frames in all double side tanks (*2)	1. All transverse webs with associated plating and longitudinals as applicable in each ballast tank (*1) 2. All transverse bulkheads including stiffening system in each ballast tanks (*1) 3. All ordinary transverse web frames in all double side tanks (*2)
2. Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3) 3. All cargo hold hatch covers and coamings (platings and stiffeners) (*4)	4. One transverse bulkhead in each cargo hold, including internal structure of upper and lower stools, where fitted (*3) 5. All cargo hold hatch covers and coamings (platings and stiffeners) (*4) 6. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (*5)	4. All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3) 5. All cargo hold hatch covers and coamings (platings and stiffeners) (*4) 6. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (*5)	4. All cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3) 5. All cargo hold hatch covers and coamings (platings and stiffeners) (*4) 6. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (*5)

(NOTES)

1. (*1) to (*5) means as follows and are illustrated in **Annex 1-6** of the Guidance.
   - (*1) : Transverse web frame or watertight transverse bulkhead in topside, hopper side and double side ballast tanks. In fore and aft peak tanks transverse web frame means a complete transverse web frame ring including adjacent structural members
   - (*2) : Ordinary transverse frame in double side tanks
   - (*3) : Cargo hold transverse bulkheads plating, stiffeners and girders
   - (*4) : Cargo hold hatch covers and coamings
   - (*5) : Deck plating and under deck structure inside line of hatch openings between cargo hold hatches
2. Close-up Survey of transverse bulkheads to be carried out at four levels:
   - Level(a) : Immediately above the inner bottom and immediately above the line of gussets(if fitted) and shedders for ships without lower stool
   - Level(b) : Immediately above and below the lower stool shelf plate(for those ships fitted with lower stools), and immediately above the line of the shedder plates
   - Level(c) : About mid-height of the bulkhead
   - Level(d) : Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks

2) Ore carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. One web frame ring complete including adjacent structural members in a ballast wing tank (*1)	1. All web frame rings complete including adjacent structural members in a ballast wing tank (*1)	1. All web frame rings complete including adjacent structural members in each ballast tank (*1)	1. All web frame rings complete including adjacent structural members in each ballast tank (*1)
	2. One deck transverse including adjacent deck structural members in each remaining ballast tank (*1)	2. All transverse bulkheads complete, including girder system and adjacent structural members, in each ballast tank (*1)	2. All transverse bulkheads complete, including girder system and adjacent structural members, in each ballast tank (*1)
	3. Forward and aft transverse bulkheads complete, including girder system and adjacent structural members, in a ballast wing tank (*1)	3. One web frame ring complete including adjacent structural members in each wing void space (*1)	3. One web frame ring complete including adjacent structural members in each wing void space (*1)
2. One transverse bulkhead lower part including girder system and adjacent structural members in a ballast tank (*1)	4. One transverse bulkhead lower part, including girder system and adjacent structural members, in each remaining ballast tank (*1)	4. Additional web frame rings in void spaces as deemed necessary by the Society (*1)	4. Additional web frame rings in void spaces as deemed necessary by the Society (*1)
3. Two selected cargo hold transverse bulkheads, including internal structure of upper and lower stools, where fitted (*3)	5. One transverse bulkhead in each cargo hold, including internal structure of upper and lower stools, where fitted (*3)	5. All cargo hold transverse bulkhead, including internal structure of upper and lower stools, where fitted (*3)	5. All cargo hold transverse bulkhead, including internal structure of upper and lower stools, where fitted (*3)
4. All cargo hold hatch covers and coamings(plating and stiffeners) (*4)	6. All cargo hold hatch covers and coamings(plating and stiffeners) (*4)	6. All cargo hold hatch covers and coamings(plating and stiffeners) (*4)	6. All cargo hold hatch covers and coamings(plating and stiffeners) (*4)
	7. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (*5)	7. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (*5)	7. All deck plating and under deck structure inside line of hatch openings between all cargo hold hatches (*5)

(NOTES)
1. (*1), (*3), (*4) and (*5) means as follows and are illustrated in **Annex 1-6** of the Guidance.
   - (*1) : Transverse web frame or watertight transverse bulkhead in ballast wing tanks and void spaces. In fore and aft peak tanks transverse web frame means a complete transverse web frame ring including adjacent structural members
   - (*3) : Cargo hold transverse bulkheads plating, stiffeners and girders
   - (*4) : Cargo hold hatch covers and coamings
   - (*5) : Deck plating and under deck structure inside line of hatch openings between cargo hold hatches
2. Close-up Survey of transverse bulkheads to be carried out at four levels:
   - Level(a) : Immediately above the inner bottom and immediately above the line of gussets(if fitted) and shedders for ships without lower stool
   - Level(b) : Immediately above and below the lower stool shelf plate(for those ships fitted with lower stools), and immediately above the line of the shedder plates
   - Level(c) : About mid-height of the bulkhead
   - Level(d) : Immediately below the upper deck plating and immediately adjacent to the upper wing tank, and immediately below the upper stool shelf plate for those ships fitted with upper stools, or immediately below the topside tanks

Table 1.3.14 Minimum requirements for thickness measurements at Special Survey of Double Skin Bulk Carriers

Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
1. Suspect area	1. Suspect area 2. Within the cargo length: 1) Two transverse sections of deck plating outside line of cargo hatch openings 3. Wind and water strakes in way of the two transverse sections considered above 4. Selected wind and water strakes outside the cargo length area 5. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.13**	1. Suspect area 2. Within the cargo length: 1) each deck plate outside line of cargo hatch openings 2) two transverse sections, one in the amidship area, outside line of cargo hatch openings 3) all wind and water strakes 3. Selected wind and water strakes outside the cargo length area 4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.13**	1. Suspect area 2. Within the cargo length: 1) each deck plate outside line of cargo hatch openings 2) three transverse sections, one in the amidship area, outside line of cargo hatch openings 3) each bottom plate 3. All wind and water strakes, full length 4. Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey according to **Table 1.3.13**

Table 1.3.15 Minimum requirements for tank testing at Special Survey of Double Skin Bulk Carriers

Tanks or spaces \ No. of Special Survey	Special Survey No. 1	Special Survey No. 2	Special Survey No. 3	Special Survey No. 4 and Subsequent
All boundaries of ballast tanks, deep tanks and cargo holds used for water ballast within the cargo length area	○	○	○	○

(NOTES)
1. For fuel oil tanks within the cargo length area, only representative tanks are to be pressure tested.
2. The Surveyor may extend the tank testing as deemed necessary.
3. Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.
4. Boundaries of ballast holds are to be tested with a head of liquid to near to the top of hatches.
5. Boundaries of fuel oil tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. Tank testing of fuel oil tanks may be specially considered based on a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.
6. The testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tanktop is carried out.

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KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 1

Classification and Surveys

GA-01-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance Relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 1 "CLASSIFICATION AND SURVEYS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which the application for Classification Survey is submitted to the Society on or after 1 July 2011.
2. The amendments to the Guidance for 2010 version and their effective date are as follows;

Effective Date 1 July 2010

CHAPTER 1 CLASSIFICATION

Section 4 Classification Survey after Construction

- 403. has been amended.

Effective Date 1 January 2011

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General

- 107. has been newly added.

Effective Date 1 July 2011

CHAPTER 1 CLASSIFICATION

Section 1 General

- has been newly added.

Section 3 Classification Survey during Construction

- 302. 2 has been amended.
- 307. 1 has been amended.

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General

- 109. 1 has been newly added.

Section 6 Docking Survey

- 604. 2 has been moved to 604. 3 (4) (a) of the Rules.

CHAPTER 3 HULL SURVEYS OF SHIPS SUBJECT TO THE ENHANCED SURVEY PROGRAMME

Section 1 General

- 102. has been newly added.

<ANNEX>

Annex 1-1 Character of Classification

- Par 1, 1.1 2-2 and Remarks(3-2) to (3-4) have been newly added.
- Par 1, 1.1 Remarks(23) has been moved to Remarks(30).
- Par 1, 1.1 17 has been amended.
- Par 1, 1.1 Remarks(30) has been amended.
- Par 1, 1.2 has been amended.
- Par 2, 2.1.2 has been newly added.

Annex 1-13 Owner's Hull Inspection and Maintenance Program

- has been newly added.

CONTENTS

CHAPTER 1 CLASSIFICATION

Section 1 General

Tests and Inspections specified in the Rules of the Society are to be carried out under attendance of the Surveyor, unless expressly specified otherwise.

Section 2 Character of Classification

201. Class notations

1. The definitions of terms specified in **201.** (2) to (4) of the Rules are as follows. If the following definition are expressly provided by the flag administration, they are to follow the provided definition.

(A) Coastal service area : Water area within 20 Nautical miles(1 Nautical mile = 1852 m) of the shore

(B) Smooth water service area : Water area within lakes, rivers and harbours

2. Upon the request of the applicant(i.e., the Owner or the Builder), character of class including class notations shall be assigned to ships which have been built to comply with the corresponding requirements of the Rules. The requirements are given in the following paragraphs.

3. In applications to **201.** (2) to (4) of the Rules, the following service restriction notations of hull, machinery and equipment shall be applied.

(1) Service restriction notations of hull

KRS 0 : Ships which have been built to comply with the following requirements for a limited service(i.e., coastal or smooth water service)

(A) Requirements specified in **Pt 3, Ch 1, 201.** (1) of the Guidance relating to the Rules for the Classification of Steel Ships(hereinafter called the Guidance)

(B) Requirements specified in **Ch 23, 202.** or **302.** of the Rules for the Classification of Steel Barges

(C) Requirements specified in **Pt 10, Ch 1, 201. 1** (1) to (3) and **2** (1) to (3) of the Guidance

(2) Service restriction notations of machinery

KRM 0 : Ships which have been built to comply with the following requirements for a limited service

(A) Requirements specified in **Pt 5, Ch 3, 203.** and **204. 2** of the Guidance

(B) Requirements specified in **Pt 6, Ch 1, 101. 1** (4) and (5) of the Guidance

(3) Service restriction notations of equipment

For ships which have been built to comply with the following requirements for a limited service(i.e., coastal or smooth water service), the notation of "C" or "S" shall be appended to the character of hull and/or machinery.

(A) C : Notation for coastal service

(a) Hull equipment

(i) Requirements specified in **Pt 3, Ch 1, 201.** (2) and (3) of the Guidance

(ii) Requirements specified in **Pt 10, Ch 1, 201. 1** (4) and (5) of the Guidance

(iii) Requirements specified in **Ch 23, 203.** of the Rules for the Classification of Steel Barges

(b) Machinery equipment

(i) Requirements specified in **Pt 5, Ch 1, 401. 1** / **Pt 8, Annex 8-3, 16** (3) (B) / **Pt 5, Ch 6, 702. 2** (2), **802. 1** (2), **804. 1** (2) and **2** (1), **903. 1** (1) and (3) / **Pt 5, Ch 7, 204. 1** (2), **206. 1** (2), **207. 2** (2), **209. 2** (2), **301. 6** (2) and **Pt 5, Ch 8, 101. 1** (1) of the Guidance

(B) S : Notation for smooth water service

(a) Hull equipment

(i) Requirements specified in **Pt 3, Ch 1, 201.** (2), (3) and **Pt 4, Ch 8, 101. 1** of the Guidance

(ii) Requirements specified in **Pt 10, Ch 1, 201. 2** (4) to (7) of the Guidance

(iii) Requirements specified in **Ch 23, 303., 304., 305.** and **306.** of the Rules for the Classification of Steel Barges

(b) Machinery equipment

(i) Requirements specified in **Pt 5, Ch 1, 401. 1** / **Pt 5, Ch 6, 702. 2** (1), **802. 1** (1), **901. 6** (2), **903. 1** (1) / **Pt 5, Ch 7, 201. 1, 409.** and **Pt 5, Ch 8, 101. 1** (1) of the Guidance

4. The details for ship type, special feature notations and additional installations notations of class notations are given in **Annex 1-1** of the Guidance.

Section 3 Classification Survey during Construction

301. Classification Survey during Construction

The hull survey for Classification Survey during Construction for ships subject to **Annex 1-12** is to be in accordance with **Annex 1-12.**

302. Approval of plans

1. The following contents shall be described in the drawings submitted to the Society for approval:

(1) Midship section
(A) Scantling draught(d_s) or length of ship(L_s) corresponding to d_s, where $d_s - d >$ 300 mm(is to be also indicated in other Key plans).
(B) Kind of Freeboard to be assigned(is to be also indicated in other plans relating to the conditions of freeboard assignment).
(C) Position of freeboard deck in ships with multiple decks.
(D) Draught in meter corresponding to designed timber freeboard, where timber load line is intended to be marked.
(E) Deck load(KN/m^2) in ships carrying deck cargoes(including timbers).
(F) Loading condition(specific gravity, etc.) in bulk carriers.
(G) Length of ship(L) specified in **Pt 3, Ch 1, 102.** of the Rules.

(2) Construction profile and deck plans
L_f and the points of fore/after end of L_f or 0.25 L_f from the fore end of L_f

(3) Shell expansion
Comparison table between the standard sheer and actual sheer on the exposed deck(in case that exposed freeboard or superstructure deck has a well formed by bulwarks and end bulkheads of superstructure).

(4) Arrangements of scuppers
(A) Lines of 0.01 L_f and 0.02 L_f above the summer load line
(B) Line of 600 mm above the summer load line
(C) Line of 450 mm below the freeboard deck

2. Omission and addition of plans and documents to be submitted

(1) Submission of the plans and documents may be omitted in case where a sister ship is intended to be built. Where the omission is desired, the following plans in triplicate are to be submitted, together with a written request format. A sister-ship means a ship intended to be built by the same builder, based on the plans and documents approved for other ships and regarded as the same or similar by the Society.
(A) General arrangement
(B) Midship section
(C) Construction profile and deck plans
(D) Shell expansion
(E) Machinery arrangement of machinery space
(F) Shafting arrangement
(G) Machinery room piping diagram
(H) Electrical power diagram
(I) Revised plans for revision of original plans and corresponding original plans
(J) Revised plans where applicable requirements of the Rules are changed

(2) In application to (1), (I) and (J), calculation sheets are to be submitted, additionally. Where the omission of plans is accepted by the Society, the omitted plans shall be regarded as the same that approved for other ships.

(3) In case of other than (1), the submission of the plans and documents may be omitted also in accordance with (1) and (2) where it is desired to build the vessels based on the plans and documents which are already approved by the Society.

(4) Additional copies of the plans and documents may be required where the required attendance of the Surveyor is anticipated at more than one location.

3. Re-examination of plans in cases where freeboard is to be altered

Reassignment of a smaller freeboard, other than that corresponding to the designed draught(d) may be desired due to allowance of the form freeboard found as a result of freeboard calculation. In such case, application for the intended draught(d_f) is to be submitted to the Society with the following documents specifying the intended d_f accompanied by calculation sheets on strength of hull members and on longitudinal hull strength for the desired d_f as early as practicable.

(1) Where $d_f - d \leq$ 300 mm :
Application for re-examination of plans and documents for the increase of draught
Where $d_s \geq d_f$, this requirement may be ignored
(2) Where $d_f - d >$ 300 mm :
Application for re-examination of plans and documents for the increase of draught
(3) In case of above (2), the length of ship corresponding to d_f is to be specified in the application for re-examination of plans and documents. In this case, key plans specifying the revised principal dimensions are to be re-submitted.
(4) The equipment number and the equipment are to comply with the requirements specified in **Pt 4, Ch 8** of the Guidance.

4. Examination and test plans

The shipbuilder is to submit the examination and test plans including the followings to the Surveyor prior to the relevant examination and test.

(1) Inspection and Test Plan(ITP)
(2) proposals for the examination of completed steelwork - generally referred to as the block plan and are to include details of joining blocks together at the pre-erection and erection stages or at other relevant stages
(3) proposals for fit up examinations where necessary
(4) proposals for testing of the structure(leak and hydrostatic) as well as for all watertight and weathertight closing appliances
(5) proposals for non-destructive examination
(6) Procedure of stability experiment
(7) Procedure of Sea Trial
(8) The coating work specification and quality control scheme(including inspection of surface preparation and coating processes for ships with PSPC notation)
(9) Proposals for the examination of cargo handling appliances(where applicable)
(10) Onboard Test Procedure
(11) any other proposals specific to the ship type or to the statutory requirements(where applicable)

304. Machinery installation

In application to **304.** of the Rules, the term "considered necessary by the Society" means the requirements specified in **Pt 6, Ch 2, 301. 1** and **2** of the Rules. (for CMA Ships or UMA Ships as defined in **Pt 9**, the requirements specified in **Pt 9, Ch 3, 203.** of the Rules are to be applied)

306. Tests

In application to **306.** of the Rules, the term "considered necessary tests" means the tests specified in **Pt 6, Ch 2, 302.** and **303.** of the Rules. (for CMA Ships or UMA Ships as defined in **Pt 9**, the requirements specified in **Pt 9, Ch 3, 204.** and **205.** of the Rules are to be applied)

307. Stability experiments

1. In application to **307. 1** of the Rules, the requirements shall not apply to the following ships not engaged on international voyage and less than 24 meters in length.

(1) Tug boat, Salvage, Dredger or Survey ship
(2) Steel barges
(3) Ships other than passenger ships or car ferries operating in water area within lakes, rivers and harbours
(4) Floating structures used for the storage in bulk of oil or waste etc.
(5) Floating structures used for the storage in bulk of dangerous goods

2. Stability experiments stated in the Rules mean inclining experiments and rolling tests. Where the rolling period could be calculated in accordance with the formula specified in **Annex 1-2** of the Guidance, the rolling tests may be dispensed with except those specially required by the Society.

3. The requirements for intact stability shall be given in **Annex 1-2** of the Guidance.

4. Where a loading instrument is installed onboard according to requirement in **307. 2** of the Rules, the approval and survey procedures are given in **Annex 1-10** of the Guidance.

Section 4 Classification Survey after Construction

401. Classification Survey after Construction

1. For ships intended to register with the Society, where it is deemed necessary to do a preliminary survey, due to the age and status of the ships, the preliminary survey is to be carried out prior to the commencement of the Classification Survey. The Classification Survey shall be carried out based on the results of the preliminary survey. In such case, certain survey items may be specially required by the Society.

2. In application to **401.** of the Rules, parts of hull, machinery, outfittings and equipment which, if necessary, are to be measured for actual scantlings are those necessary for record of particulars on hull and machinery of ship in review of register data.

402. Submission of plans

1. For the Classification Survey after Construction, the following plans and documents are to be submitted to the Society well in advance. Where deemed necessary by the Society, the list of plans and documents other than those specified below are to be notified to the owner and there are to be submitted to the Society.

(1) Hull : 2 copies(4 copies for stability information booklet and loading manual)
- (A) General arrangement
- (B) Midship section
- (C) Construction profile and deck plans
- (D) Shell expansion
- (E) Transverse bulkheads
- (F) Rudder and rudder stock construction
- (G) Stern frame
- (H) Hatches and hatch-closing arrangements(when hatch covers are provided)
- (I) Capacity plan
- (J) Loading manual(when loading manual is required)
- (K) Loading instrument(when loading instrument is required)
- (L) Lines(where freeboard assignment is required)
- (M) Hydrostatic curves
- (N) Lumber storage plan(where assignment of timber freeboard is required)
- (O) Stability information booklet

(2) Machinery : 2 copies
- (A) Machinery arrangement of machinery space
- (B) Shafting arrangement
- (C) Electric wiring diagram
- (D) Power transmission systems, intermediate shaft, thrust shaft and propeller shaft
- (E) Propeller
- (F) Piping diagram
- (G) Main engine, propulsion gears and clutch systems(or manufacturer make, model and rating information)
- (H) Steering gear system piping and arrangements and steering gear manufacturer make and model information
- (I) For steam turbine vessels, main boilers, superheaters and economisers(or manufacturer make, model and rating information) and steam piping
- (J) For vessels less than two(2) years old, torsional vibration calculations are to be submitted
- (K) Additional plans required for UMA-ship
  - Instrument and alarm list
  - Fire alarm system
  - List of automatic safety functions(e.g. slowdowns, shutdowns, etc.)
  - Function testing plan

(3) Plans required in Flag Administration or Convention(where applicable) : 2 copies
(4) Others
(A) A copy of survey reports(including Ship's Particulars and Initial Records)
(B) Copies of Classification Certificate, Statutory Certificate and Certificate of Registry
(C) Others indicating the ship's history and other particulars if necessary

2. In case that the plans and documents considered equivalent to those specified in **Par 1** are submitted, they may be accepted at the discretion of the Society.

3. Notice of review results of plans and documents

Where examination of plans and documents specified in **Par 1** above, is made by the Society, the applicant will be notified of the results. In cases where insufficient information accompanies the submitted plans and documents, the Society may require onboard inspection.

403. Classification Survey of ships classed by other classes

When a ship holding class with any Society which is subject to verification of compliance with QSCS(Quality System Certification Scheme) of IACS is intended for classification, plans and documents to be submitted and items to be surveyed etc., are listed as below. Where deemed necessary by the Society, the list of plans and documents other than those specified below are to be notified to the Owner and there are to be submitted to the Society.

1. Plan and document

(1) Hull : 1 copy
(A) General arrangement
(B) Midship section
(C) Construction profile and deck plans
(D) Shell expansion
(E) Loading manual(when loading manual is required)
(F) Stability information booklet
(G) Transverse bulkheads
(H) Rudder and Rudder stock construction
(I) Hatches and hatch-closing arrangements(when hatch covers are provided)
(J) Capacity plan
(K) Lines(where freeboard assignment is required)
(L) Hydrostatic curves
(M) Lumber storage plan(where assignment of timber freeboard is required)

(2) Machinery : 1 copy
(A) Machinery arrangement of machinery space
(B) Shafting arrangement
(C) Electric wiring diagram
(D) Power transmission systems, intermediate shaft, thrust shaft and propeller shaft
(E) Propeller
(F) Piping diagram
(G) Main engine, propulsion gears and clutch systems(or manufacturer make, model and rating information)
(H) Steering gear system piping and arrangements and steering gear manufacturer make and model information
(I) For steam turbine vessels, main boilers, superheaters and economisers(or manufacturer make, model and rating information) and steam piping
(J) For vessels less than two(2) years old, torsional vibration calculations are to be submitted
(K) Additional plans required for UMA-ship
- Instrument and alarm list
- Fire alarm system
- List of automatic safety functions(e.g. slowdowns, shutdowns, etc.)
- Function testing plan

(3) For vessels with ice class notation, plans for flexible couplings and/or torque limiting shafting devices in the propulsion line shafting(or manufacturer make, model and rating information) are to be submitted.
(4) For oil tankers, pumping arrangement at the forward and after ends and drainage of cofferdams and pump rooms are to be submitted.
(5) Plans required in Flag Administration or Convention(where applicable) : 1 copy
(6) In accordance with the agreement of TOC, owner's authorization letter indicating that the Society may request the survey status and relevant documents from previous Society.
When ship Owner is going to change or is changed, Owner's authorization may be written by the Owner who requests at the Society the Classification Survey.
(7) Others
(A) A copy of survey reports(including Ship's Particulars and Initial Records)
(B) Copies of Classification Certificate, Statutory Certificate and Certificate of Registry
(C) Others indicating the ship's history and other particulars if necessary.
(D) Hull Executive Summary(where required)

2. In case that the plans and documents considered equivalent to those specified in **Par 1** are submitted, they may be accepted at the discretion of the Society.

3. Where any of the following cases is applicable at the moment of Classification Survey of ships classed by other classes, the submission of plan and documents is to be in accordance with **402.** (However, 3 copies of plans for alterations are to be submitted)

(1) change of service area to higher grade
(2) alterations or conversions
(3) change of ship's use
(4) application of additional requirements due to change of ship's nationality.

4. Classification Survey

Classification Surveys may be, but are not required to be, credited as periodical surveys for maintenance of classification. Recommendations and/or conditions of class due for compliance at a specified periodical survey for maintenance of classification need not be carried out/complied with at a Classification Survey unless the Classification Survey is credited as the specified periodical survey for maintenance of classification or the recommendation/condition of classification is overdue.

(1) When a ship is classed by the Society as a results of transfer of class
(A) Notwithstanding the records indicating that all surveys are up-to-date, a Classification Survey is to be held as minimum technical requirements by the Society, the extent of which is to be based on the age of the vessel and the losing Society's class status as follows: However, the Society is to request, if necessary, more strict surveys than the following requirements according to the condition of ship.
(a) Hull Classification Survey
(i) For vessels of age less than 5 years the survey is to take the form of an Annual Survey.
(ii) Additionally, for vessels between 5 and 10 years of age, the survey is to include inspection of a representative number of ballast spaces.
(iii) Additionally, for vessels of 10 years of age and above but less than 20 years of age, the survey is to include inspection of a representative number of cargo spaces.
(iv) For vessels subject to ESP notation(Bulk carrier, Oil tanker and Chemical tanker, etc.), which are 15 years of age and above but less than 20 years of age, the survey is to have the scope of a Special Survey or an Intermediate Survey whichever is due next.
(v) For all vessels, which are 20 years of age and above, the survey is to have the scope of a Special Survey.
(vi) In the context of applying (iv) and (v) above, if a dry-docking of the vessel is not due at the time of Classification Survey of ships classed by other classes, consideration can be given to carrying out an underwater examination in lieu of dry-docking.

(vii) In the context of applying (i) to (vi) above, as applicable, consideration may be given by the Society to the acceptance of thickness measurements taken by the losing society provided;

① if the Classification Survey is to be credited as a periodical survey for maintenance of class, they were carried out within the applicable survey window of the periodical survey in question.

② if the Classification Survey is not to be credited as a periodical survey for maintenance of class, they were carried out;

- within 15 months prior to completion of Classification Survey when it is in the scope of a Special Survey,
- within 18 months prior to completion of Classification Survey when it is in the scope of an Intermediate Survey.

In ① and ② both cases, the thickness measurements are to be reviewed by the Society for compliance with the applicable survey requirements, and confirmatory gaugings are to be taken to the satisfactory of the Society.

(viii) In the context of applying (iii) to (vi) above, as applicable, tank pressure testing for vessels over 15 years of age is not required to be carried out as part of the Classification Survey unless the Classification Survey is being credited as a periodical survey for maintenance of class.

(ix) In the context of applying (i) to (vi) above, as applicable, compliance with IACS Unified Requirements that require compliance at the forthcoming due periodical surveys (such as S26(Strength and Securing of Small Hatches on the Exposed Fore Deck) and S27(Strength Requirements for Fore Deck Fittings and Equipment)) are not required to be carried out/completed as part of the Classification Survey unless the Classification Survey is credited as a periodical survey for maintenance of class.

(b) Machinery Classification Survey

A general examination of all essential machinery is to be held and included:

(i) The adjustment of all boiler, economizer and steam generator safety valves are to be verified and oil fuel burning equipment examined under working conditions.

(ii) All pressure vessels are to be identified with the submitted plans and/or certificates.

(iii) Insulation resistance, generator circuit breakers, preference tripping relays and generator prime mover governors are to be tested and paralleling and load distributing to be proved.

(iv) In all cases, navigation lights and indicators are to be examined under working condition and alternative source of supply to be verified.

(v) Bilge pumping and oil fuel burning installations, together with emergency fire pump and remote controls for oil valves, oil fuel pumps, lubricating oil pumps and forced draught fans are to be examined and tested under working conditions.

(vi) Recirculating and ice clearing arrangements are to be verified as conforming to Rule requirements(When ice class is required).

(vii) The main and all auxiliary machinery necessary for operation of the ship at sea together with essential controls and steering gear are to be tested under working conditions. Alternative means of steering are to be tested. A short sea trial may be held at the Surveyor's discretion if the ship has been laid up for a long period.

(viii) Initial start arrangements are to be verified.

(ix) In the case of oil tankers, the cargo oil system and electrical installation in way of dangerous spaces are to be checked for compliance with rule requirements. Where explosion protected electrical safe equipment is installed, the Surveyors are to confirm themselves that such equipment has been approved by a recognised authority. The safety devices, alarms and essential instruments of inert gas system are to be verified and the plant generally examined to ensure that it does not constitute a hazard to the ship.

Note : For the transfer of class or adding class as a double classed vessel or a dual classed vessel at ship's delivery after completion of the new construction survey of other society, items iii) and ix) may be verified by reviewing the ship's record.

(B) For vessels less than 15 years of age, an Interim Certificate of Class, or other documents enabling the vessel to trade are not to be issued, until all relevant surveys specified in (A) above have been satisfactorily completed; until all overdue surveys and all overdue recommendations/conditions of class previously issued against the subject vessel as specified to the Owner by the losing Society, have been completed and rectified by the Society.
For vessels 15 years of age and above, an Interim Certificate of Class, or other documents enabling the vessel to trade are not to be issued, until all relevant surveys specified in (A) above have been satisfactorily completed; until all overdue surveys and all overdue recommendations/conditions of class previously issued against the subject vessel as specified to the Owner by the losing Society, have been completed and rectified by the losing Society.
When facilities are not available in the first port of survey, an Interim Certificate of Class may be issued to allow the vessel to undertake a direct voyage to a port where facilities are available to complete the surveys required in (A) above. In such cases, the surveys specified in (A) above are to be carried out to the maximum extent practicable at the first port of survey, but in no case less than the scope of annual hull survey and machinery surveys as required in (A) (b).
(C) The validity of the Interim Certificate of Class and the subsequent Certificate of Class is subject to any outstanding recommendations/conditions of class previously issued against the vessel being completed by the due and as specified by the losing Society. Any outstanding recommendations/conditions of class with their due dates are to be clearly stated on the:
(a) Interim Certificate of Class and/or class survey record available on board; and
(b) Survey status when the Certificate of Class is issued.
(D) Any additional information regarding outstanding surveys or recommendations/conditions of class received from the losing Society is to be dealt with in accordance with above (B) and (C) as applicable. If this additional information is received after the Interim Certificate of Classification has been issued, any surveys or recommendations/conditions of class which are overdue are to be dealt with at the first port of call:
(a) by the Society in vessels less than 15 years of age; or
(b) by the losing Society in vessels 15 years of age or over
(2) When a vessel is classed by the Society as a double classed vessel
(A) Double classed vessel is a vessel which is classed by two Societies and where each Society works as if it is the only Society classing the vessel, and does all surveys in accordance with its own requirements and schedule.
(B) Classification Survey is to be carried out in accordance with the requirements of (1) (A) above taking account of the recommendations/conditions of class of in the status provided by the first Society.
(3) When a vessel is classed by the Society as a dual classed vessel
(A) Dual classed vessel is a vessel which is classed by two Societies between which there is a written agreement regarding sharing of work.
(B) Classification Survey having the scope of an Annual Survey as a minimum is to be carried out.
(4) When a vessel is classed by the Society as a double classed vessel or a dual classed vessel at ship's delivery after completion of the new construction survey of other society, all relevant surveys specified in (1) (A) are to be carried out and satisfactorily completed.

5. When a vessel is withdrawing class of the other Society from a double class arrangement with the Society
(A) For vessels less than 15 years of age, all overdue recommendations/conditions of class of the withdrawing Society are to be completed at the first port of call at which surveys can be carried out and all outstanding recommendations/conditions of class of the withdrawing Society are to be completed by the due date of the withdrawing Society.
For vessels of 15 years of age and over, all overdue recommendations/conditions of class of the withdrawing Society are to be completed by the withdrawing Society and all outstanding recommendations/conditions of class of the withdrawing Society are to be completed by the due date of the withdrawing Society.

(B) The validity of the Certificate of Classification is subject to any outstanding recommendations/conditions of class previously issued against the vessel by the withdrawing Society being completed by the due date and as specified by the withdrawing Society. Any outstanding recommendations/conditions of class with their due dates are to be clearly stated on the:
   (a) class survey record if available on board; and
   (b) survey status

(C) Any additional information regarding recommendations/conditions of class received from the withdrawing Society is to be dealt with in accordance with above (A) and (B) as applicable. If this additional information is received from the withdrawing Society after the Interim Certificate of Classification has been issued or the confirmation of the validation of the Certificate of Classification has been done, any recommendations/conditions of class which are overdue are to be dealt with at the first port of call at which surveys can be carried out by the relevant Society, depending on the age of the vessel.

(D) When facilities are not available in the first port of survey, a direct voyage to a port where facilities are available may be accepted to complete surveys for overdue recommendations/conditions of class of the withdrawing Society.

405. Stability experiments

Stability criteria and a standardized form of the stability information booklet are to comply with the requirements given in **307.** of the Guidance.

Section 7 Cooperation Duties of Owners

702. Cooperation to survey

In application to **702. 4** of the Rules, the Guidance means the requirements specified in **Annex 1-11** of the Guidance.

Section 8 Competence and Duties of Surveyors

801. Competence of Surveyors

In application to **801. 3** of the Rules, open-up survey or performance test may be required for the following (1) or (2).

(1) In case where abnormality is suspected from survey for general or operating conditions.

(2) In case where considered as having abnormality to require open-up survey or performance test, taking into account the records for maneuvering, operating and measuring of the ship and equipment, and the ship officers' information for ship conditions.

Section 9 Suspension/Withdrawal of Class and Reclassification

902. Withdrawal of class

When a ship classed with the Society is detained following a Port State Control inspection with serious deficiencies found, the class of the ship may be suspended or withdrawn through the deliberation of the Classification Committee.

Section 13 Classification of Other Installations or Equipment

1301. Classification

In application to **1301.** of the Rules, **Annex 1-1** of the Guidance is to be referred for the assignment of the class notation.

1303. Construction and Survey

In application to **1303.** of the Rules, the requirements of construction and survey as deemed appropriate by the Society means the requirements specified in related Rules.

1304. Maintenance of classification

In application to **1304.** of the Rules, the requirements specified by the Society means the requirements specified in the relevant technical rules of the Society. ⚓

CHAPTER 2 PERIODICAL AND OTHER SURVEYS

Section 1 General

101. Definitions

In application to **101. 11** of the Rules, the term "location prone to rapid wastage" means one of the following cases among the location specified in **Annex 1-5, Table 2** of the Guidance:
(1) Area with standing bilges
(2) Bulkheads facing fuel oil tanks being heated

104. Execution of heavier survey

In application to **104.** of the Rules, the term "as specially considered necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Rules.

107. Repairs

In application to **107. 5** (1) of the Rules, the emergency circumstance means the circumstance which affect or may affect the ships maneuvering, survival, marine pollution or protection of the cargoes directly.

108. Wear limit on structural members

In application to **108.** of the Rules, the terms "considered suitable" or "deemed appropriate by the Society" mean to comply with the requirements specified in **Pt 2** and **Pt 3** of the Rules.

109. Procedures for thickness measurements

1. In application to **109. 1** of the Rules, an appropriately qualified representative means a ship's officer.

2. Methods of thickness measurement are to comply with the requirements specified in **Annex 1-5** of the Guidance.

Section 2 Annual Survey

202. Hull, equipment and fire-extinguishing appliances

In application to **202. 2** of the Rules, the following items are to be surveyed.

1. Examining the fire pumps, fire main, hydrants, hoses and nozzles and the international shore connection and checking that each fire pump, including the emergency fire pump, can be operated separately so that two jets of water are produced simultaneously from different hydrants at any part of the ship whilst the required pressure is maintained in the fire main.

2. Checking the provision and randomly examining the condition of the portable and non-portable fire extinguishers.

3. Confirming that the fire fighter's outfits and emergency escape breathing devices(EEBDs) are complete and in good condition and that the cylinders, including the spare cylinders, of any required self contained-breathing apparatus are suitably charged.

4. Checking the operational readiness and maintenance of fire fighting systems.

5. Examining the fixed fire fighting system for the machinery, cargo, vehicle, special category and ro-ro spaces, as appropriate, and confirming that its means of operation is clearly marked.

6. Examining the fire-extinguishing and special arrangements in the machinery spaces and confirming, as far as practicable and as appropriate, the operation of the remote means of control provided for the opening and closing of the skylights, the release of smoke, the closure of the funnel and ventilation openings, the closure of power operated and other doors, the stopping of ventilation and boiler forced and induced draft fans and the stopping of oil fuel and other pumps that discharge flammable liquids.

7. Examining, as far as possible, and testing, as feasible, any fire detection and alarm system.

8. Examining the fire-extinguishing systems for spaces containing paint and/or flammable liquids and deep-fat cooking equipment in accommodation and service spaces.

9. Examining the helicopter facilities.

10. Examining the arrangements for remote closing of valves for oil fuel, lubricating oil and other flammable oils and confirming, as far as practicable and as appropriate, the operation of the remote means of closing the valves on the tanks that contain oil fuel, lubricating oil and other flammable oils.

11. Examining and testing of the general emergency alarm system.

12. Examining the fire protection arrangements in cargo, vehicle and ro-ro spaces and confirming, as far as practicable and as appropriate, the operation of the means of control provided for closing the various openings.

13. Examining, when appropriate, the special arrangements for carrying dangerous goods, including checking the electrical equipment and wiring, the ventilation, the provision of protective clothing and portable appliances and the testing of the water supply, bilge pumping and any water spray system.

203. Machinery, electrical installations and additional installations

1. In application to **203. 21** of the Rules, the term "considered satisfactory by the Surveyor" means the other cases except for the cases as specified in **Ch 1, 801.** of the Guidance.

2. In application to **203. 22** of the Rules, the Guidance means the requirements specified in **Annex 1-9** of the Guidance.

204. Additional requirements to ship types

In application to **204. 1** to **3** of the Rules, the term "considered necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

Section 3 Intermediate Survey

301. Due range

In application to **301. 3** of the Rules, survey items of Intermediate Survey mean the following items among all survey items of Intermediate Survey.

(1) Compartments survey(except compartments which are to be surveyed at each periodical survey)
(2) Thickness measurement
(3) Docking Survey as a part of Intermediate Survey(except the ships of which Docking Survey is to be carried out at each periodical survey)
(4) Overhauling survey of machinery(except the ships subject to CMS or PMS)

302. Hull, equipment and fire-extinguishing appliances

In application to **302. 2** of the Rules, the Guidance means the requirements specified in **202.** of the Guidance. In this case, for foam fire-extinguishing systems, the foam is to be tested by the manufacturer or recognized test organization and the test records are to be submitted for approval.

303. Machinery, electrical installations and additional installations

1. In application to **303. 1** (1) of the Rules, the term "deemed unnecessary by the Surveyor" means the other cases except for the cases as specified in **Ch 1, 801.** of the Guidance.

2. In application to **303. 2** (1) and (1) (A) of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

3. In application to **303. 2** (2) of the Rules, high-rotating-speed internal combustion engines of specific construction refer to those which comply with the formulae below and which can not be included in a survey of the crankshaft and bearings without complete engine overhaul.

$$C_s = \frac{S \cdot n^2}{1.8 \times 10^6} \geq 90, \qquad V = \frac{\pi \cdot d \cdot n}{6 \times 10^4} \geq 6$$

where,

S : Stroke (mm)
n : Maximum continuous revolution (rpm)
d : Diameter of crankshaft journal (mm)

4. In application to **303. 2** (3) of the Rules, the Guidance for passenger ship means that it is to be confirmed that the requirements specified in **902. 3** apply to the ship.

5. In application to **303. 4** of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

6. In application to **303. 5** of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

7. In application to **303. 6** of the Rules, the Guidance means the requirements specified in **Annex 1-9** of the Guidance.

304. Additional requirements to Ship types

In application to **304. 1** (10) of the Rules, Non-metallic membranes of pressure relief valves for cargo tanks, in principle, should be inspected every three(3) years and then replaced with new ones when they are showing probability of hardening or malfunction. However, Non-metallic membranes are may be permitted to use exceeding three(3) years subject to comply with the following inspections.

(1) To be confirmed that the function test of the pressure relief valve is carried out and found in good order. However, where deemed necessary by the surveyor in accordance with **Ch 1, 801.** of the Guidance, the open-up survey is to be carried out.

(2) To be confirmed that, on the basis of log-book or crew's statement, no leakage from the pressure relief valves during the voyage has been occurred.

(3) As a result of the examination (1) and (2) above, it is to be verified that the surface and the function of the pressure relief valves are satisfactory.

Section 4 Special Survey (Hull, Equipment and Fire-extinguishing Appliances)

401. Due range

1. In application to **401. 5** of the Rules, survey items of Special Survey mean the following items among all survey items of Special Survey.

(1) Compartments survey(except compartments which are to be surveyed at each Periodical Survey)
(2) Thickness measurement
(3) Docking Survey(except the ships of which Docking Survey is to be carried out at each periodical survey)
(4) Overhauling survey of machinery(except the ships subject to CMS or PMS)
(5) Examination of **403. 1** (3) of the Rules
(6) Examination of **Sec 5-2, 3** of the Rules

2. For passenger ships, submersibles, nuclear ships, hydrofoils, air cushion vehicles and high speed crafts the requirements specified in **401. 4** and **5** of the Rules do not apply.

403. Requirements of survey

1. In application to **403. 1** (8) of the Rules, the term "deemed appropriate by the Surveyor" means the other cases except for the cases as specified in **Ch 1, 801.** of the Guidance.

2. In application to **403. 1** (15) of the Rules, the term "considered necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

404. Fire-extinguishing appliances

In application to **404.** of the Rules, the Guidance means the requirements specified in **302.** of the Guidance.

Section 5-1 Special Survey (Machinery, Electrical Installations and Additional Installations)

502. Requirements of survey

1. In application to **502. 1** (1) (a) of the Rules, where total running hours for an internal combustion engine is confirmed and found in satisfactory by the Surveyor, the survey may be extended until next overhauling hours recommended by the manufacturer since the previous overhauling survey. However, the interval is not to exceed 5 years from the date of the previous overhauling survey. And the survey item of essential valves and valve arrangements are to be included the isolating non-return valve for starting air mains against explosion as specified in **Pt 5, Ch 2, 203. 9** of the Rules.

2. In application to **502. 1** (1) (b) of the Rules, the Guidance means the requirements specified in **303. 3** of the Guidance, and the due date of survey is same as **Par 1** above.

3. In application to **502. 2** (2) to (5), (8), (10) and (12) of the Rules, the terms "deemed necessary by the Surveyor" and "considered necessary by the Surveyor" mean the cases as specified in **Ch 1, 801.** of the Guidance.

4. In application to **502. 2** (9) (a) and (c) of the Rules, the terms "deemed necessary by the Surveyor" and "considered necessary by the surveyor" mean the cases as specified in **Ch 1, 801.** of the Guidance. In application to **502. 2** (9) (b) of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Pt 5, Ch 6, 1305.** of the Rules when open-up surveys are carried out.

5. In application to **502. 2** (9) (b) of the Rules, open type coolers which are of air-cooled type and not of shell-and-tube type are to be examined externally instead of open-up survey.

6. In application to **502. 3** (4) of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

7. In application to **502. 4** of the Rules, the Guidance means the requirements specified in **Annex 1-9** of the Guidance.

Section 6 Docking Survey

601. Due range

The docking survey intervals for passenger ship engaged on international voyages are to be subject to the relevant requirements of the International Convention for Safety of Life at Sea. But in five-year Special Survey period two times of Docking Survey with an interval not exceeding 36 months from the completion date of the previous Docking Survey and three times of In-water Survey specified in **604.** of the Rules in lieu of the Docking Survey may be carried out. However, where specific requirements are provided by the Administration the relevant requirements are to be applied.

603. Requirements of survey

1. In application to **603. 2** of the Rules, the term "special attention" means a careful examination of the connection between the bilge strakes and the bilge keels.

2. In application to **603. 3** of the Rules, the term "as deemed necessary" in that "the pressure test of the rudder may be required as deemed necessary by the Surveyor" means the case which repair work relating with the air tightness of rudder is done.

3. In application to **603. 5** of the Rules, the term "considered necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

4. In application to **603. 8** of the Rules, the Guidance means the requirements specified in **Annex 1-9** of the Guidance.

604. In-water Survey

In application to **604. 1** of the Rules, survey status, latest docking survey reports and thickness measurement records, etc. are to be considered when special consideration is given.

Section 7 Surveys of Propeller Shaft and Stern Tube Shaft, Etc.

701. Due range

1. In application to **701. 1** and **2** of the Rules, "Propeller shafts Kind 1 & 2" means that specified in **Pt 5, Ch 1, 102. 3** of the Rules.

2. In application to **701. 3** of the Rules, the Guidance means the requirements specified in **Annex 1-9** of the Guidance.

3. In application to **701. 4** of the Rules, the method for postponement of propeller shaft survey is to be in accordance with the separate requirements specified by the Society.

702. Survey items

1. In application to **702. 4** and **5** of the Rules, the term "an effective crack detection method", in principle, means a magnetic particle test. Where it is not practicable for shafts of nonmagnetic material, etc. a liquid penetrant test may be used.

2. In application to **702. 4** and **5** of the Rules, where the entire withdrawal of propeller shaft is not required and the survey may be carried out on the state that propeller is moved in the possible range, the propeller need not be entirely removed. However, where considered necessary by the Surveyor, the entire removal may be required.

3. In application to **702. 4** (2) of the Rules, where keyless propeller is force-fitted to the propeller shaft, it is to be ascertained at each time when the propeller is fitted, that the pull-up length is within the upper and lower limits of pull-up length approved by the Society in accordance with the requirements specified in **Pt 5, Ch 3, 305.** of the Guidance.

703. Extension of propeller shaft survey

1. In application to **703. 1** (1) of the Rules, the oil consumption is to be recorded as an interval determined by the Owner and the term "lubricating oil analysis data" means the periodical analysis data within six months including the following items made by recognized lubricating oil laboratory or manufacturer. The sample for analysis is to be obtained during operation condition. The water and metal content values are to be considered taking into account the type of stern tube seals used and the chemical composition of the bearing material(according to manufacturer's recommendation), and the following values in parentheses are recommended.

(1) Water contents(1 %)
(2) Chloride contents(according to manufacturer's recommendation)
(3) Contents of bearing metal particles(chromium 10 ppm, copper 50 ppm, iron 30 ppm, lead 10 ppm, nickle 10 ppm, silicon 40 ppm, tin 10 ppm)
(4) Resistance to oxidation(according to manufacturer's recommendation)

2. In application to **703. 1** (2) of the Rules, the examination of forward bearing is required only when the shaft is drawn partially by **703. 1** (1) of the Rules and a visual examination of visible parts of the bearing under the condition that forward sealing arrangements is removed is to be performed.

3. In application to **703. 1** (4) and **2** (3) of the Rules, where the entire withdrawal of propeller shaft is not required and the survey may be carried out on the state that propeller is moved in the possible range, the propeller need not be entirely removed. However, where considered necessary by the Surveyor, the entire removal may be required.

704. Survey for ships with STCM (Stern Tube Condition Monitoring) notation

In application to **704.** (1) of the Rules, the Guidance means the requirements specified in **703.** of the Guidance.

Section 8 Boiler Survey

802. Survey items

In application to **802. 1** and **4** of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance and includes the following items:

(1) The measurements of the thickness of boiler plates and tubes, and diameter of stays.
(2) The hydrostatic test at a pressure above the allowable pressure after the repairs of boiler is carried out.
(3) For the unfired steam generators, exhaust gas heaters and steam reservoirs or similar pressure vessels for the purpose of processing fishes, the same examination as the requirements specified for boilers.

Section 9 Continuous Survey of Machinery

902. Survey items

1. In application to **902. 1** and **2** of the Rules, the Guidance means the requirements specified in **Annex 1-7** of the Guidance.

2. In application to **902. 3** of the Rules, the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

3. In application to **902. 4** of the Rules, in case of passenger ships, the CMS should be complied with the followings.

(1) In principle, the CMS system cannot be applied to passenger ships. However, CMS for auxiliaries other than main and auxiliary engines can be applied.

(2) Nevertheless the main and auxiliary engines for passenger ships may be overhauled(or opened up) in accordance with the following tables.

Open-up time of main and auxiliary engine

Nos. of Main/Aux. engines	Open-up time
1 set	at the period of the Special Survey
2 sets	1 set : at the period of the Special Survey 1 set : at the period of the third Intermediate Survey
3 sets	1 set : at the period of the Special Survey 1 set : at the period of the second Intermediate Survey 1 set : at the period of the third Intermediate Survey
4 sets	1 set : at the period of the Special Survey 1 set : at the period of the first Intermediate Survey 1 set : at the period of the third Intermediate Survey 1 set : at the period of the fourth Intermediate Survey

Example for open-up survey of main & auxiliary engines(periodical survey)

Nos. of Main/Aux. engines		S	I_1	I_2	I_3	I_4	S
E×1		○	△	△	△	△	○
E×2	E_1 E_2	△ ○	△ △	△ △	○ △	△ △	△ ○
E×3	E_1 E_2 E_3	△ ○ △	△ △ △	△ △ ○	○ △ △	△ △ △	△ ○ △
E×4	E_1 E_2 E_3 E_4	△ △ △ ○	○ △ △ △	△ △ △ △	△ ○ △ △	△ △ ○ △	△ △ △ ○

(NOTES)
○ : full open-up(See **Ch 2, 502.** of the Rules)
△ : internal examinations of the cylinder and combustion side of the cylinder cover, crankshaft bearing parts and measurement for the deflection of the crank web(See **Ch 2, 303.** of the Rules).
I_1, I_2, I_3, I_4 : first, second, third, fourth Intermediate Survey between Special Surveys

4. In application to **902. 5** of the Rules, the Guidance means that it should be complied with the following requirements.

(1) The CMS may be commenced since the Classification Survey during Construction.
(2) Upon the request of owner, where deemed appropriate by the Society, the CMS may be commenced since the Classification Survey after Construction and in case of TOC(transfer of classification) the CMS may be continued to commence the CMS status executed by another society.
(3) On ships registered in the Society, where the shipowner is newly to apply for the CMS, after the Special Survey all CMS may be carried out subject to planning a regular CMS cycle at once until the date of the next Special Survey.

5. In application to **902. 6** of the Rules, the withdrawal of CMS should be satisfied with the followings:

(1) Where withdrawal of the CMS by the shipowner's request or the CMS system not carried out in accordance with the requirements is found, the CMS may be cancelled by the Society.
(2) After cancellation of CMS, if there are any CMS items of which due date would exceed 5 years at the date of the next Special Survey, the items are recommended to be inspected within 5 years from the last survey.
(3) All items scheduled for survey at Special Survey are to be carried out from the next Special Survey.

903. Planned Maintenance System

1. In application to **903. 1** of the Rules, the Guidance means the requirements specified in **Annex 1-8** of the Guidance, and the term "deemed necessary by the Surveyor" means the cases as specified in **Ch 1, 801.** of the Guidance.

2. In application to **903. 2** of the Rules, the Implementation Survey and Annual Audit mean as follows;

(1) Implementation Survey;
  (A) The Implementation Survey shall be carried out by the Society within one year from the date of approval.
  (B) During the Implementation Survey the following shall be verified by the Surveyor to ensure;
    (a) the PMS is implemented according to the approved documents, and is adapted to the type and complexity of the components/system on board;
    (b) the PMS is producing the documentation required for the Annual Audit and the requirements of surveys and testing for retention of class are complied with;
    (c) the onboard personnel is familiar with the PMS.
    (d) where this survey is carried out and the implementation is found in order, a report describing the system shall be submitted to the Society and the system may be put into service.
  (C) An Implementation Survey shall be carried out to confirm the validity of "Certificate of Approval for Planned Maintenance Scheme".
(2) Annual Audit;
  (A) An Annual Audit of the PMS shall be carried out by a Society's Surveyor and preferably concurrently with the annual survey of machinery.
  (B) The Surveyor shall review the annual report or verify that it has been reviewed by the Society.
  (C) The purpose of this survey shall be to verify that the scheme is being correctly operated and that the machinery has been functioning satisfactorily since the previous survey. A general examination of the items concerned shall be carried out.
  (D) The performance and maintenance records shall be examined to verify that the machinery has functioned satisfactorily since the previous survey or action has been taken in response to machinery operating parameters exceeding acceptable tolerance and the overhaul intervals have been maintained.
  (E) Written details of break-down or malfunction shall be made available.
  (F) Description of repairs carried out shall be examined. Any machinery part, which has been replaced by a spare one, due to damage, is to be retained on board, where possible, until examined by the Society's Surveyor.

(G) At the discretion of the Surveyor, function tests, confirmatory surveys and random check readings, where condition monitoring equipment is in use, shall be carried out as far as practicable and reasonable.

(H) Upon satisfactory completion of the above requirements, the Society shall retain the PMS

3. In application to **903. 3** of the Rules, the Guidance means the requirements specified in **Annex 1-8** of the Guidance.

4. In application to **903. 4** of the Rules, the damage and repairs for PMS should be complied with the following requirements.

(1) The damage of components/machinery, it shall be reported to the Society. The repairs of such damaged components/machinery shall be carried out to the satisfaction of the Surveyor.

(2) Any repairs and corrective action regarding machinery under PMS shall be recorded in the PMS logbook and to be verified by the Society's Surveyor at the Annual Audit.

(3) In the case of overdue outstanding recommendations or a record of unrepaired damage which would affect the PMS, the relevant items shall be kept out the PMS until the recommendation is fulfilled or the repair is carried out.

5. In application to **903. 5** of the Rules, the withdrawal of PMS should be satisfied with the following requirements.

(1) The survey arrangement for machinery under PMS can be cancelled by the Society if PMS is not being satisfactorily carried out either from the maintenance records or the general condition of the machinery, or when the agreed intervals between overhauls are exceeded.

(2) The shipowner may, at any time, cancel the survey arrangement for machinery under PMS by informing the Society in writing and for this case the items which have been inspected under the PMS since the last Annual Survey can be accepted by the Society.

Section 10 Occasional Survey

1001. Occasional Survey

1. Alteration for tank use of cargo hold as deep tank(water or oil)

When tank use is to be altered from cargo hold as deep tank to cargo hold, application of the alteration, in written form, is to be submitted by the Owners to the Society. Suction mouths in cargo holds as deep tanks are to be removed, and the end parts of the pipings are to be closed by blind flanges. Upon completion of alteration works and thereafter, tank testings for the altered cargo holds are dispensed with.

2. Alteration for tank use of each tank

When an alteration of tank use is desired, the Owners should notify the Society that the alteration will be made. The Society will review the recalculation of longitudinal strength and whether or not reinforcements will be necessary. However, this requirement does not apply to a ship treated according to **Pt 3, Ch 3, 101.** of the Rules.

3. Alteration for loading condition

When it is planned that a specialized ship is about to be loaded in an outstandingly different manner(other than that reviewed by the Society at the time of plan approval), the plans showing the calculation of longitudinal strength, shear strength and local strength should be approved by the Society.

4. In application to **1001.** (1) of the Rules, main parts of machinery refer to those which are to be examined at the time of Classification Survey during Construction and the term "deemed necessary by the Surveyor" in (6) of the Rules means the cases as specified in **Ch 1, 801.** of the Guidance.

Section 11 Alteration Survey

1103. Items of survey

In application to **1103. 2** of the Rules, "Where a complete replacement or addition of a major portion of the ship is involved at the alteration" means the case one or more whole compartments are completely replaced or added, and it is to be applied to this compartment.

Section 14 Hull Surveys for General Dry Cargo Ships

1404. Special Survey

In application to **Table 1.2.8** NOTES 1) of the Rules, the general drawing for Close-up Survey area is shown in **Annex 1-6, 1** (1) of the Guidance.

Section 17 Special Requirements for Ships Subject to Korean Ship Safety Act

1701. Special requirements

1. In application to **301.**(Due range of Intermediate Survey) **3** and **401.**(Due range of Special Survey) **4** and **5** of the Rules, ships specified in **1701. 2** of the Rules are not to be applied.

2. In application to **303.**(Machinery, electrical installations and additional installations of Intermediate Survey) **3** and **502.**(Requirement of Special Survey(Machinery, electrical installations and additional installations)) **2**, the due date of examinations/overhauling survey for internal combustion engines, which are installed on ships engaged on domestic voyage only, is to be in accordance with the relevant requirements of *Korean Ship Safety Act*.

3. The Docking Survey for ships operating in the inland waters only is able to be substituted by In-water Survey except when the Docking Survey is to be carried out in conjunction with the Special Survey, but not 3 times continuously in case of passenger ships.

4. In application to **1701. 2** of the Rules, the surveys required in **603.** of the Rules are to be carried out in drydock or on a slipway at the Intermediate Survey. However the clearance measurements for sea water lubricated stern tube bearing and rudder bearing may be omitted but not 3 times continuously. ⚓

CHAPTER 3 HULL SURVEYS OF SHIPS SUBJECT TO THE ENHANCED SURVEY PROGRAMME

Section 1 General

102. Preparations for survey

In application to **102. 6** (2) of the Rules, an appropriately qualified representative means a ship's officer.

103. Documentation on board

The Owner's inspection reports specified in **103. 3** (5) of the Rules is shown in **Annex 1-4** of the Guidance.

104. Procedure for thickness measurement

Methods of thickness measurement are to be comply with the requirements specified in **Annex 1-5** of the Guidance.

Section 2 Bulk Carriers

202. Annual Survey

1. In application to **202. 4** and **5** of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 14** of the Guidance.

2. In application to **202. 6** (2) of the Rules, the Guidance means the requirements specified as follows.

(1) General

(A) In the case of bulk carrier over 5 year of age, the Annual Survey is to include, in addition to the requirements of the Annual Surveys specified in **202.** of the Rules, an examination of the following items:

(B) Extent of Survey

(a) For bulk carriers of 5 - 15 years of age:

(i) An Overall Survey of the foremost cargo hold, including Close-up Survey of sufficient extent, minimum 25% of frames, is to be carried out to establish the condition of:

- Shell frames including their upper and lower end attachments, adjacent shell plating, and transverse bulkheads.
- Suspect areas identified at previous surveys.

(ii) Where considered necessary by the Surveyor as a result of the Overall and Close-up Survey as described in (i) above, the survey is to be extended to include a Close-up Survey of all of the shell frames and adjacent shell plating of the cargo hold.

(b) For bulk carriers exceeding 15 years of age:

(i) An Overall Survey of the foremost cargo hold, including Close-up Survey is to be carried out to establish the condition of:

- All shell frames including their upper and lower end attachments, adjacent shell plating, and transverse bulkheads.
- Suspect areas identified at previous surveys.

(C) Extent of thickness measurement

(a) Thickness measurement is to be carried out to an extent sufficient to determine both general and local corrosion levels at areas subject to Close-up Survey, as described in (B) (a) (i) and (b) (i) above. The minimum requirement for thickness measurement for thickness measurements are suspect areas identified at previous surveys. Where substantial corrosion is found, the extent of thickness measurements should be increased with the requirements of **Annex 1-5, Table 14** of the Guidance.

(b) The thickness measurement may be dispensed with provided the Surveyor is satisfied by the Close-up Survey, that there is no structural diminution and the hard protective coating where fitted remains effective.

(D) Special consideration

(a) Where the hard protective coating in the foremost cargo hold is found to be in GOOD condition, the extent of Close-up Surveys and thickness measurements may be specially considered.

Note : For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the Close-up Surveys and thickness measurement. Prior to the coating of cargo holds of existing ships, scantlings should be ascertained in the presence of a Surveyor.

203. Intermediate Survey

In application to **203. 4** (1) (c) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 14** of the Guidance.

204. Special Survey

1. In application to **204. 5** (2) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 14** of the Guidance.

2. In application to **Table 1.3.1** NOTES 1 of the Rules, the general drawing for Close-up Survey areas is shown in **Annex 1-6, 1** (2) of the Guidance.

Section 3 Oil Tankers

302. Annual Survey

In application to **302. 5** of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 15** of the Guidance.

304. Special Survey

1. In application to **304. 1** (4) of the Rules, the term "operationally tested to working pressure" means the confirmation of the leakage or excessive vibration, etc.

2. In application to **304. 4** (2) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 15** of the Guidance.

3. In application to **304. 4** (6) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Par 6** of the Guidance.

4. In application to **Table 1.3.4** NOTES 1) of the Rules, the general drawing for Close-up Survey areas is shown in **Annex 1-6, 1** (3) of the Guidance.

Section 4 Chemical Tankers

402. Annual Survey

In application to **402. 5** of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 16** of the Guidance.

404. Special Survey

1. In application to **404. 1** (4) of the Rules, the term "operationally tested to working pressure" means the confirmation of the leakage or excessive vibration, etc.

2. In application to **404. 4** (2) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 16** of the Guidance.

3. In application to **Table 1.3.7** NOTES 1) of the Rules, the general drawing for Close-up Survey areas is shown in **Annex 1-6, 1** (4) of the Guidance.

Section 5 Double Hull Oil Tankers

502. Annual Survey

In application to **502. 5** of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 17** of the Guidance.

504. Special Survey

1. In application to **504. 1** (4) of the Rules, the term "operationally tested to working pressure" means the confirmation of the leakage or excessive vibration, etc.

2. In application to **504. 4** (2) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 17** of the Guidance.

3. In application to **504. 4** (6) of the Rules, the Guidance means the requirements specified in **Annex 1-5, 6** of the Guidance.

4. In application to **Table 1.3.10** NOTES 1) of the Rules, the general drawing for Close-up Survey area is shown in **Annex 1-6, 1** (5) of the Guidance.

Section 6 Double Skin Bulk Carriers

602. Annual Survey

In application to **602. 4** and **5** of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 18** of the Guidance.

603. Intermediate Survey

In application to **603. 4** (1) (c) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 18** of the Guidance.

604. Special Survey

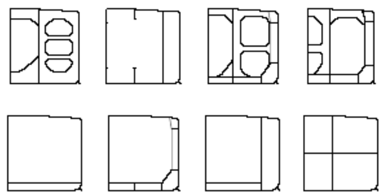
1. In application to **604. 5** (2) of the Rules, the Guidance means the requirements specified in **Annex 1-5, Table 18** of the Guidance.

2. In application to **Table 1.3.13** NOTES 1 of the Rules, the general drawing for Close-up Survey area is shown in **Annex 1-6, 1** (6) of the Guidance. ⚓

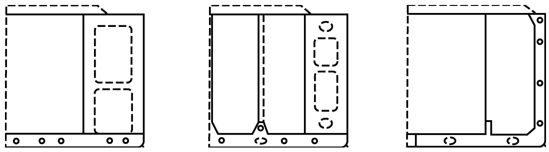
Annex 1-1 Character of Classification

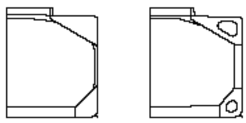
1. Class Notation

1.1 Ship Type and Special Feature Notations

Ship Types		Special Feature Notations	Remarks
1. Oil Tanker[2-0] (Double hull)[2-2] (FAC)[1] (FAO)[1] (FBC)[1] (CSR)[2-4]	'ESP'[2-1]	Crude Product Crude/Product	[1] : The notations FA, FB, FAC, FAO and FBC in rows 1, 3, 4, 8, 9 and 18 of the first column imply: FA : Flash point above 60°C FB : Flash point of 60°C and below FAC : FA with controlled tank vents FAO : FA with open tank vents FBC : FB with controlled tank vents [2-0] : See examples given in **2.0** [2-1] : The notation "ESP" shall be assigned to ships which are constructed generally with integral tanks and intended primarily to carry oil in bulk. This type notation shall be assigned to tankers of both single and double hull construction, as well as tankers with alternative structural arrangements, e.g. mid-deck designs. (Typical midship sections are given in **Fig 1**)  **Fig 1 Typical midship sections of Oil Tanker 'ESP'** [2-2] : The notation "(Double Hull)" shall be assigned to ships which are constructed primarily for the carriage of oil in bulk, which have the cargo tanks protected by a double hull which extends for the entire length of the cargo area, consisting of double sides and double bottom spaces for the carriage of water ballast or void spaces. [2-3] : The additional requirements for Oil Tanker 'ESP' and Oil Tanker(Double Hull) 'ESP' specified in **Pt 1** of the Rules are not to be applied. [2-4] : This notation shall be assigned to ships comply with the requirements specified in **Pt 12** of the Rules.
		Asphalt[2-3]	

<table>
<tr><th colspan="2">Ship Types</th><th colspan="5">Special Feature Notations</th><th>Remarks</th></tr>
<tr><td rowspan="3">2-1. Liquefied Gas Carrier</td><td>(3-1)</td><td>A</td><td>B</td><td>(C)</td><td>D or P</td><td>IMO Code(5)</td><td rowspan="4">(3-1) : See examples given in 2.1.1
(4) : The notation "LPG" shall be assigned to liquefied gas carriers carrying only propane and butane. However, the names of the following cargoes, instead of propane and butane, may be given for vessels carrying cargoes other than propane and butane under the approval of the Society.
(Example) : Ammonia, Butadiene, Propylene, VCM, Ethylene Oxide, Ethylene, etc.
(5) : As shown in the following:
1) The notation "IGC" shall be appended to vessels built in compliance with the requirements given in Pt 7, Ch 5 of the Rules and constructed on or after 1 July, 1986.
2) The notation "GC" shall be appended to vessels built in compliance with the IMO Res.A328(IX).
3) The notation "GCX" shall be appended to vessels built in compliance with the IMO Res.A329(IX).
4) For the ships except the above, additional notation is not assigned.</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">1G
2G
2PG
3G</td><td rowspan="2">2I
3M
3S
1A
1B
1C
1N
2N</td><td rowspan="2">(R)
(P)
(RP)</td><td>Design Pressure, Minimum Temperature and Specific Gravity(SG)</td><td rowspan="2">(IGC)
(GC)
(GCX)</td></tr>
<tr><td>Name of Liquefied Gas when exclusively carried</td></tr>
<tr><td colspan="2"></td><td colspan="5">LPG(4)</td></tr>
<tr><td rowspan="2">2-2. Compressed Natural Gas Carrier</td><td>(3-2)</td><td colspan="3">A</td><td colspan="2">B</td><td rowspan="2">(3-2) : See examples given in 2.1.2
(3-3) : This notation shall be assigned to ships having cargo tanks which are complied with 402. 1 (2) (A) of the Guidance for Ships Carrying CNG in Bulk.
(3-4) : This notation shall be assigned to ships having cargo tanks which are complied with 402. 1 (2) (B) of the Guidance for Ships Carrying CNG in Bulk.</td></tr>
<tr><td></td><td colspan="3">CO(3-3)
CY(3-4)</td><td colspan="2">Design Pressure, Minimum Temperature</td></tr>
</table>

Ship Types	Special Feature Notations				Remarks
(6) 'ESP'(7-1)	A	B	D or P	IMO Code(8)	(6) : See examples given in **2.2** (7-1) : The notation "ESP" shall be assigned to ships which are constructed generally with integral tanks and intended primarily to carry chemicals(liquid cargoes specified in **Pt 7, Ch 6, Sec 17** of the Rules) in bulk. This type notation shall be assigned to tankers of both single or double hull construction, as well as tankers with alternative structural arrangements. (Typical midship sections are given in **Fig 2**)  **Fig 2 Typical midship sections of Chemical Tanker 'ESP'**
	I II III II&III	1G 2G 1P	Apparent Specific Gravity (SG) Name of Chemical when exclusively carried	(IBC) (BCH) (BCX)	
3-1. Chemical Tanker (FAC)(1) (FAO)(1) (FBC)(1)					
3-2. NLS Tanker	Category Z(18)(7-2)				(7-2) : This notation shall be appended to vessels carrying only cargoes in bulk, except liquid cargoes specified in **Pt 7, Ch 6, Sec 17** of the Rules, classified as pollution category Z, or category Z and OS, which are not subject to IBC code, specified in **Pt 7, Ch 6, Sec 18** of the Rules. (8) : As shown in the following: 1) The notation "IBC" shall be appended to vessels built in compliance with the requirements given in **Pt 7, Ch 6** of the Rules and constructed on or after 1 July, 1986. 2) The notation "BCH" shall be appended to vessels built in compliance with the requirements given in **Pt 7, Ch 6** of the Rules and constructed before 30 June, 1986 and on or after 12 April, 1972. 3) The notation "BCX" shall be appended to vessels built in compliance with Para. 1.7.3 of BCH code and constructed before 11 April, 1972
4. Oil/Chemical Tanker (Double Hull)(2-2) 'ESP'(2-1)(7-1) (FAC)(1) (FAO)(1) (FBC)(1) (CSR)(2-4)	Product(9)				(9) : See special feature for chemical tanker as shown in row 3 and examples given in **2.2.**

Ship Types	Special Feature Notations		Remarks
(10)	A		(10) : See examples given in **2.3.** (11-1) : This notation shall be assigned in the following cases. (Note: The relevant requirements specified in **Pt 1, Ch 3, Sec 6** Double Skin Bulk Carriers are to be applied if applicable even if the ship has no Double Skin notation) (1) the ships, constructed before 1 July 1999, have double side skin construction (2) the ships, constructed before 1 January 2000, have double side skin construction of not less than 760 mm breadth at any location within the hold length, measured perpendicular to the side shell (3) the ships, constructed on or after 1 January 2000, have double side skin construction of not less than 1000 mm breadth at any location within the hold length, measured perpendicular to the side shell (11-2) : The notation "ESP" shall be assigned to ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo length area and intended primarily to carry dry cargoes in bulk. For ships constructed on or after 1 July 2010, however, the notation 'ESP' shall be assigned even if they lack some or all of the specified constructional feature above and (EXP) notation shall be followed. (Typical midship sections are given in **Fig 3**)  **Fig 3 Typical midship sections of Bulk Carrier 'ESP'** (11-3) : This notation shall be assigned to ships comply with the requirements specified in **Pt 11** of the Rules. (12) : The additional notation, **HC,** is normally assigned to a ship with the double bottom structure specially strengthened for the carriage of heavy cargoes having mass density, γ, specified in **Pt 3, Ch 7, 101. 6** of the Rules, not less than 1.25(t/m^3). (13) : The additional notation, **HC/E,** is normally assigned to a ship intended for the alternate loading, in addition to the requirements specified in (12) above. (14) : Where ships constructed before 1 July 2010 with other structural configurations than stated in (11-2) above comply with the applicable requirements specified in **Pt 7, Ch 3** of the Rules, the notation "Bulk Carrier", upon the request of the Owners, may be assigned to the concerned ships to the satisfaction of the Society. In such cases, the additional requirements for Bulk Carrier 'ESP' and Bulk Carrier(Double Skin) 'ESP' specified in **Pt 1** of the Rules shall not be applied. * : Bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions as **Pt 7, Ch 3, Sec 2** or **Pt 11, Ch 1, Sec 1** of the Rules. ** : Bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to BC-C conditions as **Pt 7, Ch 3, Sec 2** or **Pt 11, Ch 1, Sec 1** of the Rules. *** : Bulk carriers designed to carry dry bulk cargoes of cargo density of less than 1.0 t/m^3 as **Pt 7, Ch 3, Sec 2** or **Pt 11, Ch 1, Sec 1** of the Rules. ****: The additional notation GRAB[X] is assigned to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to [X] tons in compliance with the requirements of **Pt 11, Ch 12, Sec 1** of the Rules, the GRAB[X] notation is mandatory for ships having one of BC-A or BC-B, according to **Pt 11, Ch 1, Sec 1** of the Rules and these ships are to be complied with for an unladen grab weight X equal to or greater than 20 tons. For all other ships GRAB[X] is voluntary.
5-1. Bulk Carrier (Double Skin)[11-1] 'ESP'[11-2] 'ESP'(EXP)[11-2] (CSR)[11-3]	- HC[12] HC/E[13] BC-A* BC-B** BC-C***	GRAB[X]****	
5-2. Bulk Carrier[14] (Double Skin)[11-1] (CSR)[11-3]			

<table>
<tr><th>Ship Types</th><th>Special Feature Notations</th><th>Remarks</th></tr>
<tr><td>6. Cargo Ship</td><td>-
HC(12)
General Dry Cargo(15-1)
Liquid Cargo (Category OS only)(15-2)</td><td>(15-1) : This notation shall be assigned to all self-propelled general dry cargo ships of 500 GT and above carrying solid cargoes and the additional requirements for General Dry Cargo Ship specified in Pt 1, Ch 2, Sec 14 of the Rules are to be applied. However the following ships are to be omitted.
- Bulk Carriers and Double Skin Bulk Carriers subject to the enhanced survey programme(ESP)
- dedicated container carriers
- dedicated forest product carriers(not timber or log carriers)
- Ro-Ro cargo ships
- refrigerated cargo ships
- dedicated wood chip carriers
- dedicated cement carriers
- livestock carriers
- deck cargo ships(A ship that is designed to carry cargo exclusively above deck without any access for cargo below deck)
(15-2) : This notation shall be assigned to ships carrying only liquid cargoes in bulk classified as pollution category OS, which are not subject to IBC code, specified in Pt 7, Ch 6, Sec 18 of the Rules.</td></tr>
<tr><td>7. Ore Carrier 'ESP'(16)</td><td></td><td>(16) : The notation "ESP" shall be assigned to ships which are constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds only. (Typical midship sections are given in Fig 4)

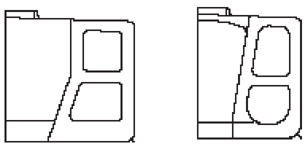



Fig 4 Typical midship sections of Ore Carrier 'ESP'</td></tr>
<tr><td>8. Ore/Oil Carrier 'ESP'(17)
(FAC)(1)
(FAO)(1)
(FBC)(1)</td><td>Crude
Product</td><td>(17) : The notation "ESP" shall be assigned to ships which are constructed generally with single deck, two longitudinal bulkheads and a double bottom throughout the cargo length area and intended primarily to carry ore cargoes in the centre holds or of oil cargoes in centre holds and wing tanks. However, these cargoes are not carried simultaneously. (Typical midship sections are given in Fig 5)

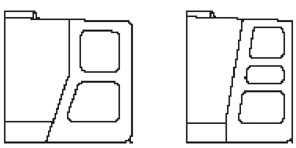
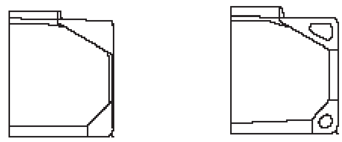



Fig 5 Typical midship sections of Ore/Oil Carrier 'ESP'</td></tr>
</table>

Ship Types	Special Feature Notations	Remarks
9. Oil/Bulk/Ore Carrier 'ESP'[18] 'ESP'(EXP)[18] (FAC)[1] (FAO)[1] (FBC)[1]	Crude Product Notations given in A of row 5	(18) : The notation "ESP" shall be assigned to ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in the cargo length area and intended primarily to carry oil or dry cargoes including ore, in bulk. However, these cargoes are not carried simultaneously. For ships constructed on or after 1 July 2010, the notation 'ESP' shall be assigned even if they lack some or all of the specified constructional feature above and (EXP) notation shall be followed. (Typical midship section is given in **Fig 6**)  **Fig 6 Typical midship sections of Oil/Bulk/Ore Carrier 'ESP'**
10. RoRo Ship	PCC Car/Cargo Car/Container Car/Bulk Palette Cassette Car Ferry[19]	(19) : The notation "Car Ferry (Open Space)" shall be assigned to vessels having vehicle region with opening capable of being ventilated naturally throughout the exposed decks and side shell plates. The detailed examples are given in **2.8.**
11. Container Ship[20]		(20) : The notation shall be assigned to ships designed and constructed to carry containers exclusively.
12. Fishing Vessel[21]	Long Liner, Stern Trawler, Side Trawler, Whaler, Purse Seiner, Gill Net, Angling, Stick-held Dip Net, Bottom Long Liner, Trap, Stow Net, Lift Net, Dredge Net, Seiner, Stab Net, Lighting	(21) : See examples given in **2.4.**

<table>
<tr><th colspan="2">Ship Types</th><th colspan="3">Special Feature Notations</th><th>Remarks</th></tr>
<tr><td colspan="2">13. Fish Carrier</td><td colspan="3">Fresh and Live Fish,
Fresh Fish,
Live Fish,
Fish Factory</td><td></td></tr>
<tr><td rowspan="2">14. Passenger Ship</td><td>(22)</td><td>A
(Type)</td><td>B
(Additional purpose)</td><td>C</td><td rowspan="2">- : Additional notation is not required for passenger ship built to carry passenger exclusively.
(22) : See examples given in 2.5.
(23-1) : Ships with Vehicle Areas specified in Pt 7, Annex 7-3 of the Guidance or ships with Special Category Spaces specified in SOLAS Ch.II-2/3.46.
(23-2) : Ships with RoRo Spaces specified in SOLAS Ch.II-2/3.41.</td></tr>
<tr><td></td><td>-
Hydrofoil
Side Wall
Air Cushion Vehicle
Hover Craft
Catamaran
Submersible</td><td>-
Cargo
Container
Leisure
Car Ferry[19] [23-1]
RoRo[23-2]</td><td>Max. submerging depth and time for submersible</td></tr>
<tr><td colspan="2">15-1.
Tug Boat,</td><td colspan="3">-
Tug/Salvage
Tug/Supply
Tug/Fire-Fighting (GA or GC)[24]
Tug/Anchor
Tug/Oil Recovery (GA, GB or GC)[25]</td><td rowspan="2">- : Additional notation is not required for tug boats or pushers built only for the purpose of tug or pusher work.
(24) : As shown in the following:
1) GA : This notation shall be assigned to ships complied with the requirements for explosion-protected electrical equipment in dangerous zone.
2) GC : This notation shall be assigned to ships not applied to the requirements for explosion-protected electrical equipment in dangerous zone.
Type A : permanent connection type
Type B : removable connection type</td></tr>
<tr><td colspan="2">15-2.
Pusher
(Type A)
(Type B)</td><td colspan="3">-
Pusher/Tug</td></tr>
<tr><td colspan="2">16. Work Vessel</td><td colspan="3">-
Launch
Offshore Structure Transport
Cable Layer
Crane
Anchor
Ice Breaker
Supply
Oil Recovery (GA, GB or GC)[25]
Salvage
Repair Work
Tender</td><td>- : Additional notation is not required for work vessels built only for the purpose of work.
(25) : As shown in the following:
1) GA : This notation shall be assigned to ships equipped for recovery and storage of spilled oil, and complied with the requirements for explosion-protected electrical equipment in dangerous zone.
2) GB : This notation shall be assigned to ships equipped for the recovery and storage of spilled oil, and complied with the requirements for explosion-protected electrical equipment at work and storage spaces.
3) GC : This notation shall be assigned to ships equipped for the recovery and storage of spilled oil, and not applied to the requirements for explosion-protected electrical equipment</td></tr>
</table>

Ship Types	Special Feature Notations	Remarks
17. Special Purpose Ship	Soil Geological Survey Boat Submersible Support Diving Support Hopper/Waste Waste Hospital Hydro Survey Seismic Survey Fire-fighting (GA or GC)[24] Buoy Laying Fishery Training Fishery Patrol Fishery Research Patrol Pilot Observation Training Research	
18. Barge (FAC)[1] (FAO)[1] (FBC)[1]	**A (Type):** - Pontoon Integrated Pusher Barge (Type A) (Type B) Hopper(or Dump) **B (Loaded cargo name or additional purpose):** Chemical[26] Oil Production Container Sand Crane Plant(Power, Sewage Treatment, etc) Pipe-Laying Piling Cable-Laying Salvage Submersible Accommodation Hotel Terminal Waste Log Leisure Heavy Cargo Oil Recovery (GA, GB or GC)[25]	- : Additional notation is not required for barge excluding 3 types of barge below, and for barges with hatch opening on the deck and built to carry cargo in cargo holds. (26) : See special feature for chemical tanker as shown in row 3, and examples given in **2.2** Type A : permanent connection type Type B : removable connection type
19-1. Dredger 19-2. Dredger (Self-propelled)	Trailing Suction Bucket Cutter Suction Dipper Grab Suction/Dump	
20. Special Purpose Submersible	(27) **A:** Manned Unmanned **B:** Self-propelled Non-propelled **C:** Research Rescue Leisure[28] Special Work **D:** Max. submerging depth and time	(27) : See examples given in **2.6.** (28) : This notation shall be assigned to special purpose submersible accompanying personnel not exceeding 13.

Ship Types	Special Feature Notations			Remarks
21. Factory Ship	Coal Briquette Factory			
[29]	A	B	C	[29] : See examples given in **2.7.**
22. Drilling Unit	Mobile Fixed Submersible	Surface Column Stabilized Deck Elevating Leg(Tripod/Pentapod) Jacket Tension Leg Guyed Tower Articulated-joint Tower Tethered and Guyed Piled Leg		
23. Production Platform				
24. Work Platform			Crane Special Work	
25. Offshore Structure			Plant(Power/Pulp, etc) Accommodation Hotel Gas/Oil Storage Island Air Port Terminal Buoy Lighting Tower	
26-1. Floating Dock				
26-2. Dock Gate				
26-3. Launching Skid Barge				
27. Refrigerated Cargo Carrier				
28. Single Point Mooring	Fixed Floating			
29. Floating Structure	Hotel Restaurant Leisure			

(Remarks) [(30)] : The following Additional Special Feature Notations may be appended to ships complying with the relevant requirements. At the request of the Owner, the Additional Special Feature Notations such as designated cargo, etc. may be appended when considered appropriate by the Society.

<table>
<tr><th>Additional Special Feature Notations</th><th colspan="2">Relevant Requirements</th></tr>
<tr><td>IWS</td><td colspan="2">to ships where an In-water Survey, in lieu of the Docking Survey, is desired according to the requirement in Ch 2, 604. of the Rules and complying with the requirements specified in Ch 2, 604. 3 (8) of the Rules.</td></tr>
<tr><td>CoC</td><td colspan="2">to ships where an Measure of Corrosion Control specified in Pt 3, Ch 1, 802. of the Rules is applied.</td></tr>
<tr><td>IA Super</td><td colspan="2">to ships where IA Super Class Ice Strengthening specified in Pt 3, Ch 20 of the Rules is applied.</td></tr>
<tr><td>IA</td><td colspan="2">to ships where IA Class Ice Strengthening specified in Pt 3, Ch 20 of the Rules is applied.</td></tr>
<tr><td>IB</td><td colspan="2">to ships where IB Class Ice Strengthening specified in Pt 3, Ch 20 of the Rules is applied.</td></tr>
<tr><td>IC</td><td colspan="2">to ships where IC Class Ice Strengthening specified in Pt 3, Ch 20 of the Rules is applied.</td></tr>
<tr><td>ID</td><td colspan="2">to ships where ID Class Ice Strengthening specified in Pt 3, Ch 20 of the Rules is applied.</td></tr>
<tr><td>PC1, PC2, PC3,
PC4, PC5, PC6, PC7</td><td colspan="2">to ships comply with polar class specified in Pt 3, Ch 21 of the Guidance.</td></tr>
<tr><td>PL10, Icebreaker PL10,
PL20, Icebreaker PL20,
PL30, Icebreaker PL30</td><td>to ships comply with POLAR class specified in Pt 3, Ch 22 of the Guidance.</td><td rowspan="2">However, arctic class ships intended for special services where intermediate ice condition value are relevant may, upon special consideration, be given intermediate notations(e.g. PL25).</td></tr>
<tr><td>ICE05, Icebreaker ICE05,
ICE10, Icebreaker ICE10,
ICE15, Icebreaker ICE15</td><td>to ships comply with ICE class specified in Pt 3, Ch 22 of the Guidance.</td></tr>
<tr><td>SeaTrust
(DSA1, DSA2, FSA1,
FSA2, FSA3, HCM)</td><td colspan="2">to ships which are constructed through applying a direct structure, fatigue assessment and hull construction monitoring requirements specified in Pt 3, Annex 3-2 to 3-4 of the Guidance.</td></tr>
<tr><td>n.s</td><td colspan="2">to ships where the sparring is omitted according to the requirements specified in Pt 4, Ch 6, 203. 2 of the Rules.</td></tr>
<tr><td>FH</td><td colspan="2">to ships where the requirements regarding longitudinal strength of hull girder in flooded condition, evaluation of allowable hold loading and evaluation of scantlings of corrugated transverse watertight bulkheads for bulk carriers specified in Pt 7, Ch 3, Sec 10 to Sec 12 of the Rules are applied.</td></tr>
<tr><td>Grab</td><td colspan="2">to ships where cargo holds are protected from loading/discharge equipment in accordance with the requirements specified in Pt 7, Annex 7-7, 2 of the Guidance.</td></tr>
<tr><td>n.f</td><td colspan="2">to ships where the construction and arrangement for fire protection is modified according to the requirements specified in Pt 8, Annex 8-3, 15 of the Guidance.</td></tr>
<tr><td>CDG</td><td colspan="2">to ships comply with the requirements specified in Pt 8, Ch 5, Sec 2 of the Rules.</td></tr>
<tr><td>ERS</td><td colspan="2">to ships where classed with the Emergency Response Service System of the Society.</td></tr>
<tr><td>PCP</td><td colspan="2">to ships where the cargo oil pipings are protected according to the requirements specified in Pt 7, Ch 1, 1002. 4 of the Guidance.</td></tr>
<tr><td>ENV
(IBWM, IAFS, IOPP,
ISPP, IGPP, IAPP,
VEC-1, VEC-2, IIHM)</td><td colspan="2">to ships where IAFS Certificate/Statement of Compliance, IBWM Certificate/Statement of Compliance, IOPP Certificate, ISPP Certificate, IGPP Certificate, IAPP Certificate, VEC Statement of Compliance-1, VEC Statement of Compliance-2 or IIHM Certificate/Statement of Compliance have been issued relating to the environmental safety. However, the notations in the bracket may be assigned one or a combination of them as applicable. (For example, ENV(IBWM, IAFS) indicates that the ship has IBWM Certificate/Statement of Compliance and IAFS Certificate/Statement of Compliance) For ships having both VEC Statement of Compliance-1 and VEC Statement of Compliance-2, only VEC-2 shall be assigned and VEC-1 shall not be assigned. Among the ships having VEC Statement of Compliance-2, VEC-L shall be assigned, instead of VEC-2, to ships comply with the additional requirements also for Lightering Operation. However, at the request of the Owner, BWMP(T, F, S, D) may be assigned instead of IBWM to ships which have no IBWM Statement of Compliance, until the International Convention for the Control and Management of Ship's Ballast Water and Sediments has entered into force, where the requirements specified in Pt 9, Ch 7 of the Rules 2007 are complied.</td></tr>
</table>

Additional Special Feature Notations	Relevant Requirements
PSPC	to ships comply with the Performance Standard for Protective Coatings specified in **Pt 3, Ch 1, 803**. of the Guidance.
BLU1, BLU2	to ships comply with the additional requirements for the safe loading and unloading specified in **Pt 3, Annex 3-1, 3** (3) of the Guidance.
(LC, LC-G, HSLC - SA0, SA1, SA2, SA3, SA4, SA5)	LC : to Light Craft as specified in **Pt 1, Ch 1, 103.** (1) of **the Rules for the Classification of High Speed and Light Crafts.** LC-G : to Light Craft as specified in **Annex 1-2** of **the Guidance Relating to the Rules for the Classification of High Speed and Light Crafts, 1998 edition.** HSLC : to High Speed and Light Craft as specified in **Pt 1, Ch 1, 103.** (2) of **the Rules for the Classification of High Speed and Light Crafts.** SA0, SA1, SA2, SA3, SA4, SA5 : The service restriction notation specified in **Pt 3, Ch 1, 121. of the Rules for the Classification of High Speed and Light Crafts.**
EDD	to ships carrying out the Extended Dry-docking Interval System specified in **Ch 2, 605.** of the Rules.
OHIMP	to ships comply with the Owner's Hull Inspection and Maintenance Program specified in **Annex 1-13** of the Guidance.

1.2 Additional Installations Notations

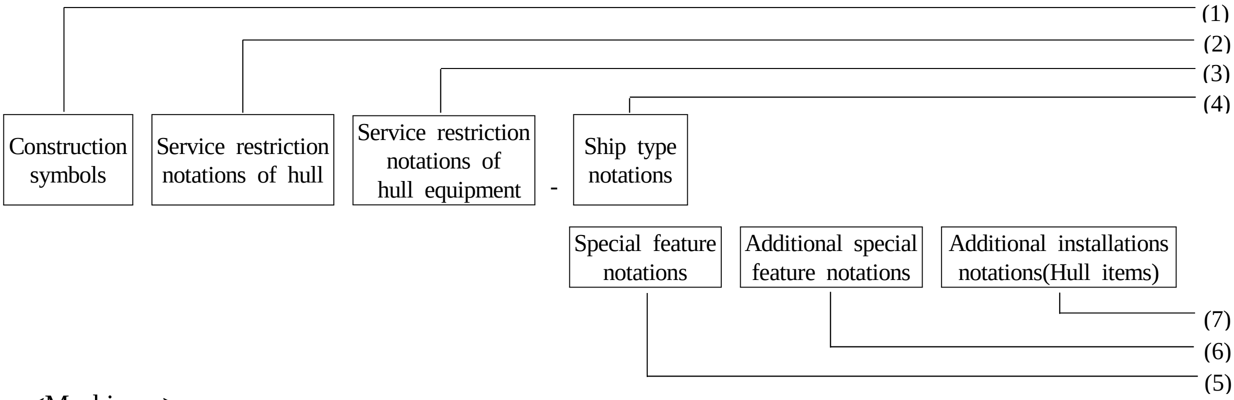
The following Additional Installations Notations may be appended to ships complying with the relevant requirements.

Additional Installations Notations		Relevant Requirements
Hull Items	LI	to ships where the Loading Instrument on Stability specified in **Pt 1, 307.** of the Rules or the Longitudinal Strength Loading Instrument specified in **Pt 3, Ch 3, 104.** of the Rules is provided onboard.
	CHA	to ships where the Cargo Handing Appliances specified in **Pt 9, Ch 2** of the Rules are provided onboard.
	HMS, HMS1	to ships where the Hull Monitoring System specified in **Pt 9, Ch 6** of the Rules is provided onboard.
	EQ-SPM	to ships where the Equipment Employed in the Mooring of Ships at Single Point Mooring specified in **Pt 4, Ch 10, 101. 3** of the Rules is provided onboard.
	PKS	to offshore units where the Position Keeping System specified in **Ch 4, Sec 6** of **the Rules for the Classification of Mobile Offshore Units** is provided onboard.
	SUR, BOU, SAT	to ships where the diving systems specified in **Pt 4, Ch 3, 102. 16** of **the Rules for the Classification of Underwater Vehicles and Diving Systems.**
Machinery Items	STCM	to ships where the Stern Tube Condition Monitoring System specified in **Ch 2, 704.** of the Rules is provided onboard.
	RMC	to ships where the Cargo Refrigerating Installations specified in **Pt 9, Ch 1** of the Rules are provided onboard.
	CMA	to ships where the Centralized Monitoring and Control System for Main Propulsion and Essential Auxiliary Machinery specified in **Pt 9, Ch 3** of the Rules is provided onboard.
	UMA	to ships where the Operating Systems for Periodically Unattended Machinery Spaces specified in **Pt 9, Ch 3** of the Rules are provided onboard.
	UMA1, UMA2, UMA3	to ships where the Automation Equipment specified in **Pt 9, Ch 3** of the Rules is provided onboard.
	DPS(0), DPS(1), DPS(2), DPS(3)	to ships where the Dynamic Positioning System specified in **Pt 9, Ch 4** of the Rules is provided onboard.
	NBS, NBS1, NBS2	to ships where Bridge Layouts and Bridge Working Environments, Navigation Equipments, Accident Prevention Systems and Bridge Work Assist Systems specified in **Pt 9, Ch 5** of the Rules are provided.
	IGS	to ships where the Inert Gas Systems specified in **Pt 8, Ch 2, 104. 5** of the Rules are provided onboard.
	COW	to ships where the Crude Oil Washing System specified in "Annex I of International Convention for the Prevention of Pollution from Ships, 1973 and Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973(MARPOL 73/78)" are provided onboard.

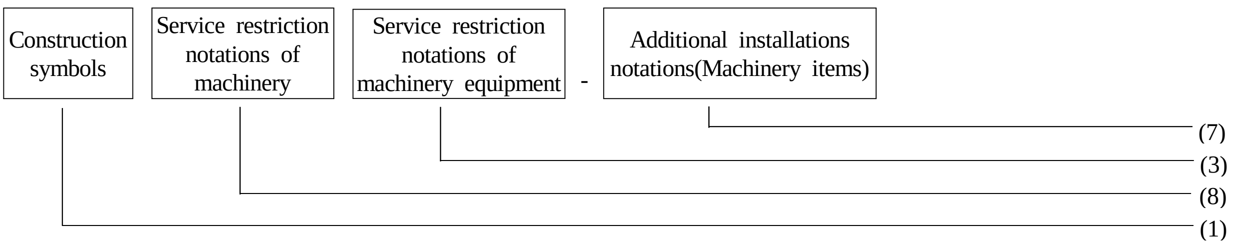
2. Written Examples of Class Notations

A typical arrangement of Class Notations will consist of the following structure.

<Hull>

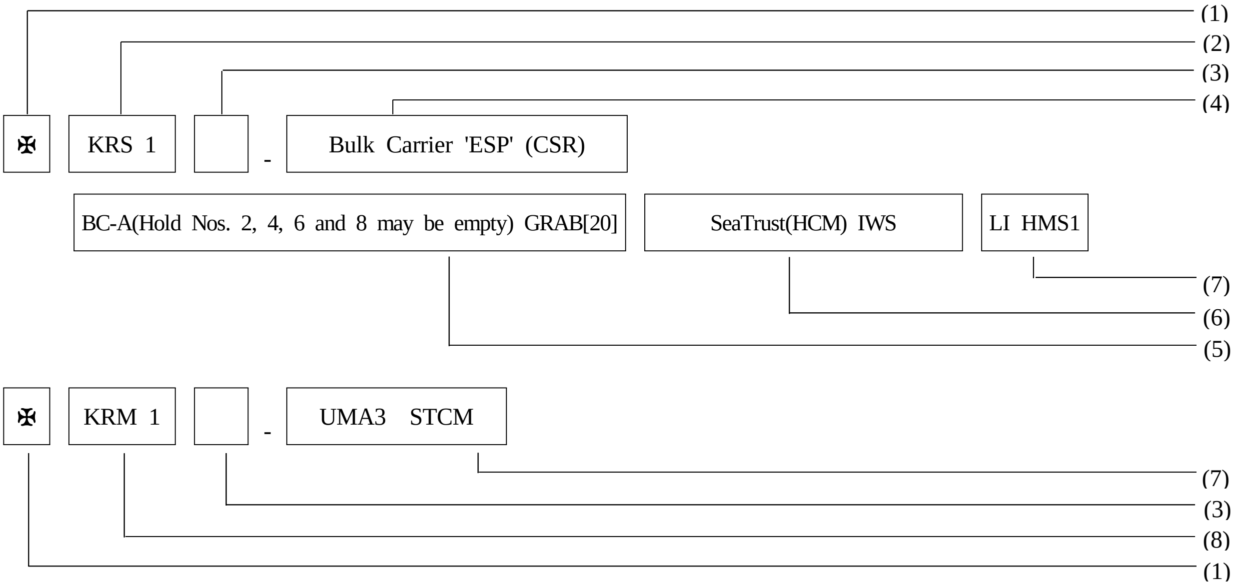


<Machinery>



(1) Construction symbols specified in **Ch 1, 201.** (1) of the Rules.
(2) Service restriction notations of hull specified in **Ch 1, 201.** (2) of the Rules.
(3) Service restriction notations of hull and machinery equipment specified in **Ch 1, 201.** (4) of the Rules.
(4) Ship type notations specified in **Ch 1, 201.** (6) of the Rules and **1.1** above.
(5) Special feature notations specified in **Ch 1, 201.** (7) of the Rules and **1.1** above.
(6) Additional special feature notations specified in **Ch 1, 201.** (7) of the Rules and **1.1** Remarks (30) above.
(7) Additional installations notations(Hull and Machinery items) specified in **Ch 1, 201.** (5) of the Rules and **1.2** above.
(8) Service restriction notations of machinery specified in **Ch 1, 201.** (3) of the Rules.

Example)



2.0 Oil Tanker

Class Character :

KRS 1 - Oil Tanker Special Feature

KRS 1 - Oil Tanker 'ESP' Special Feature

KRS 1 - Oil Tanker(Double Hull) 'ESP' Special Feature

Example :

1) For dedicated asphalt carriers

KRS 1 - Oil Tanker (FAO) Asphalt

2) For oil tankers

KRS 1 - Oil Tanker 'ESP' (FBC) Crude/Product

3) For double hull oil tankers comply with the requirements specified in **Pt 12** of the Rules

KRS 1 - Oil Tanker(Double Hull) 'ESP' (FBC) (CSR) Crude/Product

2.1.1 Liquefied Gas Carrier

Class Character :

KRS 1 - Liquefied Gas Carrier
A B (C) / D (IGC)

KRS 1C - Liquefied Gas Carrier
B (C) / P (GCX)

The symbols A, B, (C), D and P imply :

A	: Type of Ship
B	: Type of Tank
(C)	: Transportation Mode
D	: Design Pressure, Temperature and Specific Gravity (SG)
P	: Name of Product when exclusively carried

Example :

(1) For ships to comply with IGC or GC code

KRS 1 - Liquefied Gas Carrier
2G 1C (R)/0.25bar, -50°C, 1.0SG (IGC)

KRS 1C - Liquefied Gas Carrier
1C (P)/Propane (GCX)

(2) For ships not to comply with IGC or GC code

1) For ships carrying exclusively LPG, i.e., Propane or Butane

KRS 1 - Liquefied Gas Carrier
LPG

2) For ships carrying Liquefied Gases those other than LPG

KRS 1C - Liquefied Gas Carrier
VCM

A means type of ship to be determined by "damage assumption", "location of cargo tanks", "standard of damage" and "survival requirements" specified in **Pt 7, Ch 5, Sec 2** and **Sec 19** of the Rules.

Ship Type	Contents(*)
1G	Gas carrier intended to transport products which require maximum preventive measures to preclude the escape of such cargo
2G	Gas carrier intended to transport products which require significant preventive measures to preclude the escape of such cargo
2PG	Gas carrier of 150 m in length or less intended to transport products which require significant preventive measures to preclude the escape of such cargo, and where the products are carried in independent type C tanks designed for a MARVS of at least 7 bar gauge and a cargo containment system of design temperature of -55℃ or above. (Note : a ship of this description, but over 150 m in length is to be considered a type 2G ship.)
3G	Gas carrier intended to carry products which require moderate preventive measures to preclude the escape of such cargo
(NOTES) (*) : See column C of "Summary of Minimum Requirements" specified in **Pt 7, Ch 5, Sec 19** of the Rules	

B means type of tank to be determined by "cargo containment" specified in **Pt 7, Ch 5, Sec 4** of the Rules.

Tank Type	Symbol	Contents
Integral Tank	2I	(1) Tank to form a structural part of the ship's hull(primary barrier for containment of cargo) (2) Design vapour pressure Po not to normally exceed 0.25 bar(Max. 0.7 bar) (3) Boiling point of the cargo To not to be below -10 °c
Membrane Tank	3M	(1) Non-self supporting tanks which consist of a thin layer(membrane) supported through insulation by the adjacent hull structure (2) Design vapour pressure Po not to normally exceed 0.25 bar(Max. 0.7 bar) (3) Thickness of the membrane not to normally exceed 10 mm
Semi-membrane Tank	3S	(1) Non-self supporting tanks in the loaded condition, which consist of a layer, part of which is supported through insulation by the adjacent hull structure(primary barrier for containment of cargo) (2) Design vapour pressure Po not to normally exceed 0.25 bar(Max. 0.7 bar)
Independent Tank Type A	1A	(1) Gravity tanks (2) Tanks designed using the requirements of **Pt 3, Ch 15** of the Rules (3) Design vapour pressure Po less than 0.7 bar(for plane surfaces)
Independent Tank Type B	1B	(1) Gravity tanks or pressure vessels (2) Tanks designed using model tests, refined analytical tools and analysis methods (3) Design vapour pressure Po less than 0.7 bar(for plane surfaces)
Independent Tank Type C	1C	(1) Pressure vessels (2) Tanks designed using the requirements of **Pt 5, Ch 5** of the Rules (3) Design vapour pressure to be specially considered
Internal Insulation Tank Type 1	1N	(1) Tanks in which the insulation or a combination of the insulation and one or more liners functions only as the primary barrier (2) Inner hull or an independent tank structure to function as the secondary barrier when required. The inner surface of the insulation is not exposed to the cargo (3) Design criteria same as 2I, 3M and 3S
Internal Insulation Tank Type 2	2N	(1) Tanks in which the insulation or a combination of the insulation and one or more liners functions only as both the primary and the secondary barrier (2) Design criteria same as 2I, 3M and 3S
(NOTES) The number in the second column indicates: 1: independent, 2: integral, 3: membrane		

C means transportation mode.

Symbol	Contents
(R)	Fully Refrigerated
(P)	Fully Pressurized
(RP)	Refrigerated and Pressurized

2.1.2 Compressed Natural Gas Carrier

Class Character :

KRS 1 - Compressed Natural Gas Carrier
A / B

A : Type of Cargo Tank

B : Design Pressure, Minimum Temperature

Example :

KRS 1 - Compressed Natural Gas Carrier
CY/13 MPa, -30 ℃

2.2 Chemical Tanker

Class Character :

KRS 1 - Chemical Tanker 'ESP' (FBC) [A] [B] / [D] (IBC)

KRS 1C - Chemical Tanker 'ESP' (FAO) [B] / [P] (BCX)

The symbols A, B, D and P imply :

[A] : Type of Ship

[B] : Type of Tank

[D] : Specific Gravity (SG)

[P] : Name of Product when exclusively carried

Example :

(1) For chemical tanker

KRS 1 - Chemical Tanker 'ESP' (FBC) II 2G/1.0SG (IBC)

KRS 1C - Chemical Tanker (FAO) 1G/Sulphur Molten (BCX)

(2) For combination carrier of oil and chemical

KRS 1 - Oil/Chemical Tanker 'ESP' (FAC) Product/III 2G/1.2SG (IBC)

[A] means type of ship to be determined by "damage assumption", "location of cargo tanks", "standard of damage" and "survival requirements" specified in **Pt 7, Ch 6, Sec 2** of the Rules.

Ship Type	Contents(*)
I	Chemical tanker intended to transport products with very severe environmental and safety hazards which require maximum preventive measures to preclude an escape of such cargo
II	Chemical tanker intended to transport products with appreciably severe environmental and safety hazards which require significant preventive measures to preclude an escape of such cargo
III	Chemical tanker intended to transport products with sufficiently severe environmental and safety hazards which require a moderate degree of containment to increase survival capability in a damaged condition
(NOTES) (*) : See column E of "Summary of Minimum Requirements" specified in **Pt 7, Ch 6, Sec 17** of the Rules.	

B

means type of tank to be determined by "cargo containment" specified in **Pt 7, Ch 6, Sec 4** and **Sec 17** of the Rules, as shown in the following.

1G
2G
1P

Symbol	Tank Type	Contents
1	Independent Tank	(1) Gravity tanks or pressure vessels (2) Tanks designed using the requirements of **Pt 3, Ch 15** and **Pt 5, Ch 5** of the Rules.
2	Integral Tank	(1) Self-supporting hull construction tank (2) Tank having a design pressure not greater than 0.25 bar(Max. 0.7 bar) (3) Boiling point of the cargo not to be below -10°C
G	Gravity Tank	(1) Independent or integral (2) Tank having a design pressure not greater than 0.7 bar
P	Pressure Tank	(1) Independent tank (2) Tank designed using the requirements of **Pt 5, Ch 5** of the Rules (3) Tank having a design pressure greater than 0.7 bar

2.3 Bulk Carrier or Cargo Ship

Class Character :

KRS 1 - Bulk Carrier 'ESP' A	KRS 1C - Bulk Carrier(Double Skin) 'ESP' A
KRS 1 - Bulk Carrier A	KRS 1 - Cargo Ship A

Example :

(1) For ships with double bottom structures specially strengthened for the carriage of heavy cargoes

KRS 1 - Bulk Carrier 'ESP'
HC

(2) For ships with double bottom structures specially strengthened for the carriage of heavy cargoes as an alternate loading

KRS 1 - Bulk Carrier 'ESP'
HC/E(Hold Nos. 2, 4, 6 and 8 may be empty)

(3) In cases where the ship is fitted with BC-B

KRS 1 - Bulk Carrier 'ESP'
BC-B

(4) In cases where the ship is fitted with BC-B and the maximum cargo density is less than 3.0 t/m^3

KRS 1 - Bulk Carrier 'ESP'
BC-B(max cargo density --- t/m^3)

(5) In cases where the ship is fitted with BC-A

KRS 1 - Bulk Carrier 'ESP'
BC-A(Hold Nos. 2, 4, 6 and 8 may be empty)

(6) In cases where the ship is fitted with BC-A and the maximum cargo density is less than 3.0 t/m^3

KRS 1 - Bulk Carrier 'ESP'
BC-A(Hold Nos. 2, 4, 6 and 8 may be empty
with max cargo density --- t/m^3)

(7) In cases where the ship is not fitted with **Pt 7, Ch 3, 201. 5** (3) of the Rules

KRS 1 - Bulk Carrier 'ESP'
BC-A(or BC-B, BC-C) (no MP)

(8) In cases where the ship is complied with for unladen grab weight X equal to or greater than 20 tons according to **Pt 11, Ch 1, Sec 1** of the Rules

KRS 1 - Bulk Carrier 'ESP' (CSR)
BC-A(or BC-B) GRAB[X]

(9) Others

KRS 1 - Bulk Carrier

KRS 1C - Cargo Ship
HC

2.4 Fishing Vessel

Class Character :

KRS 1 - Fishing Vessel (Special Feature)

Example :

KRS 1 - Fishing Vessel Stern Trawler

KRS 1 - Fishing Vessel Long Liner and Angling

2.5 Passenger Ship

KRS 1C - Passenger Ship * [A] / [B] / [C]

*Only for submersible

Example :

KRS 1C - Passenger Ship Catamaran/Car Ferry

KRS 1C - Passenger Ship Hydrofoil

KRS 1C - Passenger Ship Submersible/Leisure/Max. 70M, 2Hrs

2.6 Special Purpose Submersible

Class Character :

KRS 1C - Special Purpose Submersible [A][B] / [C] / [D]

Example :

KRS 1C - Special Purpose Submersible Manned, Self-Propelled/Research/Max. 70M, 1.5Hrs

2.7 Drilling Unit

Class Character :

KRS 1C - Drilling Unit
A | B / C

Example :

KRS 1 - Drilling Unit Mobile, Column Stabilized

KRS 1 - Offshore Structure Fixed, Leg(Tripod)/Plant(Power)

2.8 Open Space Car Ferry

Class Notation		Remarks
Ship Type	Special Feature	
10. RoRo Ship	Car Ferry	Ships designed for the carriage of vehicles with loaded cargoes
	Car Ferry(Open Space)	-
14. Passenger Ship	Car Ferry	Passenger ships fitted with equipment capable of loading vehicles
	Car Ferry(Open Space)	-

(NOTES)

The notation "Open Space" expressed in the second column shall be assigned to the following cases.

(1) For ships without openings on the side shell plates within vehicle region and walls in the fore and after end parts of the ship, and where the sum of the area of openings on the upper deck complies with the following formula:

$$\frac{a}{A} \geq \frac{1}{2}$$

a : Sum of area of openings on the upper deck
A : Area of vehicle decks

(2) For ships with openings evenly distributed, as far as practicable, on both sides shell plates within vehicle region, and where the sum of the area of openings on the upper deck complies with the following formula:

$$\frac{a}{A} + \frac{5}{3} \cdot \frac{S_a}{S_A} \geq \frac{1}{2}$$

a and A : As specified in (1).
S_a : Sum of area of opening on one side shell plates within vehicle region
S_A : Area of one side shell plates within vehicle region

2.9 Special feature

Example :
In cases where the ship is applied to the reduced scantling as the restriction of navigation area and condition :

✠ KRS 0 - Barge Service between Korea and Sakhalin during May and June

※ Comparison of Ice Strengthening Class of the Society with Finnish-Swedish Ice Class Rules 1985 and Arctic Shipping Pollution Prevention Regulations

Ice Strengthening Class of the Society	Ice Strengthening Class of Finish-Swedish Ice Class Rules 1985	Ice Strengthening Class of Arctic Shipping Pollution Prevention Regulations
IA Super	IA Super	Type A
IA	IA	Type B
IB	IB	Type C
IC	IC	Type D
ID	II	Type D

⚓

Annex 1-2 Intact Stability

1. Application

(1) The requirements on intact stability(hereafter referred to as "stability") in this Annex apply to ships of 24 meters in length and over. However, passenger ships, tug boats, dredger, steel barges, sailing ships, twin-hull craft and dynamically supported craft may be exempted.

(2) Stability of steel barges of 24 meters in length and over, which are steel barges(pontoon barges) complying with following (A) to (E) may be applied to the requirements of **2008 IS Code, Part B, Ch 2.2.**

(A) To be non self-propelled and unmanned during navigation.

(B) Block coefficient (C_b) is to be not less than 0.9.

(C) The ratio B/D is to be not less than 3.0.

(D) To load cargoes on deck only.

(E) No opening except small manholes fitted with watertight steel covers is to be provided on deck.

(3) Stability of offshore supply vessels are to comply with the following requirements.

(A) **2008 IS Code, Part B, Ch 2.4** Offshore supply vessels

(B) **2008 IS Code, Part A, Ch 2.3** Severe wind and rolling criterion(weather criterion)

(4) Special consideration may be given to the ships registered for a restricted service.

(5) Additional to the requirements in this Annex, attention is to be paid to the stability requirements in the local regulations of the flag states in which ships are flying.

2. Stability Requirements

(1) General

(A) All designed loading conditions are deemed appropriate by the Society and it is to be verified that they comply with the requirements in (3) and (4).

(B) For ships navigating in the area where icing is expected to occur, it is to be considered that the projected area against wind is increased and the position of center of gravity is heightened due to icing on the structures.

(2) Calculation on stability

Stability is to be calculated taking into account the following conditions.

(A) The position center of gravity is to be determined on the basis of the data obtained at inclining test.

(B) Free surface effects of liquid in tanks are to be of what the results of calculation of stability curves in each heeling angle are made most severe during navigation under relevant designed loading condition. However, in the arrival condition, those are to be applied to actual loading of all liquid tanks.

(C) Even if anti-rolling devices are fitted, effect of the devices is to be ignored.

(3) General Stability Requirements

(A) For ships without timber deck cargoes, the stability curves are to comply with the following requirements.

(a) The area under the righting lever curve(GZ curve) should not be less than 0.055 metre-radians up to $\theta = 30°$ angle of heel and not less than 0.09 metre-radians up to $\theta = 40°$ or the angle of flooding θ_f, if this angle is less than 40°. Additionally, the area under the righting lever curve between the angles of heel of 30° and 40° or between 30° and θ_f, if this angle is less than 40° should not be less than 0.03 metre-radians.

(b) The righting lever GZ should be at least 0.20 m at an angle of heel equal to or greater than 30°.

(c) The maximum righting arm should occur at an angle of heel preferably exceeding 30° but not less than 25°. However, in case of ships of 2.5 and over in B/D, the stability requirements may be complied with IMO/MSC/Cir. 1281, Ch 4.

(d) The initial metacentric height G_0M that is corrected due to free surface effects should not be less than 0.15 m. However, in case of fishing vessels, it should not be less than 0.35 m.

(e) In fishing vessels with complete superstructure or fishing vessels of 70 m in length and over, the metacentric height G_0M should be at least 0.15 m.

(f) θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. The closed weathertight is that the devices for maintenance and insurance of weathertight are to satisfy the Society requirements. However, small openings through which progressive flooding cannot take place need not be considered as open.

(B) For ships loaded with timber deck cargoes, the stability curves are to comply with the following requirements:

(a) The area under the righting lever should not be less than 0.08 metre-radians up to θ = 40° or the angle of flooding if this angle is less than 40°.

(b) The maximum value of the righting lever should be at least 0.25 m.

(c) At all times during a voyage the metacentric height G_0M should not be less than 0.10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces.

(C) Where above (B) is applied, the following requirements shall be considered additionally.

(a) For ships loading with timber deck cargoes, stability is to be calculated under following conditions((b) and (c)), provided that the requirements in Regulation 44, ILLC are complied with and timber cargoes are stowed in full breadth of ships. However, when the ship has a rounded gunnel, allowance not exceeding 4 percent of the breadth of ships for loading may be given.

(b) 75 % of the volume occupied by timber may be added to buoyancy.

(c) In the arrival condition it should be assumed that the weight of the deck cargo has increased by 10 % due to water absorption, and when it is anticipated that some formation of ice will take place an allowance should be made in the arrival condition for the additional weight.

(4) Stability Requirements in Wind and Waves

(A) Stability of ships except fishing vessels is to comply with the following requirements(See **Fig 1**):

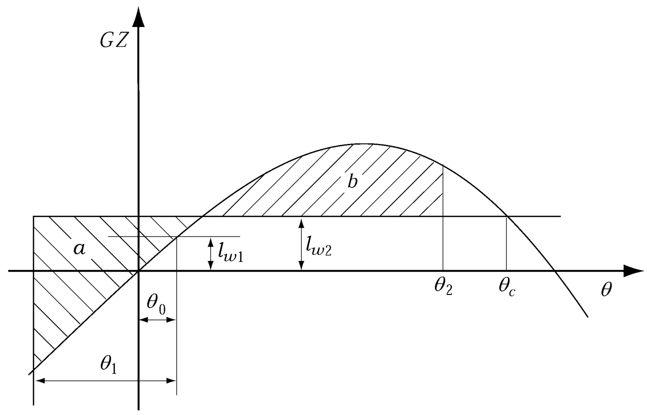


Fig 1 Stability and Wind-Heeling Moment Lever Curve (Stability Requirements in Wind and Waves)

(a) θ_0 is to be less than 16° or an angle corresponding to 80 % of immersing angle of deck edge, whichever is less.(For ships loaded with timber deck cargoes, θ_0 is to be less than 16°.)

(b) Area "b" is not to be less than area "a"

l_{w1} : Heeling moment lever caused by steady wind(m) given by the following formula.

$$l_{w1} = \frac{0.0514AZ}{W} \text{ (m)}$$

A : Projected lateral area of portion of the ship and deck cargo above the waterline (m^2).

Z : Vertical distance from the center of A to the center of the underwater lateral area or to a point at one half the draught (m).

W : Displacement (ton).
l_{w2} : Heeling moment lever caused by gust(m) given by the following formula

$$l_{w2} = 1.5\, l_{w1} \text{ (m)}$$

a : Area encircled by stability curve, l_{w2} and θ_r (m-rad).
b : Area encircled by stability curve, l_{w2} and θ_2 (m-rad).
θ_r : Angle of rolling stop motion (degree). In general, it may be given by the following formula.

$$\theta_r = \theta_0 - \theta_1 \text{ (degree)}$$

θ_c : Heeling angle at the second intersection between heeling moment lever and stability curve (degree).
θ_0 : Angle of heel under action of steady wind (degree).
θ_1 : Angle of roll to windward due to wave action (degree) given by the following formula:

$$\theta_1 = 109 X_1 X_2 k \sqrt{rs} \quad (^\circ)$$

θ_2 : Angle of flooding(θ_f), 50° or θ_c whichever is lesser
X_1 : Values obtained from **Table 1** according to the value of B/d'. In case the value of B/d' becomes intermediate, values are to be determined by interpolation.

Table 1 Values of X_1

B/d'	≤2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	≥3.5
X_1	1.0	0.98	0.96	0.95	0.93	0.91	0.90	0.88	0.86	0.84	0.82	0.80

d' : Mean draught of the ship (m).
X_2 : Values obtained from **Table 2** according to C_b'. In case C_b' becomes intermediate, values are to be determined by interpolation.

Table 2 Values of X_2

C_b'	≤0.45	0.50	0.55	0.60	0.65	≥0.70
X_2	0.75	0.82	0.89	0.95	0.97	1.0

C_b' : Block coefficient given by the following formula:

$$C_b' = \frac{W}{1.025 L' B d'}$$

L' : Length of the ship at waterline (m).
k : Values determined as follows:
(i) For round-bilged ships having neither bilge keels nor bar keels : k = 1.0
(ii) For ships with sharp bilges : k = 0.7
(iii) For ships with bilge keel or bar keel : Values obtained from **Table 3.** However, In case 100 $A_k/L'B$ becomes intermediate, values are to be de-

termined by interpolation.

Table 3 Values of k

$100\ A_k/L'B$	0	1.0	1.5	2.0	2.5	3.0	3.5	≥4.0
k	1.0	0.98	0.95	0.88	0.79	0.74	0.72	0.70

A_k : Total area of bilge keels, projected lateral area of bar keels or sum of those area (m^2).

r : Values obtained from the following formula.

$$r = 0.73 + 0.6\frac{OG}{d'}$$

OG : Distance between the center of gravity and waterline (m), and is taken as positive when the center of gravity is above waterline.

s : Values obtained from **Table 4** according to the value of T. In case of T becomes intermediate, values are to be determined by interpolation.

Table 4 Values of s

T	≤6	7	8	12	14	16	18	≥20
s	0.100	0.098	0.093	0.065	0.053	0.044	0.038	0.035

T : Rolling period (sec). However, in case of the omission of period test or that experiment results of sister ship cannot be used, it is obtained from the following formula:

$$T = \frac{2B}{\sqrt{G_0M}}\left(0.373 + 0.023\frac{B}{d'} - 0.043\frac{L'}{100}\right)\ (\text{sec})$$

G_0M : Initial metacentric height corrected by free surface effect (m).

(B) In case of the ships for restricted service, the requirements specified above (A) do not apply.

3. Guidance for Stability Information for Master

(1) General

(A) This Guidance gives the standardized form and mentioned items for preparation of Stability Information for Master(hereafter referred to as "the information") and the Stability information is recommended to meet the requirements of this Guidance as far as possible.

(B) The information is to be written in a language understandable to Master. If a language other than English is used, English version is to be attached.

(C) By reason of special operation configuration, etc., items deemed necessary are to be added. It is considered beneficial that a computer for calculation of parameters of stability is provided on board. However, omission of the information is not permitted even in the such case.

(2) Arrangement of Stability Information

The information is to be generally arranged as follows.

(A) Table of contents

In the table of contents, the title and first page of each data are to be listed in corresponding position to ensure easy access.

(B) Notice on ship operation

(a) The particular loading conditions(ballast, etc.) that are to ensure stability during navigation and loading/unloading are to be described.
(b) If the buoyancy of superstructures of car carriers, etc. having bow doors, side doors and/or stern doors is included in stability calculation, statement is to be made that those doors must be closed in watertight or weathertight condition before departure and that the stability curve is prepared under the condition with those doors closed.
(c) If any special operation for keeping ample stability is required during cargo handling, the procedure is to be stated.
(d) Notices on loading cargoes(e.g. designed maximum weight of cargoes), if any, are to be described.
(e) Any other notices deemed necessary for stability are to be described.

(C) Principal Particulars
The following items are to be listed in general.
(a) Name of ship
(b) Builder and yard number of ship
(c) Date of build(keel-lay, launch and delivery) or conversion
(d) Purpose of ship
(e) Classification character and notations
(f) Nationality, port of registry, official number and signal letters
(g) Principal dimensions(length, breadth and depth)
(h) Tonnage descriptions
(i) Output of main engine and ship speed
(j) Load line marks, convention or the Rules applied and type of free board (Type 'A', Type 'B', etc.)
(k) IMO number

(D) Explanation of Symbols used
Designations, symbols and abbreviations for various units used in stability information are to be described. The units used are preferably unified in a single system. If plural systems(for example, when SI unit and MKS unit are used) are inevitable, a conversion table between the systems is to be attached.

(E) Data for Cargoes, Stowages, etc.
(a) A list is to be prepared for densities or stowage factors of various cargoes intended to be loaded on board.
(b) Drawings in a suitable scale, which show the arrangement of cargo spaces, tanks, lockers and stores, and other compartments together with their name, are to be attached.
(c) As to weight and location of center of gravity of following items which are used in stability calculation, assumed total weight and position of center of gravity and the basis of assumption are to be listed with, if appropriate:
(i) Passengers and their effects.
(ii) Crew and their effects.
(iii) Motorcars in case of car carriers or car ferries.
(iv) Deck cargoes(If deck cargoes are anticipated to absorb water, the weight of them is to be increased by absorbed water in arrival condition).
(v) Hanging cargoes and container cargoes(The plan of loading arrangement of containers is to be provided, in which maximum gross weight tare weight and center of gravity of each container is described and each container is numbered in consideration of easy identification).

(F) Results of Stability Experiments
(a) The results of inclining tests are to include light weight and location of centre of gravity, date of inclining and surveyor's confirmed signature. When any permanent ballast are included in light condition, the material, weight and arrangement of them are to be described by the drawing.
(b) When rolling tests were carried out, the details of rolling test procedures are to be included in the test results. And an explanation of the relation between rolling period and G_0M is to be attached.

(G) Method of Utilizing Information
Explanations for following items are to be stated. In order that the master calculates stability curves and evaluates the stability of ship, examples of calculations are to be added and the basis of all data are to be clarified. Blank forms for calculation are to be attached.

(a) Calculation for displacement and location of center of gravity
(b) Calculation for draught and trim
(c) Method of preparation for GZ-curve
(d) Method of correction due to free-surface effect on GZ-curve and GM
(e) Method of estimating the effect of wind and waves
(f) Method of evaluation for GZ-curve, etc. under the applicable stability requirements
(g) Maximum permissible vertical center of gravity
(h) Other items deemed necessary(for example, when anti-rolling devices, heeling tanks, etc. are installed, the service procedures for them and operational restrictions thereto are to be explained)

(H) Applied Stability Requirements
(a) It is to be described that the ship complies with the requirements in Annex which meet the requirements in A.167, A.206, A.562 of IMO Resolutions.
(b) If any special requirements are made by the flag state other than the above-mentioned Resolutions, excerpts or summary of relevant provisions are given.
(c) For ships intended to navigate in area where icing is liable to occur, details of assumed icing are to be given together with the location, weight and center of gravity of icing.

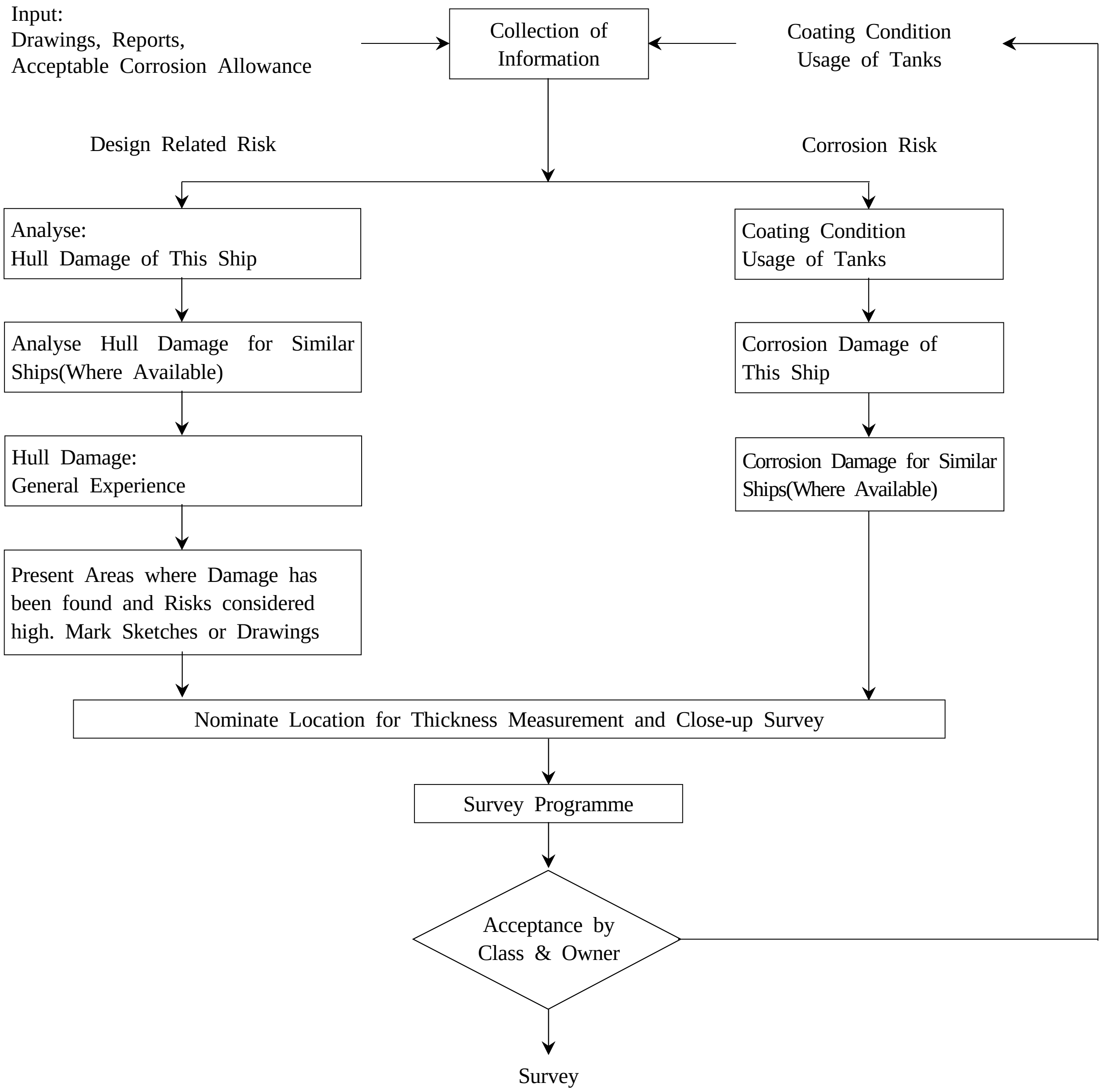
(I) Stability in Standard Loading Condition
(a) The under mentioned conditions are to be at least included in standard loading conditions unless they are cleary inappropriate.
(i) Except fishing vessels, a departure condition means a condition in which provisions and fuel are fully loaded and an arrival condition means a condition in which 90% thereof are consumed.
① Light condition
② Docking condition
③ Ballast departure condition and ballast arrival condition
④ Full load departure condition and full load arrival condition
⑤ Loading condition in which the parameters of stability are liable to be changed on a large scale(e.g., ballasting during navigation, possible icing, etc.)
(ii) For fishing vessels
① Light condition
② Departure for the fishing grounds with full fuel, stores, ice, fishing gear, etc.
③ Departure from fishing grounds with full catch and 25 % stores, fuel, etc.
④ Arrival at home port with full catch and 10 % stores, fuel, etc.
⑤ Arrival at home port with 20 % of full catch and 10 % stores, fuel, etc.
⑥ Loading condition in which the parameters of stability are liable to be changed on a large scale(e.g., ballasting during navigation, possible icing, etc.)
(b) The following items are to be stated concerning each loading condition. If there are any limitations upon loading they are to be included:
(i) Arrangement in suitable scale showing distribution of all components constituting deadweight.
(ii) Light weight, and weight, position of centre of gravity, weight moment and displacement.
(iii) Mean draught, corresponding draught, position of centre of buoyancy and centre of gravity, position of centre of flotation, MTC, trim, draughts at forward and aft perpendiculars, GG_0, KG_0 and G_0M.
(iv) GZ-curves taking effect of free surface.
(v) Evaluation of conformity with stability requirements.
(vi) Down flooding angle and other items.

(J) General data
The following items are to be included in stability data:
(a) Capacity and the location of the centre of capacity of compartments, and the moment of inertia of free surface, are to be presented in numerical tables or curves.
(b) Hydrostatic curves or numerical tables.
(c) Cross curves or numerical tables.
(d) Curve of down flooding angle or numerical tables.
(e) Projected lateral windage area or numerical tables.
(f) Maximum permissible height of center of gravity or numerical tables.
(g) Other data deemed necessary. ⚓

Annex 1-3 Example of the Survey Programme and the Survey Planning Questionnaire

1. The following process may be considered to assist in identifying critical structural areas, nomination suspect areas and in focusing attention on structural elements or areas of structural elements which may be particularly susceptible to, or evidence a history of, wastage or damage in conjunction with the preparation of the survey programme, the example is shown in **Table 1.**

(Use may be made of the IACS UR Z10's Annex I, if it necessary)



2. Prior to the development of the survey programme, the survey planning questionnaire is to be completed by the Owner based on the information set out in **Annex 1-3, Table 2** of the Guidance, and forwarded to the Society.

Table 1 Example of the Survey Programme

SURVEY PROGRAMME

For Special Survey No. _____ / Intermediate Survey at ______ years of age,
scheduled from ________________________________ to ________________________________
at ____.
(If the commencement-completion survey system is applied, outlines of each survey are to be listed in the next page)

Basic information and particulars

Name of ship :	
Class No. :	IMO No. :
Class Notation :	
Flag State :	
Port of registry :	
Gross tonnage :	
Deadweight(metric tones) :	
Length between perpendiculars(m) :	
Shipbuilder :	
Hull number :	
Date of delivery of the ship :	
Date of build / major conversion :	/
Owner :	
Thickness measurement company :	

Prepared by the Owner in co-operation with the Society;

Owner's representative :	Classification Society :
Signature ________________ Name (Place / Date)	Signature ________________ Name (Place / Date)

SURVEY PROGRAMME

Outlines of each commencement-completion survey

Date	Place	Docking (Yes/No)	Overall Survey	Close-up Survey	Thickness measurement	Tank Testing	Suspect Area

1. Preamble

1.1 Scope

1.1.1 The present survey programme covers the minimum extent of Overall Surveys, Close-up Surveys, thickness measurements and pressure testing within the cargo (length) area, cargo holds/tanks, ballast tanks, including fore and aft peak tanks, required by the Rules.

1.1.2 The arrangements and safety aspects of the survey are to be acceptable to the attending Surveyor(s).

1.2 Documentation

All documents used in the development of the survey programme are to be available onboard during the survey as required by the relevant requirements specified in the Rules.

SURVEY PROGRAMME

2. Arrangement of cargo holds, tanks and spaces

This section of the survey programme is to provide information(either in the form of plans or text) on the arrangement of cargo holds, tanks and spaces that fall within the scope of the survey.

SURVEY PROGRAMME

3. List of cargo holds, tanks and spaces with information on their use, extent of coatings and corrosion prevention system

This section of the survey programme is to indicate any changes relating to (and is to update) the information on the use of the holds and tanks of the ship, the extent of coatings and the corrosion prevention system provided in the survey planning questionnaire.

SURVEY PROGRAMME

4. Conditions for survey

This section of the survey programme is to provide information on the conditions for survey, e.g. information regarding cargo hold and tank cleaning, gas freeing, ventilation, lighting, etc.

Hold/Tank/Space	Cleaning	Gas freeing	Ventilation	Lighting	Etc.

SURVEY PROGRAMME

5. Provisions and method of access to structures

This section of the survey programme is to indicate any changes relating to (and is to update) the information on the provisions and methods of access to structures provided in the survey planning questionnaire.

SURVEY PROGRAMME

6. List of equipment for survey

This section of the survey programme is to identify and list the equipment that will be made available for carrying out the survey and the required thickness measurements.

(e.g. thickness measurement equipment, fracture detection equipment, explosimeter, oxygen-meter, breathing apparatus, lifelines, riding belts with rope and hook, whistles, safe lighting, protective clothing(safety helmet, gloves, safety shoes, etc.), etc.)

Equipment	Sets	Description	Used for

SURVEY PROGRAMME

7. Survey requirements

7.1 Overall Survey

This section of the survey programme is to identify and list the spaces that are to undergo an Overall Survey for the ship in accordance with the Rules.

Hold/Tank/Space	Remarks

SURVEY PROGRAMME

7.2 Close-up Survey

This section of the survey programme is to identify and list the hull structures that are to undergo a Close-up Survey for the ship in accordance with the Rules.

Hold/Tank/Space	Areas for Close-up Survey

SURVEY PROGRAMME

8. Identification of tanks for tank testing and pipes for pipe testing

This section of the survey programme is to identify and list the cargo holds and tanks that are to undergo tank testing for the ship and the pipes that are to undergo pipe testing(for chemical tankers) in accordance with the Rules.

Hold/Tank/Pipe	Remarks

SURVEY PROGRAMME

9. Identification of areas and sections for thickness measurements

This section of the survey programme is to identify and list the areas and sections where thickness measurements are to be taken in accordance with the Rules.

Hold/Tank	Areas and sections for thickness measurement

SURVEY PROGRAMME

10. Minimum thickness of hull structures

This section of the survey programme is to specify the minimum thickness for hull structures of the ship that are subject to survey. (indicate either (a) or preferably (b), if such information is available):

(a) ☐ Determined from the attached wastage allowance table and the original thickness to the hull structure plans of the ship;

(b) ☐ Given in the following table(s):

Area or location	Original as-built thickness(mm)	Minimum thickness(mm)	Substantial corrosion thickness(mm)

Note: The wastage allowance tables are to be attached to the survey programme.

SURVEY PROGRAMME

11. Thickness measurement company

This section of the survey programme is to identify changes, if any, relating to the information on the thickness measurement company provided in the survey planning questionnaire.

SURVEY PROGRAMME

12. Damage experience related to the ship

This section of the survey programme is to, using the tables provided below, provide details of the hull damages for at least the last three years in way of the cargo holds/tanks, ballast tanks and void spaces within the cargo (length) area. These damages are subject to survey.

Hull damages sorted by location for the ship

Cargo hold, tank or space number or area	Possible cause, if known	Description of the damages	Location	Repair	Date of repair

Hull damages for sister or similar ships (if available) in the case of design related damage

Cargo hold, tank or space number or area	Possible cause, if known	Description of the damages	Location	Repair	Date of repair

SURVEY PROGRAMME

13. Areas identified with substantial corrosion from previous surveys

This section of the survey programme is to identify and list the areas of substantial corrosion from previous surveys.

Hold/Tank/Space	Areas of substantial corrosion	Date and kind of survey

SURVEY PROGRAMME

14. Critical structural areas and suspect areas

This section of the survey programme is to identify and list the critical structural areas and the suspect areas, when such information is available.

Hold/Tank/Space	Critical structural areas	Suspect areas

SURVEY PROGRAMME

15. Other relevant comments and information

This section of the survey programme is to provide any other comments and information relevant to the survey.

SURVEY PROGRAMME

16. Appendices

Appendix 1 - List of plans

The Rules require that main structural plans of cargo holds/tanks and ballast tanks (scantling drawings), including information regarding use of high tensile steel (HTS), clad steel and stainless steel(for chemical tankers) are to be available. This appendix of the survey programme is to identify and list the main structural plans which form part of the survey programme.

Appendix 2 - Survey planning questionnaire

The survey planning questionnaire, which has been submitted by the Owner, is to be appended to the survey programme.

Appendix 3 - Other documentation

This part of the survey programme is to identify and list any other documentation that forms part of the plan.

Table 2 Example of the Survey Planning Questionnaire

SURVEY PLANNING QUESTIONNAIRE

The following information will enable the Owner in co-operation with the Society to develop a survey programme complying with the requirements of the Rules. It is essential that the Owner provides, when completing the present questionnaire, up-to-date information. The present questionnaire, when completed, is to provide all information and material required by the Rules.

Basic information and particulars

Name of ship :	
Class No. :	IMO No. :
Class Notation :	
Flag State :	
Port of registry :	
Gross tonnage :	
Deadweight(metric tones) :	
Length between perpendiculars(m) :	
Shipbuilder :	
Hull number :	
Date of delivery of the ship :	
Date of build / major conversion :	/
Owner :	
Thickness measurement company :	

Owner's representative :
Signature ________________ Name (Place / Date)

SURVEY PLANNING QUESTIONNAIRE

1. Information on access provisions for Close-up Surveys and thickness measurement

The Owner is to indicate, in the table below, the means of access to the structures subject to Close-up Survey and thickness measurement. A Close-up Survey is an examination where the details of structural components are within the close visual inspection range of the attending Surveyor, i.e. normally within reach of hand.

Hold/Tank/Space	Structure*	C(Cargo)/B (Ballast)	Access provisions				
			Temporary staging	Rafts/Boats	Ladders	Direct access	Other means (please specify)

* Each structural components which have different type of access provisions are to be specified. (e.g. Fore peak/Aft peak/Under deck/Side shell/Bottom transverse/Longitudinal/Transverse/Hatch side coamings/Topside slopping plate/Upper stool plating/Cross deck/Side shell, frames & brackets/Transverse bulkhead/Hopper slopping plating/Lower stool/Tank top/Double bottom structure/Upper stool internal structure/Lower stool internal structure, etc.)

History of bulk cargoes of a corrosive nature(e.g. high sulphur content) / History of cargo with H_2S content or heated cargo for the last 3 years together with indication as to whether cargo was heated and, where available, Marine Safety Data Sheets(MSDS)*

* Refer to resolution MSC.150(70) on Recommendation for material safety data sheets for MARPOL Annex I cargoes and marine fuel oils.

SURVEY PLANNING QUESTIONNAIRE

2. Owner's inspections

Using a format similar to that of the table below (which is given as an example), the Owner is to provide details of the results of their inspections for the last 3 years on all cargo holds/tanks, ballast tanks and void spaces within the cargo (length) area, including peak tanks.

Hold/Tank/Space	Use	Corrosion prevention system (1)	Coating extent (2)	Coating condition (3)	Structural deterioration (4)	Hold/tank/space history (5)

(1) HC=hard coating, SC=soft coating, SH=semi-hard coating, NP=no prevention
(2) U=upper part, M=middle part, L=lower part, C=complete
(3) G=good, F=fair, P=poor, RC=recoated(during the last 3 years)
(4) N=no findings recorded,
Y=findings recorded, description of findings is to be attached to the questionnaire
(5) DR=damage & repair, L=leakages,
CV=conversion(description is to be attached to the questionnaire)

Owner's representative :
Signature ________________ Name (Place / Date)

SURVEY PLANNING QUESTIONNAIRE

3. Reports of Port State Control inspections

List the reports of Port State Control inspections containing hull structural related deficiencies and relevant information on rectification of the deficiencies:

4. Safety Management System

List non-conformities related to hull maintenance, including the associated corrective actions:

5. Name and address of the approved thickness measurement company

Name	Address	Approved by

⚓

Annex 1-4 Owners Inspection Report

The Owner of ships subject to the enhanced survey programme such as bulk carriers, oil tankers and chemical tankers, etc. is to complete the Owner Inspection Report and retain it inside the ship, according to requirement **Ch 3, 103.** of the Rules. An example of the Owner Inspection Report is shown in **Table 1.**

Table 1 Example of Owner Inspection Report

Owners Inspection Report(Structural Condition)

◦ Ship's Name :________________________ ◦ Tank No./Hold No. : ________________________

◦ Grade of Steel :

· Deck :____________________________ · Side : ____

· Bottom :__________________________ · Longi. BHD : _________________________________

· Trans. BHD :______________________

Elements	Cracks	Buckling	Corrosion	Coating Cond.	Pitting	Rep., Mod	Other
Deck							
Bottom							
Side							
Longi. BHD							
Trans BHD							

◦ Repairs carried out due to :

◦ Thickness measurements carried out :
· Date :
· Result in General :

◦ Overdue Survey :

◦ Outstanding Conditions of Class :

◦ Comments :

◦ Date of Inspection : __________________________________

◦ Inspected by : __________________________________

◦ Signature : __________________________________

↓

Annex 1-5 Thickness Measurement Method for Hull Structural Members

1. General

(1) Purpose of thickness measurement

(A) Corrosion seems to be one of the common denominators in many cases of serious hull casualties resulting in losses of vessels, cargoes and human lives. The purpose of thickness measurement described in the Rules is to prevent vessels from hull casualties. Information provided in the report of hull thickness measurements for a vessel put in service indicates that the vessel is maintaining sufficient local and global strength, if necessary renewal/repair works can be made accordingly. Therefore, thickness measurement reports giving information for the assessment of hull strength(including watertight integrity) as well as for the maintenance of the hull is to be carefully considered.

(B) Where the ship has been constructed with FRP, aluminum alloy or other anti-corrosion materials, the thickness measurements may be dispensed with.

(2) Extent of thickness measurement

The standard extent of thickness measurements complying with the "Rules for Classification of Steel Ships" is given in **Table 4** to **Table 13.** However, the extent of thickness measurements may be specially considered by the Society, considering the coating and corrosion condition.

(3) Thickness measurement report

(A) The thickness measurement report submitted to the Society shall include the general particulars as shown in **Table 19,** measuring position, diagram with details of the position to be measured, original thickness, maximum allowable diminution and present thickness(gauged) and diminution, etc. Reporting form shown in **Table 20**(or equivalent form) is to be used for recording measuring position, original thickness, maximum allowable diminution, present thickness(gauged) and diminution, etc.

(B) The thickness measurement report is to be verified and countersigned by the attending Surveyor, and the record is to be kept in the Society and on board the ship.

2. Wear Limit

(1) General

(A) This annex provides standard of wear limit for decision of repair of main hull structural members. Wear limit or allowable wear quantity means allowable wear limit.

(B) When worn down thickness of hull structural members exceed the wear limit, inspections are to be carried out in detail and corresponding hull structural members are to be renewed by the date recommended by the Surveyor.

(C) Wear limit provided by this annex is based on the requirements and scantlings during construction. Therefore, the wear limit for the structural members which have scantlings larger than the required ones and margin in strength may be considered appropriately.

(D) Wear limit on hull structural members not provided by this annex follows what is deemed appropriate by the Surveyor.

(2) Wear limit on hull structural members

(A) Wear limits on structural members are provided in **Table 1.**

(B) Value of wear limit indicates the limit on equally distributed wearing.

(C) When partial corrosion occurs in stress concentrated part, partial replacement or reinforcement shall be carried out without reference to **Table 1.**

Table 1 Wear limit on members

<table>
<tr><td rowspan="8">Local

Wear
Limit</td><td rowspan="2">Name of member</td><td colspan="3">Wear limit</td></tr>
<tr><td>Class Ⅰ [3)]</td><td>Class Ⅱ [3)]</td><td>Class Ⅲ [3)]</td></tr>
<tr><td>Strength deck plating, sheer strake and longitudinals to these members,
shell plating, bottom shell plating,
bulkhead plating of deep tank,
topside sloping plating,
hopper side sloping plating,
inner bottom plating</td><td>20 % of
original thickness</td><td>(20 % of
original
thickness)
+ 1 mm</td><td rowspan="5">1 mm</td></tr>
<tr><td>Floor & girder of double bottom,
web and face of primary supporting member</td><td>20 % of
original thickness</td><td>25 % of
original thickness</td></tr>
<tr><td>Effective deck plating,
superstructure deck plating,
deck plating inside the line of cargo hatch openings,
watertight bulkhead plating[2)],
hatch cover(including stiffeners),
hatch coaming(including stiffeners),
web, face and brackets of secondary stiffener[1)]</td><td>25 % of
original thickness</td><td>30 % of
original thickness</td></tr>
<tr><td>Web, face and brackets of frames in cargo hold/tank</td><td>20 % of
original thickness
or 1.5 mm,
whichever greater</td><td>25 % of
original thickness
or 2.5 mm,
whichever
greater</td></tr>
<tr><td>Partial corrosion (e.g pitting)</td><td>30 % of
original thickness</td><td>35 % of
original thickness</td></tr>
<tr><td colspan="4">(NOTES)
1) Secondary stiffener refers to the member which is supported by the primary supporting member and does not support another reinforcement member.
2) Among watertight bulkhead platings, the bulkhead plating of tanks used for carriage of water, fuel oil and other liquids, forming a part of the hull structures, is to be treated as a bulkhead plating of deep tank.
3) For ships classed through the Classification Survey during Construction : the Class I, II and III are as follow.
(a) Class I : It is applied to ships having one or two of the following characteristics.
(i) Ships, with of length of 90 m and above, which are classed with Classification Survey during Construction in accordance with the Rules after 1st July 1998.
(ii) Ships carry for liquid cargo, which are classed with Classification Survey during Construction in accordance with the Rules after 1st July 1998.
(b) Class II : Ships, other than in Class I and III.
(c) Class III : Ships constructed with steel, which is applied to the Rules for the Classification of High Speed and Light Crafts and the Guidance Relating to the Rules for the Classification of High Speed and Light Crafts.
4) For ships classed through the Classification Survey after Construction, the separate requirements specified by the Society are to be applied.</td></tr>
<tr><td>Wear relating to the Shearing Strength</td><td colspan="4">The shearing strength evaluation is to be carried out in any of the following cases when the thickness measurement for the longitudinal strength evaluation is carried out in accordance with the separate requirements specified by the Society.
1) For oil tankers(including chemical tankers), the average corrosion of any stake in side shell or longitudinal bulkhead exceeds the followings,
Class I : 2.0 mm
Class II : 3.0 mm
2) For liquefied gas carriers, the average corrosion of any stake in side shell bulkhead exceeds the followings, or
Class I : 1.5 mm
Class II : 2.5 mm
3) For bulk carriers(including ore carriers) intended for alternate loading, the average corrosion of any stake in side shell or longitudinal bulkhead exceeds the followings
Class I : 1.5 mm
Class II : 2.5 mm</td></tr>
</table>

(3) Wear limit of hold hatch cover of bulk carriers which are contracted for construction after 1st July 1998 and before 1st January 2004 and designed by the Rules **Pt 7, Ch 3, Sec 9** is to be determined in accordance with the following requirements.

(A) Single skin hatch covers and the pontoon hatch covers

(a) Steel renewal is required where the gauged thickness is worn more than 1.5 mm (less than $t_{net}+0.5$ mm). The net thickness t_{net} is the thickness obtained by subtracting the corrosion addition from the required thickness.

(b) Where the gauged thickness is worn within the range 1.0 mm and 1.5 mm ($t_{net}+0.5$ mm and $t_{net}+1.0$ mm), coating applied in accordance with coating manufacturer's requirements or annual gauging may be adopted as an alterative to steel renewal.

(B) Internal structural members of pontoon hatch covers

Thickness gauging is required when plating renewal is to be carried out in accordance with previous (a) or when it is deemed necessary, at the discretion of the Society, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is worn more than 1.5 mm (less than t_{net}).

(4) Wear limit of hold hatch cover and hatch coatings of all bulk carriers, ore carriers and combination carriers which are contracted for construction on or after 1st January 2004 and designed by the Rules **Pt 7, Ch 3, Sec 9** is to be determined in accordance with the following requirements.

(A) Single skin hatch covers and double skin hatch covers

(a) Steel renewal is required where the gauged thickness is worn more than 1.5 mm (less than $t_{net}+0.5$ mm).

(b) Where the gauged thickness is worn within the range 1.0 mm and 1.5 mm ($t_{net}+0.5$ mm and $t_{net}+1.0$ mm), coating applied in accordance with coating manufacturer's requirements or annual gauging may be adopted as an alterative to steel renewal. Coating is to be maintained in GOOD condition, as defined in **Pt 1, Ch 2, 101. 16** of the Rules

(B) Internal structural members of double skin hatch covers

Thickness gauging is required when plating renewal is to be carried out in accordance with previous (a) or when it is deemed necessary, at the discretion of the Society, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is worn more than 1.5 mm (less than t_{net}).

(C) Hatch coamings

(a) Steel renewal is required where the gauged thickness is worn more than 1.0 mm (less than $t_{net}+0.5$ mm).

(b) Where the gauged thickness is worn within the range 0.5 mm and 1.0 mm ($t_{net}+0.5$ mm and $t_{net}+1.0$ mm), coating applied in accordance with coating manufacturer's requirements or annual gauging may be adopted as an alterative to steel renewal. Coating is to be maintained in GOOD condition, as defined in **Pt 1, Ch 2, 101. 16** of the Rules

(5) The renewal thickness($t_{renewal}$) of steel hatch covers and coamings in position I and II on exposed decks, subjected to **Pt 4, Ch 2**, of ships other than bulk carriers which are keel laid on or after 1st January 2005 are to be in accordance with as followings. (Refer to **Pt 4, Ch 2, 105. 2**)

$$t_{renewal} = t_{as-built} - t_c + 0.5 \qquad (\mathrm{mm})$$

Where,

$t_{as-built}$: as built thickness

t_c : corrosion addition according to **Pt 4, Ch 2, 105. Table 4.2.1** of the Rules

Where the corrosion addition t_c is 1.0 mm, the renewal thickness may be given by the following formula

$$t_{renewal} = t_{as-built} - t_c \quad (\mathrm{mm})$$

(6) Wear limit of corrugated transverse watertight bulkheads for bulk carriers, which are contracted for construction after 1st July 1998 and designed by the Rules **Pt 7, Ch 3, 1201.** is to be determined in accordance with the following requirements.
(A) Steel renewal is required where the gauged thickness is worn more than 3.0 mm (less than $t_{net}+0.5$ mm).
(B) Where the gauged thickness is worn within the range 2.5 mm and 3.0 mm ($t_{net}+0.5$ mm and $t_{net}+1.0$ mm), coating applied in accordance with coating manufacturer's requirements or annual gauging may be adopted as an alterative to steel renewal.
(7) Corrosion addition and steel renewal of vertically corrugated transverse watertight bulkheads between cargo holds No. 1 and 2 for bulk carriers, which are applied to **Pt 7, Annex 7-5, 1** (1) (A) of the Guidance, are to be determined in accordance with the requirements specified in **Pt 7, Annex 7-5, 1** (6).
(8) The wastage allowances of supporting hull structures associated with towing and mooring, subject to **Pt 4, Ch 10** of the Rules, of ships which are keel laid on or after 1st January 2007 are not to exceed the corrosion addition as specified in **Pt 4, Ch 10, 201. 6** and **202. 6** of the Rules.

3. Methods of Thickness Measurement

An essential part of most surveys is the determination of the residual thickness of the structure in critical areas. Ultrasonic thickness gauging by pulse echo method is used almost exclusively for this purpose. However, measuring by drilled holes may also be acceptable. As a method of thickness measurement, where ultrasonic thickness gauging methods are used, attention is to be paid to the following:
(1) Surface condition
Surfaces upon which the probe makes contact are to be sufficiently free from scale, loose paint, corroded surfaces or other foreign matters to the extent that their presence does not result in inaccurate readings when acoustic couplants such as glycerine or glycerine-water solutions are used during inspection. In special cases, readings through paint film by a special instrument may be accepted.
(2) Couplants
It is essential that good acoustic contact is achieved between the probe and the surface of the plate being measured. Therefore, acoustic couplants(e.g., coupling fluid; 75 % glycerine-water solutions or glycerine) between the probe and surface of material are usually used for better achievements. Where the direction of contact surfaces is vertical or overhead, a paste or liquid with suitable viscosity may be used to prevent acoustic couplants from dropping.
(3) Calibrations
An instrument is to be calibrated with a reference calibration standard each time it is used, and it is to be recalibrated whenever equipment calibration is suspected of being in error.

4. Location of Thickness Measurement

(1) Thickness measurements for suspect area
At each Special Survey, the thickness gaugings may be required as a result of Close-up Survey in suspect areas(i.e., locations showing substantial corrosion and/or considered by the Surveyor to be prone to rapid wastage). Details are given in **Table 2.**
(2) Location and number of thickness measuring points
The standard location and number of thickness measuring points and patterns are shown in **Table 3.** These figures show typical arrangements of ships such as bulk carriers and oil tankers, etc. and these may be used as guidance for different type of ships other than those illustrated. The location and number of thickness measuring points for other hull structural members which are not specified in this Annex are to be in accordance with what considered appropriate by the Surveyor taking into account of the ship's age and hull structure, etc.
(3) Thickness Measurement at Special Survey
The standard extent of thickness measurements at each Special Survey are given in **Table 4** to **Table 13.**

5. Additional Thickness Measurement

The extent of additional thickness measurement at those areas of substantial corrosion of ships subject to the enhanced survey programme such as bulk carriers, oil tankers and chemical tankers, etc. is shown in **Table 14** to **Table 18.**

6. Sampling method of thickness measurements for longitudinal strength evaluation and repair methods for oil tankers or double hull oil tankers subject to the enhanced survey programme

(1) Extent of longitudinal strength evaluation
Longitudinal strength should be evaluated within 0.4 L amidships for the extent of the hull girder length that contains tanks therein and within 0.5 L amidships for adjacent tanks which may extent beyond 0.4 L amidships, where tanks means ballast tanks and cargo tanks.

(2) Sampling method of thickness measurement

(A) Pursuant to the requirements of **Ch 3, 304. 4** or **504. 4** of the Rules as applicable, transverse sections should be chosen such that thickness measurements can be taken for as many different tanks in corrosive environments as possible, e.g. ballast tanks sharing a common plane boundary with cargo tanks fitted with heating coils, other ballast tanks, cargo tanks permitted to be filled with sea water and other cargo tanks. Ballast tanks sharing a common plane boundary with cargo tanks fitted with heating coils and cargo tanks permitted to be filled with sea water should be selected where present.

(B) The minimum number of transverse sections to be sampled should be in accordance with **Ch 3, Table 1.3.5** or **Table 1.3.11** of the Rules as applicable. The transverse sections should be located where the largest thickness reductions are suspected to occur or are revealed from deck and bottom plating measurements prescribed in (C) and should be clear of areas which have been locally renewed or reinforced.

(C) At least two points should be measured on each deck plate and/or bottom shell plate required to be measured within the cargo area in accordance with the requirements of **Ch 3, Table 1.3.5** or **Table 1.3.11** of the Rules as applicable.

(D) Within 0.1 D (where D is the ship's moulded depth) of the deck and bottom at each transverse section to be measured in accordance with the requirements of **Ch 3, Table 1.3.5** or **Table 1.3.11** of the Rules as applicable, every longitudinal and girder should be measured on the web and face plate, and every plate should be measured at one point between longitudinals.

(E) For longitudinal members other than those specified in (D) above to be measured at each transverse section in accordance with the requirements of **Ch 3, Table 1.3.5** or **Table 1.3.11** of the Rules as applicable, every longitudinal and girder should be measured on the web and face plate, and every plate should be measured at least in one point per strake.

(F) The thickness of each compartment should be determined by averaging all of the measurements taken in way of the transverse section on each compartment.

(3) Additional measurements where the longitudinal strength is deficient.

(A) Where one or more of the transverse sections are found to be deficient in respect of the longitudinal strength requirements, the number of transverse sections for thickness measurement should be increased such that each tank within the 0.5 L amidships region has been sampled. Tank spaces that are partially within, but extend beyond, 0.5 L region, should be sampled.

(B) Additional thickness measurements should also be performed on one transverse section forward and one aft of each repaired area to the extent necessary to ensure that the areas bordering the repaired section also comply with the requirements of the Rules.

(4) Effective repair methods

(A) The extent of renewal or reinforcement carried out to comply with the Rules should be in accordance with (B) below.

(B) The minimum continuous length of a renewed or reinforced structural member should be not less than twice the spacing of the primary members in way. In addition, the thickness diminution in way of the butt joint of each joining member forward and aft of the replaced member(plates, stiffeners, girder webs and flanges, etc.) should not be within the substantial corrosion range(75% of the allowable webs and flanges, etc.) should not be within the substantial corrosion range(75% of the allowable diminution associated with each particular member). Where differences in thickness at the butt joint exceed 15% of the lower thickness, a transition taper should be provided.

(C) Alternative repair methods involving the fitting of straps or structural member modification should be subject to special consideration. In considering the fitting of straps, it should be limited to the following conditions:

(a) to restore and/or increase longitudinal strength;

(b) the thickness diminution of the deck or bottom plating to be reinforced should not be within the substantial corrosion range(75% of the allowable diminution associated with the deck plating):

(c) the alignment and arrangement, including the termination of the straps, is in accordance with the separate requirements specified by the Society;

(d) the straps are continuous over the entire 0.5 L amidships length; and

(e) continuous fillet welding and full penetration welds are used at butt welding and, depending on the width of the strap, slot welds. The welding procedures applied should be acceptable to the Society.

(D) The existing structure adjacent to replacement areas and in conjunction with the fitted straps, etc. should be capable of withstanding the applied loads, taking into account the buckling resistance and the condition of welds between the longitudinal members and hull envelope plating.

7. Thickness measurements and renewal criteria for ships subject to the Common Structural Rules(CSR)

Thickness measurements and renewal criteria for ships subject to the Common Structural Rules(CSR) specified in **Pt 11** or **Pt 12** are to be in accordance with these relevant Part of the Rules.

Table 2 Suspect areas on which attention is to be paid

Location	Measuring Points	
Deck and upper structures	Special attention is to be given on fore parts (forward of 0.5 L amidships) of strength deck, areas with standing bilges and members with originally light scantlings in addition to the following:	
	F'cle, poop and deckhouse	Break bulkheads of superstructures, Lower parts of deckhouse walls, Pipe penetration areas, Areas with drain plugs, Deck platings of superstructures, Deck platings in way of bilge-ways, deck scuppers, deck machinery(winches, windlasses etc.), fair-leaders and bollards etc.
	Deck platings inside line of hatch openings and inside superstructures and deckhouses	Deck platings inside line of openings between cargo hatch-ways, and of deck platings inside superstructures and deckhouses.
	Hatch coamings and coaming stays	Lower parts attached to upper deck, Parts around steam pipes.
	Bulwark platings and bulwark stays	Lower parts attached to upper deck, End parts connected to superstructures and deckhouses, Platings around freeing ports.
	Winch foundation	Special attention is to be given to steam winch foundations
	Steel hatch covers	Steel pontoon covers (including cleats, etc.)
Shells	Wind and water strakes	Special attention is to be given to fore and after part outside of 0.5 L amidships.
	Shell platings connected to end brackets	After removal of limber boards and cement chocks, Close-up Survey is required.
	Shells attached to hold frames	Special attention is to be given to groovings on shells.
	Shells around chain lockers	-
	Hard spotted shells	Special attention is to be given to shells (parts or positions) in ballast tanks
Internal members	Special attention is to be given to areas with high humidity, standing bilges and poorly ventilated spaces in addition to the following :	
	Joint parts between hold frames and frame brackets	After removal of limber board, those parts are to be examined (problem areas in aged ships)
	Intersections between transverse W/T Bulkhead and inner bottom	After removal of bottom ceilings, those parts are to be examined.
	Tank top platings of double bottom tanks and of deep tanks used as ballast tanks	-
	Fillet weld parts between hold frames and side shells	Special attention is to be paid to hold frames in intermittent welds.
	Bilge wells	Special attention si to be given to bilge wells in E/R and bilge wells with piping arrangements.
	Inner bottom platings under pillars	-
	Internal members around sea water pumps in E/R	-
	Sea chest boundaries in E/R	-
	Joint parts between shaft tunnel and inner bottom	Close-up Survey is required for aged ships
	Intersections between tweendeck frames or tweendeck bulkheads and lower deck	-
	Lower parts of collision BHD and bottom of chain lockers	-
	Intersections between panting/side stringers and frames, and end parts, slot areas in way of panting/side stringers	-

Table 2 Suspect areas on which attention is to be paid (continued)

Location	Measuring Points	
Inside of tanks	Special attention is to be paid to the combined tanks (ballast and fuel oil), prone to rapid wastage, in addition to the following:	
	All of ballast tanks in front of E/R boundaries	Close-up Survey is required for tank top, bottom and boundary platings of the tanks not forming their boundaries by full envelope (both shells and decks). And special attention is to be paid to connections between frames and brackets, and on docking brackets, lightening holes
	Double bottom ballast tanks, side ballast tanks, and shaft tunnels	Special attention is to be paid to inner bottom platings meeting bulkheads, edge platings reaching to tank side brackets, and on lightening holes/slots in way of girders and on bottom shells around striking pads below sounding pipes.
	Bulkheads facing a heated zone	Special attention is to be paid to bulkheads facing E/R space, or fuel oil tanks being heated.
	Bottom platings below sounding pipes	Special attention is to be paid to bilge tanks in E/R
	Chain lockers in fore peak tanks	Special attention is to be paid to bottom platings and side boundaries of chain lockers.

Table 3 Location and number of thickness measuring points

Items	Location and number of thickness measuring points
Transverse Section	1. For oil tankers, chemical tankers or double hull oil tankers subject to the enhanced survey programme (See **Fig 1** and **Fig 2**) (1) At each transverse section, every plate within 0.1D(where D is the ship's moulded depth) of the deck and bottom is to be measured at one point between longitudinals, and all the other plate is to be measured at least one point per strake. (2) Where the thickness measurements for a transverse section are to include all longitudinal members, every longitudinal is to be measured at one point on the web and face plate. 2. For single skin bulk carriers, double skin bulk carriers or general dry cargo ships (See **Fig 3** and **Fig 4**) (1) At each transverse section, every plate of the deck and inner bottom is to be measured at one point between longitudinals, and all the other plate is to be measured at least one point per strake. (2) Where the thickness measurements for a transverse section are to include all longitudinal members, every longitudinal is to be measured at one point on the web and face plate. 3. For general ships other than **1** and **2** above (See **Fig 5**) (1) At each transverse section, every plate is to be measured at least two points per strake. (2) Where the thickness measurements for a transverse section are to include all longitudinal members, every longitudinal is to be measured at one point on the web and face plate.
Transverse Section of deck, side shell and bottom plating	At least two points on each plate(either at each 1/4 extremity of plate or at representative areas of average corrosion) are to be measured in the transverse section concerned.
Selected plates: Selected plates on deck(including deck inside line of hatch openings), tank top, bottom, inner bottom plates, etc. and wind-and-water strakes	At least two points are to be measured at representative areas of average corrosion. Where the length of the plate exceeds 6 m, two points per 6 m are to be gauged additionally. Where plates cross ballast/cargo tank boundaries separate measurements for the area of plating in way of each type of tank are to be taken. In case of side shell plating, one or two wind and water strakes are to be gauged according to No. of Special Survey. The gauging location of each plate may be selected by the attending Surveyor in consideration of the corrosion pattern.
All plates: All deck(including deck inside line of hatch openings), tank top, bottom, inner bottom plates, etc. and wind-and-water strakes	At least two points on each plate(either at each 1/4 extremity of plate or at representative areas of average corrosion) are to be measured. Where the length of the plate exceeds 6 m, two points per 6 m are to be gauged additionally. Where plates cross ballast/cargo tank boundaries separate measurements for the area of plating in way of each type of tank are to be taken.
Selected internal structures: Selected internal structure such as floors and longitudinals, transverse frames, web frames, deck beams, girders	The internal structural members to be measured in each space internally surveyed are to be 1. at least 10% outside the cargo (length) area, 2. at least 20% within the cargo (length) area. (For oil tankers, chemical tankers or double hull oil tankers subject to the enhanced survey programme see **Fig 1** and **Fig 2**, for single skin or double skin bulk carriers see **Fig 6**, for other ships see **Fig 7**)

Table 3 Location and number of thickness measuring points

Items	Location and number of thickness measuring points
Selected side shell frames in cargo holds for single skin bulk carriers or general dry cargo ships	1. 25% of frames: one out of four frames is to be chosen preferably throughout the cargo hold length on each side. 2. "Selected frames" means at least 3 frames on each side of cargo holds. (For single skin bulk carriers see **Fig 6**, for general dry cargo ships see **Fig 7**)
Transverse webs in ballast tanks for single skin bulk carriers, double skin bulk carriers or general dry cargo ships	One of the representative tanks of each type (i.e. topside or hopper or side tank) is to be chosen in the forward part. (For single skin or double skin bulk carriers see **Fig 6**, for general dry cargo ships see **Fig 7**)
Transverse frames in double skin tanks for double skin bulk carriers	25% of transverse frames: one out of four transverse frames is to be chosen preferably throughout the double skin tank length. (See **Fig 8**)
Transverse bulkheads	1. For oil tankers, chemical tankers or double hull oil tankers subject to the enhanced survey programme: See **Fig 1** and **Fig 2** 2. For single skin bulk carriers, double skin bulk carriers or general dry cargo ships (See **Fig 9** to **Fig 11**) (1) Transverse bulkheads in cargo holds - Includes bulkheads plating, stiffeners and girders, including internal structure of upper and lower stools, where fitted. - Two selected bulkheads : one is to be the bulkhead between the two foremost cargo holds and the second may be chosen in other positions (2) One transverse bulkhead in each cargo hold - The Close-up Survey and related thickness measurements are to be carried out on one side of the bulkhead; the side is to be chosen based on the outcome of the Overall Survey of both sides. In the event of doubt, the Surveyor may also require (possibly partial) Close-up Survey on the other side. (3) Transverse bulkheads in one ballast tank - The ballast tank is to be chosen based on the history of ballasting among those prone to have the most severe conditions.
Cargo hold hatch covers and coamings	See **Fig 12**

(NOTES)
1. (dotted oval) mark : means the location to be measured.
2. X mark : means the point to be measured.

Table 3 Location and number of thickness measuring points (continued)

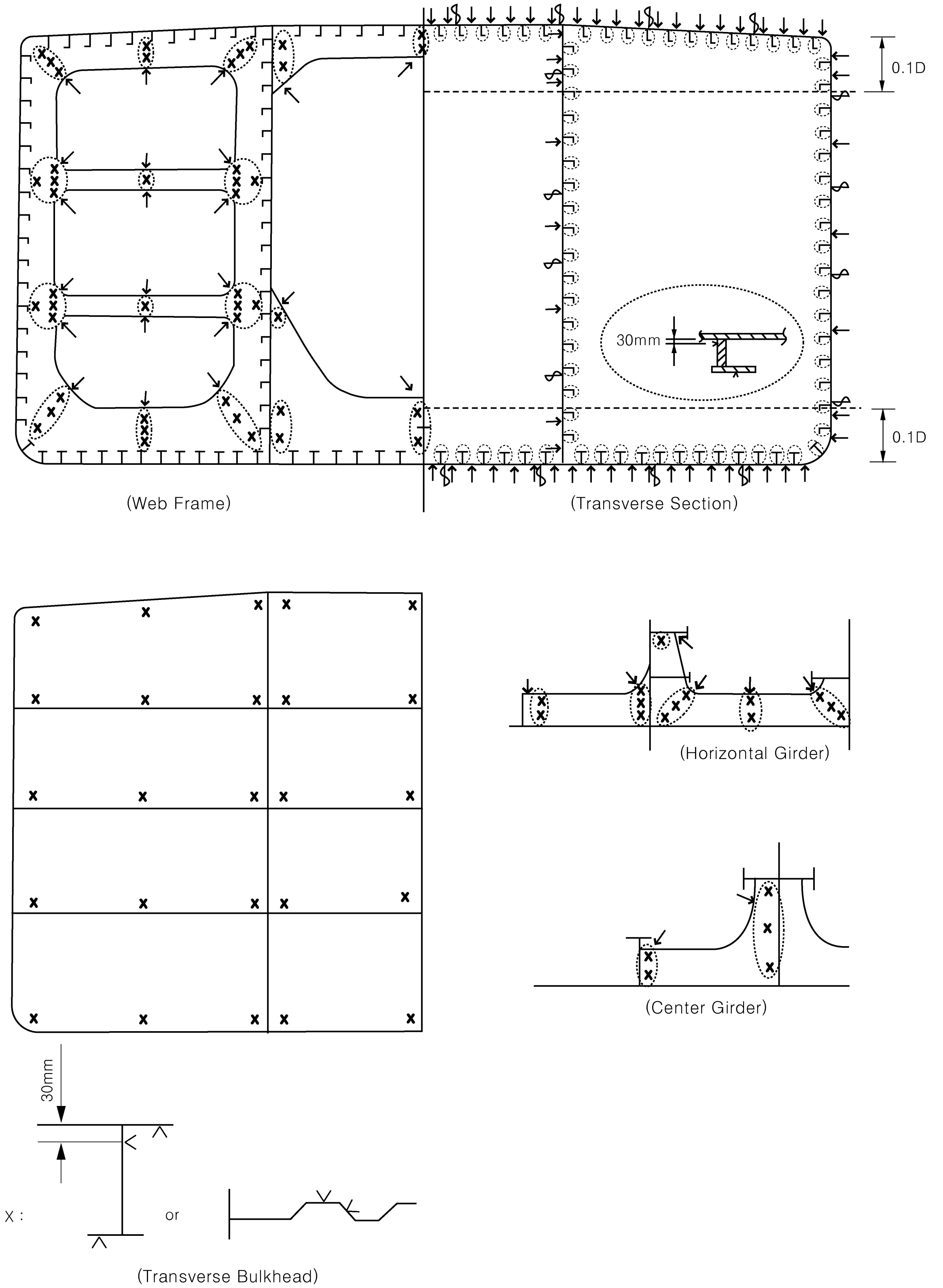


Fig 1 Locations of measurements of oil tankers and chemical tankers

Table 3 Location and number of thickness measuring points (continued)

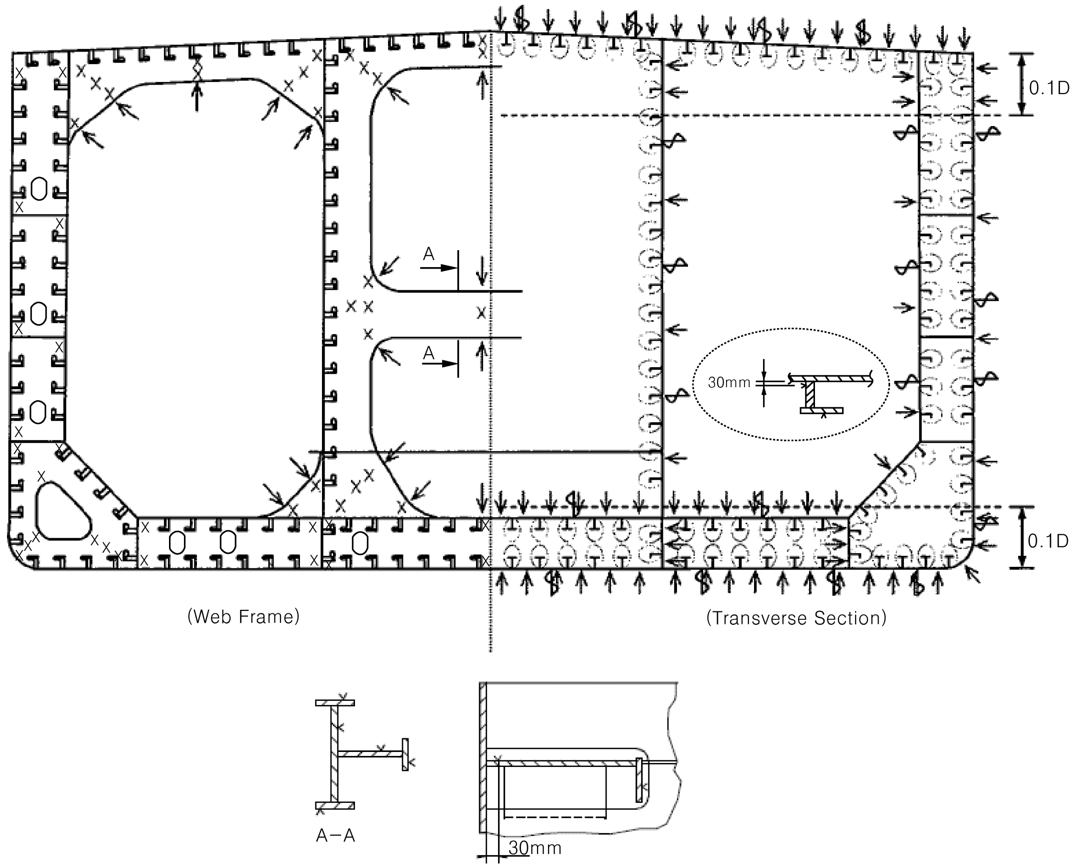


Fig 2 Locations of measurements of double hull oil tankers

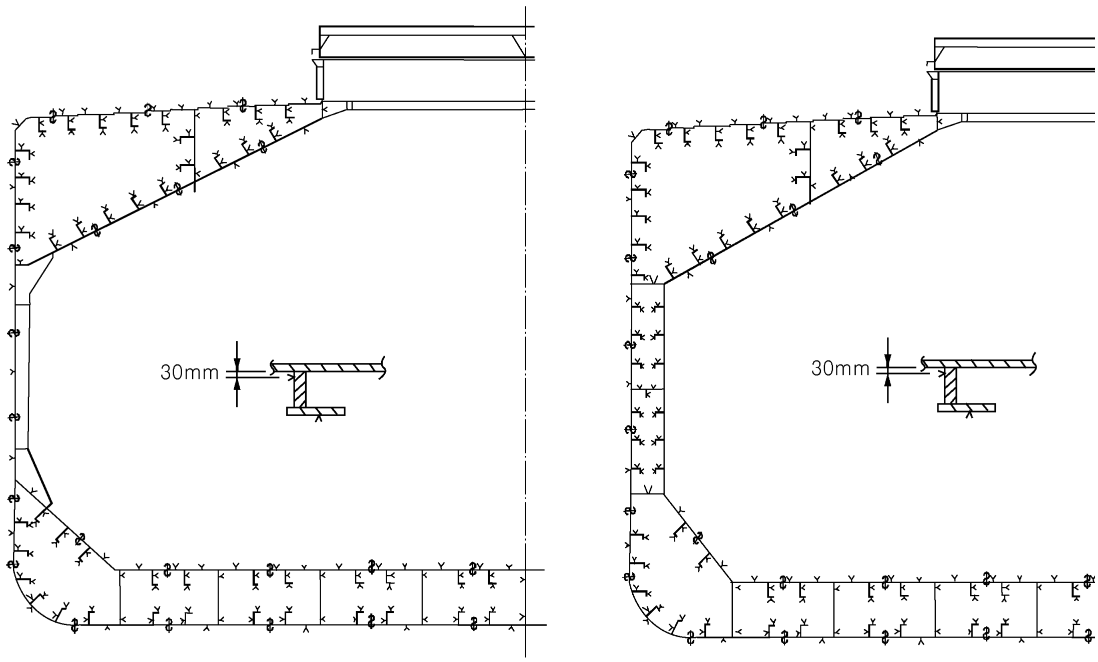


Fig 3 Locations of measurements on transverse section of single skin or double skin bulk carriers

Table 3 Location and number of thickness measuring points (continued)

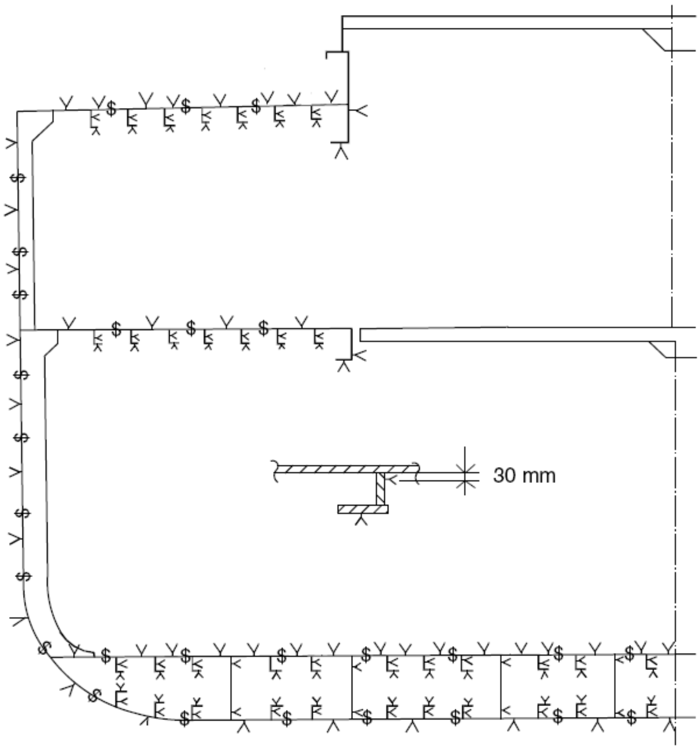
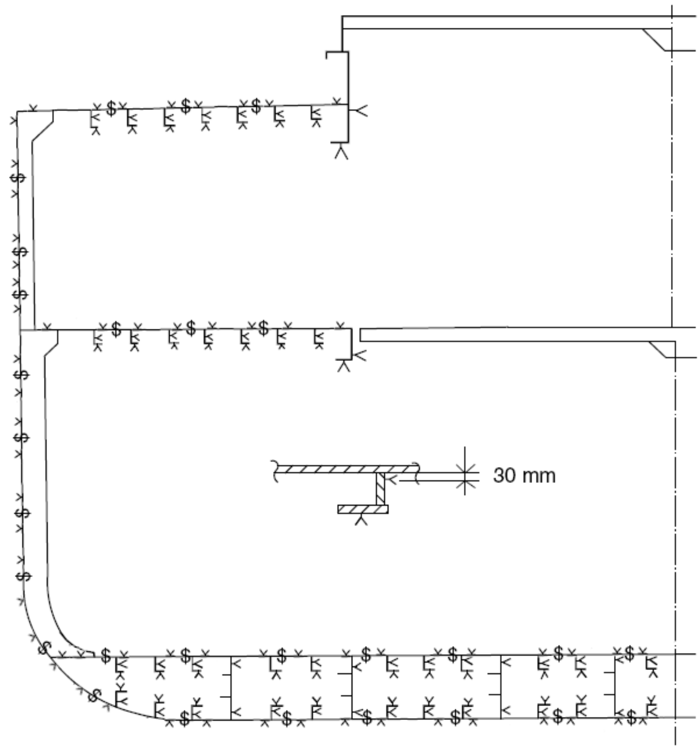


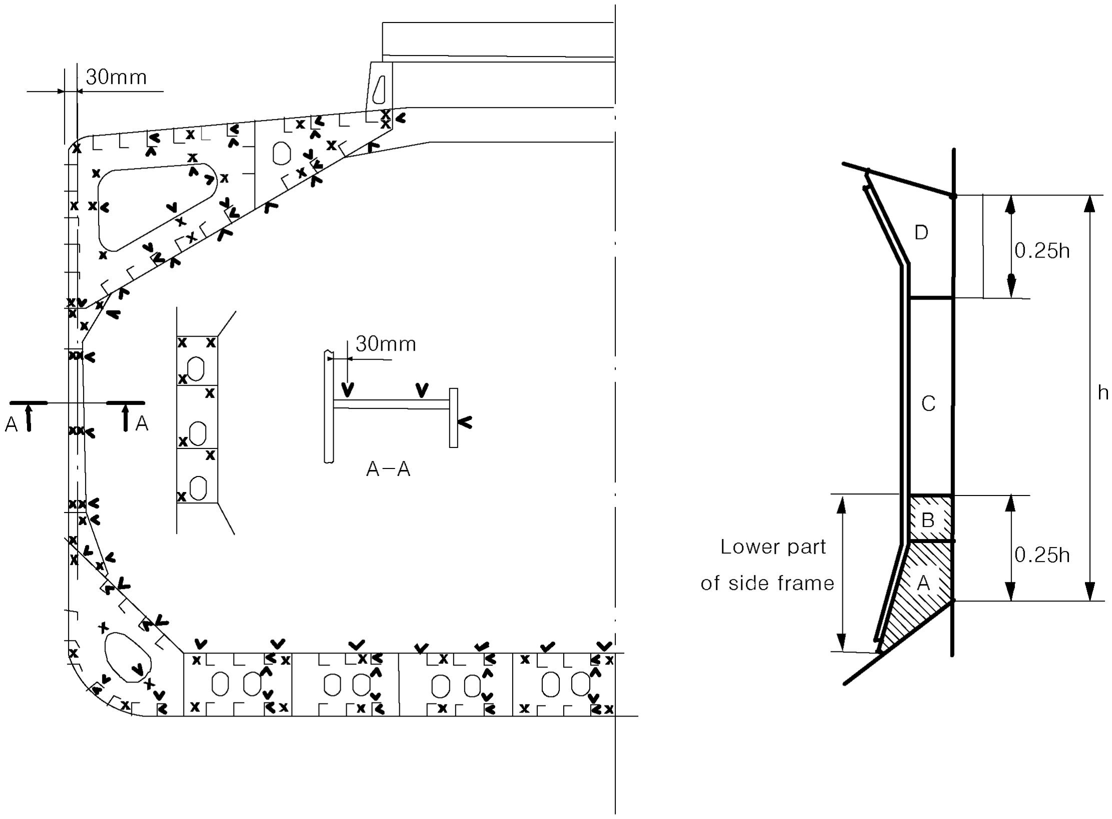
Fig 4 Locations of measurements on transverse section of general dry cargo ships



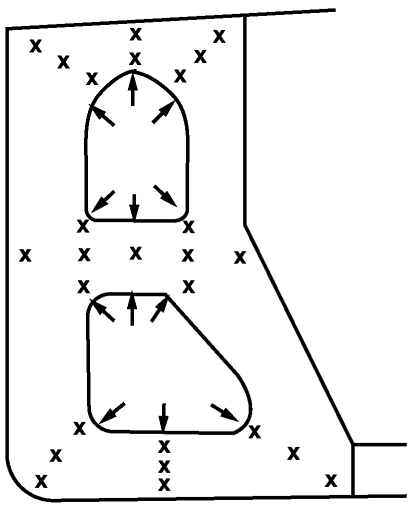
(Notes) It may also apply to other type of transverse section.

Fig 5 Locations of measurements on transverse section of general ships

Table 3 Location and number of thickness measuring points (continued)



(Bulk Carriers)

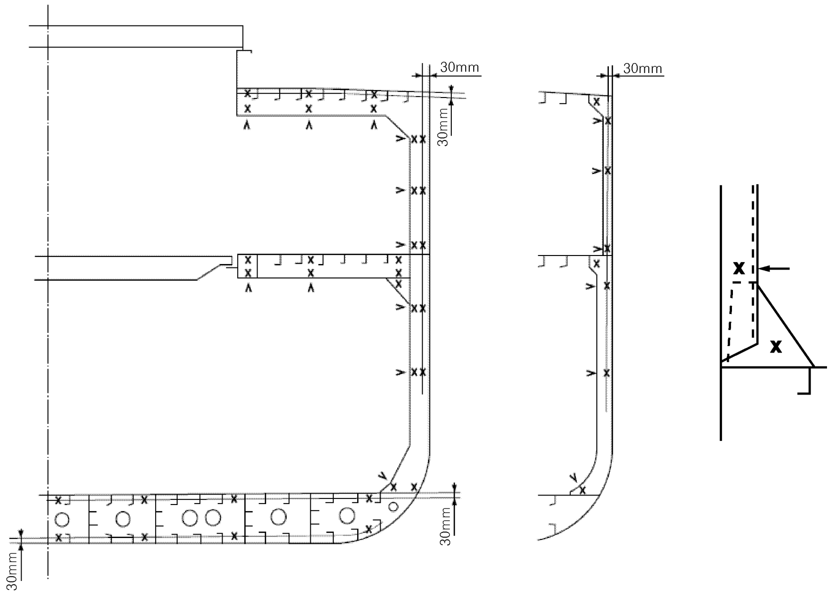


(Ore Carriers)

(Notes) The gauging pattern for web plating is to be a three point pattern for zones A, C and D, and a two point pattern for zone B. The gauging report is to reflect the average reading. The average reading is to be compared with the allowable thickness. If the web plating has general corrosion the this pattern is to be expanded to a five point pattern.

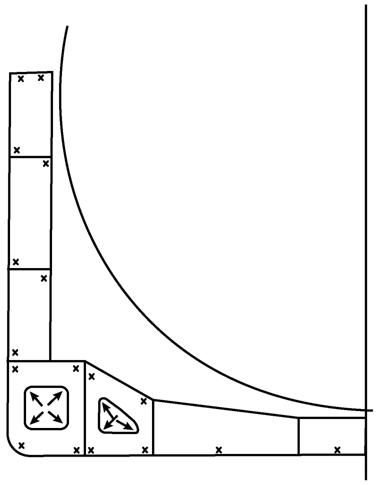
Fig 6 Locations of measurements on structural members in cargo holds and ballast tanks of single skin or double skin bulk carriers

Table 3 Location and number of thickness measuring points (continued)



(General Dry Cargo Ships)

(Notes) It may also apply to other ship types.



(Liquified Gas Carriers)

Fig 7 Locations of measurements on selected internal structural members

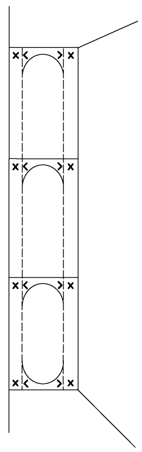


Fig 8 Locations of measurements on transverse frame in double skin tank of double skin bulk carriers

Table 3 Location and number of thickness measuring points (continued)

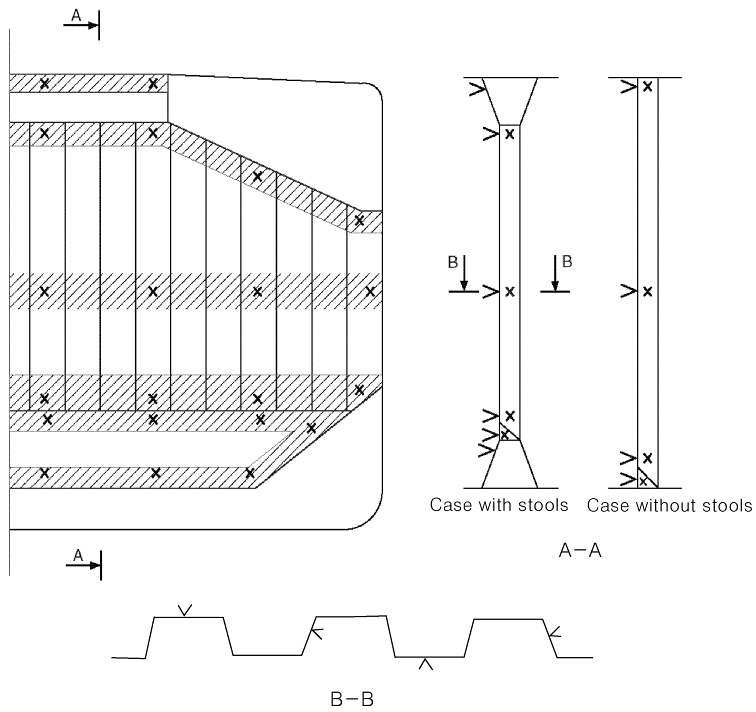
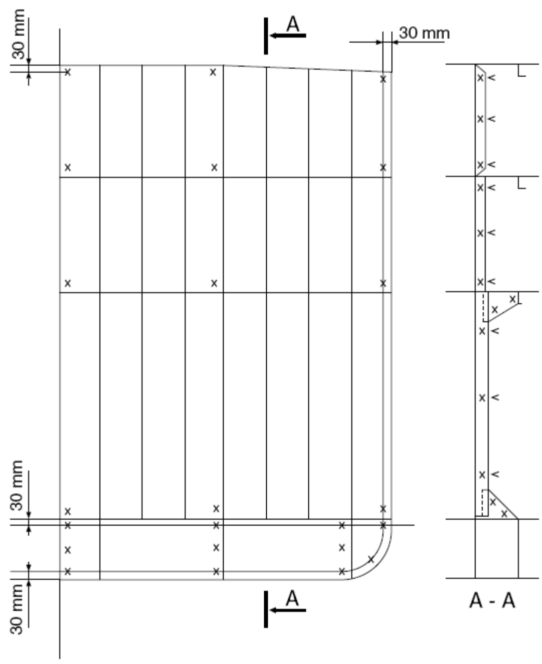


Fig 9 Locations of measurements on cargo hold transverse bulkheads of single skin or double skin bulk carriers

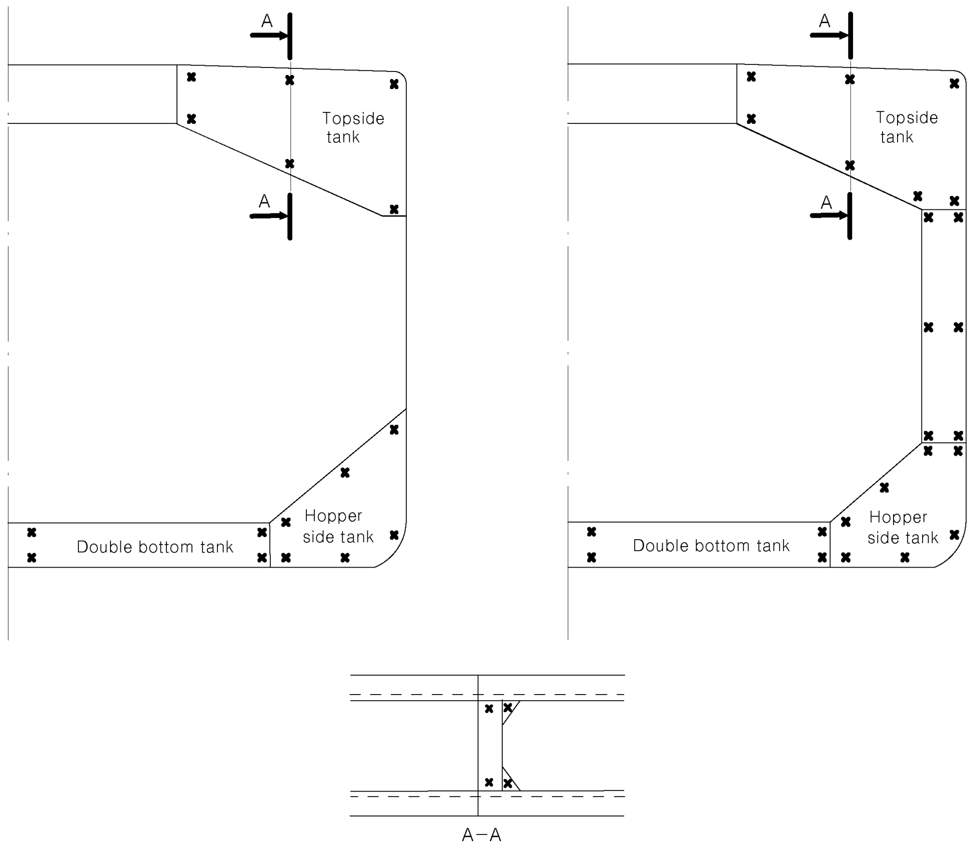


(Notes)

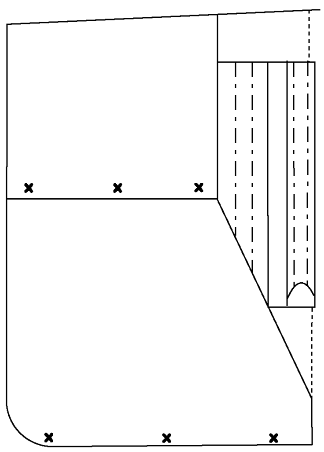
1. Cargo hold bulkhead/watertight floor plating to be measured as per main view.
2. One stiffener out of three to be measured as per view A-A.
3. It may also apply to other ship types.

Fig 10 Locations of measurements on transverse bulkheads of general dry cargo ships

Table 3 Location and number of thickness measuring points (continued)



(Bulk Carriers)

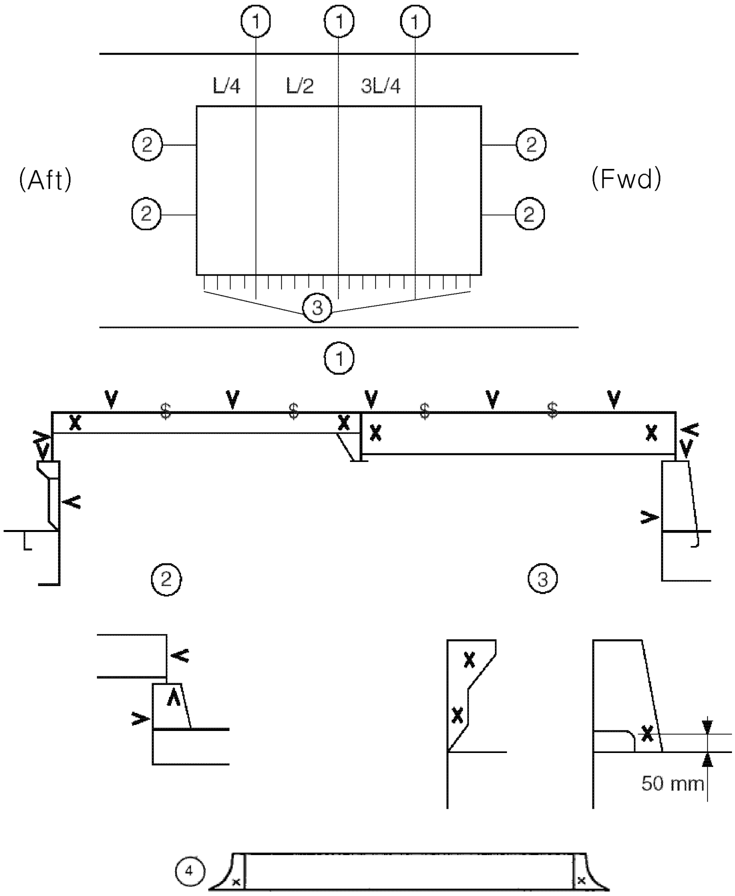


(Ore Carriers)

(Notes) Measurements to be taken in each vertical section as per view A-A.

Fig 11 Locations of measurements on transverse bulkheads in topside, hopper, double hull and double bottom ballast tanks of single skin or double skin bulk carriers

Table 3 Location and number of thickness measuring points (continued)



(Notes)
① For each hatch covers, three sections at L/4, L/2 and 3L/4 of hatch cover length, including:
- one measurement of each hatch cover plate and skirt plate
- measurements of adjacent beams or girder(including stiffeners)
- one measurement of coaming plates and coaming flange, each side

② For each hatch covers, one measurement of hatch cover skirt plate, coaming plate and coaming flange on both ends
③ One measurement of one out of three hatch coaming brackets and bars, on both sides and both ends
④ One measurement of each hatch coaming end bracket

Fig 12 Locations of measurements on hatch covers and coamings

Table 4 Extent of thickness measurements at Special Survey – General Ships

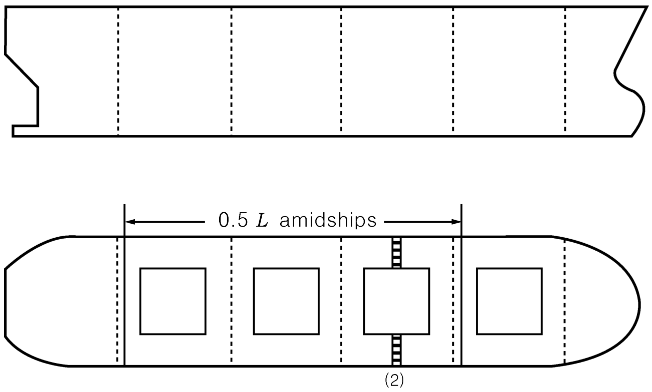
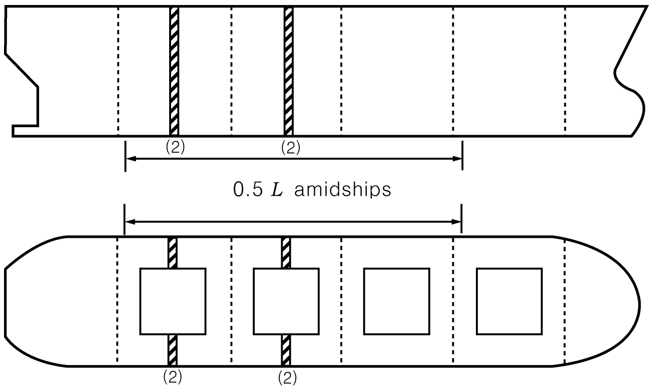
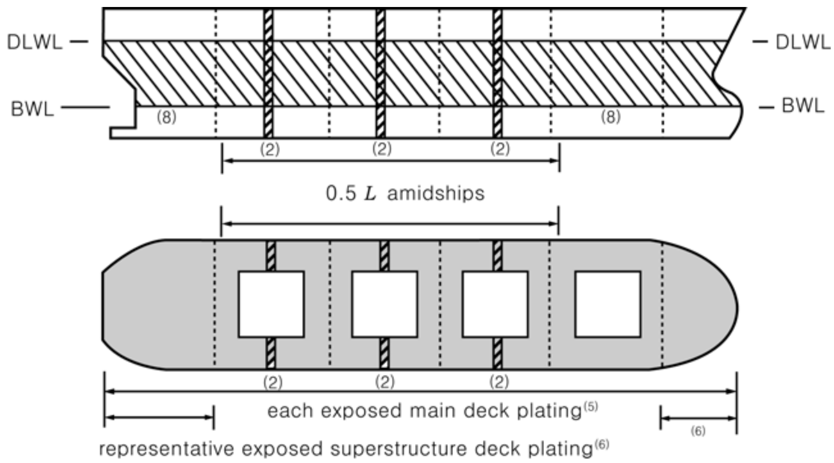
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	(1) Suspect areas throughout the vessel
Special Survey No. 2	 (1) Suspect areas throughout the vessel (2) One transverse section of deck plating in way of a cargo space within the amidships 0.5 L
Special Survey No. 3	 (1) Suspect areas throughout the vessel (2) Two transverse sections within the amidships 0.5 L in way of two different cargo spaces[4), 5), 6), 7)] (3) All cargo hold hatch covers and coamings(plating and stiffeners) (4) Internals in forepeak and afterpeak tanks (5) All transverse bulkheads in all cargo tanks[8)] (6) All transverse bulkheads in all ballast tanks[8)]

Table 4 Extent of thickness measurements at Special Survey - General Ships (Continued)

No. of Special Survey	Extent and location of measurement
Special Survey No. 4 and Subsequent	 (1) Suspect areas throughout the vessel (2) A minimum of three transverse sections in way of cargo spaces within the amidships 0.5 L 5), 6), 7) (3) All cargo hold hatch covers and coamings(plating and stiffeners) (4) Internals in forepeak and afterpeak tanks (5) All exposed main deck plating full length (6) Representative exposed superstructure deck plating(poop, bridge and forecastle deck) (7) Lowest strake and strakes in way of 'tween decks of all transverse bulkheads in cargo spaces together with internals in way (8) All wind and water strakes, port and starboard, full length (9) All keel plates full length. Also, additional bottom plates in way of cofferdams, machinery space and aft end of tanks (10) Plating of seachests. Shell plating in way of overboard discharges as considered necessary by the attending Surveyor (11) All transverse bulkheads and one web frame ring in all cargo tanks 8) (12) All transverse bulkheads and all web frame ring in all ballast tanks 8)

(NOTES)

- : Thickness gaugings for deck plates
- : Thickness gaugings for side shell plates
- : Thickness gaugings for the transverse section(applied for plates only)
- : Thickness gaugings for the transverse section(including longitudinal members)

1) In application to this table, General Ships means ships except Other Ships in **Table 1.2.4, 2.** of the Rules.
2) Thickness measurement locations are to be selected to provide the best representative sampling of areas likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.
3) Thickness measurements of internals may be specially considered by the Surveyor if the hard protective coating is in GOOD condition.
4) For ships more than 100 meters in length, at Special Survey No. 3, thickness measurements of exposed deck plating within amidship 0.5L may be required.
5) For ships less than 100 meters in length, the number of transverse sections required at Special Survey No. 3 may be reduced to one (1), and the number of transverse sections required at Special Survey No. 4 and subsequent may be reduced to two (2).
6) For the pure car carrier, the extent of thickness measurement for transverse sections may by considered as follow: Exposed deck plates, side shell plates, bottom shell plates, inner bottom plates and longitudinal members in double bottom spaces.
7) Where the evaluation of longitudinal strength is required, all longitudinal structural members at the corresponding sections are to be gauged.
8) This requirement is to be applied only for tankers(including barges) for liquid cargo.

Table 5 Extent of thickness measurements at Special Survey - Other Ships

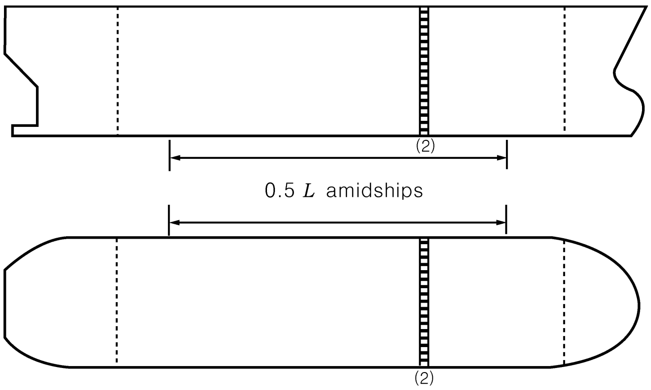
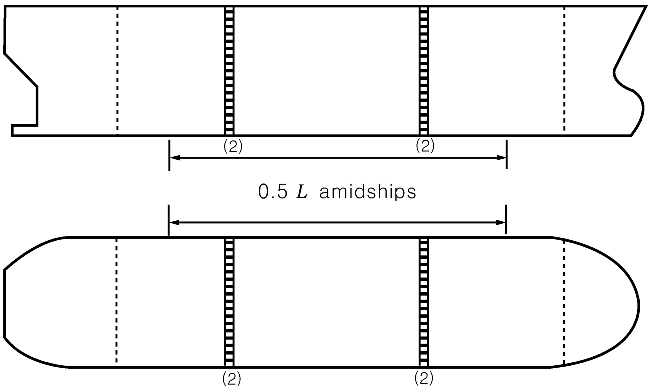
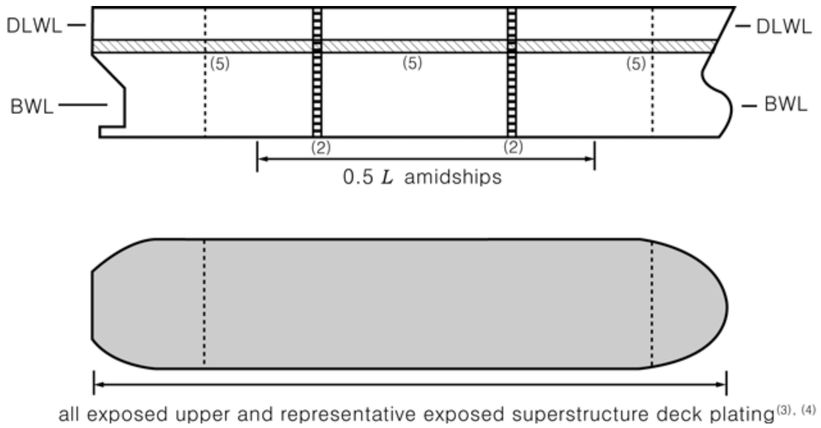
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	(1) Suspect areas throughout the vessel
Special Survey No. 2	 (1) Suspect areas throughout the vessel (2) One transverse section of deck plating[5)], side shell plating and bottom plating within the amidships 0.5 L
Special Survey No. 3	 (1) Suspect areas throughout the vessel (2) Two transverse sections of deck plating[5)], side shell plating and bottom plating within the amidships 0.5 L (3) Internals in forepeak and afterpeak tanks

Table 5 Extent of thickness measurements at Special Survey - Other Ships (Continued)

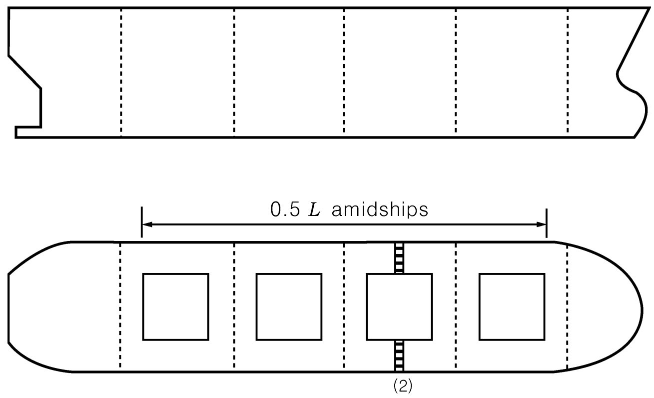
No. of Special Survey	Extent and location of measurement
Special Survey No. 4 and Subsequent	 (1) Suspect areas throughout the vessel (2) Two transverse sections of side shell plating within the amidships 0.5 L (3) Full length, all exposed main deck plating[5)] (4) Full length, representative exposed superstructure deck plating(poop, bridge and forecastle deck) (5) Full length, selected wind and water strakes (6) Full length, bottom plating and flat keel plating (7) Internals in forepeak and afterpeak tanks

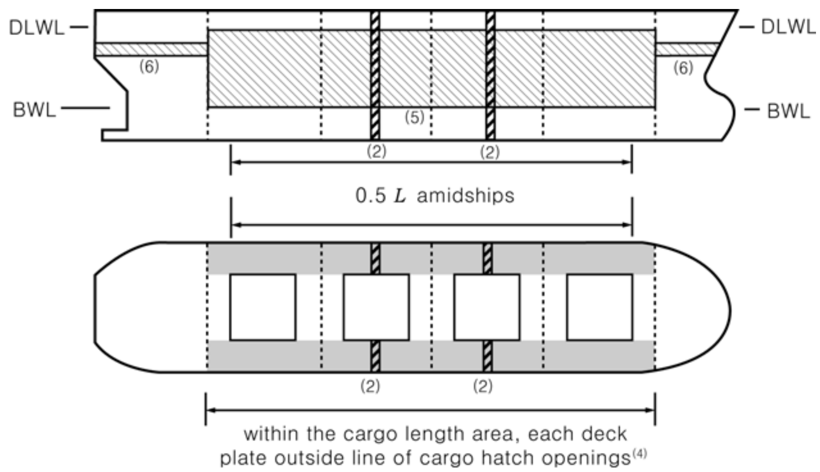
(NOTES)

: Thickness gaugings for deck plates
: Thickness gaugings for side shell plates
: Thickness gaugings for the transverse section(applied for plates only)

1) In application to this table, Other Ships means the ship specified as follows except Special Purpose Ship - Waste in **Annex 1-1, 1.1** of the Guidance.
   - the ship type **12, 13**
   - the ship less than 500 GT and not engaged on international voyages among ship type **15, 16, 17** and **19** to **29**.
2) Thickness measurement locations are to be selected to provide the best representative sampling of area likely to be most exposed to corrosion.
3) Thickness measurements of internals may be specially considered by the Surveyor if the hard protective coating is in GOOD condition.
4) When the evaluation of longitudinal strength is required, all longitudinal structural members at the corresponding sections are to be gauged.
5) For fishing vessel, thickness measurement requirements in way of deck(gutter water way part and hatch coaming part) may be modified at the discretion of the Surveyor if the structure remains effectively protected against corrosion by a permanent type special coating.

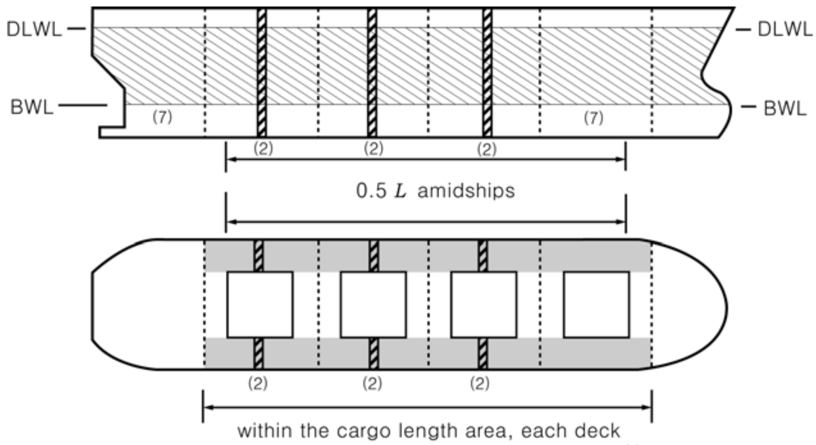
Table 6 Extent of thickness measurements at Special Survey - General Dry Cargo Ships

<table>
<tr><th>No. of
Special Survey</th><th>Extent and location of measurement</th></tr>
<tr><td>Special Survey
No. 1</td><td>(1) Suspect areas</td></tr>
<tr><td>Special Survey
No. 2</td><td>


(1) Suspect areas
(2) One transverse section of deck plating in way of a cargo length area within the amidships 0.5 L
(3) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey</td></tr>
<tr><td>Special Survey
No. 3</td><td>


(1) Suspect areas
(2) Two transverse sections within the amidships 0.5 L in way of two different cargo space
(3) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey
(4) Within the cargo length area, each deck plate outside line of cargo hatch openings
(5) All wind and water strakes within the cargo length area
(6) Selected wind and water strakes outside the cargo length area</td></tr>
</table>

Table 6 Extent of thickness measurements at Special Survey - General Dry Cargo Ships (Continued)

<table>
<tr><th>No. of
Special Survey</th><th>Extent and location of measurement</th></tr>
<tr><td>Special Survey
No. 4
and Subsequent</td><td>

(1) Suspect areas
(2) Within the cargo length area, a minimum of three transverse sections within the amidships 0.5L
(3) Within the cargo length area, each deck plate outside line of cargo hatch openings
(4) Within the cargo length area, each bottom plate, including lower turn of bilge
(5) Within the cargo length area, duct keel or pipe tunnel plating and internals
(6) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey
(7) All wind and water strakes full length</td></tr>
<tr><td colspan="2">(NOTES)
: Thickness gaugings for deck plates
: Thickness gaugings for side shell plates
: Thickness gaugings for the transverse section(applied for plates only)
: Thickness gaugings for the transverse section(including longitudinal members)

1) Thickness measurement locations are to be selected to provide the best representative sampling of area likely to be most exposed to corrosion, considering cargo and ballast history and arrangement and condition of protective coatings.
2) For ships less than 100 meters in length, the number of transverse sections required at Special Survey No. 3 may be reduced to one and the number of transverse sections at Special Survey No. 4 and subsequent surveys may be reduced to two.</td></tr>
</table>

Table 7 Extent of thickness measurements at Special Survey - Liquefied Gas Carriers

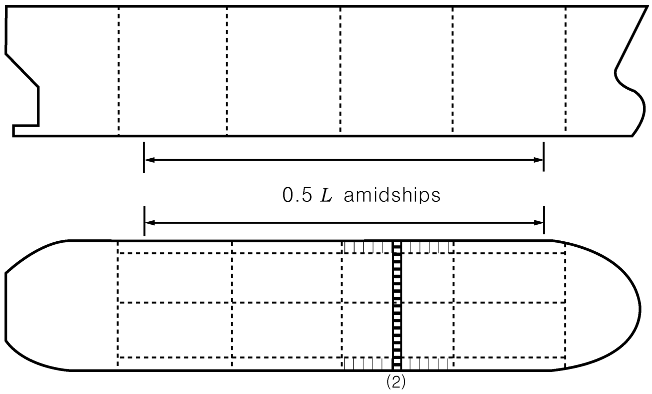
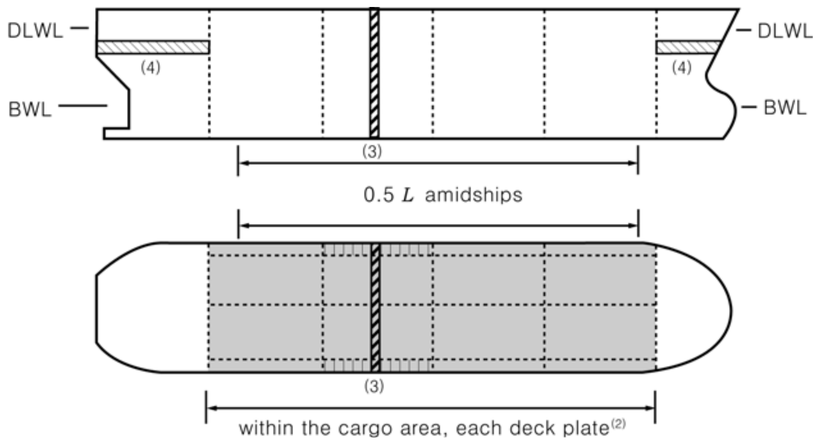
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	 (1) Suspect areas (2) One section of deck plating for the full beam of the ship within 0.5 L amidships in way of a ballast tank, if any (3) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey
Special Survey No. 2	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, one transverse section within 0.5 L amidships in way of a ballast tank, if any (4) Selected wind and water strakes outside the cargo area (5) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey

Table 7 Extent of thickness measurements at Special Survey - Liquefied Gas Carriers (continued)

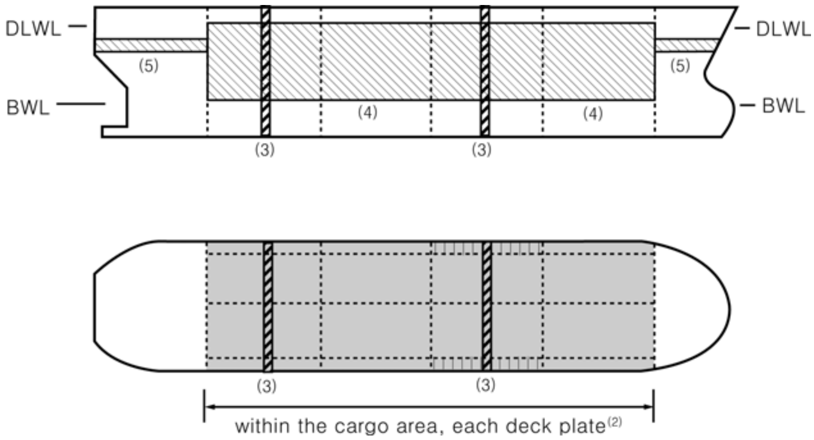
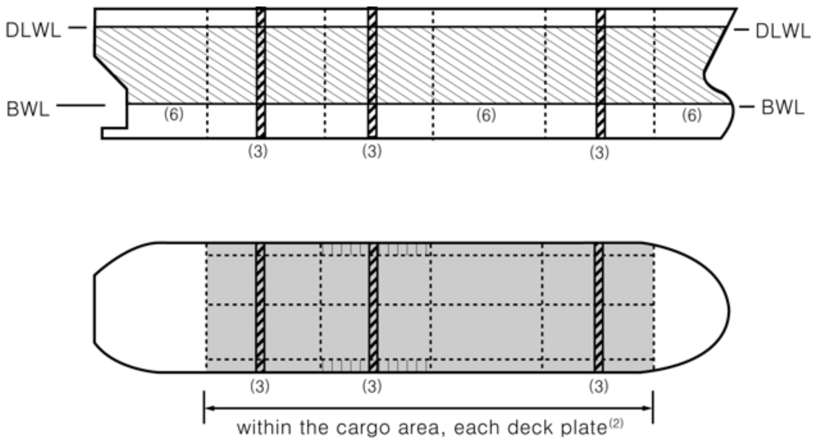
No. of Special Survey	Extent and location of measurement
Special Survey No. 3	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, two transverse sections[1)] (4) Within the cargo area, all wind and water strakes (5) Selected wind and water strakes outside the cargo area (6) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey
Special Survey No. 4 and Subsequent	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, three transverse sections[1)] (4) Within the cargo area, each bottom plate (5) Within the cargo area, duct keel plating and internals (6) All wind and water strakes, full length (7) Measurement for general assessment and recording of corrosion pattern of those structural members subject to Close-up Survey

Table 7 Extent of thickness measurements at Special Survey - Liquefied Gas Carriers (continued)

(NOTES)

: Thickness gaugings for deck plates
: Thickness gaugings for side shell plates
: Thickness gaugings for the transverse section(applied for plates only)
: Thickness gaugings for the transverse section(including longitudinal members)

1) At least one section is to include a ballast tank within 0.5 L amidships, if any.
2) For ships having independent tanks of type C, with a midship section similar to that of a general cargo ship, the extent of thickness measurements may be increased to include the tank top plating at the discretion of the Surveyor.
3) For areas in spaces where protective coatings are found to be in GOOD condition, the extent of thickness measurements may be specially considered by the Society.
4) The Surveyor may extend the thickness measurements as deemed necessary. Where substantial corrosion is found, the extent of thickness measurements is to be increased to the satisfaction of the Surveyor.

Table 8 Extent of thickness measurements at Special Survey - Bulk Carriers with ESP notation

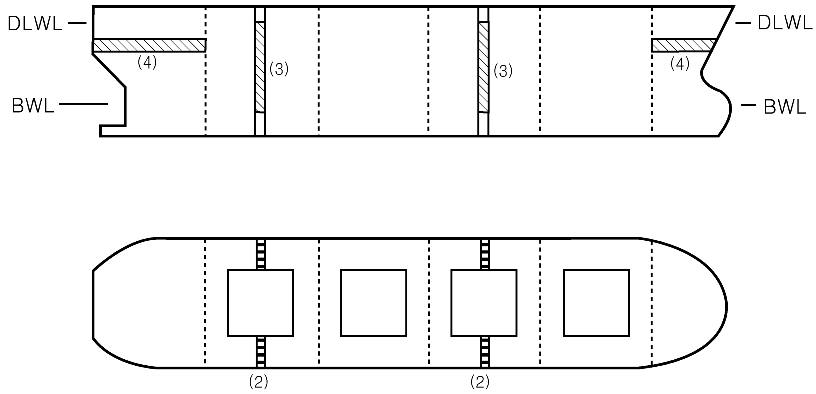
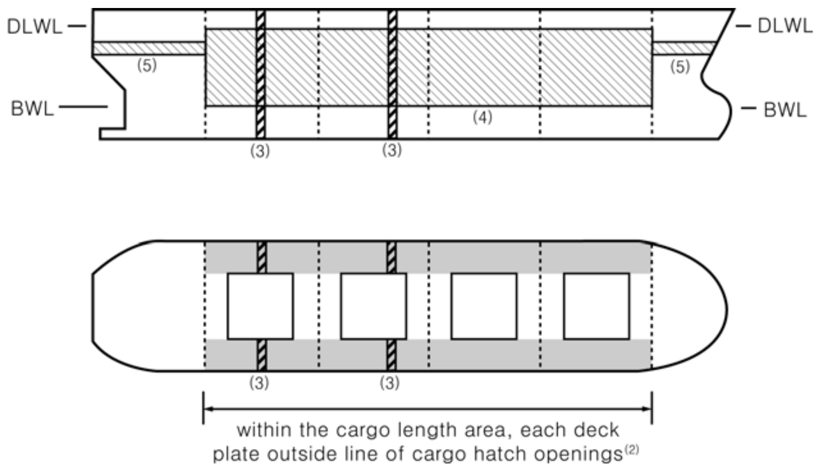
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	(1) Suspect areas
Special Survey No. 2	 (1) Suspect areas (2) Within the cargo length, two transverse sections of deck plating outside line of cargo hatch openings (3) Wind and water strakes in way of transverse sections considered under (2) above (4) Selected wind and water strakes outside the cargo length area (5) Measurement for, general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) See **Ch 3, 201. 1** (4) of the Rules, **Pt 7, Ch 3, Sec 17** of the Rules and the separate requirements specified by the Society for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31
Special Survey No. 3	 (1) Suspect areas (2) Within the cargo length, each deck plate outside line of cargo hatch openings (3) Within the cargo length, two transverse sections, one in the amidship area, outside line of cargo hatch openings (4) Within the cargo length, all wind and water strakes (5) Selected wind and water strakes outside the cargo length area (6) Measurement for, general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (7) See **Ch 3, 201. 1** (3) of the Rules and **Annex 1-5, Table 9** of the Guidance for additional thickness measurement guidelines applicable to the vertically corrugated transverse watertight bulkhead between cargo hold Nos. 1 and 2 on ships subject to compliance with IACS URs S19 and S23 (8) See **Ch 3, 201. 1** (4) of the Rules, **Pt 7, Ch 3, Sec 17** of the Rules and the separate requirements specified by the Society for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31

Table 8 Extent of thickness measurements at Special Survey - Bulk Carriers with ESP notation (continued)

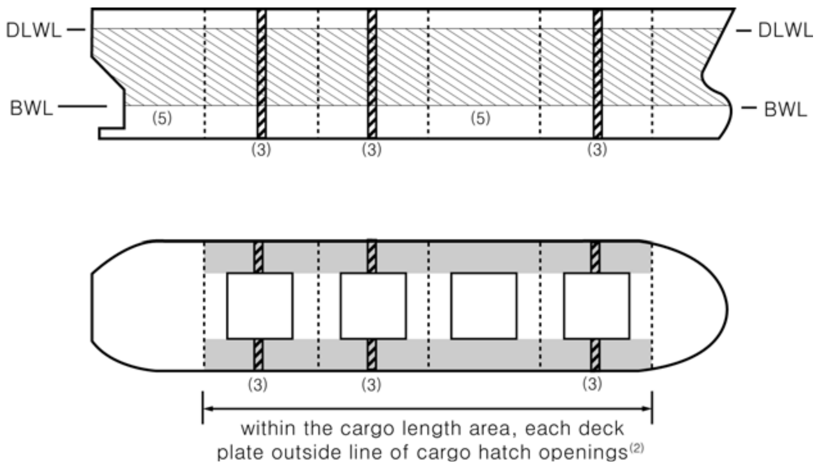
No. of Special Survey	Structural members to be measured
Special Survey No. 4 and Subsequent	 (1) Suspect areas (2) Within the cargo length, each deck plate outside line of cargo hatch openings (3) Within the cargo length, three transverse sections, one in the amid ship area, outside line of cargo hatch openings (4) Within the cargo length, each bottom plates (5) All wind and water strakes, full length (6) Measurement for, general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (7) See **Ch 3, 201. 1** (3) of the Rules and **Annex 1-5, Table 9** of the Guidance for additional thickness measurement guidelines applicable to the vertically corrugated transverse watertight bulkhead between cargo hold Nos. 1 and 2 on ships subject to compliance with IACS URs S19 and S23 (8) See **Ch 3, 201. 1** (4) of the Rules, **Pt 7, Ch 3, Sec 17** of the Rules and the separate requirements specified by the Society for additional thickness measurement guidelines applicable to the side shell frames and brackets on ships subject to compliance with IACS UR S31
(NOTES) : Thickness gaugings for deck plates : Thickness gaugings for side shell plates : Thickness gaugings for the transverse section(applied for plates only) : Thickness gaugings for the transverse section(including longitudinal members)	

Table 9 Additional thickness measurements of the vertically corrugated transverse watertight bulkhead between holds Nos. 1 and 2

Location	Vertically corrugated transverse watertight bulkhead between holds Nos. 1 and 2
Gauging point	1. The gauging is to be carried out at the levels as described below. To adequately assess the scantlings of each individual vertical corrugation, each corrugation flange, webs, shedder plate and gusset plate within each of the levels given below are to be gauged. (1) Level (A) : Ships without lower stool (See **Fig 1**) (a) The mid-breadth of the corrugation flanges at approximately 200 mm above the line of shedder plates; (b) The middle of gusset plates between corrugation flanges, where fitted; (c) The middle of the shedder plates; (d) The mid-breadth of the corrugation webs at approximately 200 mm above the line of shedder plates. (2) Level (B) : Ships with lower stool (See **Fig 2**) (a) The mid-breadth of the corrugation flanges at approximately 200 mm above the line of shedder plates; (b) The middle of gusset plates between corrugation flanges, where fitted; (c) The middle of the shedder plates; (d) The mid-breadth of the corrugation webs at approximately 200 mm above the line of shedder plates. (3) Level (C) : Ships with or without lower stool (See **Fig 1** or **Fig 2**) (a) The mid-breadth of the corrugation flanges and webs at about the mid-height of the corrugation. 2. Where the thickness changes within the horizontal levels, the thinner plate is to be gauged.

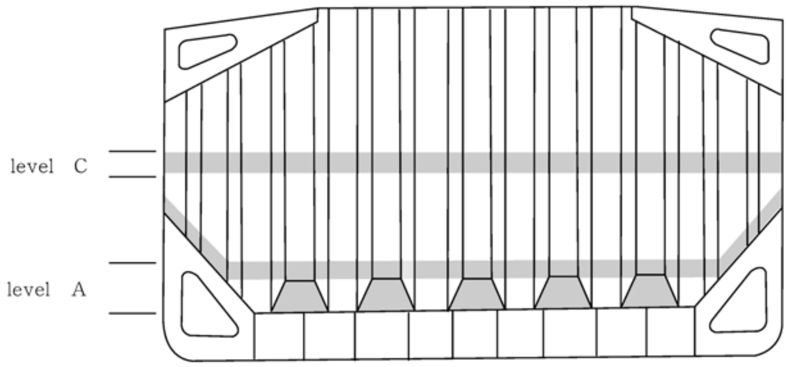


Fig 1 Ships without lower stool

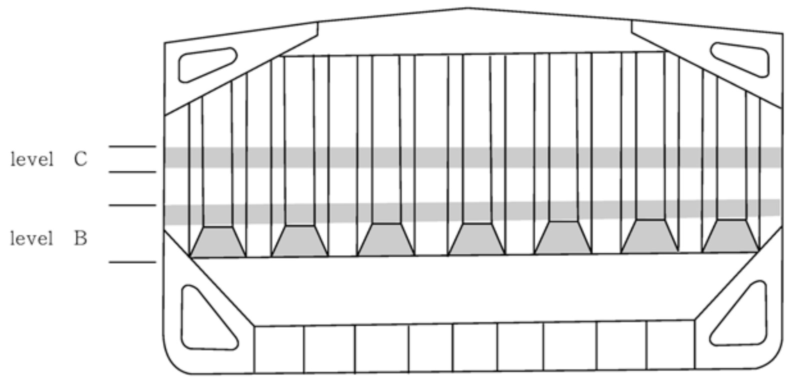


Fig 2 Ships with lower stool

Table 10 Extent of thickness measurements at Special Survey - Oil Tankers with ESP notation

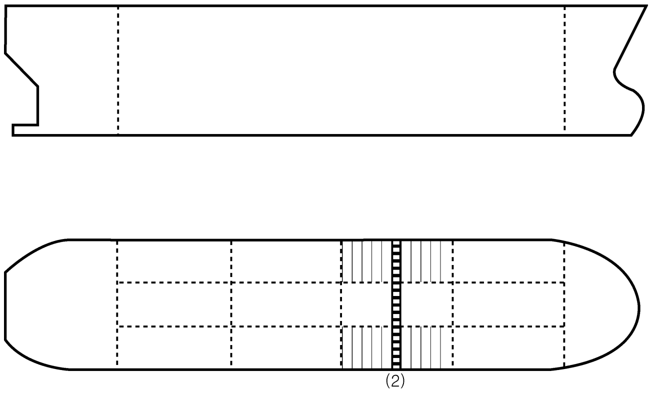
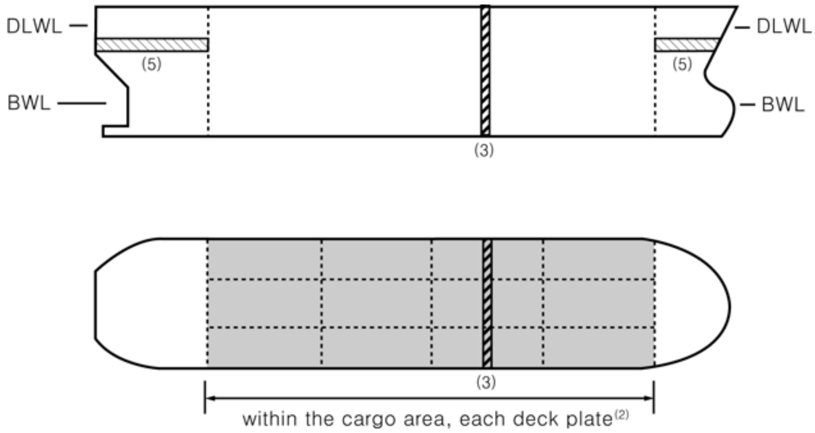
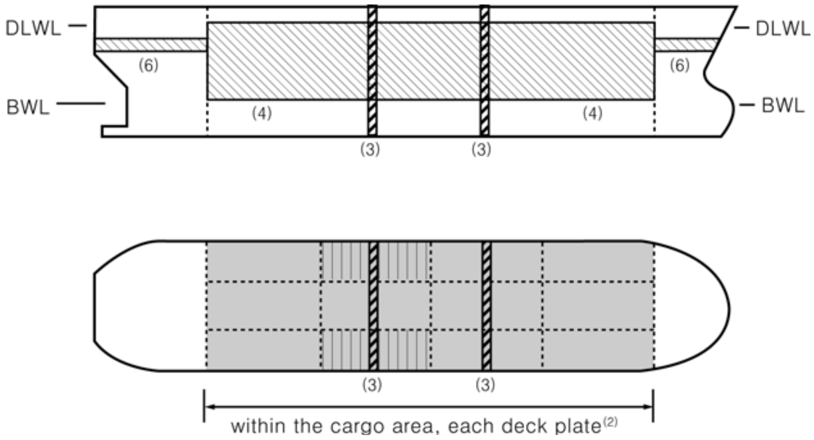
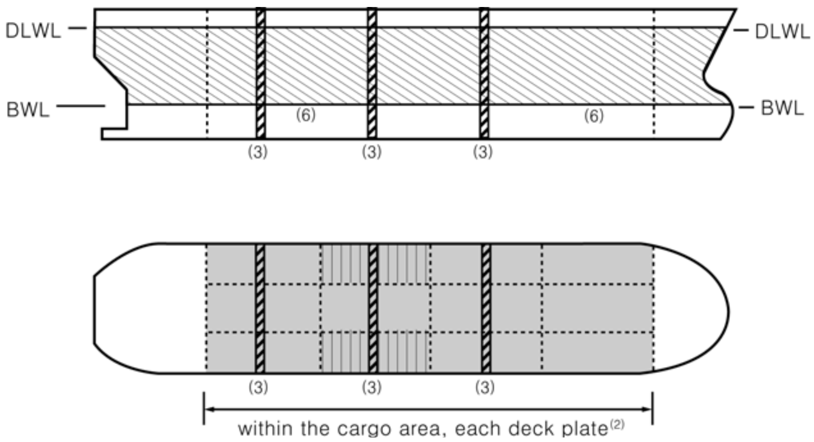
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	 (1) Suspect areas (2) One transverse section of deck plates for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast) (3) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey
Special Survey No. 2	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, one transverse section (4) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (5) Selected wind and water strakes outside the cargo area

Table 10 Extent of thickness measurements at Special Survey - Oil Tankers with ESP notation (Continued)

No. of Special Survey	Extent and location of measurement
Special Survey No. 3	 (1) Suspect area (2) Within the cargo area, each deck plate (3) Within the cargo area, two transverse sections[1)] (4) Within the cargo area, all wind and water strakes (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) Selected wind and water strakes outside the cargo area
Special Survey No. 4 and Subsequent	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, three transverse sections[1)] (4) Within the cargo area, each bottom plate (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) All wind and water strakes, full length

(NOTES)

- (grey box) : Thickness gaugings for deck plates
- (diagonal hatching) : Thickness gaugings for side shell plates
- (horizontal lines) : Thickness gaugings for the transverse section(applied for plates only)
- (heavy diagonal hatching) : Thickness gaugings for the transverse section(including longitudinal members)
- (vertical lines) : Thickness gaugings in way of the ballast tank

1) At least one section is to include a ballast tank within 0.5 L amidships.

Table 11 Extent of thickness measurements at Special Survey - Chemical Tankers with ESP notation

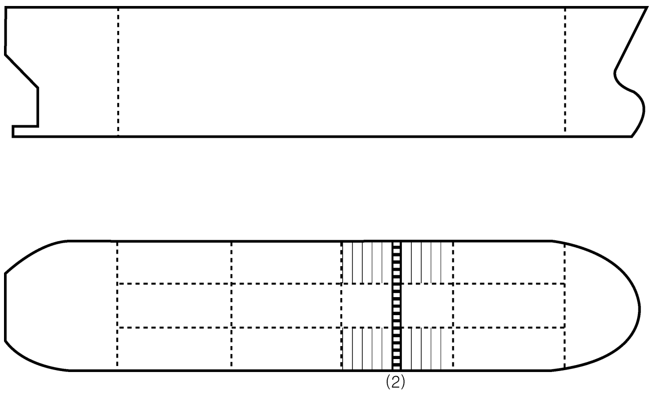
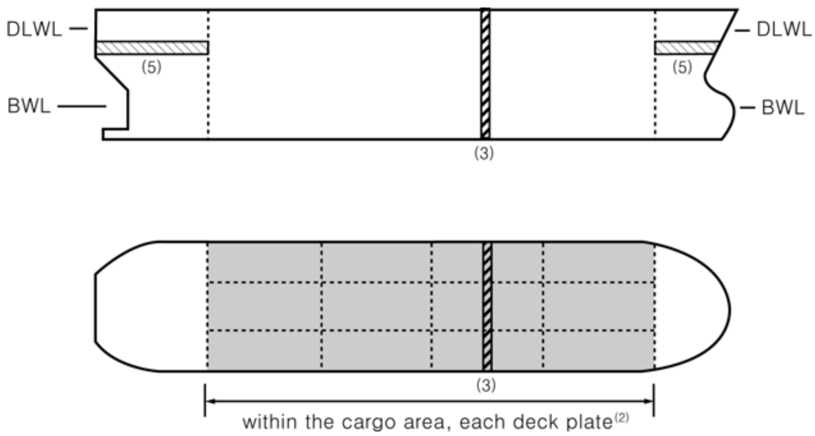
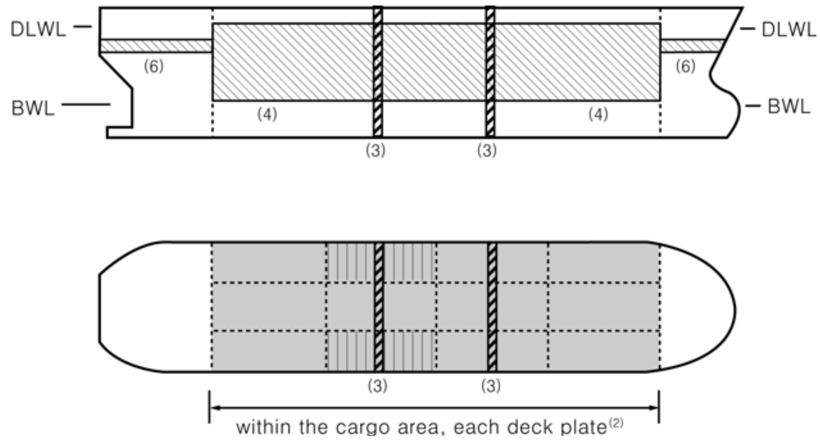
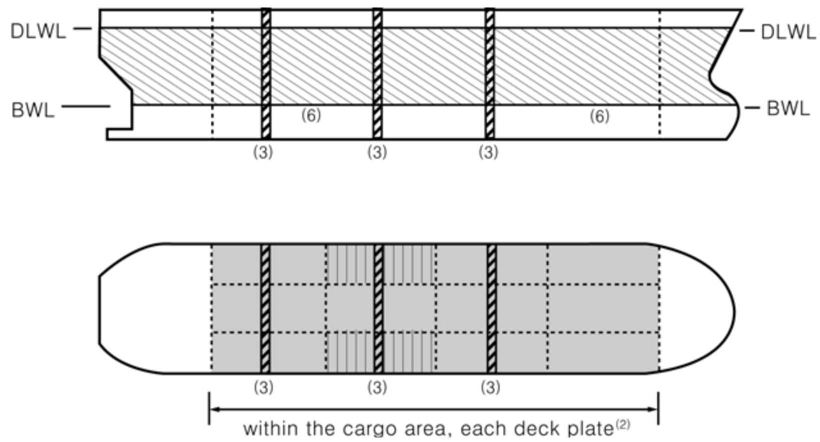
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	 (1) Suspect areas (2) One transverse section of deck plating for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast) (3) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey
Special Survey No. 2	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, one transverse section (4) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (5) Selected wind and water strakes outside the cargo area

Table 11 Extent of thickness measurements at Special Survey - Chemical Tankers with ESP notation (continued)

No. of Special Survey	Extent and location of measurement
Special Survey No. 3	 (1) Suspect area (2) Within the cargo area, each deck plate (3) Within the cargo area, two transverse sections[1)] (4) Within the cargo area, all wind and water strakes (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) Selected wind and water strakes outside the cargo area
Special Survey No. 4 and Subsequent	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, three transverse sections[1)] (4) Within the cargo area, each bottom plate (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) All wind and water strakes, full length

(NOTES)

: Thickness gaugings for deck plates
: Thickness gaugings for side shell plates
: Thickness gaugings for the transverse section(applied for plates only)
: Thickness gaugings for the transverse section(including longitudinal members)
: Thickness gaugings in way of the ballast tank

1) At least one section is to include a ballast tank within 0.5 L amidships.

Table 12 Extent of thickness measurements at Special Survey - Double Hull Oil Tankers with ESP notation

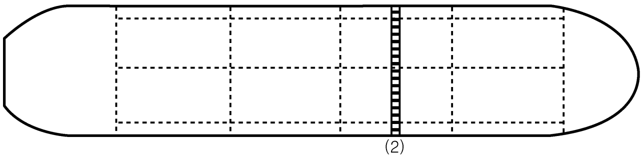
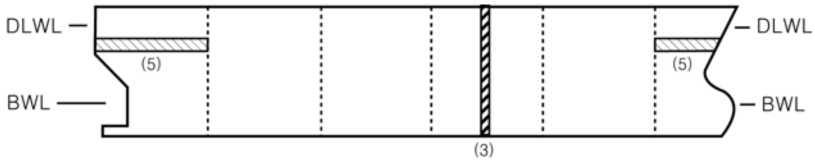
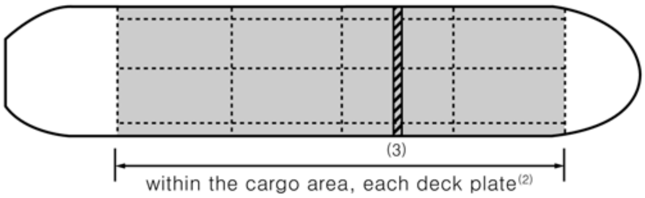
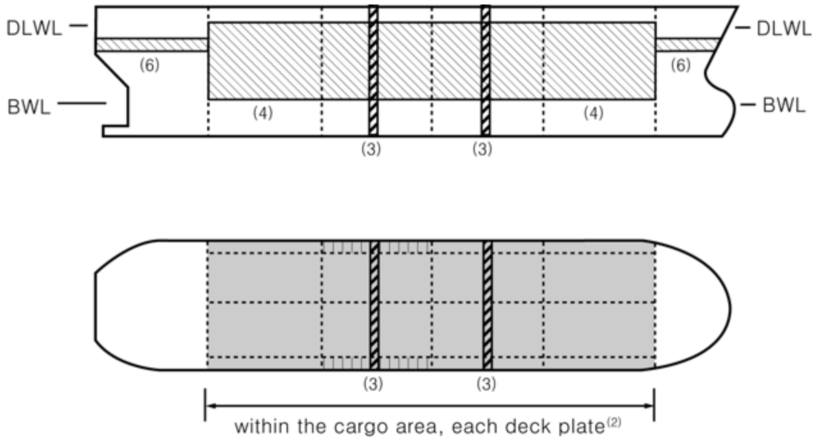
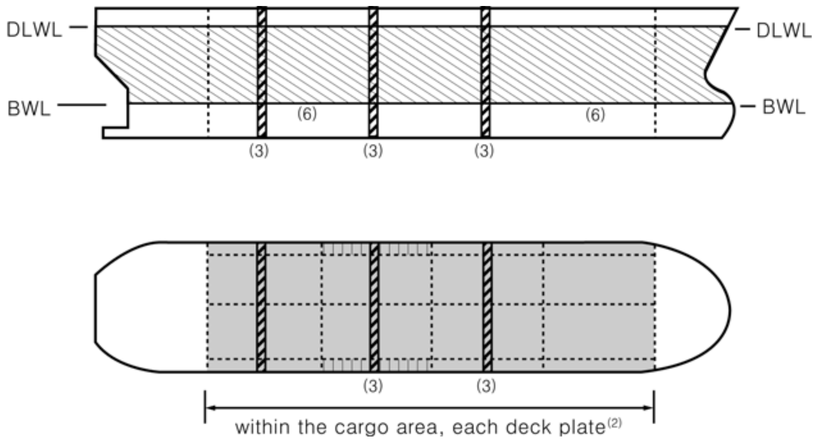
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	  (1) Suspect areas (2) One section of deck plating for the full beam of the ship within the cargo area (3) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey
Special Survey No. 2	  (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, one transverse section (4) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (5) Selected wind and water strakes outside the cargo area

Table 12 Extent of thickness measurements at Special Survey - Double Hull Oil Tankers with ESP notation (continued)

No. of Special Survey	Extent and location of measurement
Special Survey No. 3	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, two transverse sections[1)] (4) Within the cargo area, all wind and water strakes (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) Selected wind and water strakes outside the cargo area
Special Survey No. 4	 (1) Suspect areas (2) Within the cargo area, each deck plate (3) Within the cargo area, three transverse sections[1)] (4) Within the cargo area, each bottom plate (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey (6) All wind and water strakes, full length

(NOTES)

: Thickness gaugings for deck plates
: Thickness gaugings for side shell plates
: Thickness gaugings for the transverse section(applied for plates only)
: Thickness gaugings for the transverse section(including longitudinal members)
: Thickness gaugings in way of the ballast tank

1) At least one section is to include a ballast tank within 0.5 L amidships.

Table 13 Extent of thickness measurements at Special Survey - Double Skin Bulk Carriers with ESP notation

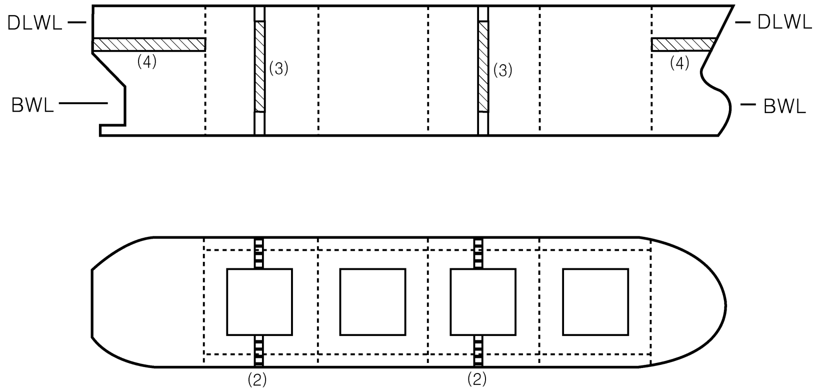
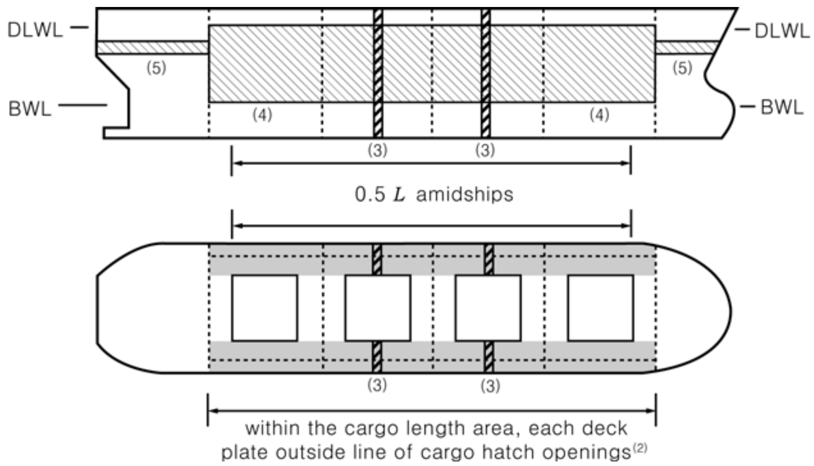
No. of Special Survey	Extent and location of measurement
Special Survey No. 1	(1) Suspect areas
Special Survey No. 2	 (1) Suspect areas (2) Within the cargo length, two transverse sections of deck plating outside line of cargo hatch openings (3) Wind and water strakes in way of the two transverse sections considered (2) above (4) Selected wind and water strakes outside the cargo length area (5) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey
Special Survey No. 3	 (1) Suspect areas (2) Within the cargo length, each deck plate outside line of cargo hatch openings (3) Within the cargo length, two transverse sections, one in the amidship area, outside line of cargo hatch openings (4) Within the cargo length, all wind and water strakes (5) Selected wind and water strakes outside the cargo length area (6) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey

Table 13 Extent of thickness measurements at Special Survey - Double Skin Bulk Carriers with ESP notation (continued)

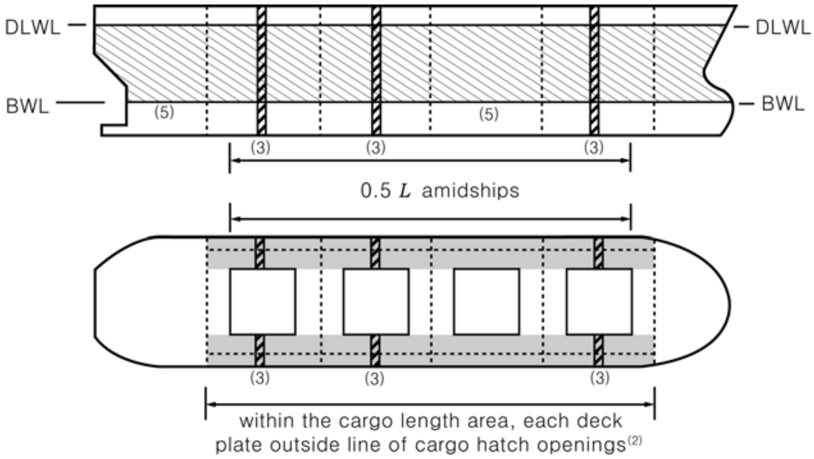
No. of Special Survey	Extent and location of measurement
Special Survey No. 4	 (1) Suspect areas (2) Within the cargo length, each deck plate outside line of cargo hatch openings (3) Within the cargo length, three transverse sections, one in the amidship area, outside line of cargo hatch openings (4) Within the cargo length, each bottom plate (5) All wind and water strakes, full length (6) Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to Close-up Survey
(NOTES) : Thickness gaugings for deck plates : Thickness gaugings for side shell plates : Thickness gaugings for the transverse section(applied for plates only) : Thickness gaugings for the transverse section(including longitudinal members)	

Table 14 Requirements for extent of thickness measurements at those areas of substantial corrosion - Bulk Carriers with ESP notation

1) Shell Structures

Structural Member	Extent of Measurement	Pattern of measurement
1. Bottom and Side Shell Plating	1) Suspect plate, plus four adjacent plates 2) See other tables for particulars on gauging in way tanks and cargo holds	1) 5 point pattern for each panel between longitudinals
2. Bottom/Side Shell Longitudinals	Minimum of three longitudinals in way of suspect areas	3 measurement in line across web 3 measurement on flange

2) Transverse Bulkheads in Cargo Holds

Structural member	Extent of Measurement	Pattern of measurement
1. Lower Stool	1) Transverse band within 25 mm of welded connection to inner-bottom 2) Transverse band within 25 mm of welded connection to shelf plate	1) 5 point between stiffeners over 1 metre length 2) 5 point between stiffeners over 1 metre length
2. Transverse Bulkhead	1) Transverse band at approximately mid height 2) Transverse band at part of bulkhead adjacent to upper deck or below upper stool shelf plate (for those ships fitted with upper stools)	1) 5 point pattern over 1 sq. metre of plating 2) 5 point pattern over 1 sq. metre of plating

3) Deck Structure including Cross Strips, Main Cargo Hatchways, Hatch Covers, Coamings and Topside Tanks

Structural Member	Extent of Measurement	Pattern of Measurement
1. Cross Deck Strip Plating	Suspect cross deck strip plating	5 point pattern between underdeck stiffeners over 1 metre length
2. Underdeck Stiffeners	1) Transverse members 2) Longitudinal member	1) 5 point pattern at each end and mid span 2) 5 point pattern on both web and flange
3. Hatch Covers	1) Side and end skirts, each 3 locations 2) 3 longitudinal bands, outboard strakes (2) and centerline strake (1)	1) 5 point pattern at each location 2) 5 point measurement each band
4. Hatch Coamings	Each side and end of coaming, one band lower 1/3, one band upper 2/3 of coaming	5 point measurement each band i.e. end or side coaming
5. Topside Ballast Tanks	1) Watertight transverse bulkheads a) lower 1/3 of bulkhead b) upper 2/3 of bulkhead c) stiffeners 2) 2 representative swash transverse bulkheads a) lower 1/3 of bulkhead b) upper 2/3 of bulkhead c) stiffeners 3) 3 representative bays of slop plating a) lower 1/3 of tank b) upper 2/3 of tank 4) Longitudinals, suspect and adjacent	1) a) 5 point pattern over 1 sq. metre of plating b) 5 point pattern over 1 sq. metre of plating c) 5 point pattern over 1 metre length 2) a) 5 point pattern over 1 sq. metre of plating b) 5 point pattern over 1 sq. metre of plating c) 5 point pattern over 1 metre length 3) a) 5 point pattern over 1 sq. metre of plating b) 5 point pattern over 1 sq. metre of plating 4) 5 point pattern both web and flange over 1 metre length
6. Main Deck Plating	Suspect plates and adjacent (4)	5 point pattern over 1 sq. metre of plating
7. Main Deck Longitudinals	Minimum of 3 longitudinals where plating measured	5 point pattern on both web and flange over 1 metre length
8. Web Frames /Transverses	Suspect plates	5 point pattern over 1 sq. metre

Table 14 Requirements for extent of thickness measurements at those areas of substantial corrosion - Bulk Carriers with ESP notation (continued)

4) Double Bottom and Hopper Structure

Structural Member	Extent of Measurement	Pattern of Measurement
1. Inner/Double Bottom Plating	Suspect plate plus all adjacent plates	5 point pattern for each panel between longitudinals over 1 metre length
2. Inner/Double Bottom Longitudinals	Three longitudinals where plates measured	3 measurements in line across web and 3 measurements on flange
3. Longitudinal Girders or Transverse Floors	Suspect plates	5 point pattern over about 1 square metre
4. Watertight Bulkhead (W.T Floors)	1) lower 1/3 of tank 2) upper 2/3 of tank	1) 5 point pattern over 1 sq. metre of plating 2) 5 point pattern alternate plates over 1 sq. metre of plating
5. Web Frames	Suspect plating	5 point pattern over 1 sq. metre of plating
6. Bottom/Side Shell Longitudinals	Minimum of three longitudinals in way of suspect areas	3 measurements in line across web 3 measurements on flange

5) Cargo Holds

Structural Member	Extent of Measurement	Pattern of Measurement
1. Side Shell Frames	Suspect frame and each adjacent frame	a) At each end and mid span : 5 point pattern of both web and flange b) 5 point pattern within 25 mm of welded attachment of both shell and lower slope plate

Table 15 Requirements for extent of thickness measurements at those areas of substantial corrosion - Oil Tankers, Ore/Oil Ships, Etc. with ESP notation

1) Bottom Structure

Structural Member	Extent of Measurement	Pattern of Measurement
1. Bottom Plating	Minimum of 3 bays across tank including aft bay Measurements around and under all bell mouths	5 point pattern for each panel between longitudinals and webs
2. Bottom Longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertically web
3. Bottom Girders and Brackets	At fore and aft transverse bulkhead bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements Two measurements across face flat5 point pattern on girder/bulkhead brackets
4. Bottom Transverse Webs	3 webs in bays where bottom plating measured, with measurements at both ends and middle	5 points pattern over 2 square metre area Single measurements on face flat
5. Panel Stiffening	Where provided	Single measurements

2) Deck Structure

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deck Plating	Two bands across tank	Minimum of three measurements per plate per band
2. Deck Longitudinals	Minimum of 3 longitudinals in each of two bands	3 measurements in line vertically on webs, and 2 measurements on flange (if fitted)
3. Deck Girders and Brackets	At fore and aft transverse bulk-head, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements Two measurements across face flat. 5 point pattern on girder/bulkhead brackets
4. Deck Transverse Webs	Minimum of two webs with measurements at middle and both ends of span	5 points pattern over about 2 square metre areas Single measurements on face flat
5. Panel Stiffening	Where provided	Single measurement

Table 15 Requirements for extent of thickness measurements at those areas of substantial corrosion - Oil Tankers, Ore/Oil Ships, Etc. with ESP notation (Continued)

3) Side Shell and Longitudinal Bulkheads

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deckhead and Bottom Strakes, and Strakes in way of Stringer Platforms	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
2. All Other Strakes	Plating between every 3rd pair of longitudinals in same 3 bays	Single measurement
3. Longitudinals-deckhead and Bottom Strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
4. Longitudinals - All Others	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
5. Longitudinals - Bracket	Minimum of three at top middle and bottom of tank in same 3 bays	5 point pattern over area of bracket
6. Web Frames and Cross Ties	3 webs with minimum of three locations on each web, including in way of cross tie connections	5 point pattern over about 2 square metre area, plus single measurements on web frame and cross tie face flats

4) Transverse Bulkheads and Swash Bulkheads

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deckhead and Bottom Strakes, and Strakes in way of Stringer Platforms	Plating between pair of stiffeners at three locations - approx. 1/4, 1/2 and 3/4 width of tank	5 points pattern between stiffeners over 1 meter length
2. All Other Strakes	Plating between pair of stiffeners at middle location	Single measurement
3. Strakes in Corrugated Bulkheads	Plating for each change of scantling at centre of panel and a flange or fabricated connection	5 point pattern over about 1 square metre of plating
4. Stiffeners	Minimum of three typical stiffeners	For web, 5 point pattern over span between bracket connections (2 measurements across web at each bracket connection, and one at centre of span)For flange, single measurements at each bracket toe and at centre of span
5. Brackets	Minimum of three at top middle and bottom of tank	5 point pattern over areas of bracket
6. Deep Webs and Girders	measurements at toe of bracket and at centre of span	For web, 5 point pattern over about 1 square metre 3 measurements across face flat
7. Stringer Platforms	All stringers with measurements at both ends and middle	5 point pattern over 1 square metre of area plus single measurements near bracket toes and on face flats

Table 16 Requirements for extent of thickness measurements at those areas of substantial corrosion – Chemical Tankers with ESP notation

1) Bottom, Inner Bottom and Hopper Structure

Structure Member	Extent of Measurement	Pattern of Measurement
1. Bottom, Inner Bottom and Hopper Structure Plating	Minimum of three bays across double bottom tank, including aft bay. Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
2. Bottom, Inner Bottom and Hopper Structure Longitudinals	Minimum of three longitudinals in each bay where bottom plating measured	Three measurements in line across the flange and three measurements on vertical web
3. Bottom Girders, including the watertight ones	At fore and aft watertight floor and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across face flat where fitted.
4. Bottom Floors, including the watertight ones	Three floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over two square metre area
5. Hopper Structure Web Frame Ring	Three floors in bays where bottom plating measured	5-point pattern over one square metre of plating. Single measurements on flange
6. Hopper Structure Transverse Watertight Bulkhead or Swash Bulkhead	· Lower 1/3 of the bulkhead	· 5-point pattern over one square meter of plating
	· Upper 2/3 of the bulkhead	· 5-point pattern over two square metre of plating
	· Stiffeners(minimum of three)	· For web, 5-point pattern over span(two measurements across web at each end and one at centre of span) · For flange, single measurements at each end and centre of span
7. Panel Stiffening	Where applicable	Single measurements

2) Deck Structure

Structure Member	Extent of Measurement	Pattern of Measurement
1. Deck Plating	Two transverse bands across tank	Minimum of three measurements per plate per band
2. Deck Longitudinals	Every third longitudinal in each two bands with a minimum of one longitudinal	Three measurements in line vertically on webs and two measurements on flange(if fitted)
3. Deck Girders and Brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across flange. 5 point pattern on girder/bulkhead brackets
4. Deck Transverse Webs	Minimum of two webs, with measurements at both ends and middle of span	5-point pattern over one square metre area. Single measurements on flange
5. Vertical Web and Transverse Bulkhead in Wing Ballast Tank for double hull design(two metres from deck)	Minimum of two webs, and both transverse bulkheads	5-point pattern over one square metre area
6. Panel Stiffening	Where applicable	Single measurements

Table 16 Requirements for extent of thickness measurements at those areas of substantial corrosion – Chemical Tankers with ESP notation (continued)

3) Side Shell and Longitudinal Bulkheads

Structure Member	Extent of Measurement	Pattern of Measurement
1. Side Shell and Longitudinal Bulkhead Plating · Deckhead and Bottom Strakes, and Strakes in way of Horizontal Girders · All Other Strakes	· Plating between each pair of longitudinals in a minimum of three bays(along the tank) · Plating between every third pair of longitudinals in same three bays	· Single measurement · Single measurement
2. Side Shell and Longitudinal Bulkhead Longitudinals on: · Deckhead and Bottom Strakes · All Other Strakes	· Each longitudinal in same three bays · Every third longitudinal in same three bays	· 3 measurements across web and 1 measurement on flange · 3 measurements across web and 1 measurement on flange
3. Longitudinals - Brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
4. Vertical Web and Transverse Bulkheads of Double Side Tanks (excluding deckhead area): · Strakes in way of Horizontal Girders · Other Strakes	· Minimum of two webs and both transverse bulkheads · Minimum of two webs and both transverse bulkheads	· 5-point pattern over approx. two square metre area · Two measurements between each pair of vertical stiffeners
5. Web Frames and Cross Ties for Other Tanks than Double Side Tanks	Three webs with minimum of three locations on each web, including in way of cross tie connections and lower end bracket	5-point pattern over approximately two square metre area of webs, plus single measurements on flanges of web frame and cross ties
6. Horizontal Girders	Plating on each girder in a minimum of three bays	Two measurements between each pair of longitudinal girder stiffeners
7. Panel Stiffening	Where applicable	Single measurements

4) Transverse Watertight and Swash Bulkheads

Structure Member	Extent of Measurement	Pattern of Measurement
1. Upper and Lower Stool, where fitted	· Transverse band within 25 mm of welded connection to inner bottom/deck plating · Transverse band within 25 mm of welded connection to shelf plate	9-point pattern between stiffeners over one metre length
2. Deckhead and Bottom Strakes, and Strakes in way of Horizontal Stringers	Plating between pair of stiffeners at three locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over one metre length
3. All Other Strakes	Plating between pair of stiffeners at middle location	Single measurement
4. Strakes in Corrugated Bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about one square metre of plating
5. Stiffeners	Minimum of three typical stiffeners	For web, 5-point pattern over span between bracket connections (two measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
6. Brackets	Minimum of three at top, middle and bottom of tank	5-point pattern over area of bracket
7. Horizontal Stringers	All stringers with measurements at both ends and middle	5-point pattern over one square metre area, plus single measurements near bracket toes and on flanges
8. Deep Webs and Girders	Measurements at toe of bracket and at centre of span	For web, 5-point pattern over about one square metre. three measurements across face flat

Table 17 Requirements for extent of thickness measurements at those areas of substantial corrosion - Double Hull Oil Tankers with ESP notation

1) Bottom, Inner Bottom and Hopper Structure

Structural Member	Extent of Measurement	Pattern of Measurement
1. Bottom, Inner Bottom and Hopper Structure Plating	Minimum of three bays across double bottom tank, including aft bay. Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
2. Bottom, Inner Bottom and Hopper Structure Longitudinals	Minimum of three longitudinals in each bay where bottom plating measured	Three measurements in line across flange and three measurements on vertical web
3. Bottom Girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of three measurements
4. Bottom Floors, including the watertight ones	Three floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over two square metre area
5. Hopper Structure Web Frame Ring	Three floors in bays where bottom plating measured	5-point pattern over one square metre of plating. Single measurements on flange
6. Hopper Structure Transverse Watertight Bulkhead or Swash Bulkhead	· Lower 1/3 of bulkhead	· 5-point pattern over two square metre of plating
	· Upper 2/3 of bulkhead	· 5-point pattern over two square metre of plating
	·Stiffeners (minimum of three)	· For web, 5-point pattern over span (two measurements across web at each end and one at centre of span). · For flange, single measurements at each end and centre of span
7. Panel Stiffening	Where applicable	Single measurements

2) Deck Structure

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deck Plating	Two transverse bands across tank	Minimum of three measurements per plate per band
2. Deck Longitudinals	Every third longitudinal in each of two bands with a minimum of one longitudinal	Three measurements in line vertically on webs and two measurements on flange (if fitted)
3. Deck Girders and Brackets (usually in cargo tanks only)	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of three measurements. Two measurements across flange. 5-point pattern on girder/bulkhead brackets
4. Deck Transverse Webs	Minimum of two webs, with measurements at both ends and middle of span	5-point pattern over one square metre area. Single measurements on flange
5. Vertical Web and Transverse Bulkhead in Wing Ballast Tank (two metres from deck)	Minimum of two webs, and both transverse bulkheads	5-point pattern over one square metre area
6. Panel Stiffening	Where applicable	Single measurements

Table 17 Requirements for extent of thickness measurements at those areas of substantial corrosion - Double Hull Oil Tankers with ESP notation (continued)

3) Structure in Wing Ballast Tanks

Structural Member	Extent of Measurement	Pattern of Measurement
1. Side Shell and Longitudinal Bulkhead Plating : · Upper Strake and Strakes in way of Horizontal Girders · All Other Strakes	· Plating between each pair of longitudinals in a minimum of three bays (along the tank) · Plating between every third pair of longitudinals in same three bays	· Single measurement · Single measurement
2. Side Shell and Longitudinal Bulkhead Longitudinals on : · Upper Strake · All Other Strakes	· Each longitudinal in same three bays · Every third longitudinal in same three bays	· 3 measurements across web and 1 measurement on flange · 3 measurements across web and 1 measurement on flange
3. Longitudinals - Brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
4. Vertical Web and Transverse Bulkheads (excluding deckhead area) : · Strakes in way of Horizontal Girders · Other Strakes	· Minimum of two webs and both transverse bulkheads · Minimum of two webs and both transverse bulkheads	· 5-point pattern over approx. two square metre area · two measurement between each pair of vertical stiffeners
5. Horizontal Girders	Plating on each girder in a minimum of three bays	Two measurements between each pair of longitudinal girder stiffeners
6. Panel Stiffening	Where applicable	Single measurements

4) Longitudinal Bulkheads in Cargo Tanks

Structural Member	Extent of Measurement	Pattern of Measurement
1. Deckhead and Bottom Strakes, and Strakes in way of the Horizontal Stringers of Transverse Bulkheads	Plating between each pair of longitudinal in a minimum of three bays	Single measurement
2. All Other Strakes	Plating between every third pair of longitudinals in same three bays	Single measurement
3. Longitudinals on Deckhead and Bottom Strakes	Each longitudinal in same three bays	Three measurements across web and one measurement on flange
4. All Other Longitudinals	Every third longitudinal in same three bays	Three measurements across web and one measurement on flange
5. Longitudinals - Brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
6. Web Frames and Cross Ties	Three webs with minimum of three locations on each web, including in way of cross tie connections	5-point pattern over approximately two square metre area of webs, plus single measurements on flanges of web frame and cross ties
7. Lower End Brackets (opposite side of web frame)	Minimum of three brackets	5-point pattern over approximately two square metre area of brackets, plus single measurements on bracket flanges

Table 17 Requirements for extent of thickness measurements at those areas of substantial corrosion - Double Hull Oil Tankers with ESP notation (continued)

5) Transverse Watertight and Swash Bulkheads in Cargo Tanks

Structural Member	Extent of Measurement	Pattern of Measurement
1. Upper and Lower Stool, where fitted	· Transverse band within 25 mm of welded connection to inner bottom/deck plating · Transverse band within 25 mm of welded connection to shelf plate	5-point pattern between stiffeners over metre length
2. Deckhead and Bottom Strakes, and Strakes in way of Horizontal Stringers	Plating between pair of stiffeners at three locations : approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over one metre length
3. All Other Strakes	Plating between pair of stiffeners at middle location	Single measurement
4. Strakes in Corrugated Bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about one square metre of plating
5. Stiffeners	Minimum of three typical stiffeners	For web, 5-point pattern over span between bracket connections (two measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
6. Brackets	Minimum of three at top, middle and bottom of tank	5-point pattern over area of bracket
7. Horizontal Stringers	All stringers with measurements at both ends and middle	5-point pattern over one square metre area, plus single measurements mear bracket toes and on flanges

Table 18 Requirements for extent of thickness measurements at those areas of substantial corrosion - Double Skin Bulk Carriers with ESP notation

1) Bottom, Inner Bottom and Hopper Structure

Structural Member	Extent of Measurement	Pattern of Measurement
1. Bottom, Inner Bottom and Hopper Structure Plating	Minimum of three bays across double bottom tank, including aft bay. Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
2. Bottom, Inner Bottom and Hopper Structure Longitudinals	Minimum of three longitudinals in each bay where bottom plating measured	Three measurements in line across flange and three measurements on the vertical web
3. Bottom Girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of three measurements
4. Bottom Floors, including the watertight ones	Three floors in the bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over two square metre area
5. Hopper Structure Web Frame Ring	Three floors in bays where bottom plating measured	5-point pattern over one square metre of plating. Single measurements on flange
6. Hopper Structure Transverse Watertight Bulkhead or Swash Bulkhead	· Lower 1/3 of bulkhead	· 5-point pattern over one square metre of plating
	· Upper 2/3 of bulkhead	· 5-point pattern over two square metre of plating
	· Stiffeners(minimum of three)	· For web, 5-point pattern over span(two measurements across web at each end and one at centre of span). · For flange, single measurements at each end and centre of span
7. Panel Stiffening	Where applicable	Single measurement

Table 18 Requirements for extent of thickness measurements at those areas of substantial corrosion - Double Skin Bulk Carriers with ESP notation (continued)

2) Deck Structure including Cross Strips, Main Cargo Hatchways, Hatch Covers, Coamings and Topside Tanks

Structural Member	Extent of Measurement	Pattern of Measurement
1. Cross Deck Strip Plating	Suspect cross deck strip plating	5-point pattern between underdeck stiffeners over 1 metre length
2. Underdeck Stiffeners	1) Transverse members 2) Longitudinal members	1) 5-point pattern at each end and mid span 2) 5-point pattern on both web and flange
3. Hatch Covers	1) Side and end skirts, each three locations 2) Three longitudinal bands, outboard strakes(2) and centerline strake(1)	1) 5-point pattern at each location 2) 5-point measurement each band
4. Hatch Coamings	Each side and end of coaming, one band lower 1/3, one band upper 2/3 of coaming	5-point measurement each band i.e. end or sid coaming
5. Topside Ballast Tanks	1) Watertight transverse bulkhead a) Lower 1/3 of bulkhead b) Upper 2/3 of bulkhead c) Stiffeners 2) Two representative swash transverse bulkheads a) Lower 1/3 of bulkhead b) Upper 2/3 of bulkhead c) Stiffeners 3) Three representative bays of slope plating a) Lower 1/3 of tank b) Upper 2/3 of tank 4) Longitudinals, suspect and adjacent	1) a) 5-point pattern over 1 sq. metre of plating b) 5-point pattern over 1 sq. metre of plating c) 5-point pattern over 1 metre length 2) a) 5-point pattern over 1 sq. metre of plating b) 5-point pattern over 1 sq. metre of plating c) 5-point pattern over 1 metre length 3) a) 5-point pattern over 1 sq. metre of plating b) 5-point pattern over 1 sq. metre of plating 4) 5-point pattern on both web and flange over 1 metre length
6. Main Deck Plating	Suspect plates and adjacent(4)	5-point pattern over 1 sq. metre of plating
7. Main Deck Longitudinals	Suspect plates	5-point pattern on both web and flange over 1 metre length
8. Web Frames/ Transverse	Suspect plates	5-point pattern over 1 sq. metre of plating

Table 18 Requirements for extent of thickness measurements at those areas of substantial corrosion - Double Skin Bulk Carriers with ESP notation (continued)

3) Structure in Double Side Spaces(including Wing Void Spaces of Ore Carriers)

Structural Member	Extent of Measurement	Pattern of Measurement
1. Side Shell and Inner Plating : · Upper strake and strakes in way of horizontal girders · All other strakes	· Plating between each pair of transverse frames/longitudinals in a minimum of three bays(along the tank) · Plating between every third pair of longitudinals in same three bays	· Single measurements · Single measurements
2. Side Shell and Inner Side Transverse Frames/ Longitudinals on : · Upper strake · All other strakes	· Each transverse frame/longitudinal in same three bays · Every third transverse frame/longitudinal in same three bays	· Three measurements across web and 1 measurement on flange · Three measurements across web and 1 measurement on flange
3. Transverse Frames/Longitudinals Brackets	Minimum of three at top, middle and bottom of tank in same three bays	5-point pattern over area of bracket
4. Vertical Web and Transverse Bulkheads : · Strakes in way of horizontal girders · Other strakes	· Minimum of two webs and both transverse bulkheads · Minimum of two webs and both transverse bulkheads	· 5-point patterns over approx. two square metre area · Two measurements between each pair of vertical stiffeners
5. Horizontal Girders	Plating on each girder in a minimum of three bays	Two measurements between each pair of longitudinal girder stiffeners
6. Panel Stiffening	Where applicable	Single measurements

4) Transverse Bulkheads in Cargo Holds

Structural Member	Extent of Measurement	Pattern of Measurement
1. Lower Stool, where fitted	· Transverse band within 25 mm of welded connection to inner bottom · Transverse band within 25 mm of welded connection to shelf plate	· 5-point pattern between stiffeners over one metre length · 5-point pattern between stiffeners over one metre length
2. Transverse Bulkheads	· Transverse band at approximately mid height · Transverse band at part of bulkhead adjacent to upper deck of below upper stool shelf plate(for those ships fitted with upper stools)	· 5-point pattern over one square metre of plating · 5-point pattern over one square metre of plating

Table 19 General Particulars

GENERAL PARTICULARS

Ship's name :
IMO Number :
Class Identification number :
Port of registry :
Gross tons :
Deadweight :
Date of build :
Classification society :

Name of Company performing thickness measurement :
Thickness measurement company certified by :
Certificate No. :
Certificate valid from to
Place of measurement :
First date of measurement :
Last date of measurement :
Special survey/intermediate survey due :*
Details of measurement equipment :
Qualification of operator :

Report Number : consisting of Sheets

Name of operator :
Signature of operator :
Company official stamp :

Name of surveyor :
Signature of surveyor :
Classification Society
Official Stamp :

* Delete as appropriate

Table 20 Thickness measurements reports

TM1-T/DHT/BC/DSBC/GE*

Report on THICKNESS MEASUREMENT of ALL DECK PLATING / ALL BOTTOM SHELL PLATING / ALL SIDE SHELL PLATING*

Ship's Name : Class Identity No. : Report No. :

STRAKE POSITION																	
PLATE POSITION	No. or Letter	Org. Thk. mm	Forward Reading						Aft Reading						Mean Diminution %		M.A.D
			Gauged		Diminution P		Diminution S		Gauged		Diminution P		Diminution S				
			P	S	mm	%	mm	%	P	S	mm	%	mm	%	P	S	mm
15th forward																	
14th																	
13th																	
12th																	
11th																	
10th																	
9th																	
8th																	
7th																	
6th																	
5th																	
4th																	
3rd																	
2nd																	
1st																	
Amidships																	
1st aft																	
2nd																	
3rd																	
4th																	
5th																	
6th																	
7th																	
8th																	
9th																	
10th																	
11th																	
12th																	
13th																	
14th																	
15th																	

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurement of :
   All strength deck plating within the cargo (length) area
   All keel, bottom shell plating and bilge plating within the cargo (length) area
   Side shell plating including selected wind and water strakes outside cargo (length) area
   All wind and water strakes within cargo (length) area
2. The strake position is to be clearly indicated as follow :
   2.1 For strength deck indicate the number of the strake of plating inboard from the stringer plate.
   2.2 For bottom plating indicate the number of the strake of plating outboard from the keel plate.
   2.3 For side shell plating give number of the strake of plating below sheerstrake and letter as shown on shell expansion.
3. For the ships which have no wide cargo openings i.e oil tankers all deck plating strakes are to be recorded, for the ships which have wide cargo openings i.e ore/oil ships and bulk carriers only the deck plating strakes outside line of openings are to be recorded.
4. Measurements are to be taken at the forward and aft areas of all plates and where plates cross ballast and cargo tank/hold boundaries separate measurements for the area of plating in way of each type of tank/hold are to be recorded.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate
T : Oil Tankers and Chemical Tankers with ESP notation
DHT : Double Hull Oil Tankers with ESP notation
BC : Bulk Carriers with ESP notation
DSBC : Double Skin Bulk Carriers with ESP notation
GE : Others
M.A.D : Maximum Allowable Diminution

Table 20 Thickness measurements reports (Continued)

TM2-T/DHT/BC/DSBC/GE(i)*

Report on THICKNESS MEASUREMENT OF SHEERSTRAKE AND DECK PLATING AT TRANSVERSE SECTIONS
(one, two or three transverse sections)

Ship's Name : Class Identity No. : Report No. :

STRENGTH DECK AND SHEERSTRAKE PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER :									SECOND TRANSVERSE SECTION AT FRAME NUMBER :									THIRD TRANSVERSE SECTION AT FRAME NUMBER :								
STRAKE POSITION	No. or Letter	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
Stringer Plate																											
1st strake inboard																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
centre strake																											
sheer strake																											
TOPSIDE TOTAL																											

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurements of :
   - Strength deck plating and sheerstrake plating transverse sections :
     One, two or three sections within the cargo (length) area comprising of the following structural items :

     (1) Strength deck plating
     (2) Stringer plate
     (3) Sheerstrake

2. For the ships which have no wide cargo openings i.e oil tankers all deck plating strakes are to be recorded, for the ships which have wide cargo openings i.e ore/oil ships and bulk carriers only the deck plating strakes outside line of openings are to be recorded.
3. The topside area comprises deck plating, stringer plate and sheerstrake (including rounded gunwales)
4. The exact frame station of measurement is to be stated.
5. The single measurements recorded are to represent the average of multiple measurements.
6. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM2-T/DHT/BC/DSBC/GE(ii)*

Report on THICKNESS MEASUREMENT OF SHELL AND BOTTOM PLATING AT TRANSVERSE SECTIONS
(one, two or three transverse sections)

Ship's Name : Class Identity No. : Report No. :

SHELL AND BOTTOM PLATING																											
	FIRST TRANSVERSE SECTION AT FRAME NUMBER :									SECOND TRANSVERSE SECTION AT FRAME NUMBER :									THIRD TRANSVERSE SECTION AT FRAME NUMBER :								
STRAKE POSITION	No. or Letter	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		No. or Letter	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%
1st below sheer strake																											
2nd																											
3rd																											
4th																											
5th																											
6th																											
7th																											
8th																											
9th																											
10th																											
11th																											
12th																											
13th																											
14th																											
15th																											
16th																											
17th																											
18th																											
19th																											
20th																											
keel strake																											
BOTTOM TOTAL																											

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurements of :
   - Shell and bottom plating transverse sections :
     One, two or three sections within the cargo (length) area comprising of the following structural items :

     (1) Side shell plating
     (2) Bilge plating
     (3) Bottom shell plating
     (4) Keel plate

2. The bottom area comprises keel, bottom and bilge plating.
3. The exact frame station of measurement is to be stated.
4. The single measurements recorded are to represent the average of multiple measurements.
5. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM3-T/DHT/BC/DSBC/GE*

Report on THICKNESS MEASUREMENT OF LONGITUDINAL MEMBERS AT TRANSVERSE SECTIONS
(one, two or three transverse sections)

Ship's Name : Class Identity No. : Report No. :

STRUCTURE MEMBER	FIRST TRANSVERSE SECTION AT FRAME NUMBER :									SECOND TRANSVERSE SECTION AT FRAME NUMBER :									THIRD TRANSVERSE SECTION AT FRAME NUMBER :								
	Item No.	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		Item No.	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S	
		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%		mm	mm	P	S	mm	%	mm	%

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurements of :
   - Longitudinal members at transverse sections :
     One, two or three sections within the cargo (length) area comprising of the following structural items :

     (1) Deck longitudinals
     (2) Deck girders
     (3) Sheerstrake longitudinals
     (4) Longitudinal bulkhead top strake
     (5) Bottom longitudinals
     (6) Bottom girders
     (7) Bilge longitudinals
     (8) Longitudinal bulkhead lower strake
     (9) Side shell longitudinals
     (10) Longitudinal bulkhead plating (remainder)
     (11) Longitudinal bulkhead longitudinals
     (12) Inner bottom plating
     (13) Inner bottom longitudinals
     (14) Topside tank sloping plating
     (15) Topside tank sloping plating longitudinals
     (16) Hopper side plating
     (17) Hopper side longitudinals
     (18) 2nd deck plating (including all lower decks)
     (19) 2nd deck plating longitudinals (including all lower decks)
     (20) 2nd deck girders (including all lower decks)
     (21) Horizontal girders in wing ballast tanks
     (22) Inner side plating
     (23) Inner side longitudinals

2. The exact frame station of measurement is to be stated.
3. The single measurements recorded are to represent the average of multiple measurements.
4. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM4-T/DHT/BC/DSBC/GE*

Report on THICKNESS MEASUREMENT OF TRANSVERSE STRUCTURAL MEMBERS in the cargo oil and ballast tanks within the cargo tank length / in the double bottom, hopper side and topside ballast tanks*

Ship's Name : Class Identity No. : Report No. :

TANK DESCRIPTION :										
LOCATION OF STRUCTURE :										
STRUCTURAL MEMBER	ITEM	Org. Thk. (mm)	M.A.D (mm)	Gauged		Diminution P		Diminution S		
				P	S	mm	%	mm	%	

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurements of transverse structural members comprising of the following structural items :

   (1) Deck transverses centre tank
   (2) Bottom transverses centre tank
   (3) Deck transverses wing tank
   (4) Side shell vertical webs
   (5) Longitudinal bulkhead vertical webs
   (6) Bottom transverses wing tank
   (7) Struts
   (8) Transverse web face plates
   (9) Doble bottom tank floors
   (10) Topside tank transverses
   (11) Hopper side tank transverses
   (12) Vertical web in wing ballast tank
   (13) Longitudinal bulkhead vertical web
   (14) Cross ties

2. The single measurements recorded are to represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM5-T/DHT/BC/DSBC/GE*

Report on THICKNESS MEASUREMENT OF W.T/O.T TRANSVERSE BULKHEADS within the cargo tanks or cargo hold spaces

Ship's Name : Class Identity No. : Report No. :

TANK/HOLD DESCRIPTION :									
LOCATION OF STRUCTURE : FRAME NO:									
STRUCTURAL COMPONENT (PLATING/STIFFENER)	Org. Thk. (mm)	M.A.D (mm)	Gauged		Diminution P		Diminution S		
			P	S	mm	%	mm	%	

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurement of W.T / O.T transverse bulkheads or cargo hold transverse bulkheads including bulkhead stiffeners and internal stiffeners of upper and lower stools.
2. The single measurements recorded are represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM6-T/DHT/BC/DSBC/GE*

Report on THICKNESS MEASUREMENT OF MISCELLANEOUS STRUCTURAL MEMBERS

Ship's Name : Class Identity No. : Report No. :

STRUCTURAL MEMBER :									SKETCH
LOCATION OF STRUCTURE :									
Description	Org. Thk. (mm)	M.A.D (mm)	Gauged		Diminution P		Diminution S		
			P	S	mm	%	mm	%	

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurement of miscellaneous structural members including the following structural items :

   (1) Hatch coamings (including stiffeners)
   (2) Deck plating between hatches
   (3) Hatch covers (including stiffeners)
   (4) Inner bulkhead plating
   (5) Superstructure deck plating
   (6) Forepeak tank internal members
   (7) Aftpeak tank internal members

2. The single measurements recorded are to represent the average of multiple measurements.
3. The maximum allowable diminution could be stated in an attached document.

* : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM7-BC/GE*

Report on THICKNESS MEASUREMENT OF CARGO HOLD TRANSVERSE FRAMES

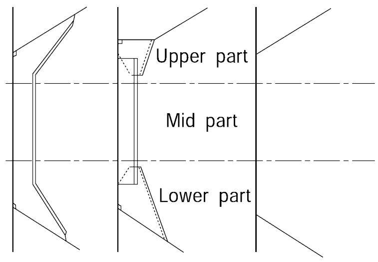
Ship's Name : Class Identity No. : Report No. :

CARGO HOLD NO. :																								
	UPPER PART								MID PART								LOWER PART							
FRAME NUMBER	Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S		Org. Thk.	M.A.D	Gauged		Diminution P		Diminution S	
	mm	mm	P	S	mm	%	mm	%	mm	mm	P	S	mm	%	mm	%	mm	mm	P	S	mm	%	mm	%

Operators Signature : Surveyors Signature :

(NOTES)

1. This report form is to be used for recording the thickness measurement of :
   Cargo hold transverse frames or diaphragms
2. The location and pattern of measurements is to be indicated on the sketches of hold frames shown below.



Typical transvers frames in cargo hold Thickness gauging area

Non-typical transverse frames in cargo hold Thickness gauging area

3. The maximum allowable diminution could be stated in an attached document.

＊ : delete as appropriate

Table 20 Thickness measurements reports (Continued)

TM8-BC/S31

Report on THICKNESS MEASUREMENT OF CARGO HOLD SIDE SHELL FRAMES

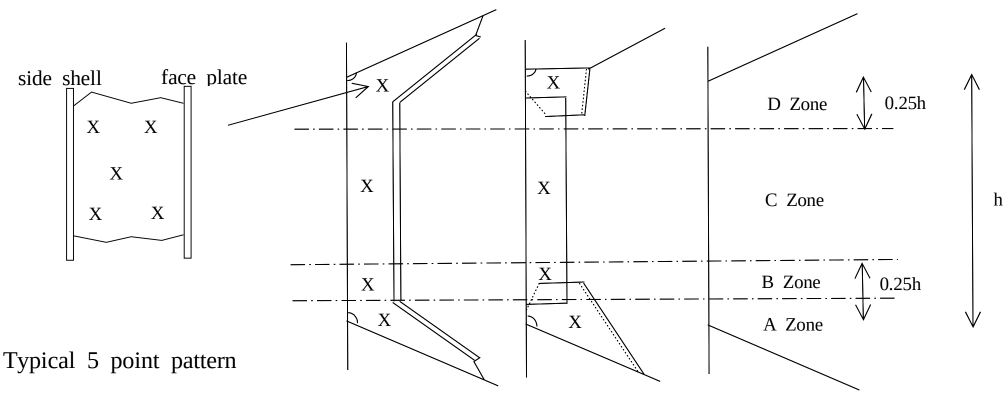
Ship's Name : Class Identity No. : Report No. :

CARGO HOLD NO. :																								
	ZONE A						ZONE B						ZONE C						ZONE D					
Frame No.	Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution		Org. Thk.	t_{REN}	t_{COAT}	t_M	Diminution	
	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%	mm	mm	mm	mm	mm	%

Operators Signature : Surveyors Signature :

(NOTES)

1. This report is to be used for recording the thickness measurement of Cargo Hold Transverse Frames for application of UR S31
2. The gauging pattern for zones A, B & D are to be a five point pattern and for zone C may be measured by taking 3 reading over the length of zone C. If the web plating of zone C has general corrosion then it should be expanded to a five pattern. The gauging pattern is to be over the depth web and the same area vertically. The gauging report is to reflect the average reading.



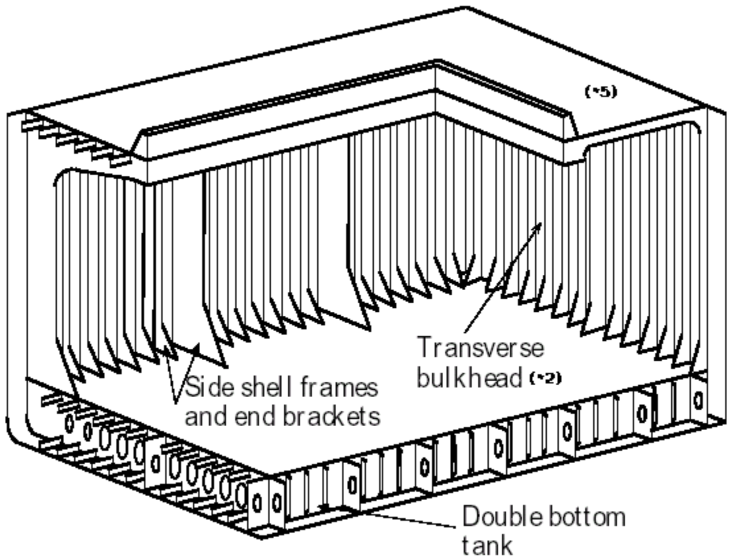
Typical 5 point pattern

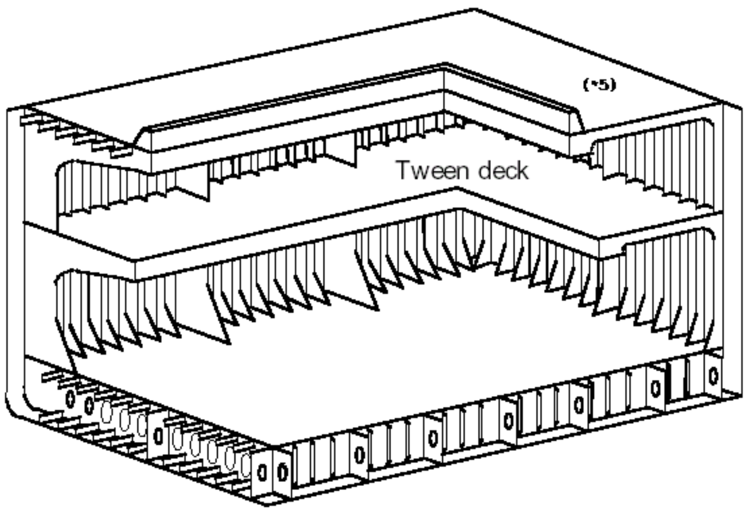
Typical Transverse Frame Non - Typical Transverse Frame

Annex 1-6 Areas of Close-up Survey, etc.

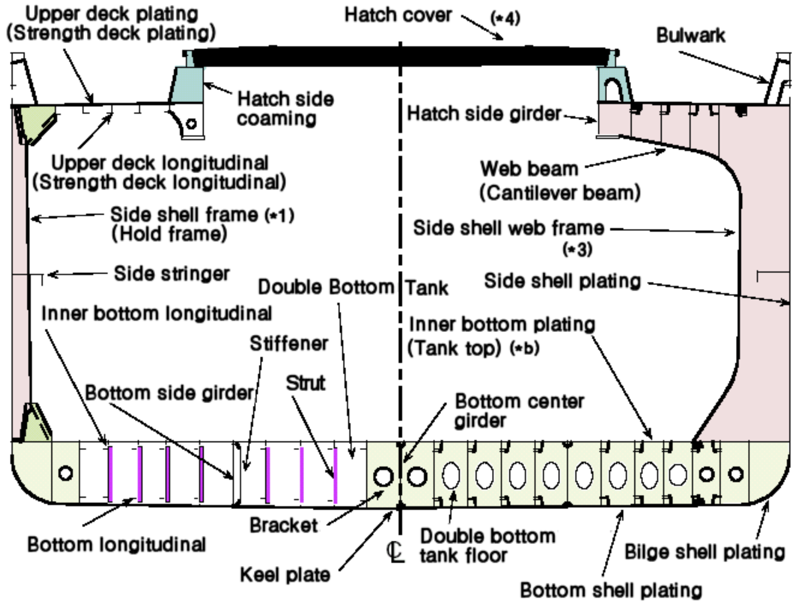
1. Guidance for areas of Close-up Survey for General Dry Cargo Ships, Bulk Carriers, Oil Tankers, Chemical Tankers, Double Hul Oil Tankers and Double Skin Bulk Carriers specified in **Table 1.2.8, Table 1.3.1, Table 1.3.4**, **Table 1.3.7, Table 1.3.10** and **Table 1.3.13** of the Rules are indicated on the diagrams as follows.

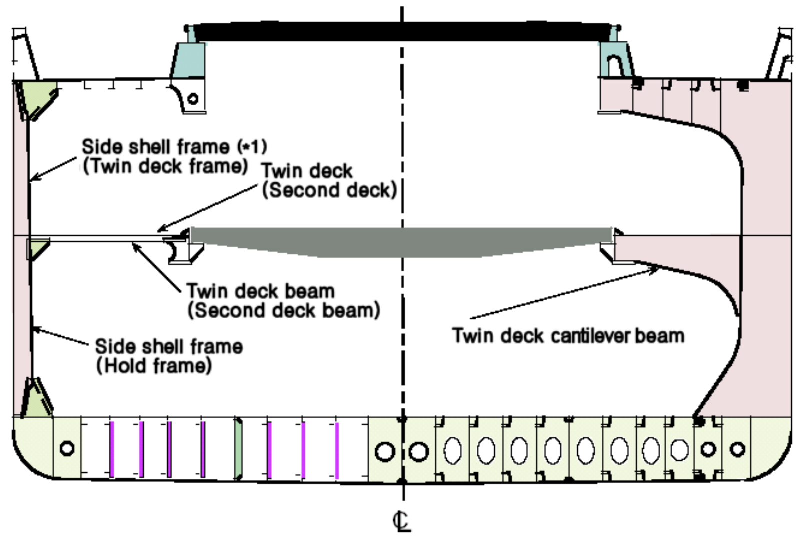
(1) Areas of Close-up Survey for General Dry Cargo Ships





(Continued)

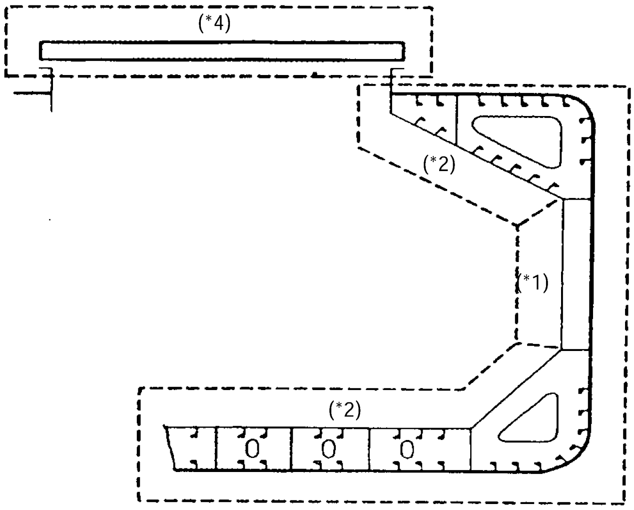




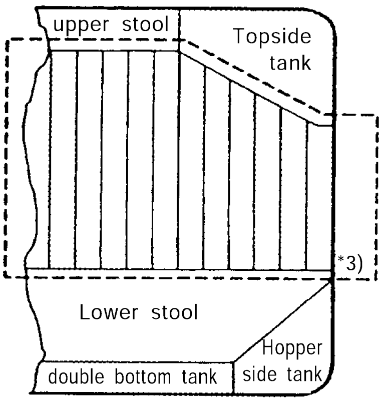
Note : (*1) through (*6) are as given in **Table 1.2.8** of the Rules

(2) Areas of Close-up Survey for Bulk Carriers with ESP notation

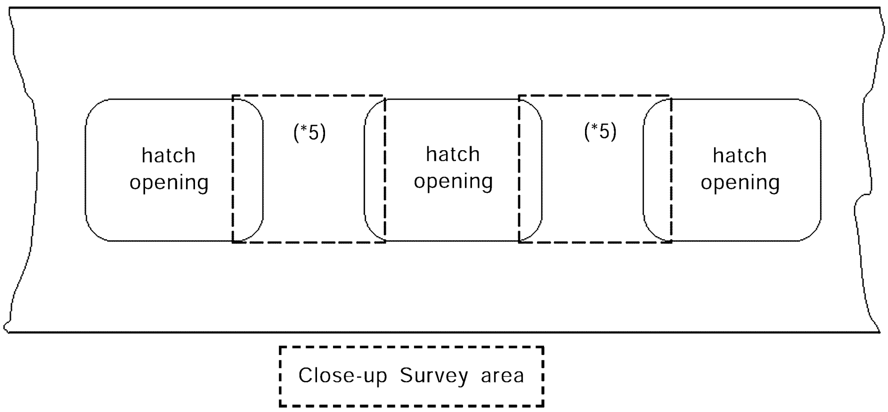
(Typical transverse section)



(Cargo hold, transverse bulkhead)



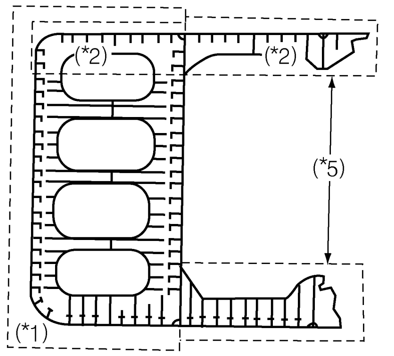
(Typical areas of deck plating inside line of hatch openings between cargo hold hatches)



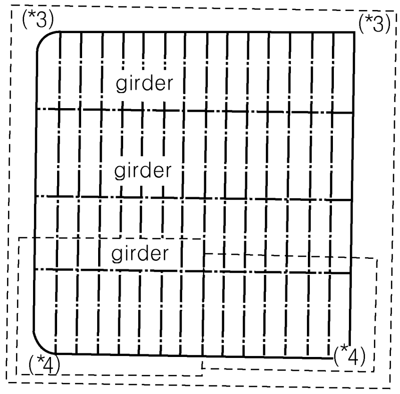
Note : (*1) through (*5) are as given in **Table 1.3.1** of the Rules.

(3) Areas of Close-up Survey for Oil Tankers with ESP notation

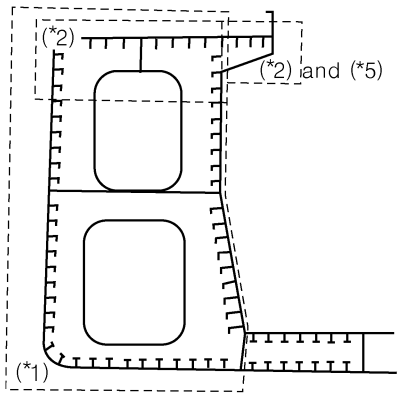
Oil Tanker
(Typical transverse section)



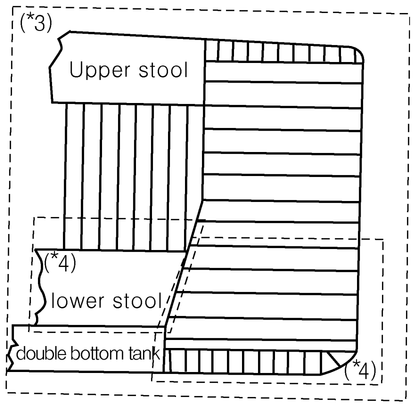
Oil Tanker
(Typical transverse bulkhead)



Ore/Oil Ship
(Typical transverse section)



Ore/Oil Ship
(Typical transverse bulkhead)



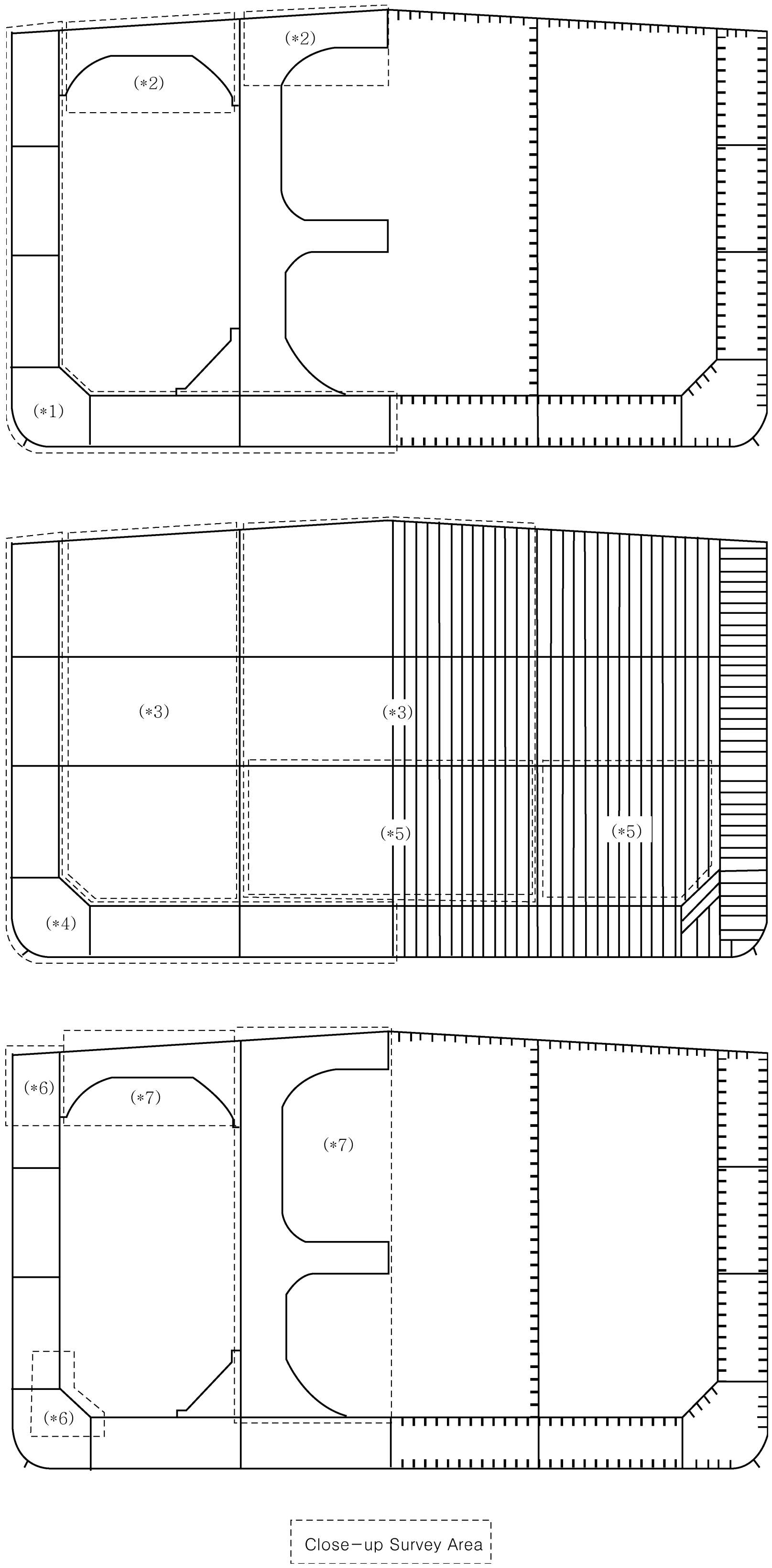
Close−up Survey area

Note : (*1) through (*5) are as given in **Table 1.3.4** of the Rules.

(4) Areas of Close-up Survey for Chemical Tankers with ESP notation

Note 1 : For single hull chemical tankers, refer to (3)
Note 2 : For double hull chemical tankers, refer to (5)

(5) Areas of Close-up Survey for Double Hull Oil Tankers with ESP notation

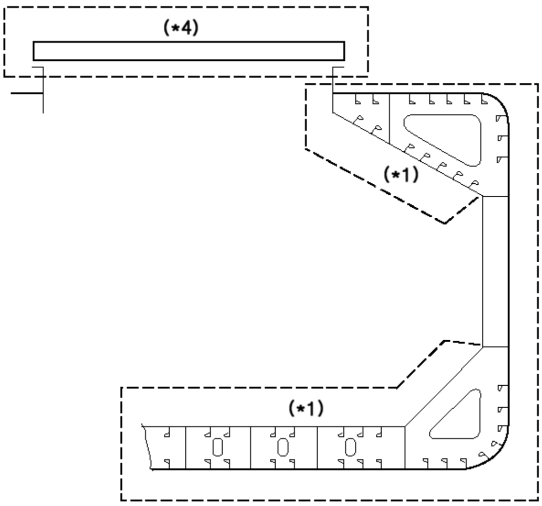


Note : (*1) through (*7) are as given in **Table 1.3.10** of the Rules.

(6) Areas of Close-up Survey for Double Skin Bulk Carriers with ESP notation

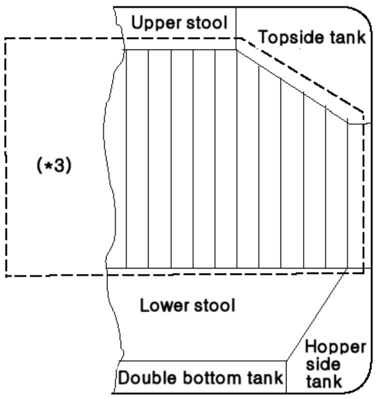
Typical transverse section

Areas (*1) and (*4)



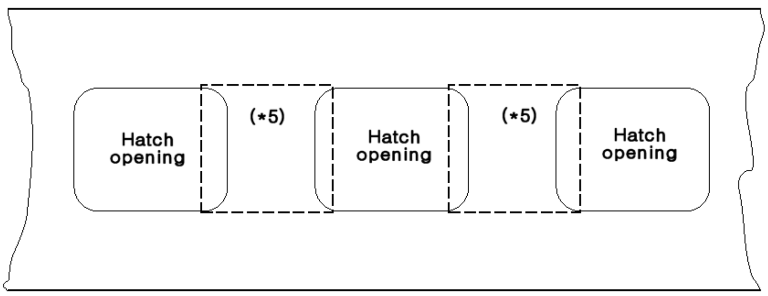
A cargo hold, transverse bulkhead

Area (*3)

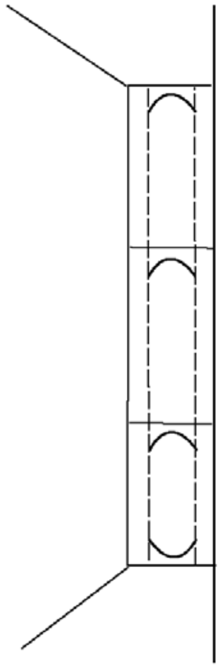


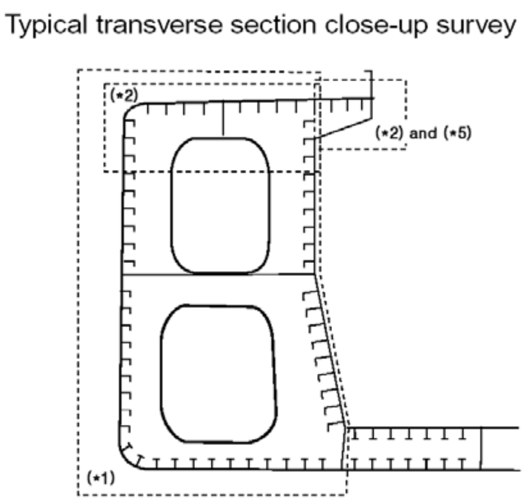
Typical areas of deck plating and underdeck structure inside line of hatch openings between cargo hold hatches

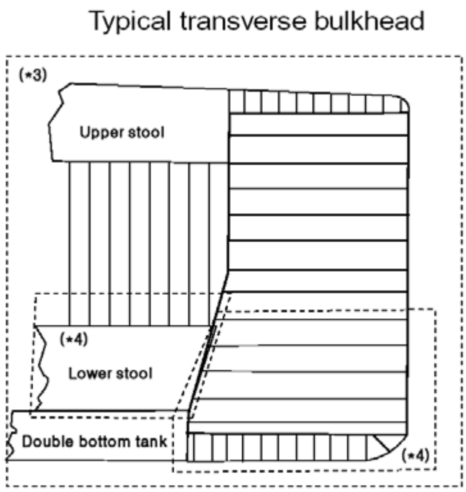
Area (*5)

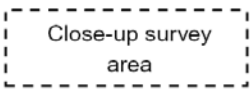


Area (*2)



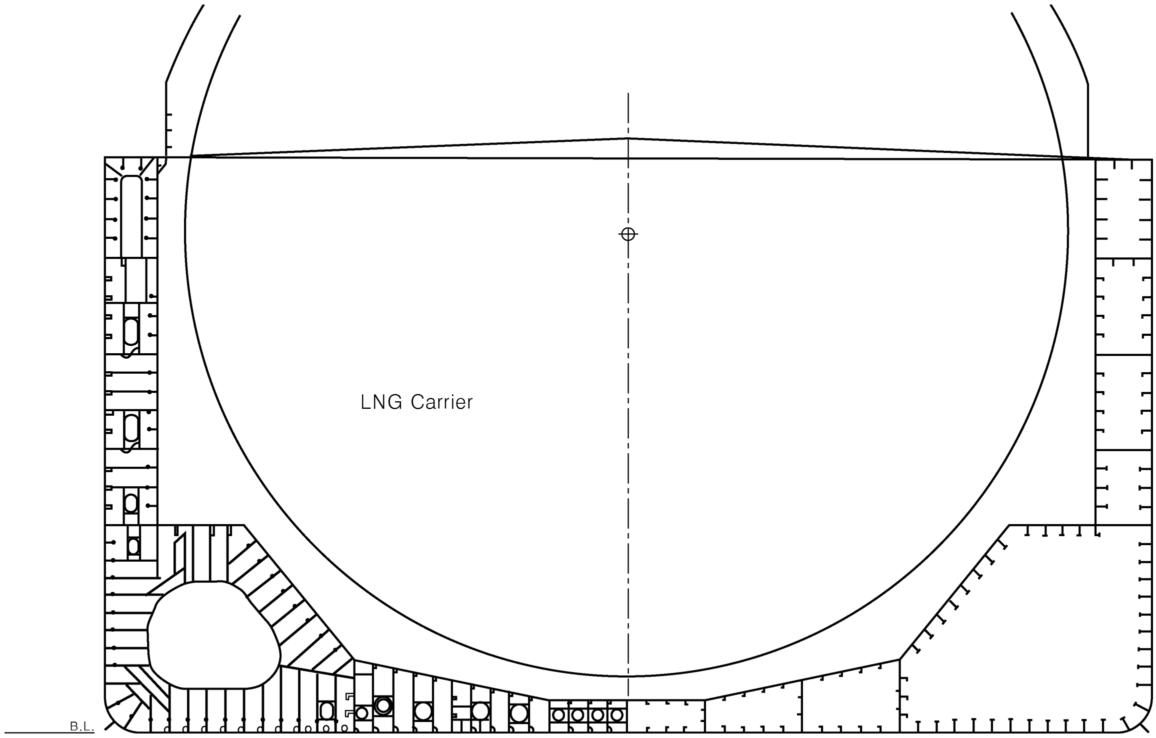


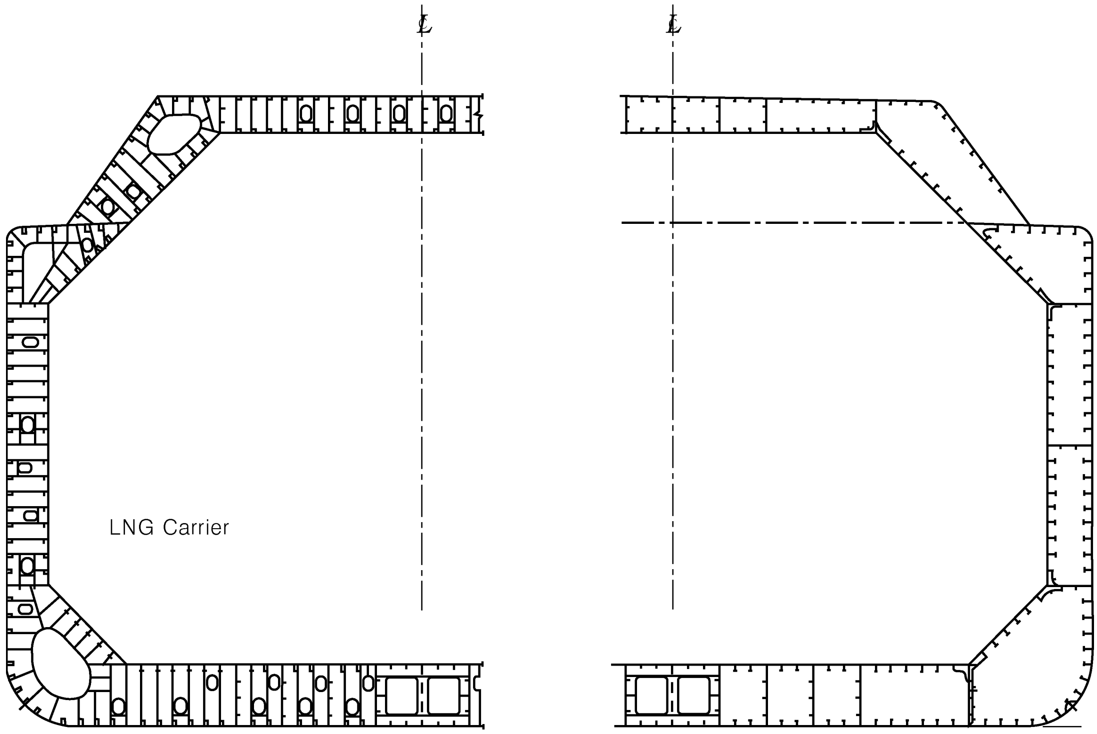


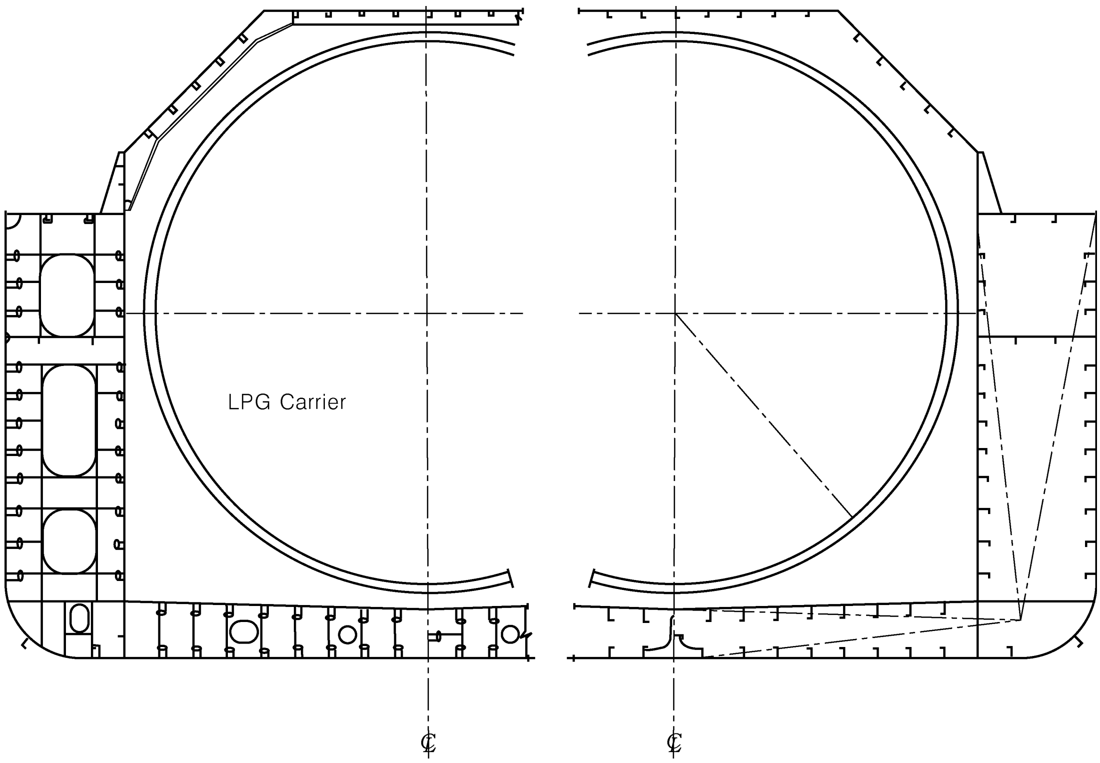


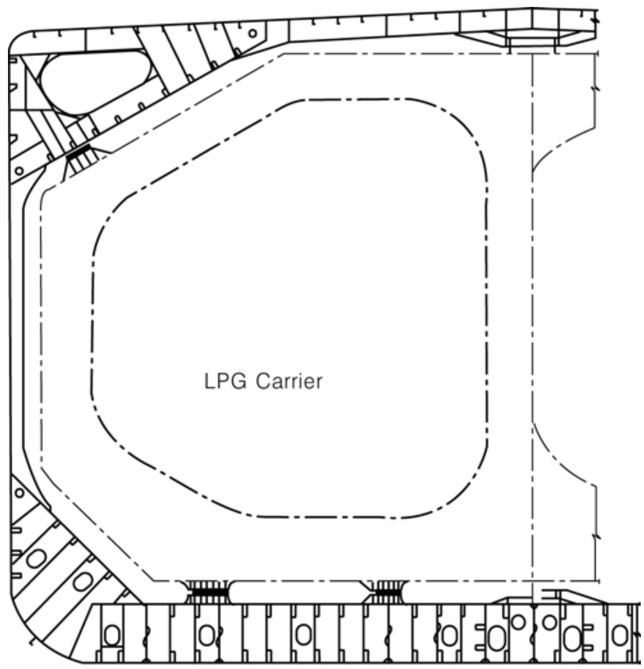
Note : (*1) through (*5) are as given in **Table 1.3.13** of the Rules

2. The typical midship sections of liquefied gas carriers specified in **Table 1.2.10** of the Rules are indicated on the diagrams as follows.






LPG Carrier
℄
℄


LPG Carrier

Annex 1-7 Continuous Machinery Survey Procedure(CMS)

1. Application of CMS

(1) Where the CMS system is intended to be applied, the Shipowner is to submit the "Application for CMS" including "CMS programme". The CMS system, in principle, is applied to machinery installation items of established type. However, the CMS system is not to be applied to non-propelled vessels unless special consideration is given by the Society. And the CMS programme is to be complied with the requirements as follows,
  (A) In principle, all items for CMS are to be included in the programme.
  (B) Consecutive survey intervals of each item are not to exceed 5 years and approximately one-fifth of all items are to be examined every year.
  (C) Preferably, open-up schedules of machinery installations are to be planned to enable the attending Surveyor to evaluate the condition of the whole system from the open-up results of any survey.
  (D) The CMS programme above may be replaced with reference to the ship's maintenance programme. In cases where the ship's maintenance programme is modified in the process of implementation, the CMS programme on board may be partially or wholly amended.

(2) On the basis of the "CMS Programme" submitted by the Shipowner, the Society is to prepare the CMS status, thereafter. the CMS status is to be forwarded from the Head Office to the Shipowner after the completion of CMS. The CMS up-date status is to be kept on board for reference by the attending Surveyor.

(3) Items covered by the CMS system are, in principle, those shown in **Table 1** of the Guidance.

(4) In principle, it is preferable to conduct the open-up survey of essential auxiliaries(normally provided in duplicate or more) alternately at similar intervals. However, the surveys of diesel engines driving generators and bilge pumps is to be conducted, as far as practicable, simultaneous with the Special Survey or Intermediate Survey.

(5) When defects are found on a part during survey, a thorough examination may be required on other similar parts of machinery installations despite the "CMS programme" schedule.

2. Confirmatory Survey for CMS inspected by the Chief Engineer

(1) Qualification of Chief Engineer
  (A) The Chief Engineer is to have sailing experience of at least 3 years as a chief engineer or be certified as a first-grade engineer by the relevant government and
  (B) The Chief Engineer has at least 1 year sailing experience on a ship installed with a similar type of propulsion engine(internal combustion engine or steam turbine for main propulsion).

(2) Where CMS permissible for the Chief Engineer's inspection are as given in **Table 2** were overhauled(or open up) at sea and inspected by the Chief Engineer in routine maintenance works, the inspections may be accepted for the CMS. Whenever such an inspection was carried out by the Chief Engineer during the ship's stay in port(where the attendance of the Society's Surveyor is not easily available), the same process as above is applicable.

(3) The confirmatory survey by the Surveyor, in principle, is to be carried out within 5 months of the day when the CMS were inspected by the Chief Engineer under the attending Surveyor as follows,
  (A) inspection of operational condition.
  (B) reviewing relevant details of the engine log book or maintenance record(e.g. acceptable computer outputs) and hears the Chief Engineer's opinion. If review of the relevant log book and checking of oil and oil filter conditions indicate they are in good working condition, these may substitute for the open up survey of machinery installations listed below. Substitute items are to be recorded in the survey report.
    (a) Oil pumps(excluding cargo oil pumps) and oil heaters
    (b) Hydraulic pumps and motors for deck machinery
    (c) Oil tanks (having a capacity of 1 m^3 or less)

(C) Reporting submitted by the Chief Engineer including following contents
(a) Signature and license number of the Chief Engineer
(b) Inspection date and place
(c) Inspection items and results.
(D) If necessary, the attending Surveyor may request the overhauling(or open-up) survey of relevant machinery according to the results of the Confirmatory Survey.

3. Unification of names and numbers for CMS items

(1) If there are items of CMS used for same purpose each ship, their names are to be unified in accordance with **Table 3**.
(2) For items of CMS used for same purpose are provided in duplicate or more on board, if their serial numbers are not assigned or uncertain, it is recommended for shipyard or shipowner to assign as belows, however, at existing ship the serial numbers of CMS are to be identified with ones attached to name plates or using name on board.
(A) Numbering from Starboard to Port
(B) Numbering from Fore to After.
(C) Numbering from Upper to Lower.
(3) In case ships not applied to the CMS, (2) above may be applied to.

Table 1 Items Covered by the CMS System

Items	Details
1. Main diesel engines	(a) Cylinder covers, cylinder liners, pistons (including piston pins and piston rods), crossheads (including pins, bearings and guides), connecting rods, crank shafts and bearings, camshafts and their driving gears, turbo chargers, scavenge air pumps or blowers, air intercoolers, attached essential pumps (bilge, lubricating oil, fuel oil and cooling water)
2. Main steam turbines	(a) Turbine rotors, blades, bearings, casings, nozzles, nozzle valves and maneuvering valves
3. Power transmission systems and shafting systems	(a) Reduction gears, reversing gears, clutches and flexible couplings (b) Intermediate shafts, thrust shafts and their bearings
4. Auxiliary engines	(a) Auxiliary engines driving generators (excluding emergency generators) or auxiliary essential machinery are to be handled in accordance with the requirements applicable to main engines.
5. Auxiliary machinery	(a) Air compressors and blowers: main and auxiliary starting air compressors (excluding those for emergency use), air compressors for control system, forced draft fans for main boilers, gas compressors and gas blowers (b) Pumps for essential uses: - Cooling fresh water pumps, cooling sea water pumps, fuel oil pumps and lubricating oil pumps for main and auxiliary engines - Fuel oil pumps, feed water pumps and water circulating pumps for main boilers - Feed water pumps and water circulating pumps for auxiliary boilers - Thermal oil pumps- Condensing pumps for main engine - Sea water service pumps - Lubricating oil pumps for reduction gears - Lubricating oil pumps for stern tubes - Hydraulic oil pumps for controllable pitch propellers - Hydraulic oil pumps for steering gears - Hydraulic oil pumps for windlass and mooring winches - Bilge pumps (excluding those for oil separators), ballast pumps and fire pumps (excluding emergency fire pumps) - Cargo oil pumps (including chemical pumps and liquefied gas pumps), stripping pumps, spray pumps and tank cleaning pumps (c) Windlass and mooring winches (d) Cargo refrigerating installations (excluding those for provision storage): compressors, pumps, evaporators and condensers (e) Fresh water generators for main boilers (f) Fuel oil heaters (excluding those for purifiers) and tank cleaning heaters (g) Condensers and feed water heaters (h) Coolers (excluding those for air compressors) (i) Inert gas systems (j) Air reservoirs (excluding those for emergency use) and other pressure vessels for essential uses (k) Fuel oil tanks not form a part of the ship's structure (l) Other items considered to be applicable under the CMS by the Society

Table 2 Machinery Permissible for the Chief Engineers Inspection, etc.

	Items	Remarks
Machinery permissible for the Chief Engineers inspection	1. Main diesel engine 2. Auxiliary diesel engine(Refer to remarks) 3. Forced draft fans & burning pumps for main boiler 4. Auxiliary machinery (1) Air compressor (2) Auxiliary blower (3) Pump (4) Heat exchanger (5) Portable fuel oil tank (6) Fresh water generator (7) Deck machinery (8) Hydraulic pumps of steering gears ※ However, for each part of the main internal combustion engine and internal combustion engine to drive main generator among machinery permissible for the Chief Engineer's inspection, open-up survey by the Surveyor for at least one of two CMS cycles is to be carried.	● The Chief Engineer's inspection for auxiliary diesel engines ● The engine is completely opened up and a careful examination is made on all cylinder units, cylinder liners, cylinder covers, cylinder cover valves, pistons, piston rings, connecting rods and top and lower bearings, piston pins, camshaft driving gears, turbo-chargers, air-intercoolers, crankcase and crankcase doors, engine foundation bolts, and crank case safety valves. ● The top halves of all main bearings are removed and two bottom halves are taken out for examination. ● An examination is made on all crankpins and journals to detect cracks, especially at fillet and areas in the vicinity of oil holes and crank shaft oil grooves. ● Crank web deflections are measured and recorded. ● Wear downs of the cylinder liners are measured and recorded. ● The L.O. cooler attached to the engine, L.O. pumps, cooling water pumps, etc. of direct driven-type are opened up and examined. ● Verify through performance tests that safety devices are in good operating condition. ● The service hours of crank pin bolts are checked and recorded.
Machinery impermissible for the Chief Engineers inspection	1. Crank shaft and its bearing of main engine, crank pin bolts and camshaft driven equipment(Refer to remarks) 2. Steam turbine (main, auxiliary, etc.) 3. Power transmission gear 4. Shafting arrangements 5. Air reservoir 6. Other items not applied to CMS by the Society (1) Refrigeration installations for provision storage (2) Electrical installations (3) Boiler (4) Cargo handling gears(cargo winch) (5) Spare parts (6) Emergency compressors, emergency air tank, emergency generators, emergency fire pumps, etc. (7) Steering gears (8) Other items not considered subject to CMS by the Society	● Measurement of crank web deflection for main diesel engine and check of foundation bolts

Table 3 Table for Unified Name of Machinery

* The following unified expressions will be used in the Society's CMS system for the machinery which has the same purpose but are variously named from ship to ship.

System	Unified name of machinery to be used in CMS system	Various names of machinery actually used in ships
Cooling Sea Water System	Main Cooling S.W. Pump	- Main Cooling S.W. Pump - Main Condenser Cooling S.W. Pump
	Reserve Cooling S.W. Pump	- Reserve Cooling S.W. Pump - Stand-by Cooling S.W. Pump
	A/E Cooling S.W. Pump	- A/E Cooling S.W. Pump - Aux. Machinery Cooling S.W. Pump - Aux. G/T Cooling S.W. Pump
	Aux. Condenser Cooling S.W. Pump	- Aux Condenser Cooling S.W. Pump - Dumping Condenser Cooling S.W. Pump - Vacuum Condenser Cooling S.W. Pump - Atmospheric Condenser Cooling S.W. Pump - Drain Cooler Cooling S.W. Pump
	M/E F.W. Generator(Cooling) S.W Pump	
	S.W. Circulating Pump	
	I.G.G Cooling Water Pump	
Sea Water Service System	S.W. Service Pump	
Cooling Fresh Water System	M/E Cooling F.W. Pump	- M/E Cooling F.W. Pump - Main Cooling F.W. Pump
	M/E Reserve Cooling F.W. Pump	- Reserve Cooling F.W. Pump - Cooling F.W. Service Pump
	Aux. Cooling F.W. Pump	- Aux Cooling F.W. Pump - Air Intercooler Cooling F.W. Pump - Turbo Charger Cooling F.W. Pump
	M/E Jacket Cooling F.W. Pump	
	M/E Piston Cooling F.W. Pump	
	Central Cooling F.W. Pump	
	A/E Cooling F.W. Pump	- A/E Cooling F.W. Pump - Harbour Cooling F.W. Pump
Fuel Oil System	M/E F.O.V. Cooling Pump	- M/E F.O.V. Cooling Pump - M/E F.O.V. Cooling F.W (or Oil) Pump
	A/E F.O.V. Cooling Pump	
	M/E F.O. Supply/Booster Pump	
	M/E F.O. Supply pump	- M/E F.O. Supply Pump - Main H.F.O. Supply pump - Main I.F.O. Supply pump - Main M.D.O. Supply pump - Reserve F.O. Supply pump - F.O. Feed pump - Res. F.O. Supply & F.O. Valve Cooling pump - F.O. Supply & F.O. Transfer pump - Stand-by F.O. Supply Pump
	M/E F.O. Booster Pump	
	M/E F.O. Service Pump	- M/E F.O. Service Pump - M/E C Oil Service Pump
	A/E F.O. Supply Pump	
	A/E F.O. Service Pump	- A/E F.O. Service Pump - A/E C Oil Service Pump

Table 3 Table for Unified Name of Machinery (Continued)

System	Unified name of machinery to be used in CMS system	Various names of machinery actually used in ships
Fuel Oil System (Cont'd)	D.O. Service Pump	- D.O. Service Pump - A Oil Service Pump
	F.O. Transfer Pump	- F.O. Transfer Pump - C Oil Transfer Pump - H.F.O. Transfer Pump - I.F.O. Transfer Pump - F.O. Shift Pump - F.O. Transfer & Shift Pump - H.F.O. & M.D.O. Transfer Pump
	D.O. Transfer Pump	- D.O. Transfer Pump - A Oil Transfer Pump - M.D.O. Transfer Pump
	M/E F.O. Circulating Pump	- F.O. Circulating Pump - F.O. Recycle Pump
	Main Boiler F.O. Service Pump	- Boiler F.O. Service Pump - Boiler F.O. Feed Pump - Boiler F.O. Supply Pump - Boiler F.O. Transfer Pump
	Main Boiler D.O. Service Pump	- Boiler D.O. Service Pump - Boiler D.O. Feed Pump - Boiler D.O. Supply Pump - Boiler D.O. Transfer Pump
	Main Boiler Burning Pump	- Boiler Burning Pump - Boiler Pilot Burner F.O. Pump
Lub. Oil System	M/E L.O. Pump	
	A/E L.O. Pump	- A/E L.O. Pump - A/E Reserve L.O. Pump - A/E L.O. Service Pump
	M/E Reserve L.O. Pump	- Reserve L.O. Pump - Aux. L.O. Pump - Stand-by L.O. Pump
	M/E L.O. Service Pump	- L.O. Service Pump - Rocker Arm L.O. Pump - Priming L.O. Pump
	M/E Crosshead L.O. Pump	
	M/E Camshaft L.O. Pump	
	M/E Piston rod Stuffing Box L.O. Pump	
	M/E Turbo-charger L.O. Pump	
	Reduction Gear L.O. Pump	
	L.O. Transfer Pump	- L.O. Transfer Pump - L.O. Shift Pump
	Stern Tube L.O. Pump	- Stern Tube L.O. Pump - Forward Seal Cooling L.O. Pump - After Seal Cooling L.O. Pump
	C.P.P. Hyd. Oil Pump	
Bilge System	Bilge Pump	- Bilge Pump - Aux. Bilge Pump - Bilge & Sanitary Pump - Bilge Transfer Pump

Table 3 Table for Unified Name of Machinery (Continued)

System	Unified name of machinery to be used in CMS system	Various names of machinery actually used in ships
Bilge System (Cont'd)	Fire & Bilge Pump	- Bilge & Fire Pump - Bilge, Fire & G.S. Pump - Bilge, Fire & Cooling S.W. Pump - Fire, G.S. & S.W. Service Pump - G.S. (& Fire) & Pump
	Bilge & Ballast (& Fire) Pump	- Bilge & Ballast Pump - Bilge, Ballast & Fire Pump - Bilge, Ballast (& Fire) & Cooling S.W. Pump
Ballast System	Ballast Pump	- Ballast Pump - Ballast & Cooling S.W. Pump - Ballast & G.S. Pump - Ballast & S.W. Service Pump
	Stripping Pump	
	Heeling Pump	- Heeling Pump - Heeling & Trimming Pump
Feed Water System	Main Boiler Feed Water Pump	- Main Boiler Feed Water Pump - Exh. Gas Boiler Feed Water Pump - Exh. Gas Economizer Feed Water Pump - L.P. Steam Generator Feed Water Pump
	Aux. Boiler Feed Water Circulating Pump	- Aux. Boiler Feed Water Pump - Aux. Exh. Gas Economizer Feed Water Pump - Aux. L.P. Steam Generator Feed Water Pump
	Main Boiler Water Circulating Pump	- Main Boiler Water Circulating Pump - Exh. Gas Boiler Water Circulating Pump - Exh. Gas Economizer Water Circulating Pump - Hot Water Circulating Pump
	Aux. Boiler Water Circulating Pump	- Aux. Boiler Water Circulating Pump - Aux. Exh. Gas Boiler Water Circulating Pump - Aux. Exh. Gas Economizer Water Circulating Pump - Hot Water Circulating Pump
	Main Condensate Pump	
	Condensate Pump for Aux. Turbine	
	Reserve Condensate Pump	- Reserve Condensate Pump - Aux. Condensate Pump - Condensate & Drain Transfer Pump
	Dump drain Transfer Pump	
	Condenser Circulating Pump	- Condenser Circulating Pump - Vacuum Condenser Circulating Pump - Atmospheric Condenser Circulating Pump - Drain Cooler Circulating Pump - Aux. Condenser Circulating Pump
Fresh Water System	F.W. Generator for Main Boiler	
Air System	Main Air Compressor	- Main Air Compressor - Main Engine Starting Air Compressor
	Reserve Air Compressor	- Aux. Air Compressor - Working Air Compressor - Topping up Air Compressor - Instrument Air Compressor - Reserve Air Compressor
	Control Air Compressor	

Table 3 Table for Unified Name of Machinery (Continued)

System	Unified name of machinery to be used in CMS system	Various names of machinery actually used in ships
Fresh Water Cooler	M/E Main Cooling F.W. Cooler	- M/E Main Cooling F.W. Cooler - Central F.W. Cooler
	M/E Jacket Cooling F.W. Cooler	
	M/E Piston Cooling F.W. Cooler	
	A/E F.O.V. Cooling F.W. Cooler	- F.O.V. F.W. Cooler - Fuel Valve & Turbo Charger F.W. Cooler - F.O.V. & Exh. V. Cooling F.W. Cooler
	A/E F.O.V. Cooling F.W. Cooler	
	A/E Cooling F.W. Cooler	
	A/E Turbo-charger Cooling F.W. Cooler	
	Exh. Valve Cooling F.W. Cooler	
	F.W. Cooler for Air Compressor	
Oil Cooler	M/E F.O.V. Cooling Oil Cooler	
	A/E F.O.V. Cooling Oil Cooler	
	M/E L.O. Cooler	- M/E L.O. Cooler - Main Turbine L.O. Cooler
	A/E L.O. Cooler	- A/E L.O. Cooler - Aux. Turbine L.O. Cooler
	M/E Turbo-charger L.O. Cooler	
	A/E Turbo-charger L.O. Cooler	
	Stern Tube L.O. Cooler	
	Reduction Gear L.O. Cooler	
	M/E Camshaft L.O. Cooler	
	C.P.P. Hyd. Oil Cooler	
Feed Water Cooler	Aux. Turbine Condenser	- Aux. Turbine Condenser - G/T Condenser
	Atmospheric Condenser	- Aux. Atmospheric Condenser - Aux. Condenser - Aux. Condenser & Drain Cooler
	Vacuum Condenser	- Vacuum Condenser
	Dump Condenser	- Dump Condenser
	Drain Cooler	- Drain Cooler - Oil Heating Drain Cooler
	Main Condenser	
Oil Heater	M/E F.O. Heater	
	A/E F.O. Heater	
	Main Boiler F.O. Heater	- Boiler F.O. Heater (Steam) - Boiler F.O. Heater (Electric)
	Aux. Boiler F.O. Heater	
Thermal Oil Heater	Thermal Oil Heater	
Feed Water Heater	Main Boiler Feed Water Heater	
	Aux. Boiler Feed Water Heater	- Aux. Feed Water Heater - Aux. Boiler Feed Water Heater
	Deaerator	- Deaerator
	Deaerating Feed Water Heater	- Deaerating Feed Water Heater
L.P. Feed Water Heater	1st Feed Water Heater	
	2nd Feed Water Heater	
	3rd Feed Water Heater	
	4th Feed Water Heater	

Table 3 Table for Unified Name of Machinery (Continued)

System	Unified name of machinery to be used in CMS system	Various names of machinery actually used in ships
Fresh Water Heater	Hot Water Heater	- Hot Water Heater - Calorifier
	Main Engine F.W. Heater	
Other Heat Exchanger	F.W. Generator for Main Boiler	
	Refrigerator Condenser	
Air Reservoir	Main Air Reservoir	- Main Air Reservoir - Main Engine Starting Air Reservoir
	A/E Air Reservoir	- Aux. Air Reservoir - Working Air Reservoir - Aux. Engine Starting Air Reservoir - Cargo Pump Engine Starting Air Reservoir - Em'cy Air Reservoir
	Service Air Reservoir	
	Control Air Reservoir	
F.O. Tank	M/E F.O. Settling Tank	- M/E F.O. Settling Tank - M/E H.F.O. Settling Tank - M/E I.F.O. Settling Tank - M/E M.D.O. Settling Tank
	M/E F.O. Service Tank	- M/E F.O. Service Tank - M/E H.F.O. Service Tank - M/E I.F.O. Service Tank - M/E M.D.O. Service Tank
	A/E F.O. Settling Tank	- A/E F.O. Settling Tank - A/E A Oil Settling Tank
	A/E F.O. Service Tank	- A/E F.O. Service Tank - A/E A Oil Service Tank - A/E F.O. Tank
	Boiler F.O. Settling Tank	- Boiler F.O. Settling Tank - Boiler H.F.O. Settling Tank - Boiler M.D.O. Settling Tank
	Boiler F.O. Service Tank	- Boiler F.O. Service Tank - Boiler H.F.O. Service Tank - Boiler M.D.O. Service Tank
	D.O. Settling Tank	
	D.O. Service Tank	
Cargo System	Cargo Pump	- Cargo (Oil) Pump - Cargo Pump (Motor) - Aux. Cargo Pump - Cargo & Ballast Pump
	Stripping Pump	
	Spray Pump	
Pump in Pump Room	Ballast Pump in Pump Room	
	Clean Ballast Pump in Pump Room	
	Ballast Pump in FWD. Pump Room(or F'CLE)	- Ballast Pump in FWD. Pump Room - Ballast Pump in F'CLE
	Bilge Pump	
	S.W. Service Pump	

Table 3 Table for Unified Name of Machinery (Continued)

System	Unified name of machinery to be used in CMS system	Various names of machinery actually used in ships
Tank Cleaning System	Tank Cleaning Pump	- Tank Cleaning Pump - Butterworth Pump - Tank Cleaning & Fire Pump - Butterworth & Tank Cleaning Pump - Tank Cleaning & Bilge, Fire, (G.S.) Pump - Butterworth & Bilge, Fire, (G.S.) Pump
	Tank Cleaning Heater	- Tank Cleaning Heater - Butterworth heater
	Tank Cleaning Drain Cooler	- Tank Cleaning Drain Cooler - Butterworth Drain Cooler
Other Machinery in Pump Room	Ventilation Fan	
Deck Machinery	Hyd. Pump for Steering Gear	
	Windlass	
	Mooring Winch	- Mooring Winch - Auto Tension Winch
	Hyd. Pump for Deck Machinery	
	Capstan	
Cargo Refrigerating Machinery	Compressor	
	Condenser Cooling Pump	- Condenser Cooling Pump - Ref. Cooling S.W. (or F.W.) Pump - Ref. & Aux. Cooling S.W. (or F.W.) Pump
	Brine Pump	
	Refrigerant Pump	
	Condenser	
	Evaporator	
	Evaporator Cooling S.W. Pump	
Machinery for Gas Carrier	Gas Compressor	
	High Duty Compressor	
	Low Duty Compressor	
	Vacuum Pump	
	Main Vaporizer	
	Forced Vaporizer	
	Boil-off/Warm-up Heater	
	Vent Gas Heater	
	N2 Generator Unit	
	N2 Buffer Tank	
	Inert Gas Generator	
	Cargo Heating Drain Cooler	
	Glycol Water Steam Heater	
	Glycol Water Electric Heater	
	Glycol Water Circulating pump	

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Annex 1-8 Planned Maintenance System Procedure(PMS)

1. General

(1) At the request of Owner, PMS is to be approved by the Society in accordance with **Fig 1** and Information and Documents given in **Table 1** including the following items are to be submitted.
  (A) organization chart identifying areas of responsibility
  (B) documentation filling procedures
  (C) listing of equipment to be considered by the Society in PMS
  (D) machinery identification procedure
  (E) preventing maintenance sheets for each machine to be considered
  (F) listing and specifications of condition monitoring equipment
  (G) baseline data for equipment with condition monitoring,
  (H) listing and schedule of preventive maintenance procedure.
(2) In addition to the above documentation the following information shall be available on board:
  (A) the above (1) in an up-to-date fashion
  (B) maintenance inspection(manufacturer's and shipyard's)
  (C) condition monitoring data including all data since last opening of the machine and the original base line data
  (D) reference documentation (trend investigation procedure etc.)
  (E) records of maintenance including repairs and renewals carried out.
(3) An annual report covering the year's service, including the following information, shall be reviewed by the Society:
  (A) clauses (1) (C), (D), (E) and (G) as well as changes to other clause in the above (1)
  (B) clause (2) (C)
  (C) full trend analysis(including spectrum analysis for vibrations) of machinery displaying operating parameters exceeding acceptable tolerances.
(4) In general, the intervals for PMS shall not exceed those specified for CMS. However, for components where the maintenance is based on running hours longer intervals may be accepted as long as the intervals are based on the manufacturer's recommendations. However, if an approved condition monitoring system is in effect, the machinery survey intervals based on CMS cycle period may be extended
(5) The PMS shall be programmed and maintained by a computerized system. However, this may not be applied to the current already approved schemes. Computerized systems shall include back-up devices, such as disks/tapes, CDs, which are to be updated at regular intervals.

2. Chief Engineer's responsibility of PMS.

(1) Where a chief engineer is entitled to be complied with the following requirements, the Society is to issue the Chief Engineer Qualification Certificate.
  (A) First-grade licence issued in the relevant nation is to be provided.
  (B) To be recommended by the shipowner(or ship management company) and approved by the Society.
(2) The chief engineer shall be the responsible person on board in charge of the PMS.
(3) Documentation on overhauls of items covered by the PMS shall be reported and signed by the chief engineer.
(4) Access to computerized systems for updating of the maintenance documentation and maintenance program shall only be permitted by the chief engineer or other authorized person.
(5) PMS items to be maintained by Chief Engineer is to be complied with **Table 2** and to be retained on board the overhauled(or opened up) records. However, PMS items not permitted by Chief Engineer's records in **Table 2** are to be surveyed under the attending surveyor as far as practicable at Annual Survey. In single main diesel engine, where vibration characteristics indicating that there is no danger of damage from uneven explosions are to be retained on board and where operating parameters of **Table 3** are monitored, main crank shafts and their bearings may be maintained by the chief engineer subject to complying with the following inspection under the Surveyor.
  (A) review condition monitoring records(**Table 3** Machinery Operating Parameter to be monitored for condition based survey)

(B) review measurement records for weardown of main bearings or bearing clearance and crank web deflection. If necessary, to measure crank web deflection or bearing clearance under the attending Surveyor.
(C) examine white metal debris in the crankcase.
(D) in case of a built-up crank shaft, examine turn-circle mark of shrinkage fitting parts and verify that there is no movement.
(E) examine cracks inside and outside of bedplate and especially cross members
(F) hear the chief engineer's view about crank pins, journals and bearings.

3. Condition monitoring system(CM)

(1) When it is ascertained that the ship under the approved PMS has been installed with condition monitoring system, the inspection for the following items has been confirmed by the Surveyor at the periodical survey, the overhaul(or open-up) intervals on the PMS may be extended. However, the (B) below are to be submitted to the Surveyor.
(A) Conditions and functions of condition monitoring equipment.
(B) Measurements and analysis results obtained from condition monitoring equipment for each machine to be considered.(Refer to **Table 3**)
(C) Operating condition of each equipment
(2) Where the measurements and analysis results obtained from the previous paragraph are to be reviewed and they are found in unsatisfactory by the Surveyor, overhauling(or opening up) examination may be requested.
(3) The Implementation Survey after installation of the condition monitoring system is to be carried out.

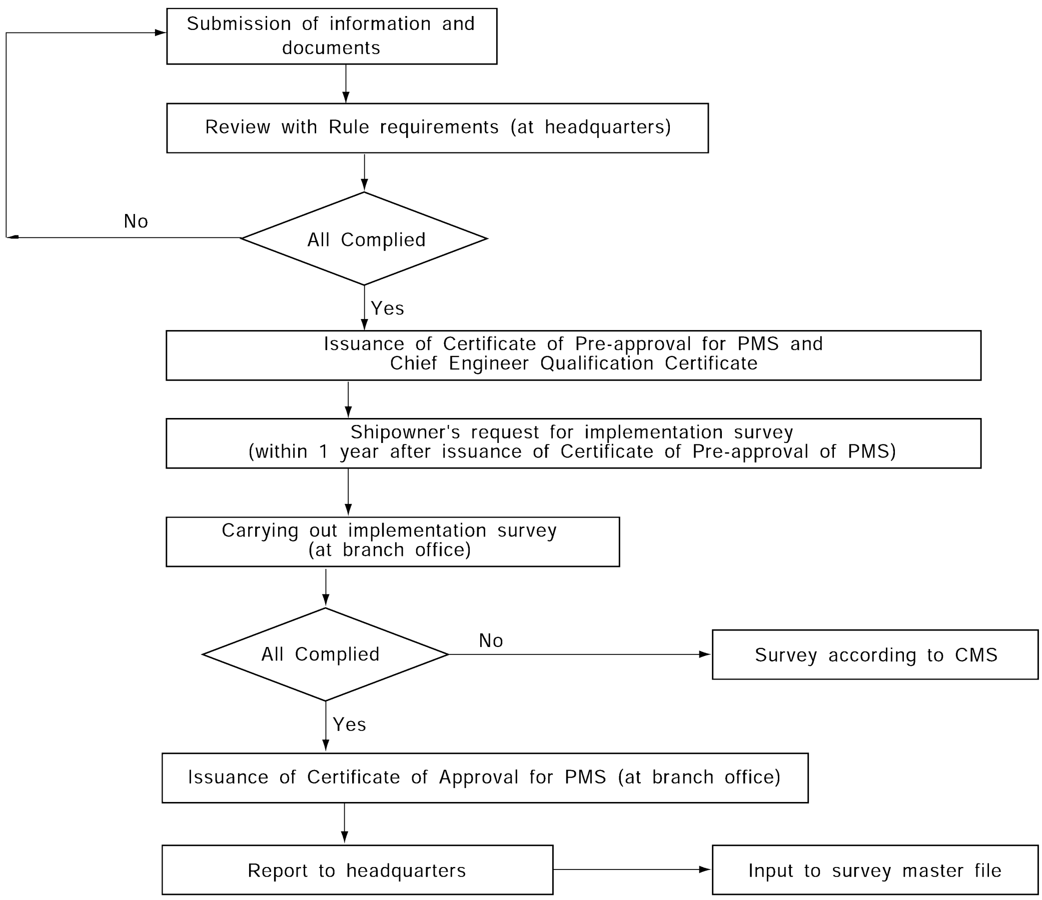

Fig 1 Flow chart for approval procedures

Table 1 Information and Documents to be submitted

Name and content	Remarks
(1) Machinery inventory content: Listing of machinery subjected to maintenance, and index or code for each machinery.	● Unify classification nomenclature for machinery to use the same names as far as possible. ● machinery index or code and CMS code. ● Identify and mark items not permitted by the chief engineer.
(2) Maintenance schedule: (A) It is to be stated for PMS of each item of machinery as follows: - Identification of overhaul survey, kind of inspection and test and content of measurement record - Intervals of overhaul survey, inspection and measurement (B) It is to be stated for CM as follows: - Layout of CM, maker, model and specification of CM equipment - Measuring points, names of measuring instruments and measuring parameters for each machinery - Intervals of measurement for each machinery - Acceptable limits for monitored condition for each machinery - Examples of input and output data	● To be satisfied the Rules requirements for overhaul survey, inspection, measurement, etc. of all machinery. ● To be overhauled with period not to exceed 5 year ● To be confirmed that quantity of machinery to be surveyed every year is not less than about 20 % of machinery covered by PMS. ● To be reviewed CM layout and feasibility of measuring parameters. ● To be sure that output format is easily recognizable by the chief engineer. ● To be reviewed the feasibility of acceptable limit.
(3) Reporting system: (A) To be stated in the program as follows: - Records of maintenance and repairs - Spare parts (B) A regular reporting system between the ship and the supporting land department of the ship company is to be stated.	● Ease in confirming that all reporting and recording procedures are carried out exactly.
(4) Documents for qualification requirements of the chief engineer: (A) Copy of chief engineer's licence (B) Chief engineer's resume	● To be satisfied with the requirements of chief engineer's qualification.

Table 2. Machinery with permission of maintenance by the chief engineer in PMS

System	Machinery with permission of maintenance by the chief engineer under a PMS	Not permission of maintenance by the chief engineer but subject to the attending Surveyor.
Main diesel engines	1. Cylinder covers 2. Valves and valve gears 3. Cylinder blocks and liners 4. Pistons and piston rods 5. Connecting rods, crossheads, top end bearings, guides, gudgeon pins and bushes 6. Crankshafts and bearings - single engine provided with CM equipment is surveyed in accordance with **Annex 1-8, 2** (5) of the Guidance satisfactorily in attendance of the Surveyor during the survey period only. - multiple engine 7. Scavenge pumps, blowers and air coolers 8. Camshafts and camshaft drives	1. Crankshafts and bearings - single engine except that the chief engineer's maintenance items in the left column. 2. Relief devices(Crankcase, scavenging air chamber, camshaft driving gear room, etc.) 3. Engine trial 4. Holding down bolts and chocks
Main Turbines	Casings, rotors, blades, bearing, nozzle, nozzle valve and control valve - with CM equipment whose monitoring of operating parameters and vibration measurement is found in satisfactory under the attending Surveyor only.	1. Holding down bolts and chocks 2. In case without CM equipment, it is to be surveyed after opening the top casing of turbine.
Auxiliary Engines	Auxiliary engines, auxiliary steam turbines and their associated coolers and pumps. - But, where those are used for driving generator, only in case that power can be supplied by at least the other 1 set to essential auxiliaries necessary for propulsion and safety of ship and cooling of refrigerated cargo, in case where any 2 sets do not work(for example; where 1 set is stand-by during the period of 1 set maintenance).	Auxiliary internal combustion engines or auxiliary steam turbines driving generators - In case of satisfying conditions in the left column, the chief engineer's maintenance may be permitted.
Shafting	1. Intermediate shafts and bearings 2. Thrust shafts and bearing(except solid type with crankshaft)	1. Reduction/increase gearing 2. Flexible couplings and clutches 3. Thrust shafts and bearing(solid type with crankshaft)
Remote Control and Automation System	Records for malfunction, abnormal alarms, etc., are to be made and submitted to the Society.	1. Main engine control system for bridge, centralized or automatic controls 2. Requirements for centralized controls or unattended machinery automations
Pressure vessels and auxiliaries	1. Pumps attached to main engine(bilge, L.O., F.O. and cooling water) 2. Independently driven pumps(bilge, ballast, F.W. cooling, S.W. cooling, L.O. and F.O. transfer) 3. Coolers and condensers (F.W. and L.O. coolers for main engine, main and auxiliary condensers and drain coolers) 4. Heaters(F.O., L.O. and feed water) 5. Other auxiliaries(air compressors including safety devices, windlasses, mooring winches, forced or induced draft fans and Independent F.O. tanks)	1. First start arrangement trial 2. All pressure vessels 3. Piping arrangements: steam pipes, sea connections and valves, maneuvering valves, bulkhead stop valves, bilge check-stop valves (including foot valves) 4. Steering gear 5. Electrical equipment Others
Others	IGS(scrubber units, blowers, independent gas generating units)	IGS(all components for inert gas system except for items covered by the chief engineer's maintenance)

Table 3. Machinery Operating Parameter for Condition monitoring System

Items	Operating Parameter
Main Diesel Engine	1. Shaft horse power 2. Engine and Shaft RPM 3. Cylinder pressure-time curves 4. Oil fuel injection pressure-time curves 5. Oil fuel temperature or viscosity 6. Charge air pressure 7. Exhaust gas temperatures 8. Engine cooling systems, temperatures and pressures 9. Engine lubricating oil system, temperatures and pressures 10. Turbo-charger RPM and vibration 11. Lubricating oil analysis data 12. Crankshaft deflections 13. Main bearing temperatures
Main Steam Turbine	1. Turbine rotor vibration 2. Turbine rotor axial displacement 3. Shaft horsepower 4. Shaft and turbine rotor FPM 5. Performance data; (1) Steam conditions at inlet and outlet of each turbine (2) Boiler performance data (3) Condenser vacuum (4) Sea temperatures (5) Steam conditions of other major steam consuming auxiliaries
Auxiliary Steam Turbine	Same as main steam turbine
Auxiliary Diesel Engine	1. Exhaust gas temperatures 2. Engine cooling systems temperatures and pressures 3. Engine L.O. system; temperatures and pressures 4. Turbo-charger RPM and vibration 5. Lub. oil analysis data 6. Crankshaft deflections
Auxiliaries	1. Cooler efficiency, inlet and outlet temperatures 2. Heater temperatures 3. Pumps and fans; vibration and performance 4. Differential pressure across filters

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Annex 1-9 Guidance for Survey of Waterjet Propulsion Systems and Azimuth or Rotatable Thruster

1. The surveys for waterjet propulsion systems and azimuth or rotatable thruster are to comply with the following requirements.

(1) Waterjet propulsion systems

(A) Annual Surveys

At each Annual Survey, the following surveys and inspections are to be carried out.

(a) General inspection of the propulsion system
(b) Verification test of steering performance
(c) Operation test of the reverser
(d) General inspection of impeller

(B) Intermediate Surveys

At each Intermediate Survey, in addition to the all requirements for Annual Survey, the surveys and inspections are to be carried out as deemed necessary by the Surveyor.

(C) Special Surveys

At each Special Survey, in addition to the all requirements for Intermediate Survey, open-up inspections for major part of the hydraulic pump are to be carried.

(D) Docking Surveys

At each Docking Survey, the following surveys and inspections are to be carried out.

(a) The wearing condition of the bearing is to be verified with means deemed appropriate by the Society.
(b) General inspection of the forward sealing device
(c) General inspection of the impeller
(d) Deflector and reverser are to be inspected.

(E) Main Shaft Surveys

(a) General inspection of the main shaft and coupling bolts
(b) General inspection of the major parts of the forward and after main shaft bearings
(c) General inspection of the major parts of the forward main shaft sealing assembly
(d) Open-up inspection for thrust bearing
(e) Inspection of the contact faces of the impeller boss and main shaft(when installed with key and spline)
(f) General inspection of the impeller

(2) Azimuth or rotatable thruster

(A) Periodical Surveys and Docking Surveys

The relevant provisions for propeller shaft, propeller, steering gear and stern tube sealing device specified in **Ch 2, Sec 2** through **Sec 7** of the Rules are to be applied with the necessary modifications.

(B) Shaft Surveys and Gear unit open-up Surveys

Inspections and surveys specified in the following (a) through (b) are to be carried out.

(a) Open-up inspection for propeller shaft sealing device
(b) Efficient crack detection specified in **Ch 2, 702. 1** through **5** of the Rules
(c) General examination for each bearing
(d) Open-up inspection for gear unit

2. For the items which are not specified in **Par 1** above, the relevant provisions for propeller shaft, propeller, steering gear and stern tube sealing device specified in **Ch 2, Sec 2** through **Sec 7** of the Rules, are to be applied with the necessary modifications. ⚓

Annex 1-10 Loading Instrument on Stability

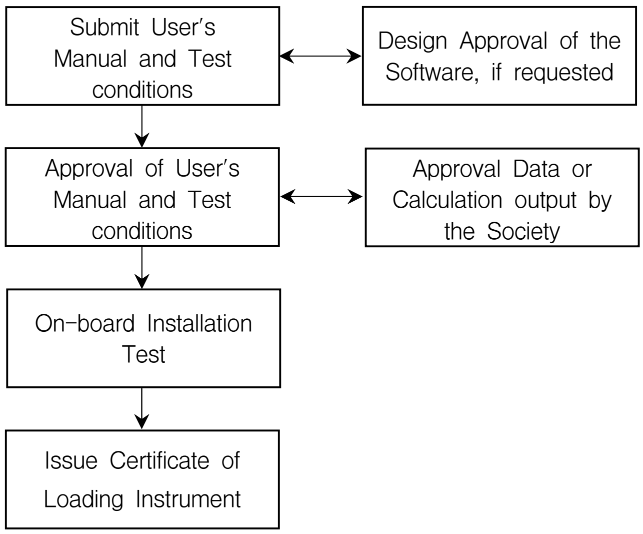
1. Application

(1) This requirement applies to ships having a length exceeding 24 metres when a loading instrument with a stability computation capability(hereinafter called "loading instrument on stability") is installed on a new ship or newly installed on an existing ship in accordance with the requirement in **Ch 1, 307.** of the Rules.

(2) For the purpose of this requirements, "new ship" means a ship for which the application for Classification Survey during Construction is made on or after 1 January 1997 and "existing ship" means a ship for the application for Classification Survey during Construction before 1 January 1997.

2. Approval procedure

(1) The procedure for approval of a loading instrument on stability is as illustrated in **Fig 1.**



* The approval of the software should be carried out in accordance with "**Guidance for Approval of Manufacturing Process and Type Approval, Etc.**"

Fig 1 Procedure for the approval of loading instrument on stability for a specific ship.

(A) User's operations manual and 3 copies of test conditions are to be submitted to Head Office. The loading instrument on stability may be approved provisionally if the stability information booklet is approved provisionally. A provisional certificate may be issued after on-board installation in this case.

(B) The requirements which are checked during approval of the user's operation manual and test conditions are as follows:
- the output of the loading instrument for the exampled test conditions are correct.
- the technical contents and forms of the user's operations manual is appropriate.

(2) Where the loading instrument on stability is intended for office use on shore(in such case it may be used for stability calculations for several different ships), this is acceptable provided that:
- the procedure in this appendix has been satisfactorily completed.
- the user's operations manual and test conditions have been approved for each of ships for which the instrument is used.
- operational performance of the hardware is to be tested but environmental testing is not normally required.
- the installation test is to be carried out and a certificate is issued if found appropriate.

3. Software for a specific ship

(1) General

(A) In order to apply the design approved software to a specific ship, details of the test conditions prepared using all relevant data used by the ship designer concerning hull form definition and compartment definition is to be submitted.

(B) The calculation result should include at least 4 test loading conditions covering the anticipated loading draughts, i.e. a maximum loading draught, a light condition draught and two intermediate draughts. In order for the Society to check the correctness of the calculation, the test conditions should be the same as presented in the stability information booklet submitted for approval. All test loading conditions must show all deadweight items and information on the free surface effect for each deadweight item.

(C) The drawings and data required to be submitted by (2) and (3) below need not be submitted if these are same that were submitted by the designers, etc.

(2) Intact Stability

(A) In order to the Society to verify the data submitted, the following information must be submitted:

- details of hull form definition, e.g., lines plans and/or offset tables, including all appendages.
- hydrostatic particulars including cross curve data
- details of compartment definition including list of volumes, center of gravity and free surface data
- details of position of down-flooding points.
- details of the relevant requirements and criteria against which the calculations must show compliance
- hard copy of output of results

(B) Hard copies of the full results for all test loading conditions are compared with the Society's calculation result(or approved stability information booklet) and the hard copies should include displacement, draughts, trim, VCG, LCG, GM, free surface correction and angle of down flooding.

The residual GZ distribution in curvilinear or tabulated form, is also to be produced for each case showing compliance with intact stability criteria.

(C) Hydrostatic and intact stability characteristics of the hull form and for each test loading condition produced by the software is to be checked against those derived by the Society's programs(or approved stability information booklet).

Characteristics to be checked will include:

- hydrostatic properties for full range of service draughts
- cross curves of stability embracing full range of service displacements
- properties of fully complied test loading conditions
- compliance with intact stability criteria
- relevant limiting $KG/GM/DWT$ values for full range of service draughts where appropriate

(3) Grain stability

(A) In addition to the documentation as specified in preceding (2) (A), the following should also be submitted for the assessment of grain stability calculations.

- Cargo hold drawings showing the structure abreast and beyond hatched including details of hatch end beams with feeding holes, if fitted
- Hatch cover details
- Details of longitudinal divisions, if applicable
- Details of the relevant regulations and criteria against which the calculation must show compliance, e.g., International Grain Code in addition to relevant intact stability criteria
- Hard copy of output of results

(B) Hard copies of the full results for all test loading conditions are to be submitted so that detailed comparisons may be made with the results from the Society's loading instrument program(or approved grain stability booklet). The output is to be include displacement, draughts, trim, VCG, LCG, GM, free surface correction, angle of down flooding, grain heeling moments and maximum allowable grain heeling moment. The residual GZ distribution, curvilinear or tabulated form, is also to be produced for each case showing compliance with intact and grain stability criteria.

(C) The results for each test condition produced by the software will be checked against those derived by the Society's programs(or approved grain stability booklet). The information to be assessed will include:
- curves or tables of grain heeling moments for every compartments, filled or partly filled, including the effects of temporary fittings
- tables of maximum permissible heeling moments or other information demonstrating compliance with the relevant requirements.

4. User's operations manual

(1) User's operations manual approved by the Society is to be provided for the loading instrument on stability. This manual should contain operating instructions for all stability calculations made by the loading instrument.

(2) The user's operations manual must be in a language readily understood by the users.
A English version, if not written in English language, should be provided if the ship on which the instrument is installed is engaged in the international voyage.

(3) The manual should contain general description of the stability software together with a full description of the operational procedure for stability calculations. In this connection, there should be a list of all terms, definitions, error messages and warnings likely to be encountered by the user.
In the case of error messages and warnings, there should be unambiguous user instructions for subsequent action to be taken in each case.

(4) In addition to the above, the following items should also be included in the user's operations manual.
- Lightship weight and co-ordinates of center of gravity
- Full deadweight description of each test loading condition
- Details of applicable Codes/Conventions, including limiting values etc.
- An example of a non-standard calculation well supported by illustrations and sample instrument output
- Hard copy of the results of each test loading condition
- Details of the frequency of testing of the instrument(The loading instrument with a stability computation capability should be handled by qualified personnel fully familiar with the instrument and it is recommended that the correct functioning of the instrument be verified by the ship's master at frequent intervals using the approved test conditions)
- Details of contingency measures in case of power failure
- Example printouts of every possible screen display, complete with explanatory text, to ensure that the user does not encounter any unfamiliar output

(5) In addition to the above, if the instrument performs also strength calculations, the manual should contain permissible values for still water bending moments and shear force and, if applicable, permissible local load for hatch covers, deck and double bottom structure, etc. ⚓

Annex 1-11 Procedural Requirements for Service Suppliers

1. General

The requirements in this Annex apply to assessment and approval of a service supplier(hereinafter referred to as the "supplier") who intends to supply a service (repairs, maintenance, inspection, tests, and measurements for survey) for a ship or mobile offshore (hereinafter referred to as the "ship") to be classed or have been classed to the Society and machinery, materials, etc (hereinafter referred to as the "products") which will be used on that ship.

(1) Firms engaged in thickness measurements on ships(except non-ESP ships less than 500 gross tonnage and all fishing vessels, and the separate requirements specified by the Society are to be applied to these ships)
(2) Firms engaged in tightness testing of hatches with ultrasonic equipment
(3) Firms carrying out in-water survey of ships and mobile offshore units
(4) Firms engaged in the examination of Ro-Ro ships bow, stern, side and inner doors
(5) Firms engaged in testing of coating systems in accordance with IMO Res.MSC.215(82) (Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Type of Ships and Double-side Skin Spaces of Bulk Carriers) and IACS PR34 (IACS Procedural Requirement on Application of the IMO Performance Standard for Protective Coatings(PSPC), Res.MSC.215(82), under IACS Common Structural Rules for Bulk Carriers and Oil Tankers)
(6) Other service firms

2. Procedure for approval and certification

(1) Document submission : The supplier is to submit a copy of the application together with two copies of each following data to the Society.
  (A) Quality manual and/or documentary procedure covering following requirements:
    (a) Code of conduct for the relevant activity
    (b) Maintenance and calibration of equipment
    (c) Training programmes for personnel(operators/technicians/inspectors)
    (d) Supervision and verification to ensure compliance with operational procedures
    (e) Recording and reporting of information
    (f) Quality management of subsidiaries and agents
    (g) Job preparation
    (h) Periodic review of work process procedures, complaints, corrective actions and issuance, maintenance and control of documents
    (i) A documented quality system in compliance with the most current version of (KS A)ISO 9000 series and including the above items, (a) to (h), would be considered acceptable.
  (B) Outline of company(e.g. organization and management structure including subsidiaries to be included in the approval/certification)
  (C) List of nominated agents, if any
  (D) Experience of the company in the specific service area, if any
  (E) List of personnel documented training and experience within the relevant service area, and qualifications according to recognised national, international or industry standards, as relevant
  (F) Description of equipment used for the particular service for which approval is sought and a guide for operators of such equipment
  (G) Check lists and record formats of the Society for reporting results of the services
  (H) Evidence of approval/acceptance by other bodies or other class, if any
  (I) Information on the other activities which may present a conflict of interest, if any
  (J) Record of customer claims and of corrective actions requested by certification bodies, if any
  (K) Where relevant, list and documentation of licenses granted by equipment's manufacturer
  (L) Other data deemed necessary by the Society for the approval

(2) Review and audit
(A) Documentation assessment
In the documentation assessment, the data submitted are investigated to confirm that the documents are in conformity with the requirements in **Par 2** (1) above.
(B) Field assessment
(a) Upon satisfactory outcome of the assessment of the documentation, a visit is made to evaluate the supplier's workshop(laboratory. etc.) and to verify the followings
(i) The supplier is duly organised and managed in accordance with the submitted documents.
(ii) It is considered in conformity with requirements in **Par 3, 4** & **5** and capable of conducting the services for which approval/certification is sought.
(b) When parts of services are produced by subcontractors, the Society may request the assessment of them for the purpose of confirming their Quality Control Standard.
(c) When an external person takes part in a service relating to quality of products at works, the Society may request the assessment of that person.
(d) When deficiencies are found, the supplier who is informed of such by documentation is to take the corrective action and report to the Society. Where deemed necessary, a visit by the Surveyor may be made to evaluate the validity of the corrective action.
(C) Renewal audit
(a) Renewal audit is to be carried out in accordance with (A) and (B) above before the expiry date of the Approval Certificate.
(b) Where deemed acceptable, the part of data to be submitted and an audit may be reduced.
(D) Occasional audit
(a) The Society may request the occasional audit if any of the following condition occurs:
(i) When important changes are made to the approved quality system
(ii) When services which were approved are changed or added
(b) In the occasional audit, it is to be confirmed by the Society that all the necessary requirement are in a satisfactory condition.
(E) Preparations for assessment and Others
(a) When the assessment is performed in accordance with the requirements specified in (A) through (D) above, the preparations are to be made by the supplier. On such occasions, service suppliers is also to be present at the assessment.
(b) In case necessary preparations have not been made or in case no responsible person is present at the assessment, the Society may suspend the assessment.
(3) Approval
Certification is conditional on a practical demonstration of the specific service performance as well as satisfactory reporting being carried out.
(A) Issuance of Approval Certificate
(a) Upon satisfactory completion of both the audit of the supplier and the demonstration test, if required, the Society issues the Certificate of Approval in accordance with the other requirements by the Society. The supplier is to be registered on the service suppliers list of the Society. The Certificate is to clearly state that the type and scope of services and any limitations or restrictions imposed.
(b) Where several servicing stations are owned by a supplier, each station is to be assessed and approved except as specified in **Par 4** (B) below.
(B) The term of validity for the Approval Certificate
(a) The valid term of an approval certificate is 3 years from the date of the initial or the renewal approval.
(b) In case where the renewal assessment is carried out within 3 months before the expiry date, the valid term of the certificate is three(3) years from the expiry date.
(c) In case where the extension of the valid term of the approval Certificate is requested by the supplier, the Society may extend the valid term within the period of three(3) months after expiration of the term of validity. However, in this case, the term of validity for the renewed approval certificate is the next day of the expiry date of the previous certificate.

(C) Change in the quality assurance system
(a) In case where any change to the company organization, the quality manual, etc. having effect on the quality system, it is to be immediately communicated to the Society by the supplier.
(b) Important changes having significant effect on the approved quality system are as follows:
(i) Overall alteration or abolition of the quality manual, etc.
(ii) Alteration of major management(Owner, director's committee, etc.)
(iii) Alteration of organization(consolidation of the quality system, etc.)
(iv) Alteration, abolition and transfer of the major facilities specified in quality manual
(D) Suspension and withdrawal of certification
(a) Where non-conformities in the approved quality system are found by the Surveyor, or where conditions for the issuance of the certificate or for its maintenance have deteriorated, the supplier is to correct the non-conformities. Such corrections are to be verified by the Society if necessary. In case corrective actions are not taken within the specified period, the Society may suspend the approved certificate for a given period. In case the corrective actions are not taken for the suspended period, the Society may withdraw the approval.
(b) The Society can withdraw the approval if any of the following conditions occur:
(i) Where the important changes having significant effect on the quality system is not communicated to the Society.
(ii) Where the occasional audit or renewal audit is not carried out in the relevant period.
(iii) Where a request for withdrawal is made by the supplier.
(iv) Where the service is carried out improperly or the result of inspection is reported improperly, and where the fact that the services provided are not in compliance with the approval condition are ascertained.
(v) Where the approval fees are not paid.
(vi) Where wilful acts or omissions are ascertained.
(c) A supplier whose approval has been cancelled, may apply for re-approval provided that the non-conformities which resulted in cancellation are corrected, and the Society is issue the approval certificate after it is confirmed that the corrective action has effectively been implemented.

3. General Requirements of the Suppliers

(A) Extent of approval
The supplier is to demonstrate, as required by (B) - (I), that it has the competence and control needed to perform the services for which approval is sought.
(B) Training of personnel
The supplier is responsible for the qualification and training of its personnel to a recognised national, international or industry standard as applicable. Where such standards do not exist, the supplier is to define standards for the training and qualification of its personnel relevant to the functions which are authorized to perform. The personnel is to also have an adequate experience and be familiar with the operation of any necessary equipment. The personnel is to have a minimum of one(1) year on-the-job training or equivalent experience. Where it is not possible to perform internal training, a program of external training may be considered as acceptable.
(C) Supervision
The supplier is to provide supervision for all services provided. The appointed supervisor is responsible for work performed and the final report. The responsible supervisor is to have minimum of two(2) years experience as a personnel within the approved activity of the supplier. For a supplier consisting of one person, that person shall meet the requirements of a supervisor.
(D) Personnel records
The supplier is to maintain the records of the approved personnel and submit them when the records are requested by the Surveyor. The record is to contain information on age, formal education, training and experience for the approved services.

(E) Equipment and facilities
The supplier is to have the necessary equipments and facilities for the service. A record containing information on maintenance and calibration of the equipments used is to be maintained.

(F) Procedures
The supplier is to have documented work procedures covering all services supplied.

(G) Subcontractors
The supplier is to submit the information on agreements and arrangements to the Society, if any parts of the services provided are subcontracted. Particular emphasis shall be given to quality management by the supplier in following-up of such subcontracts. Subcontractors providing any other than subcontracted personnel or equipment shall also meet the requirements of **Par 2** (1) (A) and **Par 3.**

(H) Verification
The supplier is to verify that the services provided are carried out in accordance with approved procedures.

(I) Reporting
The report is to be prepared in a form acceptable to the Society and it shall include a copy of the Certificate of Approval of the Society.

(J) Quality system
The supplier is to have a documented system covering at least the items in **Par 2** (1) (A) (a) to (h).

4. Service Suppliers in Relations with the Equipment Manufacturer

(A) A company which works as a service station for manufacturer(s) of equipment(and as a service supplier in this field), is to be assessed by the manufacturer(s) and nominated as their agent. The manufacturer is to ensure that appropriate instruction manuals, material etc. are available for the agent as well as of proper training of the agent's technicians. Such suppliers is to be approved either on a case by case basis, or in accordance with (B).

(B) If a manufacturer of equipment(and service supplier) applies to the Society for inclusion of his nominated agents and/or subsidiaries in the approval, then he must have implemented a quality system certified in accordance with the most current version of (KS A)ISO 9000 series, with effective controls of his agents and/or subsidiaries, and when these agents/subsidiaries have an equally effective quality system complying with the relevant requirements specified in the most current version of (KS A)ISO 9000 series. Such approvals shall be based upon an evaluation of the quality system implemented by the parent company against the most current version of (KS A)ISO 9000 series. The Society may require follow-up to confirm adherence to this quality system by performing audits on such agents or subsidiaries against the most current version of (KS A)ISO 9000 series.

5. Special Requirements for Various Categories of Service Suppliers

(1) Firms engaged in thickness measurements on ships

(A) Extent of engagement
Thickness measurement of structural material of ships except non-ESP ships less than 500 gross tonnage and all fishing vessels, and the separate requirements specified by the Society are to be applied to these ships.

(B) Supervisor and Personnel

(a) The responsible supervisor and personnels shall be qualified according to a recognised national or international industrial Non-Destructive Examination Standard(e.g. EN 473 level II or ISO 9712 level II).

(b) The supervisor and personnel are to have adequate knowledge of the Ship structures sufficiently to select a representative position for each measurements.

(C) Equipment
On coated surfaces, instruments using pulsed echo technique(either with oscilloscope or digital instruments using multiple echo, single crystal technique) are required. Single echo instruments may be used on un-coated surfaces, which have been cleaned and grinded.

(D) Procedures
Documented work procedures are at least to contain information on survey preparation, selection and identification of test locations, surface preparation, protective coating preservation, calibration checks, and report preparation and content.
(E) Report
(a) The report is to be made on the basis of the **Annex 1-5** of the Guidance.
(b) The report is to be documented and maintained by supplier for each separate ship with being signed by the Surveyor.

(2) Firms engaged in tightness testing of hatches with ultrasonic equipment
(A) Extent of engagement
The suppliers undertaking tightness tests of hatches by ultrasonic equipment as an alternative to hose testing with water.
(B) Personnel
The personnel is to have the following qualifications:
(a) Have knowledge of different hatch designs, their functioning and sealing features
(b) Have experience with operation and maintenance of different hatch designs
(c) Be able to document a theoretical and practical training onboard in using ultrasonic equipment specified
(C) Equipment
The ultrasonic equipment to be used is to be type approved by the Society. It should be demonstrated for the Surveyor that the equipment is fit for the purpose of detecting leakages in hatch covers.
(D) Procedures
The supplier is to have documented work procedures including the manual for the ultrasonic equipment specified, its adjustment, its maintenance, its operation and approval criteria.

(3) Firms carrying out in-water survey
(A) Extent of engagement
In-water survey of ships and mobile offshore units.
(B) Training of personnel
(a) The supplier is responsible for the qualification of his personnels and the diving equipment utilized when carrying out survey.
(b) Following knowledges for training of personnel are to be documented.
(i) Ship's underwater structure and appendages, tail shaft, propeller, rudder and its bearings, etc.
(ii) Under-water thickness gauging and non-destructive testing in accordance with a recognised national or international industrial NDT standard
(iii) Bearing clearance measurements on rudders and tail shaft
(iv) Under-water video monitoring with TV-monitors on deck, as well as still picture work
(v) Operation of under-water communication system
(vi) Special equipment and tools like hull cleaners, grinders, cutters, etc.
(c) Plan for training of personnel
A plan for training of personnel in the reporting system should be included the minimum Rule requirements for relevant ship types, ship's underwater structure, measuring of bearing clearances, the recognition of corrosion damage, buckling and deteriorated coatings, etc.
(C) Supervisor
The supervisor is to be qualified according to the supplier's general requirements and have minimum two(2) years experience as a personnel carrying out survey.
(D) Personnel carrying out survey
The personnel carrying out survey is to have at least one(1) year of experience as an assistant personnel carrying out survey(minimum 10 different assignments).
(E) Equipment
The followings are to be available:
(a) Closed circuit colour television with sufficient illumination equipment
(b) Two-way communication between diver and surface staff
(c) Video recording device connected to the closed circuit television
(d) Under water still photography camera
(e) Equipment for carrying out thickness gauging, non-destructive testing and measurements (e.g. clearances, indents, etc.) as relevant to the work to be performed.

(f) Equipment for cleaning of the hull

(F) Procedures and guidelines

The supplier is to have documented operational procedures and guidelines for how to carry out the survey and handle the equipment. These are to include:

(a) Two-way communication between diver and surface staff

(b) Video recording and closed circuit television operation

(c) Guidance of the diver along the hull to ensure complete coverage of the parts to be surveyed

(G) Verification

The supplier must have the surveyor's verification of each separate job, documented in the report by his signature

(4) Firms engaged in the examination of Ro-Ro ships bow, stern, side and inner doors

(A) Extent of engagement

Inspection of securing and locking devices, hydraulic operating system, electric control system for the hydraulics, electric indicator systems, and supporting, securing and locking devices and tightness testing.

(B) The supplier is to be certified in accordance with the relevant requirements specified in the most current version of (KS A)ISO 9000 series.

(C) Reference documents

The supplier is to have access to SOLAS 1974 as amended and IACS Internal Guidelines No.8 - Check-list for Surveys of Ro-Ro Ships Shell and Inner Doors Guidelines for Surveyors, or its equivalent, by the Society.

(D) In addition to **Par 3** (c), the Senior Service Engineer(Supervisor) is to have a minimum two(2) years education from a technical school.

(E) Required Equipment

(a) For Inspection of Supporting Securing and Locking Devices, Hinges and Bearings.

(i) Equipment for measuring clearances(i.e. feeler gauges, vernier calipers, micrometers).

(ii) Non-destructive examination(i.e. dye penetrant, magnetic particle inspection)

(b) For Tightness Testing

(i) Ultrasonic leak detector or equivalent

(c) For Inspection of Hydraulic Operating System

(i) Pressure gauges

(ii) Particle counter for analysing the quality of hydraulic fluid

(d) For Inspection of Electric Control System and Indication System

(i) Digital multi-meter

(ii) Earth fault detector

(F) Procedures and Instructions

(a) The supplier is to have access to drawings and documents, including the Operating and Inspection Manual.

(b) The supplier is to have access to the service history of the doors.

(c) The supplier is to use, complete and sign a checklist which has been found acceptable by the Society.

(G) Report

(a) After completion of the inspection, the report for each separate ship is to be made and verified by the Supplier.

(b) The report is to be signed by the Surveyor, documented and maintained.

(5) Firms engaged in testing of coating systems in accordance with IMO Res.MSC.215(82) and IACS PR34

(A) Laboratories

(a) Extent of Engagement

Testing of coating systems in accordance with IMO Res.MSC.215(82) and IACS PR34

(b) The supplier is to provide to the Society the following information:

(i) A detailed list of the Laboratory test equipment for the IMO Res.MSC.215(82) coating approval.

(ii) A detailed list of reference documents comprising a minimum those referred to in IMO Res.MSC.215(82) that are available in the laboratory.

(iii) Details of testing panel preparation, procedure of test panel identification, coating application, test procedures and a sample test report.

(iv) Details of exposure method and site for weathering primed test panels.

(v) A sample daily or weekly log/form for recording test condition and observations including unforeseen interruption of the exposure cycle with corrective actions.
(vi) Details of any sub-contracting agreements.
(vii) Comparison test report with an approved coating system or laboratory if available.

(c) Reporting - Reference is made to the following IACS Recommendations;
(i) Rec.101 : IACS Model Report for IMO Res.MSC.215(82) Annex 1 "Test Procedures for Coating Qualification"
(ii) Rec.102 : IACS Model Report for IMO Res.MSC.215(82) Annex 1 "Test Procedures for Coating Qualification", Section 1.7 - Crossover Test

(d) Audit of the test laboratory is to be based on this procedure and the standards listed in the IMO Res.MSC.215(82).

(6) Other service firms
Where the supplier providing the service other than (1) through (5) wishes to obtain the approval of the Society, other specified requirements are to be applied. ⚓

Annex 1-12 Hull Survey for Classification Survey during Construction

1. Scope

The scope of this Annex includes the following main activities:

(1) Examination of the parts of the ship covered by classification rules and by applicable statutory regulations for hull construction, to obtain appropriate evidence that they have been built in compliance with the rules and regulations, taking account of the relevant approved drawings.

(2) Appraisal of the manufacturing, construction, control and qualification procedures, including welding consumables, weld procedures, weld connections and assemblies, with indication of relevant approval tests.

(3) Witnessing inspections and tests as required in the classification rules used for ship construction including materials, welding and assembling, specifying the items to be examined and/or tested and how(e.g. by hydrostatic, hose or leak testing, non destructive examination, verification of geometry) and by whom.

(4) Appraisal of material and equipment used for ship construction and their inspection at works is not included in this Annex. Details of requirements for hull and machinery steel forgings and castings and for normal and higher strength hull structural steel are given in IACS UR W7(Hull and Machinery Steel Forging), W8(Hull and Machinery Steel Casting) and W11(Normal and High Strength Hull Structural Steels) respectively. Acceptance of these items is verified through the survey process carried out at the manufacturer's works and the issuing of the appropriate certificates.

2. Definitions

(1) The hull structure is defined as follows:

(A) hull envelope including all internal and external structures,

(B) superstructures, deckhouses and casings,

(C) welded foundations, e.g. main engine seatings,

(D) hatch coamings, bulwarks,

(E) all penetrations fitted and welded into bulkheads, decks and shell,

(F) the fittings of all connections to decks, bulkheads and shell, such as air pipes and ship side valves − all ILLC 1966, as amended, items.

(G) welded attachments to shell, decks and primary members, e.g. crane pedestals, bitts and bollards, but only as regards their interaction on the hull structure.

(2) Reference to documents also includes electronic transmission or storage.

(3) Definition of survey methods which the Surveyor is directly involved in: Patrol, Review, Witness

(A) Patrol, the act of checking on an independent and unscheduled basis that the applicable processes, activities and associated documentation of the shipbuilding functions identified in **Table 1** continue to conform to classification and statutory requirements.

(B) Review, the act of examining documents in order to determine traceability, identification and to confirm that processes continue to conform to classification and statutory requirements

(C) Witness is the attendance at scheduled inspections in accordance with the agreed Inspection and Test Plans or equivalent to the extent necessary to check compliance with the survey requirements.

3. Applications

(1) This Annex covers the survey of all new construction of steel ships intended for classification and for international voyages except for:

(A) those defined in SOLAS I/3

(B) High Speed Craft as defined in I/1.3.1 of the 2000 High Speed Craft Code

(C) Mobile Offshore Drilling Units as defined in I/1.2.1 of the MODU Code

(2) This Annex covers all statutory items, relevant to the hull structure and coating, i.e. Load Line and SOLAS Safety Construction.

(3) This Annex does not cover the manufacture of equipment, fittings and appendages regardless whether they are made inside or outside of the shipyard, examples being as follows. Evidence of acceptance shall be provided by accompanying documentation from class Surveyor at manufacturer and verified at the shipyard:
(A) hatch covers,
(B) doors and ramps integral with the shell and bulkheads,
(C) rudders and rudder stock,
(D) all forgings and castings integral to the hull.
(4) This Annex applies to the installation into the ship, welding and testing of:
(A) the items listed in (3) above
(B) equipment forming part of the watertight and weather tight integrity of the ship.
(5) This Annex applies to the hull structures and coating constructed at any of the following:
(A) shipbuilder’s facilities,
(B) sub-contractors at the shipbuilder’s facilities,
(C) sub-contractors at their own facilities or at other remote locations

4. Qualification and monitoring of personnel

(1) Exclusive Surveyors of the Society, as defined in IACS PR5(Definition of Exclusive Surveyor and Non-Exclusive Surveyor and Procedure for Employment and Control of Non-Exclusive Surveyors), are to confirm through patrol, review and witness as defined in **Par 2** (3), that the ships are built using approved plans in accordance with the relevant rules and statutory requirements. The Surveyors are to be qualified to be able to carry out the tasks and procedures are to be in place to ensure that their activities are monitored. Details are specified in PR6(Procedure for Activity Monitoring of Surveyors/ISM Code Auditor) and PR7(Procedure for Qualification and Training of Surveyors).

5. Survey of the hull structure

(1) **Table 1** provides a list of surveyable items for the hull structure and coating covered by this Annex, including:
(A) description of the shipbuilding functions
(B) classification and statutory survey requirements
(C) survey method required for classification
(D) relevant IACS and statutory requirement references
(E) documentation to be available for the Surveyor during construction
(a) the shipbuilder is to provide the Surveyors access to documentation required by classification, this includes documentation retained by the shipbuilder or other third parties
(b) the list of documents approved or reviewed by the Society for the specific new construction are as follows:
(i) plans and supporting documents
(ii) examination and testing plans
(iii) NDE plans
(iv) welding consumable details
(v) welding procedure specifications
(vi) welding plan or details
(vii) welder’s qualification records
(viii) NDE operator's qualification records
(F) Documents to be inserted into the ship construction file. Refer to **Par 10** for details
(G) A list of specific activities which are relevant to the shipbuilding functions. This list is not exhaustive and can be modified to reflect the construction facilities or specific ship type.
(2) Evidence is also to be made available, as required, by the shipbuilder, to the Surveyor whilst the construction process proceeds to prove that the material and equipment supplied to the ship has been built or manufactured under survey relevant to the classification rules and statutory requirements.

6. Review of the construction facility

(1) The Society is to familiarize themself with the yard's production facilities, management processes and safety for consideration in complying with the requirements of **Table 1** using "Shipyard review record" of **Annex 1-12-1** or equivalent prior to any steelwork or construction taking place in the following circumstances:
  (A) where the Society has none or no recent experience of the construction facilities − typically after a one year lapse - or when significant new infrastructure has been added,
  (B) where there has been a significant management or personnel re-structuring having an impact on the ship construction process,
  (C) or where the shipbuilder contracts to construct a vessel of a different type or substantially different in design.

7. Newbuilding survey planning

(1) Prior to commencement of surveys for any newbuilding project, the Society is to discuss with the shipbuilder at a kick off meeting the items listed in **Table 1**. The purpose of the meeting is to agree how the list of specific activities shown in **Table 1** is to be addressed. The meeting is to take into account the shipbuilder's construction facilities and ship type including the list of proposed subcontractors. A record of the meeting is to be made, based upon the contents of the **Table 1** − the **Table 1** can be used as the record with comments made into the appropriate column. If the Society has nominated a Surveyor for a specific newbuilding project then the Surveyor is to attend the kick off meeting. The builder is to be asked to agree to undertake ad hoc investigations during construction where areas of concern arise and for the builder to agree to keep the Society advised of the progress of any investigation. Whenever an investigation is undertaken, the builder is to be requested, in principle, to agree to suspend relevant construction activities if warranted by the severity of the problem.
(2) The records are to take note of specific published Administration requirements and interpretations of statutory requirements.
(3) The shipyard shall be requested to advise of any changes to the activities agreed at the kick off meeting and these are to be documented. E.g. if the shipbuilder chooses to use or change sub-contractors, or to incorporate any modifications necessitated by changes in production or inspection methods, rules and regulations, structural modifications, or in the event where increased inspection requirements are deemed necessary as a result of a substantial non-conformance or otherwise.
(4) Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. Structural fabrication is to be carried out in accordance with IACS Recommendation 47, "Shipbuilding and Repair Quality Standard", or a recognized fabrication standard which has been accepted by the Society prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey of the Society.
(5) The kick-off meeting may be attended by other parties(owner, administrations, etc.) as defined in IACS PR3(Transparency of Classification and Statutory Information) subject to agreement by the shipbuilder.
(6) In the event of series ship production consideration may be given to waiving the requirement for a kick off meeting for the second and subsequent ships provided any changes are documented as required in (1) and (3) above.

8. Examination and test plan for newbuilding activities

(1) The shipbuilder is to provide plans of the items which are intended to be examined and tested. These plans need not be submitted for approval and examination at the time of the kick off meeting. They are to include:
  (A) proposals for the examination of completed steelwork - generally referred to as the block plan and are to include details of joining blocks together at the pre-erection and erection stages or at other relevant stages
  (B) proposals for fit up examinations where necessary
  (C) proposals for testing of the structure(leak and hydrostatic) as well as for all watertight and weathertight closing appliances

(D) proposals for non-destructive examination
(E) any other proposals specific to the ship type or to the statutory requirements.
(2) The plans and any modifications to them are to be submitted to the Surveyors in sufficient time to allow review before the relevant survey activity commences.

9. Proof of the consistency of surveys

(1) The Society is to be able to provide evidence, e.g. through records, check lists, inspection and test records, etc. that its Surveyors have complied with the requirements of the newbuilding survey planning and duly participated in the relevant activities shown in the shipbuilder's examination and test plans.

10. Ship Construction File

(1) The shipbuilder is to deliver documents for the Ship Construction File. In the event that items have been provided by another party such as the shipowner and where separate arrangements have been made for document delivery which excludes the shipbuilder, that party has the responsibility. The Ship Construction File shall be reviewed by the Surveyor for content in accordance with the requirements of (2) below.
(2) It is recognised that the purpose of documents held in the Ship Construction File on board the ship, is to facilitate inspection(survey) and repair and maintenance, and, therefore, is to include in addition to documents listed in **Table 1**, but not be limited to:
(A) as-built structural drawings including scantling details, material details, and, as applicable, wastage allowances, location of butts and seams, cross section details and locations of all partial and full penetration welds, areas identified for close attention(for general dry cargo ships, liquefied gas carriers and ships subject to the enhanced survey programme) and rudders,
(B) manuals required for classification and statutory requirements, e.g. loading and stability, bow doors and inner doors and side shell doors and stern doors − operations and maintenance manuals(IACS UR S8(Bow Doors and Inner Doors) and S9(Side Shell Doors and Stern Doors))
(C) ship structure access manual, as applicable,
(D) copies of certificates of forgings and castings welded into the hull(IACS UR W7(Hull and Machinery Steel Forging) and W8(Hull and Machinery Steel Casting)),
(E) details of equipment forming part of the watertight and weathertight integrity of the ship,
(F) tank testing plan including details of the test requirements(IACS UR S14(Testing Procedures of Watertight Compartments)),
(G) corrosion prevention specifications(IACS UR Z8(Corrosion Protection Coating for Salt Water Ballast Spaces) and Z9(Corrosion Protection Coatings for Cargo Hold Spaces on Bulk Carriers)),
(H) details for the in-water survey, if applicable, information for divers, clearances measurements instructions etc., tank and compartment boundaries,
(I) docking plan and details of all penetrations normally examined at drydocking.
(J) Coating Technical File, for ships subject to compliance with the IMO Performance Standard for Protective Coatings(PSPC) as a class requirement under the IACS Common Structural Rules.

Appendix 1-12-1 Shipyard review record
Table 1
Appendix 1-12-2 Ship Construction File Form Example

Appendix 1-12-1 Shipyard review record

Name of Shipyard	Date

1. Details of any management systems

Obtained Approval	Certified by	Expiry Date	Remarks (scope, etc.)
ISO-9001			
ISO 14001			
ISO 18001			
Other:			

2. Construction Equipment: (Documents such as a brochure of shipyard can be attached in lieu of completing this section.)

2.1 Building Berth (B) or Dock (D)

* In case of berth, Depth is not applicable.

B / D	Name	Length (m)	Width (m)	Depth* (m)	Building Capacity (Gross Tonnage)	Crane (Ton x No.)

2.2 Outfitting Quays

Name	Length (m)	Width (m)	Depth (m)	Berthing Capacity (Gross Tonnage)	Crane (Ton x No.)

2.3 Main Fabrication and Erection Facilities

(1) Marking and cutting of steel plates(including internal members)
- Marking method (Manual, Photo x ______, EPM x ______, NC x ______ others ______)
- NC cutting machine (Gas x ______, Plasma x ______, Laser x ______)
  Control procedure of NC (On-line, other)
- Cutting equipment (Edge planer x ______, Roll-shear x ______)

(2) Marking and cutting of section bar
- Marking method (Manual, NC) - Marking of reference curved line (Manual, NC)
- Cutting method (Manual, NC) - In case of NC (Gas x ______, Plasma x ______)

(3) One-side automatic welding machine (Yes, No)
- Type of welding machine (Flax Backing x ______, Flux and Copper Backing x ______ other ______)
- Existence of special surface plate for plate welding (Yes, No)

(4) Fillet welding machine (Gravity, Automatic) Percentage of automatization except gravity: about ____%
- Line welder (No, Yes: submerged arc x ______ heads, CO_2 x ______ heads)
- Small automatic fillet welding machine (No, Yes: Name: ______________________ x ______)
- Welding robot (No, Yes: Portal x ______, Rectangular x ______, Articulated x ______)

(5) Painting equipment
- Plate shot blasting/primer coating machine (No, Yes: Max. Width ______ m, Length ______ m)
- Section bar shot blasting/primer coating machine (No, Yes: Max. Length ______ m)
- Special coating factory (No, Yes: ______ m x ______ m x ______ sections)

(6) Vertical automatic welding machine (No, Yes: EG x ______, SEG x ______, ES x ______)
EG: Electrogas SEG: Simplified Electrogas ES: Electroslag

(7) Other main fabrication facilities

3. Shipyard control of Qualified Welders

(1) Normal steel

		certification	traceability	supervision	maintenance of qualification
Shipyard workers	confirm system in place	Yes/No	Yes/No	Yes/No	Yes/No
Subcontracted workers	confirm system in place	Yes/No	Yes/No	Yes/No	Yes/No

4. Feature of Construction Procedure

(1) Subcontract of hull blocks(weight)
- Sub members (No, Yes: Ratio of subcontracted works ______ %, No., of subcontractors ______)
- Blocks (No, Yes: Ratio of subcontracted works ______ %, No., of subcontractors ______)

(2) Method of plate block assembly
- Method fitting and welding longitudinals and transverse webs on jointed panels
- Method welding longitudinals on jointed panels prior to fitting and welding transverse webs
- Method fitting and welding a frame consists of longitudinals and transverse webs on jointed panels
- Method jointing panels with pre-assembled longitudinals by welding prior to fitting and welding transverse webs
- Other (please specify in (5) below)

(3) - pre-erection outfitting carried out
grand block/mega block adopted
Method of erection at building berth/dock
- Max. weight of loading block: ton
- Construction method in building dock/berth/land construction etc. (1 ship, 1.5 ships: Semi-tandem, dual entrance)
- Block loading process (single starting block, multi starting blocks, inserting block : No, Yes)

(4) Final dock (No, Yes: In-house, Other place of the same company, Use other company)

(5) Other feature of construction procedure

5. Quality Control System: (Refer to Quality Manual, if available.)

Item and description	Result	Remarks
(1) Existence of the organization chart including the departments of design, purchasing, manufacturing and quality assurance - Are the function, responsibility and competence of the organization clear?		
(2) Quality control organization - Existence of quality control organization - Number of employees in this organization - Existence of procedures or plans related to tests and inspections	______ persons including the chief	
(3) Pre-inspection system of shipyard - Is pre-inspection carried out prior to Class inspection? - Are pre-inspectors assigned? (Check the list.) - Number of pre-inspectors (related to hull only) - Are inspection results marked on the object and/or recorded in the checklist?	______ persons	
(4) Records of inspections and tests - Are records made and kept properly? - Does the responsible person verify the records? - Can the adoption of necessary corrective actions against non-conformity happened be checked?		
(5) Condition at the time of the surveys in the presence of class Surveyors - Is the schedule of the surveys changed often? - Are pre-inspection, shipyard inspection and repairs completed beforehand? - Are the sufficient preparations for surveys such as scaffoldings, lighting, cleaning made?		
(NOTES) Above-mentioned (3) and (4) include the acceptance inspection of subcontracted items.		

6. Measures for Safety and Health

Item and description	Result	Remarks
(1) Are conditions of scaffolding, nets, safety belt, lighting and ventilation good?		
(2) Does sufficient attention paid for radiographic examination and operation of cherry picker?		
(NOTES)		

7. Control System of Non-Destructive Examination(NDE)

Item and description	Result	Remarks
(1) Number of NDE supervisors in shipyard (including persons responsible for judging results)	______ persons	
(2) Dependence on subcontracted NDE work - Number of shipyard employees - Number of sub-contractors	 ______ persons ______ persons	
(3) NDE sub-contractor company's name and official technical qualifications	Name ___________________ (approved by) ___________ Name ___________________ (approved by) ___________	
(4) Grade and number of NDE employees with official technical qualifications in shipyard Specialized in radiography Specialized in ultrasonic Specialized in surface detection	 _____ Grade _____ persons _____ Grade _____ persons _____ Grade _____ persons	
(5) If non-destructive examinations are subcontracted, the grade and number of officially qualified persons Specialized in radiography Specialized in ultrasonic Specialized in surface detection	 _____ Grade _____ persons _____ Grade _____ persons _____ Grade _____ persons	
(6) Non-destructive examination equipment (in-house) - Number of radiographic equipment - Number of ultrasonic equipment	 ______ ______	
(NOTES) Even if all works are subcontracted, it is recommendable to attach the qualified person(s) who can verify the works.		

8. Quality Control on Production Line

Item and description	Result	Remarks
8.1 Preventive measures for misuse of materials		
(1) Job title of supervisor and person in charge of collating ordered steel and received steel, and checking of mill sheet	Title of supervisor: ______ Title of person in charge: ______	
(2) Are means for checking the material grade in hand prescribed for high-grade steels		
(3) Are regulations prescribed for checking the material grade for high-tensile steel and steel for low-temperature applications? Are there regulations for inscribing high tensile steel on the surface of the high tensile steel and special indication for steel for low temperature applications?		
(4) Are procedures for re-using of remaining cut-off mild steel?		
(5) Are there procedures for re-using of remaining cut-off high-tensile steel?		
(6) In the case of (4) and (5) above, can a collation be made with the mill sheet?		
(7) Section of controlling the lists of remaining cut-off steel	Name of section: ______	
(NOTES) - In case of high tensile steel, are means identifying different grades - In the case of (3) and (4) above, are the materials approved by other classes controlled similarly?		
8.2 Shot blasting/Primer coating		
(1) Existence of surface preparation standards		
(2) Existence of coating thickness control standards - Existence of thickness measurement records		
(NOTES) - The standard is to include the description related traceability after shot blasting and primer coating.		

8.3 Marking and cutting (Assembly work)

(1) Existence of standards for accuracy and periodical inspection of tape measures, tapes, stencils, etc.		
(2) Existence of standards for accuracy of cut dimensions and edge preparation		
(3) Existence of standards for finish of cutting face		
(4) What is the frequency and extent of maintenance and inspection carried out for ensuring accuracy of NC cutter and/or flame planer?		
(5) In case of NC, are the disks, tapes etc. maintained in good condition?		
(6) What are the measures adopted and guidance given to make the worker fully conversant with cutting work standards for maintaining accuracy?		

(NOTES)
- In case of (2) and (3) above, check items are to include confirmation of edge preparations free from piercing hole.
- NC for section bars is also to be in accordance with the above.

8.4 Bending and strain free

(1) Existence of standards for maximum heating temperatures during water cooling and at the time of bending and distortion removal of steel by quick heating and cooling		
(2) Existence of regulations for plate thickness and bending radius for flange processing		
(3) What are the measures adopted and guidance given to make the worker fully conversant with maintaining quality and accuracy during the bending process?		

(NOTES)

8.5 Control of Welding Procedure

(1) Are all welding procedures applied to the ships approved by the Society or other IACS members?		
(NOTES)		

8.6 Treatment of serious non-conformities

(1) Are repair plans submitted to the Society when serious non-conformities happened?		
(2) Were the NDE(RT/UT) plans submitted at appropriate timing?		
(3) Was the extent of tests extended considering the results of the test?		

(NOTES)

8.7 Hydrostatic and Watertight Tests

(1) Is the test plan submitted to the Society?		
(2) Are vacuum tests applied to?		
(3) Are local air injection tests during sub-assembly works applied to?		
(4) If (2) or (3) above is applied to, are the test procedures approved by the Society?		

(NOTES)

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
	Shipbuilding quality control function								
1	**Welding**								
1.1	**Welding consumables**	Classification approved separately at the manufacturer	Review approval status and patrol, verify storage, handling and treatment in accordance with manufacturer's requirements	UR W17		Consumable specification and approval status	Not required	Identify consumables against approved list	
								Verify temporary and permanent storage facilities	E.g. kept dry, covered, where applicable heated
								Verify traceability	E.g. random batch number checking
1.2	**Welder qualification**	Qualified welders	Review of welder certification and patrol	Rec 47		Shipyards records with individual's identification	Not required	Verify welder qualification standard, e.g. class or recognised standard approval	
								Verify welder approved for weld position	
								Verify validity of qualification certificate	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
1.3	**Welding – mechanical properties (welding procedures)**	All weld joint configurations, positions and materials to be covered by weld procedures approved by the classification society or by another IACS member available	Review and patrol	UR W28		Approved weld procedure specification and welding plan relevant to the ship project or process	Not required	Verify procedures are available at relevant workstations	
		The classification society witnesses all new weld procedure qualification tests carried out in the shipyard whenever the classification society is surveying in the shipyard	Witness					Verify weld procedures records have been approved and cover all weld processes and positions in accordance with classification or recognised standards and are available for the Surveyors reference	
1.3a	**Welding equipment**	Correctly calibrated and maintained	Patrol and review			Shipbuilders maintenance and calibration records	Not required	Verify condition of machinery and equipment	
								Verify machines are calibrated by appropriate staff	
								Verify calibration carried out in accordance with manufacturer's recommendations	
								Verify calibration in accordance with maintenance schedule	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
1.3b	**Welding environment**	Satisfactory environment	Patrol	Rec 47			Not required	Verify welding areas clean, dry, well lit	
								Confirm relevant measures taken for any pre or post heat treatment, drying of surfaces prior to welding	
								Confirm shielding gases, fluxes protected	
1.3c	**Welding supervision**	Sufficient number of skilled supervisors	Patrol	Rec 20 and 47				Verify supervision is effective	
1.4	**Welding-surface discontinuities**	Substantially free from significant indications, satisfactory profile and size	Visual examination, surface detection techniques, review of documents and patrol of operator	Rec 20 and 47		Shipbuilders and recognised standards and Rules as applicable, welding and NDE plans, NDE reports, operator qualifications	Not required	Identify workstations where NDE is carried out, e.g. panel line butt welds, castings into hull structure	
								Verify NDE carried out in accordance with approved plans where applicable	
								Verify suitability of NDE methods	
								Verify operators suitably qualified particularly where sub-contractors have been employed	
								Verify NDE is carried out according to the acceptable process	
								Review NDE records	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
1.5	**Welding – embedded discontinuities**	NDE is to be carried out by qualified operators capable of ensuring that welds are substantially free from significant indications.	Radiography and ultrasonic testing, review of documents and patrol of operator, examination of films	Rec 20 and 47		Shipbuilders and recognised standards and Rules as applicable, welding and NDE plans, NDE reports, operator qualifications	Not required	Identify workstations where NDE is carried out, e.g. panel line butt welds, castings into hull structure	
								Verify NDE carried out in accordance with approved plans where applicable	
								Verify suitability of NDE methods	
								Verify operators suitably qualified particularly where sub-contractors have been employed	
								Verify that records have been completed and in accordance with recognised standards, e.g. IQI(Image Qualify Indicator) and sensitivity recorded	
								Verify that reports and radiographs have been evaluated correctly by the shipbuilder. Systematic review of radiographs carried out by the Surveyor	
								Verify equipment calibration satisfactory and in accordance with manufacturers and recognised standards requirements	
								Verify NDE is carried out according to the acceptable process	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
2	Steel preparation and fit up								
2.1	Surface preparation, marking and cutting	Traceability and acceptability of material, check of steel plates & profiles materials type, scantling identification, testing marks	Patrol	Rec 47		Material certificates, shipbuilder's marking/cutting production documents at the workstage – documents retained at the facility	Not required	Verify stockyard storage satisfactory	
								Verify material traceability, e.g. stamping identification against material certification, archiving of records	
								Verify transfer marking after treatment line	
								Verify standard of shotblasting and priming	
								Verify suitability of primer	
								Verify that steel grades can be identified	
								Verify machinery adjusted to maintain within IACS or manufacturers recommendations	
								Verify accuracy of marking and cutting	
								Verify storage of piece parts	
2.2	Straightening	Approval of straightening methods/ procedures against deformation	Patrol and review	Rec 47		Recognised standards, approved procedures	Not required	Verify that straightening processes are approved for the grade and type of steel, e.g. tmcp, z plate	
								Verify that plates and sections are within recognised tolerances	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
2.3	**Forming**	Maintain material properties. Acceptance of forming method against unproper deformations	Patrol	Rec 47		Shipbuilders procedure for hot forming	Not required	Verify that temperature control is exercised by the operator	
								Verify that suitable methods of temperature control are available when forming special steels and materials	
								Verify that forming processes are acceptable	
2.4	**Conformity with alignment/fit up/gap criteria**	Check alignment/fit up/gap against reference standards	Patrol	Rec 47		Shipbuilders and recognised standards and Rules as applicable	Not required	Verify the processes to ensure satisfactory fit up and alignment at all workstations	
								Verify that edge preparations are re-instated where lost during fitting operations	
								Verify remedial procedures are in place to compensate for wide gaps and alignment deviations	
2.5	**Conformity for critical areas with alignment/fit up or weld configuration**	Check alignment/fit up/gap against approved drawings	Patrol and review	Rec 47		Shipbuilders and recognised standards and Rules as applicable, approved plan or standard, builder's records	Approved plans of critical areas if applicable	Verify that the information relevant to the latest approved drawings is available at the workstations	
								Verify the processes to ensure satisfactory fit up and alignment at all workstations	
								Verify that edge preparations are re-instated where lost during fitting operations	
								Verify remedial procedures are in place to compensate for wide gaps and alignment deviations	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
3	Steelwork process, e.g. sub assembly, block, grand and mega block assembly, pre-erection and erection, closing plates	Compliance with approved drawings, visual examination of welding and material, check alignment and deformations	Patrol of the process and witness of the completed item	Rec 47		Approved plans, shipbuilders inspection records, Shipbuilders and recognised standards and Rules as applicable, construction plan (steelwork sub-division)		Verify that the information relevant to the latest approved drawings is available at the workstations	
								Verify that correct weld sizes have been adopted	
								Verify operation of the welding processes at the different work stages is satisfactory	
								Verify that piece parts are identifiable	
								Verify that fit ups are within recognised tolerances	
								Verify that correct welding requirements specified in reference 1 of this table have been adopted	
								Verify processes for closing plates etc. are acceptable	
								Confirm that steelwork is in accordance with the approved plan	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
4	**Remedial work and alteration**	Welding, check against deformation, alignment	Review records and witness	Rec 47		Permanent record of shipyard surveyable item		Verify that records have been maintained of significant deviations from the approved plans, for situations such as mis cut openings, re-routing outfit items	
								Verify that all deviations brought to the attention of the classification society by the shipbuilder are acceptable	
5	**Tightness testing, including leak and hose testing, hydropneumatic testing**	Absence of leaks	Patrol of the process and witness of the test	UR S14	Reg. II-1/14 of SOLAS as amended	Approved tank testing plan, shipbuilders inspection records	Approved tank testing plan	Confirm that tank testing is carried out in accordance with the approved plan	
								Confirm the methods used to carry out leak testing	
								Confirm that correct test pressures maintained for leak, hose and hydro and hydropneumatic testing is satisfactory	
								Verify that adequate records of the tank testing have been maintained	
6	**Structural testing**	Structural adequacy of the design	Witness testing	UR S14	Reg. II-1/14 of SOLAS as amended	Approved tank testing plan, shipbuilders inspection records	Approved tank testing plan	Confirm that tank testing is carried out in accordance with the approved plan	
								Confirm that correct test pressures maintained for testing is satisfactory	
								Verify that adequate records of the tank testing have been maintained	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
7	Corrosion prevention systems, e.g. coatings, cathodic protection, impressed current except for coating system subject to PSPC	Salt water ballast tanks with boundaries formed by the hull envelope, and also bulk carrier hold internal surfaces, coamings and hatch covers shall have an efficient protective coating. Safety aspects of cathodic systems to be dealt with separately.	Review and report on builder's & manufacturer's documentation	UR Z8 and Z9, UI SC122, UR F1	Reg. II-1/3-2 of SOLAS as amended	Manufacturer's and builder's specification	Corrosion prevention specifications	Verify that applied coatings are approved and review records of application	
								Verify that adequate records have been maintained and copied to the ship construction file	
	Application Antifouling Systems		Review		AFS Convention	Painting Specification	Painting Specification and Mfg Declaration	Verify that adequate records have been maintained and copied to the ship construction file	
7.1	Application of Protective Coatings for Dedicated Seawater Ballast Tanks in all Types of Ships and Double-Side Skin Spaces of Bulk Carriers subject to PSPC	Monitor implementation of the coating inspection requirements	Patrol and review	UI SC223, PR34	Reg. II-1/3-2 of SOLAS as amended	Coating Standard	Coating Technical File	Verify that applied coatings are approved and review records of application in accordance with Chapter 7 of Annex to MSC.215(82)	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
8	Installation, welding and testing of the following								
8.1	Hatch covers	Tightness and securing	Witness	UR S14 & Rec 14	Reg. 13-14-15 and 16 of ILLC '66	Approved tank testing plan, shipbuilders inspection records	Details required, structural drawings	Confirm leak test of hatch covers	
								Confirm operation and securing test	
8.2	Doors and ramps integral with the shell and bulkheads	Tightness and securing	Witness	UR S14	Reg. II-1/18 of SOLAS as amended, Reg. 12 and 21 of ILLC '66	Approved tank testing plan, shipbuilders inspection records	Details required	Confirm leak test	
								Confirm operation and securing test	
								Confirm safety device operation	
								Ensure correct maintenance logs/manuals supplied with the ship construction file	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
8.3	Rudders	Fitting	Witness	UR S14		Approved plan, shipbuilders inspection records	Details required, structural drawings	Confirm alignment and mounting and fitting up to the connection to the tiller	
								Confirm function test	
								Verify fitting of pintles and all securing bolts	
								Verify all fit up records including all clearances maintained and placed into ship construction file	
8.4	Forgings and castings	Compliance with approved drawings, visual examination of welding and material, check alignment and deformations	Patrol of the process and witness of the completed item	UR W7 & W8		Approved plans, shipbuilders inspection records, Shipbuilders and recognised standards and Rules as applicable, construction plan (steelwork sub-division)	Copies of certificates of forgings and castings	Verify casting and forgings against material certificate	
								Verify that correct welding and fit up requirements specified in reference 1, 2.4 and 2.5 of this table have been adopted	
								Verify that material certificates are included in the ship construction file	
	Appendages							Verify that correct welding and fit up requirements specified in reference 1, 2.4 and 2.5 of this table have been adopted	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
8.5	Equipment forming the watertight and weathertight integrity of the ship, e.g. overboard discharges, air pipes, ventilators	Tightness and securing	Witness		Reg. II-1/19 of SOLAS as amended; Reg. 17-18-19-20-22-23 of ILLC '66	Approved tank testing plan, shipbuilders inspection records	Details required	Verify that correct welding and fit up requirements specified in reference 1, 2.4 and 2.5 of this table have been adopted	
								Verify Compliance with Load line Convention 1966 as amended - i.e. all fittings in accordance with the record of freeboard assignment	
				UR P3				Verify air pipes, vents etc closing device are approved type	
								Verify material certificates for overboard discharges where applicable	
								Verify record of freeboard assignment and all material certificates included in the ship construction file	
	Freeboard marks and draft marks	Within allowable tolerances and in accordance with the freeboard assignment	Witness	UI LL4	Reg. 4-5-6-7 and 8 of ILLC '66		Details required	Verify freeboard marks in accordance with load line assignment	
								Verify draft marks in accordance with the agreed tolerances specified by the builder unless more onerous flag state requirements	

Table 1

Reference	Shipbuilding function	Survey Requirements for Classification	Survey Method required for Classification	IACS reference*	Statutory requirements and relevant reference	Documentation available to classification Surveyor during construction	Documentation for ship construction file	Specific activities	Classification Society proposals for the project
	Principal dimensions	Within allowable tolerances	Review and witness	Rec 47			Details required	Verify principal dimensions in accordance with recognised standard	
								Verify dimensions included in ship construction file	
	Safety Construction certification	No outstanding imperfections or defects	Witness		Reg. 10 of SOLAS as amended			Verify that Administration requirements have been incorporated into the hull structure	

Shipbuilder's name	
Project	
Project duration	
Kick off meeting date	
Representing builder	
Representing Class Society	

* IACS Recommendations are not mandatory requirements.

< Supplement of Table 1 >

- Prior to commencement of survey for any newbuilding project, the Society is to discuss with the shipbuilder at a kick off meeting the items listed in **Table 1**. The purpose of the meeting is to agree how the list of specific activities shown in **Table 1** is to be addressed. The meeting is to take into account the shipbuilder's construction facilities and ship type including the list of proposed subcontractors.
- A record of the meeting is to be made, based upon the contents of the **Table 1** - the **Table 1** can be used as the record with comments made into the appropriate column.
- The shipyard shall be requested to advise of any changes to the activities agreed at the kick off meeting and these are to be documented.
  (E.g. if the shipbuilder chooses to use or change sub-contractors, or to incorporate any modifications necessitated by changes in production or inspection methods, rules and regulations, structural modifications, or in the event where increased inspection requirements are deemed necessary as a result of a substantial non-conformance or otherwise.)
- In the event of series ship production consideration may be given to waiving the requirement for a kick off meeting for the second and subsequent ships provided any changes are documented as required in the class rules.

- Additional meeting items, etc. :

No.	Items	Result	
1	If the Society has nominated a Surveyor for a specific newbuilding project then the Surveyor is to attend the kick off meeting.	A Surveyor has nominated and attended.	(Yes / No)
2	The kick-off meeting may be attended by other parties, such as owner, administrations, etc. subject to agreement by the shipbuilder.	Owner, administrations, etc. has attended.	(Yes / No)
		Attended by :	
3	The builder is to be asked to agree to undertake ad hoc investigations during construction where areas of concern arise and for the builder to agree to keep the Society advised of the progress of any investigation. (The builder is to be requested to agree to suspend relevant construction activities if warranted by the severity of the problem)	The builder was asked and agreed.	(Yes / No)
4	Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting.	Shipbuilding quality standards was reviewed and agreed.	(Yes / No)
		Shipbuilding quality standards :	
5	The records are to take note of specific published Administration requirements and interpretations of statutory requirements.	The specific published Administration requirements and interpretations of statutory requirements is exist and the relevant documents are attached.	(Yes / No)

Appendix 1-12-2 Ship Construction File Form Example

Ship Construction File

M / V	" "
IMO No.:	
Hull No.:	

Shipbuilder :

The shipbuilder is to deliver documents for the Ship Construction File. In the event that items have been provided by another party such as the shipowner and where separate arrangements have been made for document delivery which excludes the shipbuilder, that party has the responsibility.

It is recognized that the purpose of documents held in the Ship Construction File on board the ship, is to facilitate inspection(survey) and repair and maintenance, and therefore, is to include but not to limited to:

1. Final Drawings:

As-built structural drawings including scantling details, material details, and, as applicable, wastage allowances, location of butts and seams, cross section details and locations of all partial and full penetration welds, areas identified for close attention(for general dry cargo ships, liquefied gas carriers and ships subject to the enhanced survey programme) and rudders

And the followings are to be included.
(1) Approved plans of critical areas if applicable
(2) Hatch cover structural drawings and details if applicable
(3) Rudder structural drawings and details
(4) Freeboard marks and draft marks details
(5) Principal dimensions details

List of Final Drawings

Serial No.	DWG No.	Title of DWG	DWG Box No.

2. Manuals required for classification and statutory requirements, e.g. loading and stability, bow doors and inner doors and side shell doors and stern doors - operations and maintenance manuals(IACS UR S8(Bow Doors and Inner Doors) and S9(Side Shell Doors and Stern Doors)), including ship structures access manual, as applicable.

List of Manuals

Serial No.	Manual No.	Title of Manual	Manual Box No.

3. Copies of certificates of forgings and castings welded into the hull(IACS UR W7(Hull and Machinery Steel Forging) and W8(Hull and Machinery Steel Casting))

List of Copies of Certificates

Serial No.	Cert. No.	Title of Certificate	Remarks

(Note: Copies of Certificates are attached)

4. Details of equipment forming part of the watertight and weather tight integrity of the ship(e.g. overboard discharges, air pipes, ventilators)

List of Drawings or Copies of Certificates

Serial No.	DWG/Cert. No.	Title of DWG/Certificate	Box No.

(Note: Details(drawings, copies of certificates, etc.) of the relevant equipments are attached, or kept at specified box)

5. Tank testing plan including details of the test requirements(IACS UR S14(Testing Procedures of Watertight Compartments))

6. Corrosion prevention specifications(IACS UR Z8(Corrosion Protection Coating for Salt Water Ballast Spaces) and Z9(Corrosion Protection Coatings for Cargo Hold Spaces on Bulk Carriers))

7. Details for the in-water survey, if applicable, information for divers, clearances measurements instructions etc., tank and compartment boundaries.

8. Docking plan and details of all penetrations normally examined at drydocking.

9. Coating Technical File, for ships subject to compliance with the IMO Performance Standard for Protective Coatings(PSPC) as a class requirement under the IACS Common Structural Rules.

Annex 1-13 Owner's Hull Inspection and Maintenance Program

1. General

(1) The Owner's Hull Inspection and Maintenance Program is recommended as an assistant means for maintaining compliance with classification requirements between periodical surveys of the Society by means of owner's inspection and maintenance for the hull structure and corrosion prevention system on a regular basis. This program will not substitute the periodical survey to maintain the classification.
(2) This program can be applied to all type of ships at the request of the Owners. However, when an existing ship applies to enter the program, this program can be applied where deemed appropriate by the Society considering survey history, damage history and coating conditions, etc.
(3) The OHIMP notation shall be assigned as an additional special feature notation to ship comply with this Owner's Hull Inspection and Maintenance Program.
(4) The OHIMP notation and the application of this program may be cancelled by the Society if the program is not being satisfactorily carried out, should either the maintenance records or the general condition of the hull structure be determined to be unacceptable.
(5) In the case of a change of Owner, the application of this program is to be reconsidered.
(6) This program may be supported and maintained by a computerized system as deemed appropriate by the Society.

2. Requirements

(1) Outstanding recommendations/conditions of class related to the hull, should be completed prior to the ship being able to participate in this program.
(2) Surveys to maintain the classification are to be up-to-date, and without outstanding recommendations/conditions of class related to the hull structure and corrosion prevention system which would affect this program.
(3) In addition to the regular inspection and maintenance in accordance with the Owner's Hull Inspection and Maintenance Program, if there is a damage which may affect the classification at hull structure or corrosion prevention system, the occasional or additional inspections and maintenance are to be carried out and the damage is to be examined by the Society at the first port of call. If it necessary the voyage repairs are to be carried out in accordance with **Ch 2, 107. 5** of the Rules. The relevant details are to be recorded in the Owner's Hull Inspection and Maintenance Program as part of the report.

3. Approval and survey

(1) Documents and approval
The Owner is to submit a comprehensive Owner's Hull Inspection and Maintenance Program manual, which is to include the followings, to the Society for approval. The Society will issue an approval document for the Owner's Hull Inspection and Maintenance Program after review the presented documents.
(A) Safety policy and enclosed space entry procedures of the company.(For information only)
(B) General Arrangement
(C) Midship Section
(D) Complete list of each spaces and areas,(i.e., cargo holds, cargo tanks, ballast tanks, void spaces, cofferdams, pipe tunnels, etc.) covered by the Owner's Hull Inspection and Maintenance Program.
(E) Details of any corrosion prevention system and coating condition for each of the space and area specified in (D) above
(F) Inspection intervals corresponding to each space and area, or group of space and areas
(G) Maintenance descriptions detailing the minimum work necessary for the satisfactory inspection of the each space and area

(H) Sample reports and reporting procedures to confirm that the Owner's Hull Inspection and Maintenance Program is working properly onboard. There is to be a system for reporting the following information to the Owners office and for recording onboard;
(a) Details of the inspections carried out(details are to include proper structure identification such as tank/hold information, frame number, deck, shell plating, stringers, bulkheads and longitudinals as identified on the ship's drawings)
(b) The conditions as found
(c) Any findings, repairs or maintenance undertaken
(I) Selection of designated qualified inspector that conduct the inspection, including name, title and date of last related training
(J) Training information on qualified inspector to carry out these inspection
(K) Other documentations as deemed necessary by the Society

(2) Implementation survey
(A) The implementation survey is to be carried out within one year from the date of the approval of the Owner's Hull Inspection and Maintenance Program to verify that the Owner's Hull Inspection and Maintenance Program is implemented in accordance with the approval document.
(B) During the implementation survey, the attending Surveyor is to check the following items.
(a) An approval document for the Owner's Hull Inspection and Maintenance Program
(b) Documents specified in (1)
(c) Whether the Master and designated qualified inspectors are familiar with the Owner's Hull Inspection and Maintenance Program
(d) Check whether the Owner's Hull Inspection and Maintenance Program is operated satisfactorily.

(3) Annual audit
(A) An annual audit is to be carried out to check the operation of the Owner's Hull Inspection and Maintenance Program at Annual Survey
(B) At the annual audit the attending Surveyor is to check the following items.
(a) An approval document for the Owner's Hull Inspection and Maintenance Program
(b) Approved Owner's Hull Inspection and Maintenance Program manual
(c) Whether the Master and designated qualified inspectors are familiar with the Owner's Hull Inspection and Maintenance Program
(d) Ship's survey status and history
(e) The Owner's Hull Inspection and Maintenance Program information is being updated and the planned inspections are being carried and reported upon by a qualified inspector responsible for maintaining the detail of the program as required
(f) General review of the Owner's Hull Inspection and Maintenance Program inspections accomplished within the previous year is to be carried out
(g) If the inspection report(s) indicate damages or other defects that affect or may affect classification, then the affected area is to be examined.

4. Qualified inspector training

(1) The ship's designated inspector that will be carrying out the inspections for the Owner's Hull Inspection and Maintenance Program is to undergo training as deemed appropriate by the Society prior to being accepted as qualified inspector for this program.
(2) The training can be done either internally or externally as decided by the Owner. As a minimum, the training program is to include topics such as means of access, coating evaluation, terminology of ship structure, classification survey, typical hull defects and/or critical structural areas associated with the ship type, acceptance and evaluation criteria, reporting, etc. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 1 CLASSIFICATION AND SURVEYS

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2011

Rules for the Classification of Steel Ships

Part 2 Materials and Welding

Rules

2011

Guidance Relating to the Rules for the Classification of Steel ships

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Guidance

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Part 2

Materials and Welding

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Amendments to the Rules for the Classification of Steel Ships
(PART 2 MATERIALS AND WELDING, 2010 Edition)

Effective Date 1 July 2011

CHAPTER 1 MATERIALS

Section 1 General
- 101. 3. has been newly established.

Section 2 Test Specimens and Testing Procedures
- 202. 1. (5) and Table 2.1.2 have been amended

Section 3 Rolled Steels
- 301. 8. (3) has been amended.
- 308. 1. (4) has been newly established.

Section 4 Steel Tubes and Pipes
- Table 2.1.57 of 403. has been amended.

Section 5 Castings
- 501. 6. (2) has been amended.

Section 6 Steel Forgings
- Table 2.1.82 of 601. has been amended.

CHAPTER 2 WELDING

Section 3 Welding Work and Inspection
- Table 2.2.3 of 303. has been amended.

Section 4 Welding Procedure Qualification Tests
- 406. 2. (2) and (3) have been amended.

Section 5 Welders and Welder Performance Qualification Tests
- Table 2.2.13-1 and Table 2.2.13-2 of 502. 5. have been amended.
- Table 2.2.14 of 502. 6. has been amended.
- 503. 6. (2), (b) has been amended.

Section 6 Welding Consumables
- 601. 5. (1) has been amended and 601. 5. (2) has been deleted.
- 601. 6. (1) has been amended and 601. 6. (2) has been newly established.
- Table 2.2.16, Table 2.2.17, Table 2.2.18, Table 2.2.19, Table 2.2.20 and Table 2.2.21 of 602. have been amended.
- 602. 6. and Table 2.2.22 have been amended.

- Table 2.2.25, Table 2.2.28, Table 2.2.29, Table 2.2.30, Table 2.2.31 and Table 2.2.32 of 603. have been amended.
- 603. 6. (2) has been newly established.
- 603. 7. has been amended.
- Table 2.2.33, Table 2.2.35, Table 2.2.36 and Table 2.2.37 of 604. have been amended.
- Table 2.2.39, Table 2.2.41 and Table 2.2.42 of 605. have been amended.
- Table 2.2.45, Table 2.2.46 and Table 2.2.48 of 606. have been amended.
- 606. 5. has been amended.

CONTENTS

CHAPTER 1 MATERIALS

SECTION 1 General

101. Application

1. The requirements in this Chapter apply to the materials intended to be used for the components specified in each Part of hull construction, equipment and machinery.

2. The materials other than those prescribed in this Chapter may be used where specially approved in connection with the design. In such cases, the detailed data relating to the chemical compositions and mechanical properties, etc. of the materials are to be submitted for approval.

3. Reinforced plastic materials used for construction or repair of plastic pipes, FRP ships or composite vessel should be in accordance with the Guidance relating to the Rules specified by the Society.

102. Approval of manufacturing process and manufacturing control

1. Approval of manufacturing process

(1) The materials prescribed in this Chapter, unless otherwise specially provided, are to be manufactured by open-hearth, electric furnace, basic oxygen processes, or other processes at works approved by the Society. In this case, the manufacturer is to obtain the approval in accordance with the Guidance specially specified by the Society in advance concerning the process of manufacture (melting process, ingot casting, rolling, casting, forging and heat treating).
(2) The manufacturing process of semi-finished products such as ingots, slabs, blooms and billets for the normal and higher strength hull structural steels or forgings are to be approved in accordance with the Guidance specially specified by the Society in advance
(3) The rolled steel manufacturer supplied semi-finished products from other steel works or hot coil processor is required to obtain the approval of the manufacturing process according to the requirement of proceeding (1) as appropriate.
(4) The requirements specified in Pars (1) and (2) may be applied to the non-ferrous material prescribed in this Chapter.

2. Manufacturing control

(1) It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications.
(2) Where control imperfection inducing possible inferior quality of product occurs, the manufacturer is to identify the cause and establish a countermeasure to prevent its recurrence. Also, the complete investigation report is to be submitted to the Surveyor.
(3) For further use, each product affected by previous (2) is to be tested to the Surveyor's satisfaction. The frequency of testing for subsequent products offered may be increased to gain confidence in the quality at the discretion of the Society.
(4) When steel is not produced at the works at which it is rolled, a certificate is to be supplied to the Surveyor at the rolling mill stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the cast from which it was made and the ladle analysis. The Surveyor is to have access to the works at which the steel was produced.

103. Chemical composition

1. The chemical composition of samples taken from each ladle of each cast is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory and is to comply with the appropriate requirements for chemical composition provided in this Chapter.

2. The Manufacturer’s declared analysis will be accepted subject to occasional checks if required by the Surveyor.

3. Product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

104. Testing and inspection

1. The materials are to be tested and inspected in the presence of the Society's Surveyor except otherwise specially provided, and are to comply with the requirements in this Chapter.

2. The materials other than those prescribed in this Chapter are to be tested and inspected according to the specification for the testing approved in accordance with the requirements in **101. 2.**

3. The Society may accept to omit the tests for materials having the appropriate certificates.

4. Where the materials are manufactured by the approval of quality assurance scheme specially specified by the Society, a part or all of test and inspection in the presence of the Society's Surveyor may be omitted.

105. Execution of testing and inspection

1. The manufacturers shall afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify that the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by the Rules, and for verifying the accuracy of the testing equipment.

2. All tests and inspections are to be carried out at the place of manufacture before dispatch. The test specimens and procedures are to be in accordance with **Sec 2** of this chapter. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.

3. In the case of special order, the manufacturer is to show the order specifications, special requirements, etc. of the materials to the Surveyor prior to the material test.

4. Surface inspection and verification of dimensions are the responsibility of the steel maker. The acceptance by the Surveyor shall not absolve the steel maker from this responsibility.

106. Identification of materials

1. The manufacturer is to take a suitable measure for the identification of ingots, slabs, castings, forgings, and finished pieces, etc. which will enable the material to be traced to its original heat, roll, etc.

2. The steelmaker is to adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast. The Surveyor is to be given full facilities for so tracing the material when required.

3. Where small products such as castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Society.

107. Test certificates

1. The Certificate for Materials Inspection is to be issued to the materials that have been satisfactorily tested and inspected in accordance with the requirements in this Chapter.

2. The Certificate for Materials Inspection is to contain in addition to the dimensions and weight of steels at least the following particulars;

(1) Purchaser's name or purchaser's order number and if known the hull number for which the material is intended.
(2) Identification of the cast and rolled piece.
(3) Identification of the steelworks.
(4) Material grade mark
(5) Chemical composition (ladle analysis values of elements controlled by the requirements) and carbon equivalent calculated by following a formula. (if required)

$$Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} (\%)$$

(6) Mechanical properties.
(7) Condition of heat treatment (e.g. normalized or controlled roll except for as rolled)
(8) Deoxidization procedure is to be stated. (rimmed steel only)

3. Notwithstanding the previous provisions, the accepted material may be omitted the issue of the Certificate for Materials Inspection where the manufacturer supplies the Mill Sheets stated the requirement of the previous **Par 2** for each accepted steel grade to the Surveyor for his signature. In this case, the manufacturer is to enter the following statement on the certificate to show that the steel material has been made by an approval process and that it has withstand satisfactory the required tests. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steel works in English or Korean, and is to be signed by the personnel of the manufacturing shop in charge of product quality assurance or inspector.

"We hereby certify that the material has been made by an approval process and has been satisfactorily tested in accordance with the Rules of Korean Register of Shipping."

108. Quality and repair of defects

1. All materials are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

2. In the event of any material proving unsatisfactory during subsequent working or fabrication, such material may be rejected, notwithstanding any previous satisfactory testing and/or certification where the Surveyor considers necessary.

3. Welding or other means for the purpose of repairing defects is not permitted, unless the extent and method of repair (including welding procedure and heat treatment) are approved by the Surveyor. The repair of defects is to be carried out in the presence of the Surveyor, unless otherwise agreed.

4. Where repair by grinding is carried out then the remaining plate thickness below the ground area must be within the allowable under thickness tolerance.

109. Retest procedures

1. Where a part of the results of any test except impact test does not comply with the requirements, but the remainders are satisfactory, additional test specimens twice in number may be taken from the same material and retests for the failed test may be carried out. In such a case, all of the test specimens are to comply with the requirements.

2. Impact test

(1) Where the result of the impact test is unsatisfactory, additional tests may be carried out, with the exception of the cases specified in (i) and (ii) below, by taking a set of test specimens out of the same piece from which the above-mentioned test specimens have been taken.
  (i) The absorbed energy of all test specimens is under the required average absorbed energy.
  (ii) The absorbed energy of two of the test specimens is under 70 % the required average absorbed energy.

(2) In case of the previous (1), all pieces of the same lot from which the test specimens have been taken, may be accepted, provided that the average absorbed energy of the six test specimens, including those which have been rejected as unsatisfactory, is not less than the required average absorbed energy, and that not more than two individual results are lower than the required average absorbed energy and of these, not more than one result is below 70 % of the required average absorbed energy.

3. If a heat treated material fails to meet the requirements in any test, retest and heat treatment may be allowed two times(three times including the first test). In this case, however, the material is not to be considered as having complied with the requirements, unless all tests fully comply with the test requirements.

4. If the percentage of elongation of any tension test specimen is less than that specified and any part of fracture is outside the one-fourth of the gauge length from the centre of gauge length, the test is to be considered as invalid, and a retest for the material from which the first test specimen has been taken may be allowed.

110. Marking

1. Every material complying with the requirements is to be clearly stamped with the Society's brand 𝒦ℛ and material grade mark, and marked with the following particulars at least in one position by the maker:

(1) Name or mark to identify the steel works.
(2) Number or mark to identify the material.
(3) Name or mark to identify the purchaser. (if required by the purchaser)

2. Materials which have been specially approved by the Society in accordance with the requirements in **101. 2** are to have the letter "S" after the material grade mark.

3. Materials which are unsuitable for stamping may be marked with brands, seals or by other suitable means.

4. The marking particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products are to be encircled with paint or otherwise marked so as to be easily recognisable.

5. Materials which can not be stamped and marked in accordance with the requirements in **Pars 1** and **2** due to small size may be properly marked in the lump.

6. Where a number of light materials are securely fastened together in bundles the manufacturer may, subject to the agreement of the Society, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

7. In the event of any material bearing the Society's brand failing to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

SECTION 2 Test Specimens and Testing Procedures

201. General

1. Application

(1) Test specimens and mechanical testing procedures for materials are to comply with the requirements of this Section, unless otherwise specially provided in each Section.

(2) Where test specimens and testing procedures differing from those prescribed in this Section are used, they are to be approved by the Society.

2. Testing machine

(1) The testing machines used for the tests relative to this Chapter are to be managed by competent personnel on machines.

(2) Tension/compression testing machines are to be calibrated in accordance with *KS B ISO* 7500-1 or other recognised standard.

(3) Impact testing machines are to be calibrated in accordance with *KS B ISO* 148-2 or other recognised standard.

(4) The accuracy of tensile test machines is to be within ±1%

3. Selection of test specimens

(1) The test specimens are to be selected according to each requirement in this Chapter.

(2) Except where otherwise specified or agreed with the Surveyor, test samples are not to be detached from the material until being stamped by the Surveyor.

(3) If test samples are cut from material by flame cutting or shearing, a reasonable margin is required to enable sufficient material to be removed from the cut edges during final machining.

(4) The preparation of test specimens is to be done in such a manner that test specimens are not subjected to any significant cold working or heating.

(5) If any test specimen shows defective machining or defects having no relation to the substantial nature, it may be discarded and substituted by another test specimen.

202. Form and dimension of test specimen

1. Tensile test specimen

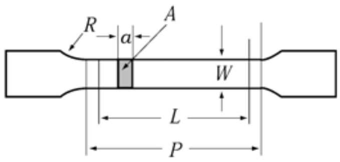
(1) Tensile test specimens are classified as standard test specimen and proportional test specimen as shown in **Table 2.1.1** depend on the shape and dimension of test specimen.

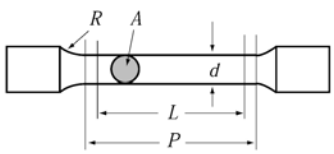
Table 2.1.1 Kinds of tensile test specimen

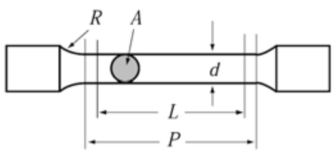
Kind	Flat	Round	Pipe
Proportional	*R*14*B*	*R*14*A*	*R*14*B*, *R*14*C*
Standard	*R*1*A*, *R*1*B*, *R*5, *R*13*B*	*R*4, *R*8*C*, *R*10	-

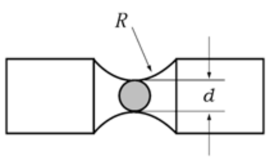
(2) Tensile test specimens are to be of the forms and sizes given in **Fig 2.1.1**

(3) The gauge length may be rounded off the nearest 5 mm, provided that the difference between this length and L is less than 10 % of L.

<table>
<tr><th>Shapes</th><th>Kind</th><th>Type</th><th>Forms of specimen(1)</th><th>Size of specimen(2)</th><th>Materials to be applied</th></tr>
<tr><td rowspan="5">Flat(3)</td><td>Proportional</td><td>R 14B</td><td rowspan="5">


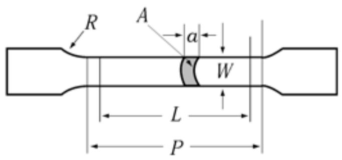
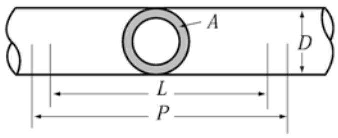
</td><td>a = t
W = 25 mm
L = $5.65\sqrt{A}$ (4)
P ≅ $L+2\sqrt{A}$
R = 25 mm</td><td>Rolled steels 3 mm thick or more,
Aluminium alloy 12.5mm thick or less</td></tr>
<tr><td rowspan="4">Standard</td><td>R 1A</td><td>a = t
W = 40 mm
L = 200 mm
P ≅ 220 mm
R = 25 mm</td><td>Rolled steel plates for boiler,
Rolled steel plates for pressure vessel</td></tr>
<tr><td>R 1B</td><td>a = t
W = 25 mm
L = 200 mm
P ≅ 212.5 mm
R = 25 mm</td><td>Rolled steels 3 mm thick or more,</td></tr>
<tr><td>R 5</td><td>a = t
W = 25 mm
L = 50 mm
P ≅ 60 mm
R = 15 mm</td><td>Rolled steel plates for pressure vessel</td></tr>
<tr><td>R 13B</td><td>a = t
W = 12.5 mm
L = 50 mm
P ≅ 60 mm
R = 25 mm</td><td>Rolled steels less than 3 mm thick</td></tr>
<tr><td rowspan="4">Round</td><td>Proportional</td><td>R 14A</td><td>


</td><td>L = 5 d(5)
P ≅ $L+0.5d$
R = 10 mm(6)</td><td>Rolled steels, Castings, Forgings, Spheroidal or nodular graphite iron castings, Copper alloy Aluminium alloy 12.5mm thick or more</td></tr>
<tr><td rowspan="3">Standard</td><td>R 4</td><td rowspan="2">


</td><td>d = 14 mm
L = 50 mm
P ≅ 60 mm
R = 15 mm</td><td>Rolled steel plates for pressure vessel</td></tr>
<tr><td>R 10</td><td>d = 12.5 mm
L = 50 mm
P ≅ 60 mm
R = 15 mm</td><td>Rolled steel plates for boiler</td></tr>
<tr><td>R 8C</td><td>


</td><td>d = 20 mm
R = 25 mm</td><td>Grey iron castings</td></tr>
</table>

Fig 2.1.1 Types and forms of tensile test specimens (unit : mm)

Shapes	Kind	Type	Forms of specimen	Size of specimen	Materials to be applied
Pipe	Proportional	R 14B		a = t $W \geq 12$ mm $L = 5.65\sqrt{A}$ $P \cong L + 2W$ R = 25 mm	Steel tubes, copper and copper alloy pipes and tubes
		R 14C		$L = 5.65\sqrt{A}$ $P \cong L + 0.5D$ P is the distance between the grips	

NOTES:
(1) The notations used are defined as follows.
d : Diameter, A : Cross section, a : Thickness, R : Transition radius, W : Width
D : External tube diameter, L : Gauge length, t : Plate thickness, P : Parallel test length
(2) The both ends of the test specimens may be machined to such shapes as to fit the holder of the testing machine.
(3) When the capacity of the available testing machine is insufficient to allow the use of test specimen of full thickness, this may be reduced by machining one of the rolled surfaces.
(4) Gauge length L should preferably be greater than 20 mm.
(5) d ≥ 10 mm to 20 mm, preferably 14 mm
(6) For nodular cast iron and materials with a specified elongation less than 10%, R ≥ 1,5

Fig 2.1.1 Types and forms of tensile test specimens (unit : mm)

(4) The manufacturers may use the test specimens approved by the Society, besides those specified in (2). In this case, the elongation measured at the tensile tests is to be corrected by the following formula:

$$n = a \cdot E \left(\frac{\sqrt{A}}{L} \right)^b$$

where:

E = equivalent elongation for the proportional test specimens specified in (1) (%).

n = actual measured elongation of test specimen (%).

A = actual cross-sectional area of test specimen (mm^2).

L = actual gauge length of test specimen (mm).

a, b = constants given in bellow in accordance with the kind of materials.

Material \ Constant	a	b
Material 1	2.0	0.40
Material 2	2.6	0.55

NOTES:
1. Material 1 : For carbon and low alloy steels with a tensile strength not exceeding 590 N/mm^2 in the hot rolled, annealed, normalized or normalized and tempered conditions.
2. Material 2 : For carbon and low alloy steels in the quenched and tempered condition.
3. The values of a and b for other kinds of materials than Material 1 and Material 2 are to be as deemed appropriate by the Society.

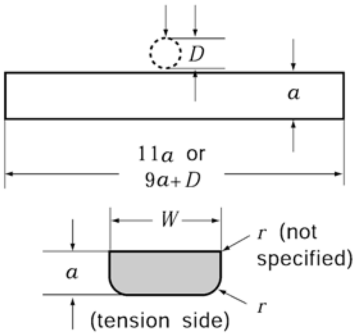
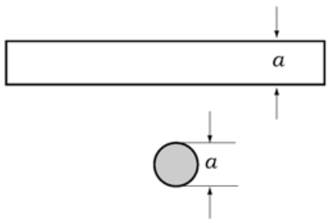
(5) The machine-finished parallel part of test specimens is to be uniform throughout the entire length and the permissible variation (difference between the maximum and minimum values) is to be as specified in **Table 2.1.2.**

Table 2.1.2 Permissible Variation (unit : mm)

Round specimen		Flat specimen with thickness equal to or greater than 6 mm				Flat specimen with thickness less than 6 mm			
Nominal diameter (d)	Permissible variation	Nominal Thickness (t)	permissible variation	Nominal width (w)	permissible variation	Nominal Thickness (t)	permissible variation	Nominal width (w)	permissible variation
10≤d<12	0.025	6≤t<12	0.02	25≤w<40	0.05	0.6≤t<1.2	0.002	12.5≤w<25	0.02
12≤d<16	0.03	12≤t<20	0.04	40≤w	0.10	1.2≤t<2.5	0.004	25≤w	0.04
16≤d	0.04	20≤t	0.05			2.5≤t<6	0.01		

2. Bend test specimen

Bend test specimens are to be of size and dimensions given in **Fig 2.1.2** according to the kind of materials.

Kinds	Size of specimens	Dimensions	Materials to be applied
R 1		a = 20 W = 25 r = 1~2	Headers(**Ch 4, 405**)
		a = t W = 30 r = 1~2 Where the thickness of materials exceeds 25*mm*, the thickness of test specimen may be reduced to 25*mm* with its surface machined on compression side only.	Rolled steels(Steel plate) (**Ch 3**)
R 2		a = d Where the diameter or the width across flat of materials exceeds 35*mm*, they may be machined finished to a circular section of diameter not less than 35*mm*.	Rolled steels (Rolled steel bars for boiler) (**Ch 3, 307.**)

NOTES:
The following designations are used:
a : Thickness, diameter or width
r : Edge radius
D : Diameter of mandrel
d : Diameter or width
W : Width
t : Thickness of material

Fig. 2.1.2 Size and Dimensions of Bend Test Specimens (Unit: *mm*)

3. Impact test specimen

(1) Impact test specimens are to be provided in a set of three specimens, and the test specimens are to be machine finished to the forms and dimensions given in **Fig 2.1.3** and **Table 2.1.3**

unless the section thickness of the product is less than 12 mm

(2) The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface, casting surface and forging surface according to the kind of materials. The position of the notch is not to be nearer than 25 mm to a flame cut or sheared edge.

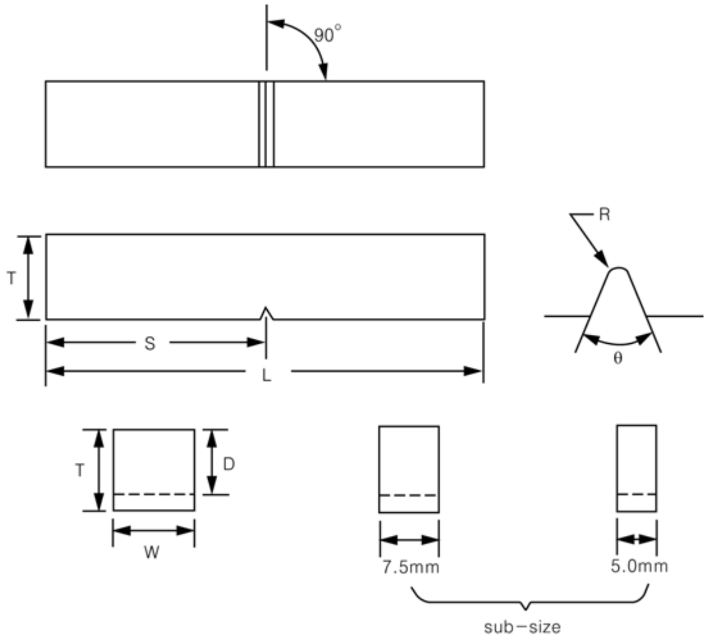


Fig 2.1.3 Impact test specimen

Table 2.1.3 Dimensions of impact Test Specimens

Dimensions	Kinds	Charpy V-notch test specimen
Length (mm)	L	55 ± 0.6
Width (mm)	W	10 ± 0.11
Thickness (mm)	T	10 ± 0.06
Angle of notch (mm)	θ	45 ± 2
Depth below notch (mm)	D	8 ± 0.06
Root radius of notch (mm)	R	0.25 ± 0.025
Distance of notch from end of test specimen (mm)	S	27.5 ± 0.42
Angle between plane of symmetry of notch and longitudinal axis of test specimen (deg)	-	90 ± 2

(3) Where the impact test specimens, having the size specified in (1) above for rolled steels, tubes and pipes cannot be taken, the width W may be the sub-size values given in **Table 2.1.4.** In this case, the average absorbed energy of rolled steels, tubes and pipes is not to be less than the value(by counting fractions of 0.05 and over as 0.1 and disregarding the rest) multiplying the absorbed energy by values given in **Table 2.1.4** in accordance with the width of the test specimens.

Table 2.1.4 Multiplier to Absorbed Energy

Thickness and width of sub-size specimen t×W (mm)	Multiplier for absorbed energy
	Average absorbed energy of 3 test specimens
10 × 5 ± 0.06	2/3
10 × 7.5 ± 0.11	5/6

(4) Where the thickness of a test specimen is less than 6 mm, and where impact test specimen having the sub-size specified in **Table 2.1.4** cannot be taken in welded parts of tubes and pipes, the impact test may be omitted.
(5) In all cases, the largest size charpy specimens possible for the material thickness shall be machined.

4. Confirmation for test specimen

The size and dimensions of test specimens are to be carefully inspected and verified by suitable means before testing.

203. Testing procedure

1. Tensile test

(1) When well-defined yield phenomena exists, the value of yield strength(yield stress) is to be measured at the first peak obtained during yielding. When no well defined yield phenomenon exists, the 0.2 % proof stress (Rp0.2) is to be determined. For austenitic and duplex stainless steel products, the 1 % proof stress (Rp1) may be determined in addition to Rp 0.2 as approved by the Society.
(2) Where the value of yield point or yield stress is measured at tensile test, the rate of loading shall be as specified in **Table 2.1.5.**

Table 2.1.5 Rate of loading

Modulus of Elasticity of the material (E) (N/mm^2)	Rate of stressing ($N/mm^2/sec$)	
	Min.	Max.
< 150,000	2	20
≥150,000	6	60

(3) After reaching the yield or proof load, for ductile material the machine speed during the tensile test is not to exceed that corresponding to a strain rate of $0.008s^{-1}$. For brittle materials, such as cast iron, the elastic stress rate is not to exceed 10 $N/mm^2/sec$

2. Impact test

The impact test is to be conducted on a Charpy impact testing machine having a capacity not less than 150 J and a striking velocity between 4.5 and 6 m/sec, with the test specimens at temperature controlled within +2℃ of the specified temperature.

SECTION 3 Rolled Steels

301. Rolled steels for hull structural

1. Application

(1) The requirements are to apply to hull structural rolled steels (hereinafter referred to as "steels") not exceeding 100 mm in thickness.
(2) Any requirement regarding steels over the thickness specified in **Table 2.1.5** is to be left to the discretion of the Society.
(3) Where improved through thickness properties are specified for plates and wide flats with thickness of 15 mm and over, the tensile test of through thickness property specified in **310.** is to be carried out in addition to the requirements of **301.**
(4) Steels other than those specified in **301.** are to be in accordance with the requirements of **101. 2.**

2. Kinds

Steels are classified as specified in **Table 2.1.5.**

Table 2.1.5 Grades of Rolled Steels for hull

Kinds		Grade	Thickness t (mm)
Normal strength steel(1)	Plates(3)	*A*, *B*, *D*, *E*	$t \leq 100$
	Sections and bars		$t \leq 50$
Higher strength steels(2)	Plates(3)	*AH* 32, *DH* 32, *EH* 32, *FH* 32 *AH* 36, *DH* 36, *EH* 36, *FH* 36 *AH* 40, *DH* 40, *EH* 40, *FH* 40	$t \leq 100$
	Sections and bars	*AH* 32, *DH* 32, *EH* 32, *FH* 32 *AH* 36, *DH* 36, *EH* 36, *FH* 36 *AH* 40, *DH* 40, *EH* 40, *FH* 40	$t \leq 50$

NOTE:
(1) Provision is made for four grades of normal strength steels based on the impact test requirements.
(2) For higher strength steels, provision is made for three strength levels(315, 355 and 390 N/mm^2) each subdivided into four grades(ex. : *AH* 32, *DH* 32, *EH* 32 and *FH* 32) based on the impact test temperature.
(3) Steel plates include flat bars not less than 600 mm in width.

3. Manufacturing process

(1) Where steel plates are manufactured from the continuous casting slabs, the maximum thickness for approval is to be determined, as a rule, with the roll ratio of 6 as standard. However, upon consideration of the manufacturing process, the roll ratio may be reduced to 4 (3 for steel plate thickness in excess of 50 mm).
(2) The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table 2.1.6.** For steel plates and wide flats over 50mm thick and When thermo-mechanical controlled processing (hereinafter referred to as "TMCP") is used as heat treatment, slight deviations in the chemical composition may be allowed as approved by the Society.

4. Heat treatment

The heat treatment of each grade is to comply with the requirements given in **Table 2.1.8** and **Table 2.1.9.**

5. Mechanical properties

The mechanical properties of steels are to comply with the requirements given in **Table 2.1.7.**

Table 2.1.6 Deoxidation Practice and Chemical Composition

Kinds	Grade	Thickness, t(mm)	Deoxidation Practice	Chemical Composition (%) (5): C	Si	Mn	P	S	Cu	Cr	Ni	Mo	Al(8)	Nb	V	Ti	N
Normal strength steels	*A*	$t \le 50$	Killed and Semi-killed(1)	0.21 max. (3)(4)	0.50 max.	2.5×C min. (4)	0.035 max.	0.035 max.	-	-	-	-	-	-	-	-	-
		$t > 50$	Killed														
	B	$t \le 50$	Killed and Semi-killed	0.21 max. (4)	0.35 max.	0.8 min. (4)(6)											
		$t > 50$	Killed														
	D	$t \le 25$	Killed	0.21 max. (4)	0.35 max.	0.6 min. (4)							0.015 min. (2)(9)				
		$t > 25$	Fine grain treated(2)														
	E	$t \le 100$	Killed and Fine grain treated	0.18 max. (4)	0.35 max.	0.7 min. (4)							0.015 min. (9)				
Higher strength steels (13)	*AH 32*	$t \le 100$	Killed and Fine grain treated	0.18 max.	0.50 max.	0.90~1.60 (7)	0.035 max.	0.035 max.	0.35 max.	0.20 max.	0.40 max.	0.08 max.	0.015 min. (10)	0.02~0.05 (10)(11)	0.05~0.10 (10)(11)	0.02 max. (11)	-
	DH 32																
	EH 32																
	AH 36																
	DH 36																
	EH 36																
	AH 40	$t \le 50$															
	DH 40																
	EH 40																
	FH 32			0.16 max.		0.90~1.60	0.025 max.	0.025 max.			0.80 max.						0.009 max. (12)
	FH 36																
	FH 40																

NOTES:
(1) For sections up to 12.5 mm in thickness inclusive, subject to a special approval by the Society, rimmed steel may be accepted.
(2) For steels above 25 mm in thickness, aluminium treatment is to be used as a fully killed, fine grain practice. However, killed steel up to 50 mm in thickness may be accepted at the discretion of the Society.
(3) For steel sections, maximum carbon content may be increased to 0.23 %.
(4) The value of $C + Mn/6$ is not to exceed 0.40 %.
(5) Where additions of any other element have been made as part of the steelmaking practice, the content is to be indicated on the test certificate.
(6) When an impact test as killed steels is conducted, the minimum manganese content may be reduced to 0.60 %.
(7) For steels up to 12.5 mm in thickness inclusive, the minimum manganese content may be reduced to 0.70 %.
(8) Aluminium content is to be represented by the acid soluble aluminium content, but may be determined by the total aluminium content. In such a case, the total aluminium content is not to be less than 0.020 %.
(9) Upon the approval by the Society, grain refining elements other than aluminium may be used.
(10) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
(11) The total niobium, vanadium and titanium content is to be less than 0.12 %.
(12) If Aluminium is present, the maximum content of nitrogen may be increased to 0.012 %.
(13) For TMCP steels, carbon equivalent values(*Ceq*) and/or cold cracking susceptibility(*Pcm*) of each steel is to be left to the discretion of the Society.

Table 2.1.7 Mechanical Properties

Grade	Tensile test			Impact test						
	Yield strength (N/mm²)	Tensile strength (N/mm²)	Elongation[6] ($L=5.65\sqrt{A}$) (%)	test temp (℃)	Average absorbed energy [1](J)					
					Thickness, t (mm)					
					$t \le 50$		$50 < t \le 70$		$70 < t \le 100$	
					L[2]	T[2]	L[2]	T[2]	L[2]	T[2]
A	235 min.	400~520[3]	22 min.	+20	-	-	[4]	[4]	[4]	[4]
B				0[5]	27 min.	20 min.	34 min.	24 min.	41 min.	27 min.
D				-20						
E				-40						
AH 32	315 min.	440~570	22 min.	0	31 min.	22 min.	38 min.	26 min.	46 min.	31 min.
DH 32				-20						
EH 32				-40						
FH 32				-60						
AH 36	355 min.	490~630	21 min.	0	34 min.	24 min.	41 min.	27 min.	50 min.	34 min.
DH 36				-20						
EH 36				-40						
FH 36				-60						
AH 40	390 min.	510~660	20 min.	0	39 min.	26 min.	46 min.	31 min.	55 min.	37 min.
DH 40				-20						
EH 40				-40						
FH 40				-60						

NOTE:
(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to be failed.
(2) L (or T) denotes that the longitudinal axis of the test specimen is arranged parallel (or transverse) to the final direction of rolling.
(3) For all thickness of Grade *A* section, the upper limit of the specified tensile strength, may be exceeded.
(4) For Grade *A* steel over 50 mm in thickness with *ARS* or *CRS* heat treatment, impact tests are required. In this case, the average absorbed energy is to comply with the requirements of Grade *B* steel.
(5) For Grade *B* steels up to 25 mm in thickness, generally no impact testing is required.
(6) The minimum elongation for *R* 1*B* test specimen (L=200mm) is to be in compliance with the requirement given in the Table below.

Grade \ Thickness t (mm)	$3\le t\le 5$	$5<t\le 10$	$10<t\le 15$	$15<t\le 20$	$20<t\le 25$	$25<t\le 30$	$30<t\le 40$	$40<t\le 100$
A, *B*, *D*, *E*, *AH* 32, *DH* 32, *EH* 32, *FH* 32	14	16	17	18	19	20	21	22
AH 36, *DH* 36, *EH* 36, *FH* 36	13	15	16	17	18	19	20	21
AH 40, *DH* 40, *EH*40, *FH* 40	12	14	15	16	17	18	19	20

Table 2.1.8 Heat Treatment and Size of lot for Impact Test specimen for Normal Strength Steels

Grade	Deoxidation practice	Products[5]	Heat treatment and Size of Lot for Impact Test Specimen[(1)(2)(3)(4)]				
			Thickness(mm)				
			0 – 12.5	12.5 – 25	25 – 35	35 – 50	50 – 100
A	Rimmed[(6)]	Sections	*AR*<->				
	Semi-killed	All	*AR*<->				
	Killed	Plates	*AR*<->				*N*<-> *TMCP*<-> *CRS*<50>[(6)] *ARS*<50>[(6)]
		Sections and bars	*AR*<->				
B	Semi-killed	All	*AR*<->		*AR*<50>		
	Killed	Plates	*AR*<->		*AR*<50>		*N*<50> *TMCP*<50> *CRS*<25> *ARS*<25>
		Sections and bars	*AR*<->		*AR*<50>		
D	Killed	All	*AR*<50>		*TMCP*<50> *N*<50> *CR*<50>		
	Fine grain treated	Plates	*AR*<50>			*TMCP*<50> *N*<50> *CR*<50>	*TMCP*<50> *N*<50> *CRS*<25>
		Sections and bars	*AR*<50>			*TMCP*<50> *N*<50> *CR*<50> *ARS*<25>	
E	Killed and Fine grain treated	Plates	*TMCP*<P> *N*<P>				
		Sections and bars	*TMCP*<25> *N*<25> *CRS*<15> *ARS*<15>				

NOTES:

(1) Indication symbols used in heat treatment are as follows(the same holds henceforth in this Section):
AR : As Rolled *CR* : Controlled Rolling Condition *N* : Normalized Condition
TMCP : Thermo-Mechanical Controlled Processing
ARS : As Rolled Condition subject to special approval of the Society
CRS : Controlled Rolled Condition subject to special approval of the Society.

(2) In the Table, "marks" put at the end of each symbol for heat treatment stand for the volume of each lot. For examples, <50>, <25> and <15> each indicate that steels not greater than 50, 25 and 15 tonnes in weight (belonging to the same charge in the same manufacturing process) are to be taken as one lot; <P>, Piece, indicates that steel material rolled directly from one slab, billet or steel ingot is to be taken as one lot; and <-> indicates that no impact test is required. The term "piece" is understood to mean the rolled product from a single slab, billet or ingot if this is rolled directly into plates, sections or bars.

(3) *TMCP*, *N* or *CR* may be applied to instead of being left in a state of *AR*. In this case, steels are to be treated equivalent to those left in a state of *AR* with regard to the fundamental unit of lot.

(4) Steel plates include flat bars not less than 600 mm in width.

(5) For sections up to 12.5 mm in thickness, subject to a special approval by the Society, rimmed steel may be accepted.

(6) See Note (4) of **Table 2.1.7**

Table 2.1.9 Heat Treatment and Size of Lot for Impact Test Specimen for Higher Strength Steels

Grade	Deoxidation practice		Products[5]	Heat treatment and Size of Lot for Impact Test Specimen[1][2][3][4] — Thickness (mm): 0–12.5	12.5–20	20–25	25–35	35–50	50–100
AH 32 *AH 36*	Killed and Fine grain treated	Nb and/or V[5]	Plates	*AR*<50>	*TMCP*<50> *N*<50> *CR*<50>				*TMCP*<50> *N*<50> *CR*<25>
			Sections and bars	*AR*<50>	*TMCP*<50> *N*<50> *CR*<50> *ARS*<25>				
		Al alone or with Ti	Plates	*AR*<50>		*ARS*<50>			
						TMCP<50> *N*<50> *CR*<50>			*TMCP*<50> *N*<50> *CR*<25>
			Sections and bars	*AR*<50>		*TMCP*<50> *N*<50> *CR*<50> *ARS*<25>			
DH 32 *DH 36*		Nb and/or V[5]	Plates	*AR*<50>	*TMCP*<50> *N*<50> *CR*<50>				*TMCP*<50> *N*<50> *CR*<25>
			Sections and bars	*AR*<50>	*TMCP*<50> *N*<50> *CR*<50> *ARS*<25>				
		Al alone or with Ti	Plates	*AR*<50>		*ARS* <25>			
						TMCP<50> *N*<50> *CR*<50>			*TMCP*<50> *N*<50> *CRS*<25>
			Sections and bars	*AR*<50>		*TMCP*<50> *N*<50> *CR*<50> *ARS*<25>			
EH 32 *EH 36*		Any grain refining treated elements	Plates	*TMCP*<P> *N*<P>					
			Sections and bars	*TMCP*<25> *N*<25> *CR*<15> *ARS*<15>					
FH 32 *FH 36*			Plates	*TMCP*<P> *N*<P> *QT*<P>					
			Sections and bars	*TMCP*<25> *N*<25> *QT*<25> *ARS*<15>					
AH 40			Plates	*AR*<50>	*TMCP*<50> *N*<50> *CR*<50>				*TMCP*<50> *N*<50> *QT*<P>
			Sections and bars	*AR*<50>	*TMCP*<50> *N*<50> *CR*<50>				
DH 40			Plates	*TMCP*<50> *N*<50> *CR*<50>					*TMCP*<50> *N*<50> *QT*<P>
			Sections and bars	*TMCP*<50> *N*<50> *CR*<50>					
EH 40			Plates	*TMCP*<P> *N*<P> *QT*<P>					
			Sections and bars	*TMCP*<25> *N*<25> *QT*<25>					
FH 40			Plates	*TMCP*<P> *N*<P> *QT*<P>					
			Sections and bars	*TMCP*<25> *N*<25> *QT*<25>					

NOTES:

(1) Indication symbols used in heat treatment are as follows (the same holds henceforth in this Section);
AR : As rolled *CR* : Controlled Rolling Condition *N* : Normalized Condition
TMCP : Thermo-Mechanical Controlled Processing *QT* : Quenched and Tempered Condition
ARS : As Rolled Condition subject to special approval of the Society
CRS : Controlled Rolled Condition subject to special approval of the Society.

(2) In the Table, "marks" put at the end of each symbol for heat treatment stand for the volume of each lot. For examples, <50>, <25> and <15> each indicate that steels not greater than 50, 25 and 15 tonnes in weight (belonging to the same charge in the same manufacturing process) are to be taken as one lot; <P>, Piece, indicates that steel material rolled directly from one slab, billet or steel ingot is to be taken as one lot; and <-> indicates that no impact test is required. The term "piece" is understood to mean the rolled product from a single slab, billet or ingot if this is rolled directly into plates, sections or bars.

(3) *TMCP*, *N* or *CR* may be applied to instead of being left in a state of *AR*. In this case, steels are to be treated equivalent to those left in a state of *AR* with regard to the fundamental unit of lot.

(4) Steel plates include flat bars not less than 600 mm in width.

(5) Niobium treatment stands for the addition of *Nb* either singly or in any combination, regardless of the Nb content, for grain refining. (Refer to Note (10) of **Table 2.1.6**)

6. Selection of test samples

(1) All material in a batch presented for acceptance tests is to be of the same product form e.g. plates, flats, sections, etc. from the same cast and in the same condition of supply. The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.

(2) For the samples of steel from which tensile test specimens are cut, except where specially approved by the Society, steels not greater than 50 tonnes in mass (where the amount of scatter is to be less than 10 mm in thickness or diameter even when they belong to the same cast in the same manufacturing process) are to be treated as one lot, and the largest one in thickness or diameter is to be selected from each lot.

(3) For the samples of steel from which impact test specimens are cut, unless otherwise specially provided or except where specially approved by the Society, the thickest test sample is to be selected from each lot specified in **Table 2.1.8** and **Table 2.1.9,** according to the substance of deoxidation practices, type of products and kind of heat treatments

(4) The test samples are to be taken from the following portions according to the requirements (a) to (c) below and **Fig 2.1.4,** unless otherwise specified:

(a) *Plates and flat bars wider than 600* mm :
One end at a portion approximately 1/4 of the width from the flange end of the plates or flat bars.

(b) *Sections and flat bars not exceeding 600* mm *in width:*
One end at a portion approximately 1/3 of the width from the flange end. In case of channels, bulb plates and H-section, the test samples may be taken from the portion approximately 1/4 of the depth from the centre line of the web.

(c) *Bars:*
The test samples are to be taken so that the axis of each test specimen may lie as near as possible to the portion specified in (i) and (ii) below. This rule, however, does not apply when, because dimensions of cross section are insufficient for standard test specimens, a piece cut in a proper length from the product having the largest diameter of a certain lot is used as it is for a tensile test.

(i) For non-circular sections, at approximately 1/6 of the largest distance from the outside.
(ii) For circular section, at approximately 1/6 of the diameter from the outside.

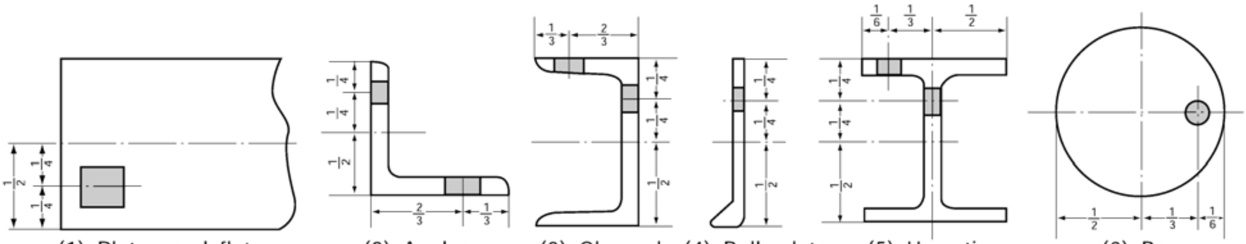


Fig. 2.1.4 Selection of Test Samples

7. Selection of test specimens

(1) Test specimens are not to be heat treated separately from the product.

(2) Tensile test specimens are to be taken according to (a) to (c) below.

(a) One test specimen is to be taken from one test sample.

(b) The test specimens are to be taken with their longitudinal axis normal to the final direction of rolling. For sections, bars and flat bars not exceeding 600 mm in width or when specially approved by the Society, however, they are to be taken with their longitudinal axis parallel to the final direction of rolling.

(c) Flat test specimens of full product thickness are, generally, to be used. Round test specimen may be used when the plates and shapes(except bars) thickness exceeds 40 mm or for bars. When tensile test specimens of bar type are taken from plates and shapes except bars, they are to be taken at a portion approximately 1/4 of the thickness from the surface.

(3) Impact test specimens are to be taken according to (a) to (c) below.
  (a) A set of test specimens is to be taken from one test sample.
  (b) The test specimens are to be taken with their longitudinal axis parallel (L direction) to the final direction of rolling. When deemed necessary by the Society, however, they are to be taken with their longitudinal axis normal (T direction) to the final direction of rolling.
  (c) When the product thickness does not exceed 40 mm, the test specimens are to be cut with their edge within 2 mm from the "as rolled" surface. When the product thickness exceeds 40 mm, the test specimen is to be taken at a portion where the axis of the test specimen corresponds to approximately 1/4 of the thickness (1/6 of the diameter of bars) from the surface.

8. Surface inspection and verification of dimensions

(1) The maximum permissible under thickness tolerance for plates and wide flats is -0.3 mm. Tolerances for over thickness may be taken from KS or proprietary specification which give reasonable equivalence. But the thickness tolerances for plates with thickness less than 5 mm may be specially agreed by the Society.
(2) Tolerances for rolled steel other than plates and wide flats may be specially agreed.
(3) Tolerances for length, width and flatness should be in accordance with a recognized national or international standard which specially agreed by the Society.
(4) The thickness is to be measured at random locations whose distance from longitudinal edge is to be at least 10 mm.

9. Quality and repair of defects

(1) The quality of finished steel is to be in accordance with the requirements specified in **101. 1.** and **2.** The steel is to be reasonably free from segregations and non-metallic inclusions.
(2) If plates and wide flats are ordered with ultrasonic inspection or required by the Society, the test procedure and acceptance criteria are to be made in accordance with an accepted standard at the discretion of the Society. However, the probe frequency is to be of 4MHz in general.
(3) The surface defects may be removed by local grinding. However, the procedure of removal of defect and repair is to be in accordance with the Guidance relating to the Rules specified by the Society.

10. Retest Procedures

(1) Where the tensile test fails to meet the requirements, two further tensile tests may be made from the same piece. If both of these additional tests meet all of the requirements, the piece and the remaining pieces from the same lot may be accepted.
(2) If one or both of the additional tests referred to above are unsatisfactory, the piece from which the above-mentioned test pieces have been taken is to be rejected. However, the remaining material from the same lot may be accepted, provided that two of the remaining pieces in the lot, selected in the same way, are tested with satisfactory results.
(3) (a) Where the result of the impact test is unsatisfactory, additional tests may be carried out, with the exception of the cases specified in (i) and (ii) below, by taking a set of test specimens out of the same piece from which the above-mentioned test specimens have been taken.
    (i) The absorbed energy of all test specimens is under the required average absorbed energy.
    (ii) The absorbed energy of two of the test specimens is under 70% the required average absorbed energy.
  (b) In case of the previous (a), all pieces of the same lot from which the test specimens have been taken, may be accepted, provided that the average absorbed energy of the six test specimens, including those which have been rejected as unsatisfactory, is not less than the required average absorbed energy, and that not more than two individual results are lower than the required average absorbed energy and of these, not more than one result is below 70 % of the required average absorbed energy.
(4) When the initial piece, representing a lot, gives unsatisfactory results from the additional Charpy V-notch impact tests referred to the preceding (3), this piece is to be rejected but the remaining material in the lot may be accepted provided that two of the remaining pieces in the lot are tested with satisfactory results. If unsatisfactory results are obtained from either of these two

pieces, then the lot of material is to be rejected. The pieces selected for these additional tests are to be the thickest remaining in the batch.

(5) If any test specimen fails because of faulty preparation, visible defects or (in the case of tensile test) because of fracturing outside the range permitted for the appropriate gauge length, the defective test piece may, at the Surveyors discretion, be disregarded and replayed by an additional test piece of the same type.

(6) Where the test pieces fail in the retests specified above, the piece from which the test pieces have been taken is to be rejected, However, at the consultation of the manufacturer and the orderer, the remaining pieces in the lot may be resubmitted individually for test and those pieces which give satisfactory results may be accepted.

(7) At the consultation of the manufacturer and the order, the rejected piece may be resubmitted after heat treatment of re-heat treatment, or may be resubmitted as any other grade of steel and then, may be accepted, provided that the required tests are satisfactory.

11. Marking

Steels which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.** and material supplied in the thermo-mechanical controlled processing condition is to have the letters TM added after the material grade mark. (e.g. *EH* 40*TM*)

302. Rolled steel plates for boiler

1. Application

(1) These requirements are to apply to the steel plates (hereinafter referred to as "steel plates") for boilers and pressure vessels to be used at high temperatures.

(2) Steel plates other than those specified in **302.** are to comply with the requirements in **101. 2.**

2. Kinds The steel plates are classified as specified in **Table 2.1.10.**

Table 2.1.10 Grades of Steel Plates

Grade	Max. thickness (mm)
RSP 42	200
RSP 46	
RSP 49	
RSP 46A	150
RSP 49A	

3. Heat treatment

(1) For steel plates of the "*RSP* 42, *RSP* 46 and *RSP* 49" grade with 50 mm or less and of the "*RSP* 46*A* and *RSP* 49*A*" grade with 38 mm or less in thickness, they are to be as rolled. They, however, may be heat treated(normalized or annealed for stress relieving) as deemed necessary by the manufacturer.

(2) For steel plates of the "*RSP* 42, *RSP* 46 and *RSP* 49" grade more than 50 mm and of the "*RSP* 46*A* and *RSP* 49*A*" grade more than 38 mm in thickness, they are to be either normalized to obtain the normal grain size or heated uniformly to such a temperature at the time of hot forming that an effect equivalent to normalizing can be achieved. In case of normalizing, it is, in principle, to be performed by the manufacturer.

4. Chemical composition

The chemical composition of steel plates is to comply with the requirements given in **Table 2.1.11.**

Table 2.1.11 Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th colspan="7">Chemical composition (%)</th></tr>
<tr><th>Thickness
t (mm)</th><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Mo</th></tr>
<tr><td>RSP 42</td><td>$t \leq 25$
$25 < t \leq 50$
$50 < t \leq 200$</td><td>0.24 max.
0.27 max.
0.30 max.</td><td rowspan="5">0.15～0.40</td><td rowspan="2">0.90
max.</td><td rowspan="5">0.030
max.</td><td rowspan="5">0.030
max.</td><td rowspan="3">-</td></tr>
<tr><td>RSP 46</td><td>$t \leq 25$
$25 < t \leq 50$
$50 < t \leq 200$</td><td>0.28 max.
0.31 max.
0.33 max.</td></tr>
<tr><td>RSP 49</td><td>$t \leq 25$
$25 < t \leq 50$
$50 < t \leq 200$</td><td>0.31 max.
0.33 max.
0.35 max.</td><td>1.20
max.</td></tr>
<tr><td>RSP 46A</td><td>$t \leq 25$
$25 < t \leq 50$
$50 < t \leq 100$
$100 < t \leq 150$</td><td>0.18 max.
0.21 max.
0.23 max.
0.25 max.</td><td rowspan="2">0.90
max.</td><td rowspan="2">0.45~0.60</td></tr>
<tr><td>RSP 49A</td><td>$t \leq 25$
$25 < t \leq 50$
$50 < t \leq 100$
$100 < t \leq 150$</td><td>0.20 max.
0.23 max.
0.25 max.
0.27 max.</td></tr>
<tr><td colspan="8">NOTES:
1. For RSP 46 with 25 mm and over in thickness, carbon and manganese content may be 0.30 % or less and 1.00 % or less, respectively.</td></tr>
</table>

5. Mechanical properties

The mechanical properties of steel plates are to comply with the requirements given in **Table 2.1.12.**

Table 2.1.12 Mechanical Properties

Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	
			R1A	*R10*
RSP 42	225 min.	410 ~ 550	21 min.	25 min.
RSP 46	245 min.	450 ~ 590	19 min.	23 min.
RSP 49	265 min.	480 ~ 620	17 min.	21 min.
RSP 46*A*	255 min.	450 ~ 590	19 min.	23 min.
RSP 49*A*	275 min.	480 ~ 620	17 min.	21 min.

NOTE:
(1) *R1A* tensile test specimen is to be used for steel plate up to 50mm in thickness and *R*10 test specimen for steel plate more than 50 mm in thickness. However *R*10 test specimen can be used for steel plate more than 40 mm in thickness.
(2) For material under 8 mm in thickness, a deduction from the specified percentage of elongation of 1 % is to be made for each decrease of 1 mm of the specified thickness.
(3) For the plates over 90 mm in thickness, the elongation may be reduced from that mentioned in the above Table by 0.5 % for each increment of 12.5 mm or fraction thereof exceeding 90 mm in thickness. Such reduction, however, is limited to 3 %.
(4) In case where the elongation of *RSP*46*A* with thickness between 6mm and 20 mm exclusive and *RSP*49*A* steel plate is insufficient within 3 % of the specified value, It will be able to regard as satisfactory if the elongation of the gauge length 50 mm which includes a rupture part is of 25 % or more.

6. Selection and heat treatment of test samples

(1) For the steel plates which are not to be heat treated, one test sample is to be taken from each plate as rolled directly from one slab or ingot
(2) For the steel plates which are to be heat treated, one test sample is to be taken from every similarly heat treated plate as rolled directly from one slab or ingot.
(3) For steel plates to which stress relieving is required after welding or stress relieving is applied by the purchaser one or several times repeatedly during their working process, instruction of that effect is to be given at the time when they are placed for an order. In case where the procedure of stress relieving is not specified by the purchaser, a heat treatment is to be applied for the test samples by heating them slowly and uniformly to the temperature of 600℃ to 650℃, holding at that temperature for a period of over one hour per 25 mm of thickness, and then, to be cooled to 300℃ in the furnace before exposure in a still atmosphere.
(4) The test samples are to be taken from the portion approximately 1/4 of the width from the side end of the plates.

7. Selection of test specimens

Tensile test specimens are to be taken according to (1) to (3) below.
(1) One test specimen is to be taken from one test sample.
(2) The test specimens are to be taken with their longitudinal axis normal to the final direction of rolling.
(3) The test specimens of bar type are to be taken from the portion approximately 1/4 of the thickness from the surface.

8. Tolerance for thickness

Surface inspection and verification of dimensions are to be in accordance with the requirements in **301. 8.** The minus tolerance for the nominal thickness of plates is to be 0.25 mm.

9. Retest procedure

Where the tensile tests from the first test specimens selected fail to meet the requirements, additional tests may be conducted according to the requirements given in **109.**

10. Marking

(1) Steel plates which have satisfactorily complied with the required tests are to be marked with the identification mark relating to heat treatment in addition to the requirements in **110.**
(2) The marks relating to heat treatment are to be as specified in the following:
  (a) Where the plates are normalized : *N* (e.g. : *RSP* 46N)
  (b) Where the test specimens are normalized : *TN* (e.g. : *RSP* 46TN)
  (c) Where the test specimens are heat treated corresponding to the stress relieving to be applied : SR (e.g. : *RSP* 46N-SR, *RSP* 46TN-SR)

303. Rolled steel plates for pressure vessel

1. Application

(1) These requirements are mainly to apply to the steel plates for pressure vessels to be used at atmospheric temperature (hereinafter referred to as "steel plates")
(2) The steel plates having characteristics differing from those specified in **303.** are to comply with the requirements in **101. 2.**

2. Kinds

The steel plates are classified as specified in **Table 2.1.13.**

Table 2.1.13 Grades of Steel Plates

Grade	Max. thickness to be applied (mm)
RPV 24	200
RPV 32	100
RPV 36, *RPV* 46, *RPV* 50	75

3. Heat treatment

(1) *RPV* 24, *RPV* 32 and *RPV* 36 plates are to be as rolled. The plates, however, may be controlled-rolled, TMCP or properly heat treated as deemed necessary by the Society.
(2) *RPV* 46 and *RPV* 50 plates are to be quenched and tempered, But, they may be normalized, controlled-rolled, *TMCP* or as rolled under the approval by the Society.

4. Chemical composition

The chemical composition of steel plates is to comply with the requirements given in **Table 2.1.14.** Where deemed necessary, other elements than specified in **Table 2.1.14** may be added. In that case, such elements are to be stated in the test sheets.

Table 2.1.14 Chemical Composition

Grade	Chemical composition (%)						Carbon equivalent (%)	
	C		Si	Mn	P	S	$t \le 50$(mm)	$50 < t \le 75$(mm)
RPV 24	$t \le 100$ mm	0.18 max.	0.15~0.35	1.40 max.	0.030 max.	0.030 max.	-	-
	$t > 100$ mm	0.20 max.						
RPV 32	0.18 max.		0.15~0.55	1.50 max.			-	-
RPV 36	0.20 max.		0.15~0.55	1.60 max.			-	-
RPV 46	0.18 max.		0.15~0.75	1.60 max.			0.44 max.	0.46 max.
RPV 50	0.18 max.		0.15~0.75	1.60 max.			0.45 max.	0.47 max.

NOTE:
(1) Where deemed necessary, other elements than specified in **Table 2.1.14** may be added. In that case, such elements are to be stated in the test sheets.
(2) For *RPV*46 and *RPV*50 steel plates which not to be quenched and tempered, slight deviations in the chemical composition may be allowed as approved by the Society.

5. Mechanical properties

The mechanical properties of steel plates are to comply with the requirements given in **Table 2.1.15.**

Table 2.1.15 Mechanical Properties

Grade	Tensile test							Impact test		
	Yield strength (N/mm^2) Thickness of plate t (mm)			Tensile strength (N/mm^2)	Elongation(%) Thickness of plate t (mm)			Test temp. (℃)	Average absorbed energy(J)	Absorbed energy of individual test specimen(J)
	$t \le 50$	$50<t\le100$	$100<t\le200$		$t\le16$(2)	$16<t\le40$(2)	$40<t$(3)			
RPV 24	235 min.	215 min.	195 min.	400～510	17 min.	21 min.	24 min.	0	47 min.	27 min.
RPV 32	315 min.	290 min.	-	490～610	16 min.	20 min.	23 min.			
RPV 36	355 min.	335 min.(1)	-	520～640	14 min.	18 min.	21 min.			
RPV 46	450 min.	430 min.(1)	-	570～695	19 min.(4)	26 min.(4)	20 min.	-10		
RPV 50	490 min.	470 min.(1)		610～735	18 min.(4)	25 min.(4)	19 min.			

NOTE:
(1) To be applied for the plates 75 mm or less in thickness (2) To be tested with *R1A* test specimen.
(3) To be tested with *R4* test specimen. (4) To be tested with *R5* test specimen.

6. Selection of test samples

(1) For the steel plates which are not to be heat treated, one test sample is to be taken from each plate as rolled directly from one slab or ingot.
(2) For the steel plates which are to be heat treated, one test sample is to be taken from every similarly heat treated plate as rolled directly from one slab or ingot.
(3) For steel plates to which stress relieving is required after welding or stress relieving is applied by the purchaser, test samples are to be heat treated in accordance with the requirements in **302. 6** (3)
(4) The test samples are to be taken from the portion approximately 1/4 of the width from the side end of the plate.

7. Selection of test specimen

(1) Tensile test specimens are to be taken according to (a) to (c) below.
   (a) One test specimen is to be taken from one test sample.
   (b) The test specimens are to be taken with thier longitudinal axis normal to the final direction of rolling .
   (c) The test specimens of bar type are to be taken from the portion approximately 1/4 of the thickness from the surface.
(2) Impact test specimens is to be taken according to (a) to (c) below.
   (a) A set of test specimens are to be taken from one test sample.
   (b) The test specimens are to be taken with their longitudinal axis parallel (L direction) to the final direction of rolling. Where deemed necessary by the Society, however, they are to be taken with their longitudinal axis normal (T direction) to the final direction of rolling.
   (c) The test specimens are to be taken at a portion where the axis of the test specimen corresponds to approximately 1/4 of the thickness from the surface.

8. Tolerance for thickness

Surface inspection and verification of dimensions are to be in accordance with the requirements in **301. 8.** The minus tolerance for the nominal thickness of plates is to be 0.25 mm.

9. Retest procedures

Where the tensile test and impact tests from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **109.**

10. Marking

(1) Steel plates which have satisfactorily complied with the required tests are to be marked with the identification mark relating to heat treatment in addition to the requirements in **110.**
(2) The marks relating to heat treatment in (1) are to be as specified in the following:
   (a) Where the plates are controlled-rolled : *CR* (e.g.: *RPV* 36*CR*)
   (b) Where the plates are normalized : *N* (e.g. : *RPV* 32*N*)
   (c) Where the plates are quenched and tempered : *QT* (e.g. : *RPV* 46*QT*)
   (d) Where the plates are heat treated in *TMCP* condition : *TM* (e.g. : *RPV* 36*TM*)
   (e) Where the test specimens are normalized : *TN* (e.g. : *RPV* 32*TN*)
   (f) Where the test specimens are heat treated corresponding to the stress relieving to be applied : *SR* (e.g. : *RPV* 32*N-SR*, *RPV* 32*TN-SR*)

11. Steel plates equivalent to standard

(1) The mild steel plates of grade *RD* and *RE*, the high tensile steels of rolled steels for hull specified in **301.** are taken as equivalent to the plates specified in **303.,** in case where the test specimens are taken as required in **Pars 6** and **7** and test results comply with the requirements in **301.** In this case, "*PV*" is to be suffixed to the markings to indicate the kind of plates specified in **301.**
(2) Any requirements regarding heat treatment of steel plates specified in (1) is left to the discretion of the Society.

304. Rolled steels for low temperature service

1. Application

(1) The requirements are to apply to the rolled steels not exceeding 40 mm in thickness intended for tanks and ship's hull structures adjacent to tanks of liquefied gas carriers, and other parts such a hull structures of refrigerated cargo carrier which are exposed to low temperature (hereinafter referred to as "steels").
(2) Any requirement regarding the steels over 40 mm in thickness is left to the discretion of the Society.
(3) The requirements other than those specified in **304.** are applicable to the requirements in **301.**
(4) The steels other than those specified in **304.** are to comply with the requirements in **101. 2.**

2. Kinds

Steels are classified as specified in **Table 2.1.16.**

Table 2.1.16 Grades and Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Deoxidation</th><th colspan="6">Chemical composition (%)</th><th rowspan="2">Carbon equivalent (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Ni</th></tr>
<tr><td>RL 24A</td><td rowspan="10">Fully killed Aluminium treated fine grain</td><td>0.16 max.</td><td rowspan="5">0.10~0.50</td><td rowspan="5">0.70~1.60</td><td rowspan="5">0.030 max.</td><td rowspan="5">0.025 max.</td><td rowspan="5">-</td><td rowspan="5">0.41 max.</td></tr>
<tr><td>RL 24B</td><td>0.14 max.</td></tr>
<tr><td>RL 27</td><td>0.14 max.</td></tr>
<tr><td>RL 33</td><td>0.14 max.</td></tr>
<tr><td>RL 37</td><td>0.14 max.</td></tr>
<tr><td>RL 2N30</td><td>0.14 max.</td><td rowspan="5">0.30 max.</td><td rowspan="2">0.70 max.</td><td rowspan="5">0.025 max.</td><td rowspan="5">0.025 max.</td><td>2.10~2.50</td><td rowspan="5">-</td></tr>
<tr><td>RL 3N32</td><td>0.14 max.</td><td>3.25~3.75</td></tr>
<tr><td>RL 5N43</td><td>0.12 max.</td><td>1.50 max.</td><td>4.75~6.00</td></tr>
<tr><td>RL 9N53</td><td rowspan="2">0.10 max.</td><td rowspan="2">0.90 max.</td><td rowspan="2">8.50~9.50</td></tr>
<tr><td>RL 9N60</td></tr>
</table>

3. Heat treatment

The heat treatment of steels is to comply with the requirements given in **Table 2.2.17.**

4. Deoxidation practice and chemical composition

(1) The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table 2.1.16.** When deemed necessary, chemical elements other than those given in the table may be added.
(2) When heat treatment has been conducted according to *TMCP*, the chemical composition of steels specified in **Table 2.1.16** may be modified subject to the approval by the Society.

5. Mechanical properties

The mechanical properties of steels are to comply with the requirements given in **Table 2.1.17.** Where deemed necessary by the Society. other tests on notch toughness may be required additionally.

6. Selection of test sample

(1) For steel plates, one test sample is to be taken from each plate as rolled directly from one slab or ingot.
(2) For test samples used in other steels than steel plates, steels not greater than 10 tonnes in mass (having the same cross-sectional dimensions and being from the same cast manufactured by the same process) are to be treated as one lot, and one test sample is to be taken from each lot.

(3) The requirements specified in **301. 6** (4) are to be applied to the selection of the test samples.

Table 2.1.17 Heat Treatment and Mechanical Properties

Grade	Heat treatment	Tensile test			Impact test [3][4]		
		Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)[2] ($L = 5.65\sqrt{A}$)	Test temp.[5] (℃)	Average absorbed energy (J)	
						L	*T*
RL 24*A*	Normalized or *TMCP*	235 min.	400~510	20 min.	-40	41 min.	27 min.
RL 24*B*					-50		
RL 27		265 min.	420~540		-60		
RL 33	Quenched and tempered or *TMCP*	325 min.	440~560				
RL 37		360 min.	490~610	19 min.			
RL 2*N*30	Normalized or normalized and tempered[1]	295 min.	420~570		-70		
RL 3*N*32		315 min.	440~590		-95		
RL 5*N*43		420 min.	540~690		-110		
RL 9*N*53	Double normalized and tempered[1]	520 min.	690~830	18 min.	-196		
RL 9N60	Quenched and tempered[1]	590 min.	690~830				

NOTES:

(1) Heat treatment may be conducted according to *TMCP*, subject to the special approval by the Society.

(2) The minimum elongation for *R*1*B* test specimen (*L*=200mm) is to be in compliance with the requirements given in the Table below.

Minimum Elongation (%)

Grade \ Thickness *t* (mm)	$t \le 5$	$5 < t \le 10$	$10 < t \le 15$	$15 < t \le 20$	$20 < t \le 25$	$25 < t \le 30$	$30 < t \le 35$	$35 < t \le 40$
RL 24*A*, *RL* 24*B*, *RL* 27	13	14	15	16	17	18	18	19
RL 33	12	13	14	15	16	17	18	19
RL 37	11	12	13	14	15	16	17	18
RL 2*N*30, *RL* 3*N*32, *RL* 5*N*43	12	13	14	15	16	17	17	18
RL 9*N*53, *RL* 9*N*60	10	11	12	13	14	15	16	17

(3) *L* (or *T*) indicates that the longitudinal axis of the test specimen is arranged parallel (or transverse) to the final direction of rolling.

(4) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

(5) Impact test temperature for steels specified in **Pt 7, Ch 5** is to comply with the requirements given in **Table 2.1.18.**

Table 2.1.18 Impact Test Temperature of Steels Specified in Pt 7, Ch 5.

Grade	Thickness t (mm)	Test temp (℃)[1]
RL 24*A* *RL* 24*B* *RL* 27 *RL* 33 *RL* 37	$t \le 25$	-20 or (Td-5) [2]
	$25 < t \le 30$	-20 or (Td-10) [2]
	$30 < t \le 35$	-20 or (Td-15) [2]
	$35 < t \le 40$	(Td-20)
RL 2*N*30	$t \le 25$	-70
	$25 < t \le 30$	-70 or (Td-10) [2]
	$30 < t \le 35$	-70 or (Td-15) [2]
	$35 < t \le 40$	-70 or (Td-20) [2]
RL 3*N*32	$t \le 25$	-95
	$25 < t \le 30$	-95 or (Td-10) [2]
	$30 < t \le 35$	-95 or (Td-15) [2]
	$35 < t \le 40$	-95 or (Td-20) [2]
RL 5*N*43	$t \le 25$	-110
	$25 < t \le 30$	-110 or (Td-10) [2]
	$30 < t \le 35$	-110 or (Td-15) [2]
	$35 < t \le 40$	-110 or (Td-20) [2]
RL 9*N*53	$t \le 40$	-196
RL 9*N*60		

NOTES:
(1) Td is the design temperature (℃).
(2) The test temperature is to be the lower of those specified above.

7. Selection of test specimens

(1) Tensile test specimens are to be taken according to the requirements specified in **301. 7** (2).
(2) Impact test specimens are to be taken according to the following (a) and (b):
(a) The requirements specified in **301. 7** (3) are to apply.
(b) For steel plates, the test specimens are to be taken with their longitudinal axis normal (T direction) to the final direction of rolling; for other steels than steel plates, they are to be taken with their longitudinal axis parallel (L direction) to the final direction of rolling.

8. Surface inspection and verification of dimensions

Surface inspection and verification of dimensions are to be in accordance with the requirements in **301. 8.** The minus tolerance for the nominal thickness of plates is to be 0.25 mm.

9. Retest procedures

Where the tensile test and impact tests from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **109.**

10. Marking

Steels which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.** For steels to which the requirements given in Notes (1) and (5) of **Table 2.1.17** have been applied, "*TM*" and impact test temperature "*T*" are to be suffixed to the markings. (e.g. *RL* 33*TM*-50*T*)

305. Rolled stainless steels

1. Application

(1) These requirements are to apply to the rolled stainless steels (hereinafter referred to as "steels") for tanks in low temperature service or corrosion-resisting service.
(2) The requirements other than those specified in **305.** are applicable to the requirements in **301.**
(3) Steels other than those specified in **305.** are to comply with the requirements in **101. 2.**

2. Kinds

Steels are classified as specified in **Table 2.1.19.**

Table 2.1.19 Grades and Chemical Composition of Stainless Steels

<table>
<tr><th rowspan="2">Grade</th><th colspan="10">Chemical composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Ni</th><th>Cr</th><th>Mo</th><th>N</th><th>Others</th></tr>
<tr><td>RSTS 304</td><td>0.08 max.</td><td rowspan="6">1.00 max.</td><td rowspan="2">2.00 max.</td><td rowspan="16">0.040 max.</td><td rowspan="16">0.030 max.</td><td>8.00~10.50</td><td rowspan="4">18.00~20.00</td><td rowspan="7">-</td><td rowspan="2">-</td><td rowspan="3">-</td></tr>
<tr><td>RSTS 304L</td><td>0.030 max.</td><td>9.00~13.00</td></tr>
<tr><td>RSTS 304N1</td><td rowspan="2">0.08 max.</td><td rowspan="2">2.50 max.</td><td>7.00~10.50</td><td>0.10~0.25</td></tr>
<tr><td>RSTS 304N2</td><td>7.50~10.50</td><td>0.15~0.30</td><td>Nb≤0.15</td></tr>
<tr><td>RSTS 304LN</td><td>0.030 max.</td><td rowspan="12">2.00 max.</td><td>8.50~11.50</td><td>17.00~19.00</td><td>0.12~0.22</td><td rowspan="10">-</td></tr>
<tr><td>RSTS 309S</td><td rowspan="3">0.08 max.</td><td>12.00~15.00</td><td>22.00~24.00</td><td rowspan="4">-</td></tr>
<tr><td>RSTS 310S</td><td>1.50 max.</td><td>19.00~22.00</td><td>24.00~26.00</td></tr>
<tr><td>RSTS 316</td><td rowspan="9">1.00 max.</td><td>10.00~14.00</td><td rowspan="3">16.00~18.00</td><td rowspan="4">2.00~3.00</td></tr>
<tr><td>RSTS 316L</td><td>0.030 max.</td><td>12.00~15.00</td></tr>
<tr><td>RSTS 316N</td><td>0.08 max.</td><td>10.00~14.00</td><td>0.10~0.22</td></tr>
<tr><td>RSTS 316LN</td><td>0.030 max.</td><td>10.50~14.50</td><td>16.50~18.50</td><td>0.12~0.22</td></tr>
<tr><td>RSTS 317</td><td>0.08 max.</td><td rowspan="3">11.00~15.00</td><td rowspan="3">18.00~20.00</td><td rowspan="3">3.00~4.00</td><td rowspan="2">-</td></tr>
<tr><td>RSTS 317L</td><td rowspan="2">0.030 max.</td></tr>
<tr><td>RSTS 317LN</td><td>0.10~0.20</td></tr>
<tr><td>RSTS 321</td><td rowspan="2">0.08 max.</td><td rowspan="2">9.00~13.00</td><td rowspan="2">17.00~19.00</td><td rowspan="2">-</td><td rowspan="2">-</td><td>Ti≥5×C</td></tr>
<tr><td>RSTS 347</td><td>Nb≥10×C</td></tr>
</table>

3. Heat treatment

The steels are generally to receive a solid solution treatment.

4. Chemical composition

The chemical composition of steels is to comply with the requirements given in **Table 2.1.19.**

5. Mechanical properties

(1) The mechanical properties of steels are to comply with the requirements given in **Table 2.1.20.**

Table 2.1.20 Mechanical Properties of Stainless Steels

<table>
<tr><th rowspan="2">Grade</th><th colspan="3">Tensile</th><th colspan="3">Hardness test</th></tr>
<tr><th>Yield strength (N/mm^2)</th><th>Tensile strength (N/mm^2)</th><th>Elongation(%) ($L=5.65\sqrt{A}$)</th><th>Brinell HB</th><th>Rock well HRB</th><th>Vickers HV</th></tr>
<tr><td>RSTS 304</td><td>205 min.</td><td>520 min.</td><td rowspan="2">40 min.</td><td rowspan="2">187 max.</td><td rowspan="2">90 max.</td><td rowspan="2">200 max.</td></tr>
<tr><td>RSTS 304L</td><td>175 min.</td><td>480 min.</td></tr>
<tr><td>RSTS 304N1</td><td>275 min.</td><td>550 min.</td><td rowspan="2">35 min.</td><td>217 max.</td><td>95 max.</td><td>220 max.</td></tr>
<tr><td>RSTS 304N2</td><td>345 min.</td><td>690 min.</td><td>248 max.</td><td>100 max.</td><td>260 max.</td></tr>
<tr><td>RSTS 304LN</td><td>245 min.</td><td>550 min.</td><td rowspan="5">40 min.</td><td>217 max.</td><td>95 max.</td><td>220 max.</td></tr>
<tr><td>RSTS 309S</td><td rowspan="3">205 min.</td><td rowspan="3">520 min.</td><td rowspan="4">187 max.</td><td rowspan="4">90 max.</td><td rowspan="4">200 max.</td></tr>
<tr><td>RSTS 310S</td></tr>
<tr><td>RSTS 316</td></tr>
<tr><td>RSTS 316L</td><td>175 min.</td><td>480 min.</td></tr>
<tr><td>RSTS 316N</td><td>275 min.</td><td rowspan="2">550 min.</td><td>35 min.</td><td rowspan="2">217 max.</td><td rowspan="2">95 max.</td><td rowspan="2">220 max.</td></tr>
<tr><td>RSTS 316LN</td><td>245 min.</td><td rowspan="6">40 min.</td></tr>
<tr><td>RSTS 317</td><td>205 min.</td><td>520 min.</td><td rowspan="2">187 max.</td><td rowspan="2">90 max.</td><td rowspan="2">200 max.</td></tr>
<tr><td>RSTS 317L</td><td>175 min.</td><td>480 min.</td></tr>
<tr><td>RSTS 317LN</td><td>245 min.</td><td>550 min.</td><td>217 max.</td><td>95 max.</td><td>220 max.</td></tr>
<tr><td>RSTS 321</td><td rowspan="2">205 min.</td><td rowspan="2">520 min.</td><td rowspan="2">187 max.</td><td rowspan="2">90 max.</td><td rowspan="2">200 max.</td></tr>
<tr><td>RSTS 347</td></tr>
</table>

(2) The results of hardness test, according to the test method, are to comply with the requirements given in **Table 2.1.20.**

(3) Other tests on notch toughness or corrosion resistance may be required, where deemed necessary by the Society.

6. Selection of test samples

(1) One test sample is to be taken from every similarly heat treated plate as rolled directly from one slab or ingot.

(2) The requirements provided in **301. 6** (4) are to be applied to the selection of the test samples.

7. Selection of test specimens

(1) Tensile test specimens are to be taken according to the requirements specified in **301. 7** (2).

(2) The hardness test specimen may be a portion of tensile test specimen.

8. Tolerance for thickness

Surface inspection and verification of dimensions are to be in accordance with the requirements in **301. 8.** The minus tolerance for the nominal thickness of plates is to be 0.25 mm.

9. Marking

Steels which have satisfactorily complied with the required tests are to be marked with identification mark in accordance with the requirements in **110.**

306. Round bars for chain

1. Application

(1) These requirements are to apply to the rolled round bars (hereinafter referred to as "Chain bars") for chain specified in **Pt 4, Ch 8, Sec 4.**
(2) The requirements other than those specified in **306.** are applicable to the requirements in **301.**
(3) Chain bars having characteristics differing from those specified in **306.** are to comply with the requirements in **101. 2.**

2. Kinds

The chain bars are classified as specified in **Table 2.1.21.**

Table 2.1.21 Grades of Chain Bars

Grade		Application	used for
Grade 1 chain bar	*RSBC* 31	Un-studded chain Grade 1 chain	Ship's stud link anchor chain cables and accessories
Grade 2 chain bar	*RSBC* 50	Grade 2 chain	
Grade 3 chain bar	*RSBC* 70	Grade 3 chain	
Grade *R*3 chain bar	*RSBCR* 3	Grade R3 chain	Offshore mooring chain and accessories
Grade *R* 3*S* chain bar	*RSBCR* 3*S*	Grade R3S chain	
Grade *R* 4 chain bar	*RSBCR* 4	Grade R4 chain	

3. Deoxidation practice and chemical composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table 2.1.22.** Elements other than specified in **Table 2.1.22** may be added subject to a special approval by the Society.

Table 2.1.22 Deoxidation Practice and Chemical Composition (%)

Grade	Deoxidation	C	Si	Mn	P	S	Al(1)
RSBC 31	Killed	0.20 max.	0.15~0.35	0.40 min.	0.040 max.	0.040 max.	-
RSBC 50(2)	Fine-grained killed	0.24 max.	0.15~0.55	1.60 max.	0.035 max.	0.035 max.	0.020 min.
RSBC 70(2)		0.36 max.	0.15~0.55	1.00~1.90	0.035 max.	0.035 max.	0.020 min.
RSBCR 3	Fine-grained killed	(3)					
RSBCR 3*S*							
RSBCR 4							

NOTE:
(1) *Al* content is to be represented by the total *Al* content and may be replaced partly by other fine graining elements.
(2) If the Society agrees, additional alloying elements may be added.
(3) Detailed chemical composition is to be approved by the Society. For Grade *RSBCR* 4, the steel should contain a minimum of 0.2 % molybdenum.

4. Heat treatment

Chain bars are to be as rolled condition.

5. Mechanical properties

(1) The mechanical properties of chain bars are to comply with the requirements given in **Table 2.1.23.**

Table 2.1.23 Mechanical Properties

Grade	Tensile test				Impact test(1)(2)	
	Yield strength (N/mm^2)(3)	Tensile strength (N/mm^2)(3)	Elongation(%) ($L=5d$)	Reduction of area (%)	Test temp (℃)	Average absorbed energy (J)
RSBC 31	-	370~490(6)	25 min.	-	-	-
RSBC 50	295 min.	490~690	22 min.	-	0	27 min.(2)
RSBC 70	410 min.	690 min.	17 min.	40 min.	0(4)	60 min.(4)
RSBCR 3	410 min.	690 min.	17 min.	50 min.	-20(5)	40 min.(5)
RSBCR 3S	490 min.	770 min.	15 min.	50 min.	-20(5)	45 min.(5)
RSBCR 4	580 min.	860 min.	12 min.	50 min.	-20	50 min.

NOTES:
(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.
(2) For *RSBC* 50 which will be heat treated according to **Pt 4, Ch 8, 405.**, no impact testing is required.
(3) The yield ratio (the aim value of yield to tensile ratio) for grade *RSBCR* 3, *RSBCR* 3S, or *RSBCR* 4 is to be maximum 0.92.
(4) Impact test of RSBC 70 may be carried out at the temperature of -20℃ where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 35 J.
(5) Impact test of grade *RSBCR* 3 and *RSBCR* 3S may be carried out at the temperature of 0℃ where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 60*J* for grade *RSBCR* 3 and 65*J* for grade *RSBCR* 3S.
(6) Lower limit of tensile strength of *RSBC* 31 may be 300 N/mm^2 with the approval of the Society.

(2) Hydrogen embrittlement test is to be carried out in accordance with the following procedure:
(a) One tensile test specimen is to be tested within max. 3 hours after machining. Alternatively, tensile test specimen may be cooled to -60℃ immediately after machining and kept at that temperature for a period of max. 5 days.
(b) The other specimen is to be tested after baking at 250℃ for 4 hours.
(c) A slow strain rate not exceed $0.0003S^{-1}$ as far as practicable is used during the entire test, and tensile strength, elongation and reduction of area are to be measured.
(d) The test result is to comply with the following formula.

$$Z_{(1)} \ / \ Z_{(2)} \geq 0.85$$

$Z_{(1)}$ is the reduction of area measured by the test specified in (2) (a)
$Z_{(2)}$ is the reduction of area measured by the test specified in (2) (b)

6. Selection of test sample

(1) Chain bars not greater than 50 tonnes in weight (from the same cast manufactured by the same process) are to be treated as one lot, and one test sample largest in diameter is to be taken from each lot.
(2) Test sample mentioned in above (1), prior to sampling, must be subjected to the heat treatment provided for the finished chain cable. Details of the heat treatment must be indicated by the chain cable manufacturer. In case of no indication, heat treatment of the test sample is to comply with the requirements given in **Pt.4, Sec.8 406.** for each grade.

7. Selection of test specimens

(1) Test specimens are to be taken in accordance with the **Table 2.1.24**

Table 2.1.24 Number of test specimens

Grade	Number of tensile test specimens	Number of impact test specimens
RSBC 31	1 piece	-
RSBC 50	1 piece	1 set (3 piece)(1)
RSBC 70 *RSBCR* 3 *RSBCR* 3*S* *RSBCR* 4	1 piece	1 set (3 piece)

NOTES:
(1) In case where note (2) of **Table 2.1.23** is applied, no impact test specimen need to be taken.

(2) For grades *RSBCR* 3*S* and *RSBCR* 4 in addition to the test specimen required by (1), two tensile test specimens having a diameter of 20 mm in principle, are to be taken for the hydrogen embrittlement test. In this case, test specimen is to be taken from the central region of bar materials heat-treated in the same manner as (a) or (b).
(a) In case of continuous casting, test samples representing both the beginning and the end of the charge(except the mixed zone of the charge) shall be taken.
(b) In case of ingot casting test samples representing two different ingots shall be taken.
(3) The test specimens are to be taken with their longitudinal axis parallel to the final direction of rolling.
(4) The tensile and impact test specimens are to be taken from the test sample in the longitudinal direction at a depth of 1/6 diameter from the surface or as close as possible to this position. (See **Fig 2.1.5**)

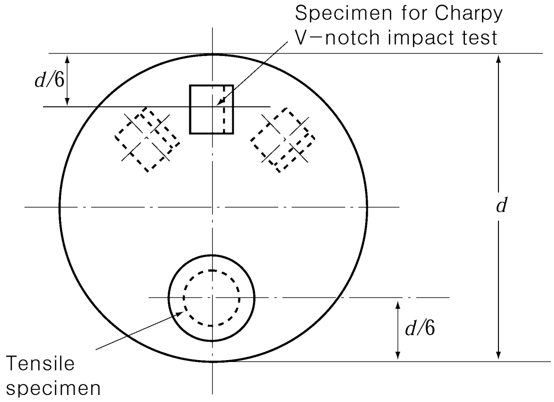


Fig 2.1.5 Selection of test specimens

(5) The longitudinal axis of the notch is to correspond approximately to the radial direction of each test specimen.

8. Surface inspection, non-destructive inspection and verification of dimensions

(1) Surface inspection for all grades is to be carried out and it is to be confimed that there are no harmful defects.
(2) For grades *RSBCR* 3, *RSBCR* 3*S* and *RSBCR* 4, all round bar for chains are subjected to ultrasonic examination at an appropriate stage of the manufacture and it is to be confirmed that there are no harmful defects.
(3) For grades *RSBCR* 3, *RSBCR* 3*S* and *RSBCR* 4, one hundred percent of round bars for chains is to be examined by magnetic particle or eddy current methods and it is to be confirmed by magnetic particle or eddy current methods and it is to be confirmed that there are no harmful defects.
(4) Notwithstanding the requirements of (2) and (3), the frequency of non-destructive inspection may be reduced where the quality control conditions of the manufacturer are satisfactorily met. However, non-destructive inspection of samples required in **5.** are to be carried out in every case.
(5) The diameter and roundness of all grades of chain bars are to be within the tolerances specified in **Table 2.1.25.**

Table 2.1.25 Dimensional tolerance

Nominal Diameter (mm) (1)	Tolerance on diameter (mm)	Tolerance on roundness (d_{max} - d_{min}) (mm) (2)
less than 25	-0, +1.0	0.6 max.
25 ~ 35	-0, +1.2	0.8 max.
36 ~ 50	-0, +1.6	1.1 max.
51 ~ 80	-0, +2.0	1.50 max.
81 ~ 100	-0, +2.6	1.95 max.
101 ~ 120	-0, +3.0	2.25 max.
121 ~ 160	-0, +4.0	3.00 max.

NOTES:
(1) For nominal diameter of bar materials which have more than 161 mm, dimensional tolerances are to be as deemed appropriate by the Society.
(2) d_{max} and d_{min} mean the maximum and minimum diameter of a round bar.

9. Retest procedures

(1) Where the tensile test and impact tests from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **109.**
(2) If failure to pass the tensile test or impact test is definitely attributable to improper heat treatment of the test sample, a new test sample may be taken from the same piece and reheat treated. The complete test (both tensile and impact test) is to be repeated; and the original results obtained may be disregarded.

10. Marking

Chain bars which have satisfactorily complied with the required tests are to be marked with identification marks in accordance with the requirements in **110.**

307. Rolled steel bars for boiler

1. Application

(1) These requirements are to apply to hot rolled steel bars intended to be used for the stay bolts for boilers (hereinafter referred to as "steel bars").
(2) The steel bars having characteristics differing from those specified in **307.** are to comply with the requirements of **101. 2.**

2. Kinds

The steel bars are classified as specified in **Table 2.1.26.**

Table 2.1.26 Grades and Chemical Composition

Grade	Chemical composition (%)		
	C	S	P
RSB 42	0.30 max.	0.04 max.	0.05 max.
RSB 46	0.33 max.		

3. Heat treatment

The heat treatment of steel bars is to be as deemed appropriate by the Society.

4. Chemical composition

The chemical composition of steel bars is to comply with the requirements given in **Table 2.1.26.**

5. Mechanical properties

The mechanical properties of steel bars are to comply with the following requirements.

(1) The tensile test of steel bars is to comply with the requirements given in **Table 2.1.27.**

(2) The bend test specimen is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion to an inside redius given in **Table 2.1.28.**

Table 2.1.27 Mechanical Properties

Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) ($L=5.65\sqrt{A}$)
RSB 42	225 min.	410~490	24 min.
RSB 46	245 min.	450~540	22 min.
NOTE: The required value of yield strength for the steel bars exceeding 100 mm in diameter may be taken as 205 N/mm^2 for *RSB* 42 and 225 N/mm^2 for *RSB* 46, regardless of the above requirements.			

Table 2.1.28 Bend Test

<table>
<tr><th rowspan="2">Dia. of bar (mm)</th><th colspan="2">Ratio of inside radius of bend to diameter of test specimen</th></tr>
<tr><th>RSB 42</th><th>RSB 46</th></tr>
<tr><td>$d \le 25$</td><td>$\frac{3}{4}$</td><td>1</td></tr>
<tr><td>$25 < d \le 50$</td><td>1</td><td rowspan="2">$1\frac{1}{4}$</td></tr>
<tr><td>$50 < d \le 75$</td><td rowspan="2">$1\frac{1}{4}$</td></tr>
<tr><td>$75 < d$</td><td>$1\frac{1}{2}$</td></tr>
</table>

6. Selection of test samples

For the test samples of steel bars, steel bars which belong to the same cast manufactured by the same process and where the amount of scatter is to be less than 10 mm in diameter, are to be treated as one lot, and test samples are to be taken from each lot accord ing to the mass of the lot and to the requirements provided in **Table 2.1.29.**

7. Selection of test specimens

(1) Each one piece of tensile and bend test specimen is to be taken from one test sample.

(2) Test specimens are to be taken with their longitudinal axis parallel to the final direction of rolling.

(3) Tensile test specimens are to be taken from the sample in the longitudinal direction at a depth of 1/6 diameter from the surface or as close as possible to this position. (See **Fig 2.1.5**)

8. Tolerance for diameter

The tolerance for diameter of the steel bars is to comply with the requirements in **Table 2.1.30.**

9. Marking

Steel bars which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.**

Table 2.1.29 Number of Test Samples

Weight of group (ton)	Number of test samples
25 and under	1 each
Over 25 up to 30	2 each
Over 30	2 each plus 1 each for each 10 tons of excess or fraction thereof

Table 2.1.30 Tolerance for Diameter

Diameter of bar (mm)	Tolerance
$d < 16$	± 0.4 mm
$16 \le d < 28$	± 0.5 mm
$28 \le d$	± 1.8 %

308. High Strength Quenched and Tempered Steels for Welded Structures

1. Application

(1) The requirements given in **308.** are to apply to weldable high strength quenched and tempered steel plates and wide flats not exceeding 70 mm in thickness intended for mobile offshore units, tanks of liquefied gas carriers and process pressure vessels (hereinafter referred to as "steels")
(2) Any requirements regarding the steels over 70 mm in thickness are left to the discretion of the Society.
(3) Product forms other than plates and wide flats, such as section and tubulars, may be provided to the requirements given in **308.** when specially agreed to by the Society.
(4) Steels for hull structures should be in accordance with the Guidance specified by the Society.
(5) The requirements other than those specified in **308.** are applicable to the requirements in **301.**
(6) Steels having characteristics differing from those specified in **308.** are to comply with the requirements in **101. 2.**

2. Kinds

Steels are classified as specified in **Table 2.1.31.**

Table 2.1.31 Grade of Steels

Kind	Grade
Weldable high strength quenched and tempered steel	*AH* 43, *DH* 43, *EH* 43, *FH* 43
	AH 47, *DH* 47, *EH* 47, *FH* 47
	AH 51, *DH* 51, *EH* 51, *FH* 51
	AH 56, *DH* 56, *EH* 56, *FH* 56
	AH 63, *DH* 63, *EH* 63, *FH* 63
	AH 70, *DH* 70, *EH* 70, *FH* 70

3. Deoxidation practice and chemical composition

(1) The deoxidation practice and chemical composition of steels are to comply with the requirements given in **Table 2.1.32.** Where deemed necessary, other elements than specified in **Table 2.1.32** may be added.
(2) Where heat treatment has been conducted according to TMCP, the requirements given in **Table 2.1.32** may be modified subject to the special approval by the Society.
(3) The cold cracking susceptibility(*Pcm*) for evaluating weldability should be in accordance with the Guidance relating to the Rules specified by the Society. The maximum *Pcm* to be achieved is to be agreed with the Society and included in the approved specification.

4. Heat treatment

The steels shall be in the quenched and tempered condition. Special consideration may be given to the supply of those steels in thicknesses up to 50 mm in the TMCP condition subject to approval of the Society.

5. Mechanical properties

(1) The mechanical properties of steels are to comply with the requirements given in **Table 2.1.33.**
(2) In the case of other product forms where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those listed in **Table 2.1.33.**
(3) Where deemed necessary by the Society, other test on notch-toughness and weldability may be required in addition to the tests specified in **Table 2.1.33.**

6. Selection of test samples

(1) One test sample is to be taken from every similarly heat treated plate as rolled directly from one slab or ingot.
(2) The requirements specified in **301. 6** (4) are to be applied to the selection of the test samples.

7. Selection of test specimens

(1) Tensile test specimens are to comply with the requirements shown in (a) to (c) below:

(a) Tensile test specimens are to be taken according to the requirements specified in **301. 7** (2).

(b) Normally flat tensile test specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side.

(c) Where the thickness exceeds 40mm, full thickness specimens may be prepared but when instead a machined round tensile test specimen is used then the axis must be located at a position lying at a distance of t/4 from the surface or as near as possible to this position.

(2) Impact test specimens are to be taken according to the requirements specified in **304. 7** (2).

Table 2.1.32 Deoxidation Practice and Chemical Composition (%)

Grade	De-oxidation practice	*C*	*Si*	*Mn*	*P*	*S*	*Cu*	*Cr*	*Mo*	*V*	*B*	*N*
AH 43	Fully killed fine grain	0.21 max.	0.55 max.	1.70 max.	0.035 max.	0.035 max.	-	-	-	-	-	0.020 max.
DH 43		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
EH 43		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
FH 43		0.18 max.		1.60 max.	0.025 max.	0.025 max.						
AH 47		0.21 max.		1.70 max.	0.035 max.	0.035 max.						
DH 47		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
EH 47		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
FH 47		0.18 max.		1.60 max.	0.025 max.	0.025 max.						
AH 51		0.21 max.		1.70 max.	0.035 max.	0.035 max.						
DH 51		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
EH 51		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
FH 51		0.18 max.		1.60 max.	0.025 max.	0.025 max.						
AH 56		0.21 max.		1.70 max.	0.035 max.	0.035 max.						
DH 56		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
EH 56		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
FH 56		0.18 max.		1.60 max.	0.025 max.	0.025 max.						
AH 63		0.21 max.		1.70 max.	0.035 max.	0.035 max.	0.50 max.	1.00 max.	0.60 max.	0.10 max.	0.006 max.	
DH 63		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
EH 63		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
FH 63		0.18 max.		1.60 max.	0.025 max.	0.025 max.		1.20 max.				
AH 70		0.21 max.		1.70 max.	0.035 max.	0.035 max.						
DH 70		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
EH 70		0.20 max.		1.70 max.	0.030 max.	0.030 max.						
FH 70		0.18 max.		1.60 max.	0.025 max.	0.025 max.						

Table 2.1.33 Heat Treatment and Mechanical Properties

Grade	Heat treatment	Tensile test			Impact test(2)(3)		
		Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)(5) ($L=5.65\sqrt{A}$)	Test temp.(4) (℃)	Average absorbed energy(J)	
						L	*T*
AH 43	Quenched and tempered(1)	420 min.	530~680	18 min.	0	42 min.	28 min.
DH 43					-20		
EH 43					-40		
FH 43					-60		
AH 47		460 min.	570~720	17 min.	0	46 min.	31 min.
DH 47					-20		
EH 47					-40		
FH 47					-60		
AH 51		500 min.	610~770	16 min.	0	50 min.	33 min.
DH 51					-20		
EH 51					-40		
FH 51					-60		
AH 56		550 min.	670~830	16 min.	0	55 min.	37 min.
DH 56					-20		
EH 56					-40		
FH 56					-60		
AH 63		620 min.	720~890	15 min.	0	62 min.	41 min.
DH 63					-20		
EH 63					-40		
FH 63					-60		
DH 70		690 min.	770~940	14 min.	0	69 min.	46 min.
AH 70					-20		
EH 70					-40		
FH 70					-60		

NOTES:

(1) Heat treatment may be conducted according to TMCP, instead of quenching and tempering, subject to the special approval by the Society.

(2) L (or T) denotes that the longitudinal axis of each test specimen is parallel (or normal) to the final direction of rolling.

(3) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

(4) Impact test temperature for steels specified in **Pt 7, Ch 5** are given in **Table 2.1.34.**

(5) The minimum elongation for *R1B* test specimen (*L*=200mm) is to be in compliance with the requirements given in the Table below.

Grade	Thickness (mm)						
	$t \le 10$	$10 < t \le 15$	$15 < t \le 20$	$20 < t \le 25$	$25 < t \le 40$	$40 < t \le 50$	$50 < t \le 70$
AH 43, *DH* 43, *EH* 43, *FH* 43	11	13	14	15	16	17	18
AH 47, *DH* 47, *EH* 47, *FH* 47	11	12	13	14	15	16	17
AH 51, *DH* 51, *EH* 51, *FH* 51	10	11	12	13	14	15	16
AH 56, *DH* 56, *EH* 56, *FH* 56	10	11	12	13	14	15	16
AH 63, *DH* 63, *EH* 63, *FH* 63	9	11	12	12	13	14	15
AH 70, *DH* 70, *EH* 70, *EH* 70	9	10	11	11	12	13	14

Table 2.1.34 Impact Test Temperature for Steels specified in Pt 7, Ch 5

Grade	Thickness t (mm)	Impact test		
		Test temp (℃)	Average absorbed energy (J)	
			L	T
AH 43, DH 43, AH 47, DH 47 AH 51, DH 51, AH 56, DH 56 AH 63, DH 63, AH 70, DH 70	$t \le 20$	0	41	27
	$20 < t \le 40$	-20		
	$40 < t \le 50$	-30		
	$50 < t$	(1)		

NOTE: (1) Temperature is to be as deemed appropriate by the Society.

8. Surface inspection and verification of dimensions

(1) Surface inspection and verification of dimensions are the responsibility of the steel manufacturer and the minus tolerance in the nominal thickness of plates is to be 0.25 mm. For steels except steel plates, any requirement regarding the minus tolerance is left to the discretion of the Society.
(2) If required by the Society the manufacturer is to perform ultrasonic examinations in accordance with an approved standard.
(3) If required by the Society, through thickness tensile tests are to be performed in accordance with requirements specified in **310.**

9. Retest procedures

(1) Where the tensile test from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **109. 1.**
(2) Regarding the impact tests, additional tests are to be carried out according to the requirements given in **109. 2.**
(3) For other product forms the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements of **Table 2.1.33**
(4) Normally sub-surface test specimens will be taken, however, for material with a thickness in excess of 40mm, impact tests should be taken at the quarter thickness (t/4) location.

10. Marking

Steels which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.** For steels to which the requirements given in Note (4) of **Table 2.1.33** have been applied, the "impact test temperature T" are to be suffixed to the marking. (e.g. DH 63-25T)

309. Stainless clad steel plates

1. Application

(1) The requirements in **309.** are to apply to the stainless clad steels not exceeding 50 mm in thickness intended for tanks of ships carrying dangerous chemicals in bulk, tank circumference hull construction units and corrosion-resisting tanks (hereinafter referred to as "steel plates").
(2) The requirements other than those specified in **309.** are to be in accordance with the requirements in **301.**
(3) Steel plates over 50 mm in thickness and having characteristics differing from those specified in **309.** are to comply with the requirements in **101. 2.**

2. Process of manufacture

(1) Manufacture of steel plates is to comply with the processes shown in (a) to (e) below:
(a) Rolling
(b) Explosive pressing
(c) Overlay rolling
(d) Cast rolling
(e) Explosive rolling
(2) Application of any other process of manufacture than those specified in (1) is left to the discretion of the Society.

3. Structural metals

(1) Base and clad materials for steel plates are to be mild steel plates of rolled steels for hull specified in **301.** and steel plates of rolled stainless steels specified in **305.,** respectively. In case of overlay rolling or cast rolling, clad materials are to comply with the specified chemical composition of welding materials or stainless steel casting applied as a clad.
(2) The material grade marks are to be signified by a combination of base metal and clad material. (ex. *A* + *RSTS*316)

4. Heat treatment

The steel plates are to comply with the requirements for heat treatment of the base metal.

5. Mechanical properties

(1) The mechanical properties of steel plates are to comply with the requirements given in **Table 2.1.35.**

Table 2.1.35 Mechanical Properties

Grade	Tensile test(1)			Shearing strength test(3)	Impact test
	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Shearing strength (N/mm^2)	
A *B* *D* *E*	235 min.	σ_B min.(2)	To be complied with requirement for base metal	200 min.	To be complied with requirement for base metal

NOTES:
(1) The tensile test specimen is to be *R*1*B* test specimen (*L*=200mm)
(2) σ_B is to be obtained from the following formula:

$$\sigma_B = \frac{t_1\sigma_1 + t_2\sigma_2}{t_1 + t_2}$$

where:
σ_B = Tensile strength of steel plates (N/mm^2)
σ_1 = Specified minimum tensile strength of base metal (N/mm^2)
σ_2 = Specified minimum tensile strength of clad material (N/mm^2)
t_1 = Thickness of base metal (mm)
t_2 = Thickness of clad material (mm)
(3) Any requirement for the procedure of shear strength test is left to the discretion of the Society. In case of overlay rolling, shear strength test may be omitted.

(2) Where deemed necessary by the Society according to the use of steel plates, tests on corrosion resistance may be required.

6. Selection of test samples

(1) One test sample is to be taken from each steel plate, being from the same manufacturing process, which belong to the plate as rolled from a slab or ingot of a certain base metal. In case of overlay rolling, a separate test sample which is applied the same condition of manufacturing process can be made.
(2) The requirements specified in **301. 6** (4) are to be applied to the selection of the test samples.

7. Selection of test specimens

(1) Tensile test specimens are to be taken according to the requirements specified in **301. 7** (2).
(2) Impact test specimens are to be taken according to the requirements specified in **301. 7** (3). In this case, the thickness of the test specimens is to agree with that of the base metal from which the clad material has been removed.

(3) Shearing strength test specimens are to be taken according to the requirements specified in the following (a) to (b):
(a) One test specimen is to be taken from one test sample.
(b) The size and dimensions of the test specimens, are to be determined according to **Fig 2.1.6.**

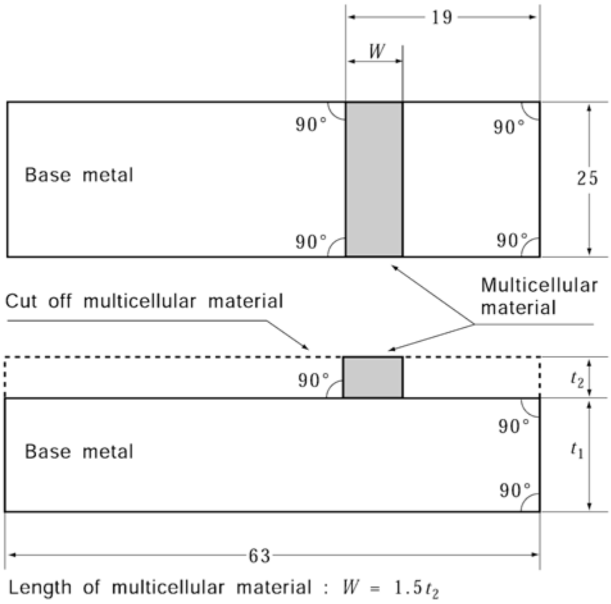


Fig 2.1.6 Size and Dimensions of Shearing Test Specimens (unit: mm)

8. Surface inspection and verification of dimensions

The minus tolerance for the nominal thickness of plates is left to the discretion of the Society.

9 Quality and repair of defects

(1) Each steel plate is to be subjected to ultrasonic testing. Any requirement for the test procedure is left to the discretion of the Society.
(2) Each cladding defects does not exceed 50 mm in length and 20 ㎠ in area. All defect areas do not exceed 1.5 % of the total surface in question.
(3) Any cladding defects over the length and area of (2) may be repaired by welding in accordance with the requirements given in **301. 9** (3)

10. Marking

(1) The test certificates are to comply with the requirements given in **107.** and are to contain the particulars as to the process of manufacture of steel plates and the thickness of the clad material.
(2) Steel plates which have satisfactorily complied with the required tests are to be suffixed with the following marks relating to the process of manufacture of the steel plates, in addition to the marks showing the kinds of the base and clad materials. (e.g. A + $RSTS$ 316 - R)

Rolling	:	[-R]
Cast rolling	:	[-ER]
Explosive pressing	:	[-B]
Explosive rolling	:	[-BR]
Overlay rolling	:	[-WR]

310. Additional requirements for through thickness properties

1. Application

(1) The requirements in **310.** are to apply to hull structural rolled steels and weldable high strength quenched and tempered steel plates and wide flats with thickness of 15 mm and over which is required improved through thickness properties to minimise the possibility of lamellar tearing during fabrication.
(2) The requirements are applicable to the other steels than the material specified in (2) above, where deemed appropriate by the Society.

2. Through thickness properties

The through thickness properties of steels are to comply with the requirements given in **Table 2.1.36** as the result of tensile tests whose specimens are taken in the through thickness direction of the product.

Table 2.1.36 Through thickness properties

Grade	Application	Reduction of area acceptance values(1)	
		Minimum average(%)	Minimum individual(%)
Z25	normal use	25	15
Z35	severe service condition	35	25

Note
(1) The minimum average value for the reduction of area of at least 3 tensile test specimens taken in the through thickness direction must be that shown for the appropriate grade given in Table. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade.

3. Deoxidation practice and chemical composition

In addition to the requirements of the appropriate steel specification given in **301.** or **308.**, the maximum sulphur content is to be 0.008% determined by the ladle analysis.

4. Selection of test specimens

(1) For steel, of same thickness, belonging to the same charge and same heat treatment condition, one test sample is to be taken from each lot specified in **Table 2.1.37.**

Table 2.1.37 Batch size dependent on product and sulphur content

Product	S > 0.005%	S≤0.005%
Plates	<P>	<50>
Wide flats of normal thickness ≤25mm	<10>	<50>
Wide flats of normal thickness >25mm	<20>	<50>

Note
(1) In the Table, <50>, <20> and <10> each indicate that steels not greater than 50, 20 and 10 tones are to be taken as one lot; <P> indicates that steel rolled directly from one slab or steel ingot is to be taken as one lot. The term "piece" is understood to mean the rolled product from a single slab or ingot if this is rolled directly into plates, sections or bars.

(2) The test samples are to be taken from one end (top of ingot when applicable) of the portion corresponding to the middle of the plates or flat bars as shown in **Fig 2.1.7.**

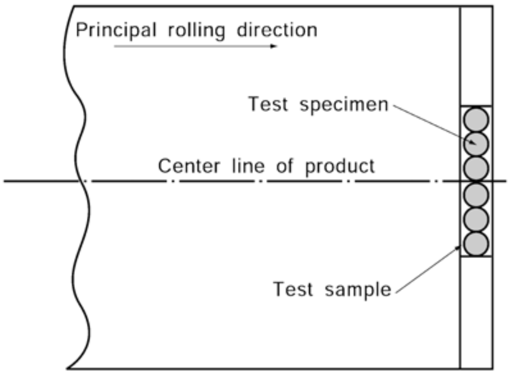


Fig 2.1.7 Selection of Test Samples

5. Selection of test specimens

(1) Three round tensile test specimens are to be taken from one test sample in the through thickness direction.

(2) The test specimens are to be taken according to the requirements for dimensions provided in **Table 2.1.38.**

Table 2.1.38 Dimensions of Specimen

Product thickness t (mm)	Diameter of test specimen d (mm)	Parallel length P (mm)
$15 \leq t \leq 25$	$d = 6$	$P \geq 2d$
$t > 25$	$d = 10$	$P \geq 2d$

(3) Where the product thickness does not allow to prepare specimens of sufficient length suitable for the gripping jaws of the testing machine, the ends of the specimens may be built up by suitable welding methods. The welding is not to impair the portion of the specimen within the parallel length.

6. Retest procedure

(1) Acceptance, rejection and retest criteria for the through thickness properties of steels are to comply with the requirements given in **Fig 2.1.8**

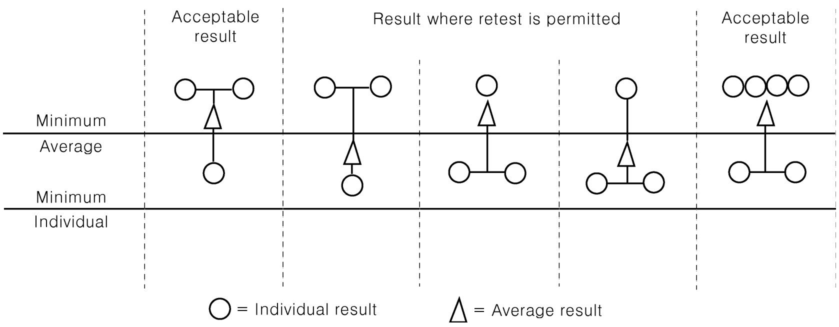


Fig 2.1.8 Acceptance, rejection and retest criteria for the through thickness properties of steels

(2) **Fig 2.1.8** shows the three cases where a retest situation is permitted. In these instances three more tensile tests are to be taken from the remaining test sample or remaining steel plates of same piece. The average of all 6 tensile tests is to be greater than the required minimum average with no greater than two results below the minimum average.

(3) In the case of failure after retest, either the lot represented by the piece is rejected or each piece within the lot is required to be tested.

(4) The test is considered invalid and further replacement test is required if the fracture occurs in the weld or heat affected zone.

7. Ultrasonic tests

(1) Ultrasonic testing should be carried out on each piece in the final supply condition.

(2) Any requirement for the test procedure and acceptance criteria are left to the discretion of the Society. However, the probe frequency is to be of 4MHz in general.

8. Marking

Steels which have satisfactorily complied with the requirements specified in **310.** are to have the notation Z25 or Z35 after the material grade mark. (e.g. *EH*36 *Z*25, *EH*36 *Z*35)

SECTION 4 Steel Tubes and Pipes

401. Steel tubes for boilers and heat exchangers

1. Application

(1) The requirements are mainly to apply to steel tubes intended for heat transfer at inside or outside of the tubes; for example, smoke tubes, water tubes, stay tubes, superheater tubes of boilers, other tubes for high temperature heat exchangers, etc. (hereinafter referred to as "steel tubes").

(2) Steel tubes other than those specified in (1) are to comply with the requirements in **101. 2.**

2. Kinds

The steel tubes are classified as specified in **Table 2.1.39.**

Table 2.1.39 Kinds

Description	Grade
Carbon steel tubes for boilers and heat exchangers	*RSTH* 35 *RSTH* 42 *RSTH* 52
Alloy steel tubes for boilers and heat exchangers	*RSTH* 12 *RSTH* 22 *RSTH* 23 *RSTH* 24

3. Heat treatment

The heat treatment of steel tubes is to comply with the requirements given in **Table 2.1.40.**

Table 2.1.40 Heat treatment

<table>
<tr><th rowspan="2">Grade</th><th colspan="2">Seamless steel tube</th><th colspan="3">Electric-resistance welded steel tube</th></tr>
<tr><th>Hot working</th><th>Cold working</th><th>As weld</th><th>Hot working</th><th>Cold working</th></tr>
<tr><td>RSTH 35</td><td rowspan="2">As drawn</td><td rowspan="2">Low temperature annealed, Normalized or full annealed</td><td rowspan="2">Normalized</td><td>As drawn</td><td rowspan="3">Normalized(1)</td></tr>
<tr><td>RSTH 42</td><td>Low temperature annealed</td></tr>
<tr><td>RSTH 52</td><td colspan="4">Normalized</td></tr>
<tr><td>RSTH 12</td><td colspan="5">Low temperature annealed, Isothermal annealed, Full annealed, Normalized or Normalized and tempered(2)</td></tr>
<tr><td>RSTH 22</td><td colspan="5">Low temperature annealed , Isothermal annealed, Full annealed or Normalized and tempered(2)</td></tr>
<tr><td>RSTH 23
RSTH 24</td><td colspan="2">Isothermal annealed, Full annealed or Normalized and tempered at 650℃ and over</td><td colspan="3">-</td></tr>
<tr><td colspan="6">NOTES
(1) Steel tubes which are normalized prior to cold working may be finished by annealing
(2) Low temperature annealing is not to be applied to electric resistance welded steel tube</td></tr>
</table>

4. Chemical composition

The chemical composition of steel tubes is to comply with the requirements given in **Table 2.1.41.**

Table 2.1.41 Chemical Composition

Grade	Chemical composition (%)						
	C	Si	Mn	P	S	Cr	Mo
RSTH 35	0.18 max.	0.10~0.35	0.30~0.60	0.035 max.	0.035 max.	-	-
RSTH 42	0.32 max.		0.30~0.80				
RSTH 52	0.25 max.		1.00~1.50				
RSTH 12	0.10~0.20	0.10~0.50	0.30~0.80				0.45~0.65
RSTH 22	0.15 max.	0.50 max.	0.30~0.60			0.80~1.25	
RSTH 23		0.50~1.00		0.030 max.	0.030 max.	1.00~1.50	
RSTH 24		0.50 max.				1.90~2.60	0.87~1.13

NOTE:
In case where approved by the Society, *RSTH* 35 and *RSTH* 42 may be the killed steel of below 0.10 % Si.

5. Mechanical properties

The mechanical properties of steel tubes are to comply with the following requirements.

(1) *Tensile test* : The tensile test of steel tubes is to comply with the requirements given in **Table 2.1.42.**

Table 2.1.42 Mechanical Properties

Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L=5.65\sqrt{A}$)
RSTH 35	175 min.	340 min.	26 (22) min.
RSTH 42	255 min.	410 min.	21 (17) min.
RSTH 52	295 min.	510 min.	
RSTH 12	205 min.	380 min.	
RSTH 22 *RSTH* 23 *RSTH* 24		410 min.	

NOTES:
1. The values of elongation in parenthesis are applicable to the test specimens taken transversely. In this case, the sampling material is to be heated 600℃ to 650℃ after flattened and annealed in order to make it free from strain.
2. In case where test specimen of non-tubular section is taken from an electric-resistance welded steel tube, the test specimen is to be taken from the parts that do not include the welded line.

(2) *Flattening test* : A tubular section which is taken from the end of the steel tube is to stand being flattened cold between parallel plates, without cracking or showing flaw, until the distance between the plates becomes less than the value of H calculated by the following formula. In this case, the length L of steel tube is to be not less than 50 mm, however, not more than 100 mm. For electric-resistance welded steel tubes, however, the welded line is to be placed at right angle to the direction of the applied force as shown in **Fig 2.1.9** (a) For tubes, however, of 15 % of outside diameter and over in thickness, C-type test specimen may be used, having a part of its circumference discarded as shown in **Fig 2.1.9** (b)

$$H = \frac{(1+e)t}{e + \frac{t}{D}}$$

where:

H = Distance between flattening plates (mm).

t = Thickness of steel tube (mm).

D = Outside diameter of steel tube (mm).

e = Constant given in **Table 2.1.43** which varies according to the grade of steel tubes.

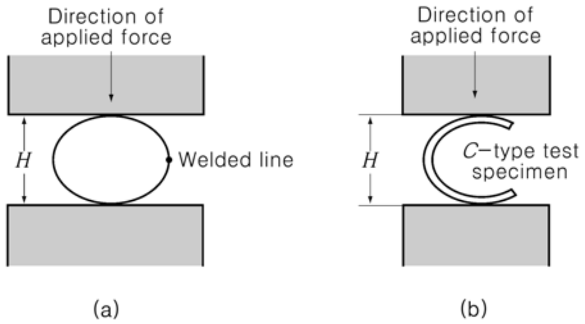


Fig 2.1.9 Flattening test

Table 2.1.43 Value of e

Grade	Value of e
RSTH 35	0.09
RSTH 42, *RSTH* 12, *RSTH* 22, *RSTH* 23, *RSTH* 24	0.08
RSTH 52	0.07

(3) *Flaring test* : A section of steel tube which is taken from its end is to stand being flared cold with a tool having an included angle of 60 degrees, until the steel tube at the mouth of the flare is expanded without cracking or showing flaw to the diameter shown in **Table 2.1.44.** The rate of penetration of the mandrel shall not exceed 50 mm/min. In this case, the length of test specimen is to be 1.5 D, however, not less than 50 mm.

Table 2.1.44 Outside Diameter of Steel Tube End after Flaring

Grade	Outside diameter of steel tube end
RSTH 35, *RSTH* 42, *RSTH* 52	1.2 times the outside diameter of steel tube
RSTH 12, *RSTH* 22, *RSTH* 23, *RSTH* 24	1.14 times the outside diameter of steel tube

(4) *Reverse flattening test* : A section of steel tube of 100 mm in length which is taken from the steel tube is to be slotted longitudinally on the opposite side of the welded line, opened and flattened without cracking or showing flaw on the inside of the welded line. There is also to be no misalignment, lack of penetration and overlap. But, this test is applied for electric-resistance welded steel tubes only.

(5) *Hydraulic test* :

(a) Steel tubes are to be hydraulically tested to a satisfactory result by 2 times and over the maximum working pressure at the mill. But the minimum test pressure is to be 7 MPa.

(b) The test pressure prescribed in (a) need not exceed the pressure calculated by the following formula:

$$P = \frac{2.0St}{D}(Mpa)$$

where:

t = Thickness of steel tube (mm)

D = Outside diameter of steel tube (mm)

S = 60 % of the prescribed minimum yield strength (N/mm^2)

(c) Where each steel tube is hydraulically tested as a regular procedure during the process of manufacturing at the mill, which makes a number of steel tubes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(d) A non-destructive inspection deemed appropriate by the Society may be substituted for the hydraulic test specified in (a).

6. Selection of test specimen

The test specimens are to be taken in accordance with the following requirements, from each grade and each size which has been heat treated at the same time in the same heating furnace for heat-treated tubes and from each grade and each size for non-heat-treated steel tubes respectively.

(1) *Seamless steel tubes*
One sampling steel tube is to be selected from each lot of 50 tubes or fraction thereof and each one specimen for tensile test, flattening test and flaring test is to be taken from each sampling steel tube.

(2) *Electric-resistance welded steel tubes*
For electric-resistance welded steel tubes, in addition to the requirements in (1), one sampling steel tube is to be selected from each lot of 100 tubes or fraction thereof, and one reverse flattening test specimen is to be taken from each of the sampling steel tubes.

7. Tolerance for dimensions

The tolerances for the outside diameter and thickness are to comply with the requirements in **Table 2.1.45.** and **Table 2.1.46.** respectively.

Table 2.1.45 Tolerance for Outside Diameter of steel Tubes

Outside diameter of steel tube D (mm)	Tolerance for Outside Diameter (mm)			
	Seamless steel tube		Electric-resistance welded steel tube	
	Hot finished	Cold working	Other than cold working	Cold working
D <25	+ 0.4 - 0.8	± 0.10	± 0.15	± 0.10
25≤ D <40		± 0.15	± 0.20	± 0.15
40≤ D <50		± 0.20	± 0.25	± 0.20
50≤ D <60		± 0.25	± 0.30	± 0.25
60≤ D <80		± 0.30	± 0.40	± 0.30
80≤ D <100		± 0.40	+ 0.40 - 0.60	± 0.40
100≤ D <120	+ 0.4 - 1.2	+ 0.40 - 0.60	+ 0.40 - 0.80	+ 0.40 - 0.60
120≤ D <160		+ 0.40 - 0.80	+ 0.40 - 1.00	+ 0.40 - 0.80
160≤ D <200	+ 0.4 - 1.6	+ 0.40 - 1.20	+ 0.40 - 1.20	+ 0.40 - 1.20
200≤ D	+ 0.4 - 1.8	+ 0.40 - 1.60	+ 0.40 - 1.60	+ 0.40 - 1.60

Table 2.1.46 Tolerance for thickness

Kind	Thickness t (mm) / Outside diameter D (mm)	t<2	2≤t<2.4	2.4≤t<3.8	3.8≤t<4.6	4.6≤t
Hot finished seamless steel tube	D < 100	-	+40 % 0 %	+35 % 0 %	+33 % 0 %	+28 % 0 %
	D ≥ 100		-			
Cold drawn seamless steel tube and Electric-resistance welded steel tube of cold working	D < 40	+0.4mm 0 mm	+22 % 0 %			
	D ≥ 40	+22 %, 0 %				
Electric-resistance welded steel tube of other than cold working	D < 40	+0.3mm 0 mm	+18 % 0 %			
	D ≥ 40	+18 %, 0 %				

NOTE:
For hot finished seamless steel tubes. the tolerance for deviation in wall thickness is to be 22.8 % and under of the thickness of the steel tube. But, for steel tubes of less than 5.6 mm in thickness, this note is not applied.

8. Quality

(1) Each steel tubes are hydraulically or non-destructively tested as a regular procedure during the process of manufacturing at the mill and are free from leakages or harmful defects.
(2) The steel tubes are to be of uniform quality. For electric-resistance welded steel tubes, deposit metal projected on outside of tubes is to be removed and finished smooth and that projected on inside of tubes is to be removed to have a height not more than 0.25 mm.

9. Retest procedures

Where the tensile test, *flattening test, flaring test* or *reverse flattening test* fails to meet the requirements, additional tests may be conducted according to the requirements given in **109.**

10. Marking

(1) The name or brand of the manufacturer, grade of tubes, size and symbol of the method of the manufacture relating to (2) below are to be legibly stamped or stenciled before shipment on each length steel tube in case of 30 mm and above in outside diameter and on each bundle or container of steel tubes in case of less than 30 mm in outside diameter. The Society''s brand indicating compliance with the requirements is to be stamped in the vicinity of the foregoing marks.
(2) The symbols indicating the method of manufacture are to be as specified in the following:
Hot finished seamless steel tube ········ *-S-H*
Cold drawn seamless steel tube ········ *-S-C*
Electric-resistance welded steel tube of other than hot and cold working ······ *-E-G*
Electric-resistance welded steel tube of hot working ········ *-E-H*
Electric-resistance welded steel tube of cold working ········ *-E-C*

402. Steel pipes for pressure piping

1. Application

(1) These requirements are mainly to apply to seamless steel pipes and electric-resistance welded steel pipes intended for use in piping which is prescribed in **Pt 5, Ch 6** (hereinafter referred to as "steel pipes").
(2) Steel pipes for general purpose specified in **102. 2** (4) of **Pt 5, Ch 6** are to comply with the requirements of *KS D* 3507(SPP) or equivalent thereto. However, tests in the presence of the Surveyor are not required.
(3) The steel pipes having characteristics differing from those specified in **402.** are to comply with the requirements in **101. 2.**

2. Kinds

The steel pipes are classified as specified in **Table 2.1.47.**

Table 2.1.47 Grades of Steel Pipes

<table>
<tr><th>Kind</th><th>Grade</th><th>Schedule applied</th></tr>
<tr><td>Grade 1
Carbon steel pipe for pressure service</td><td>RST 138
RST 142</td><td>Sch.10~Sch.80</td></tr>
<tr><td>Grade 2
Carbon steel pipe for high pressure service</td><td>RST 238
RST 242
RST 249</td><td>Sch.40~Sch.160</td></tr>
<tr><td>Grade 3
Carbon steel pipe for high temperature service</td><td>RST 338
RST 342
RST 349</td><td rowspan="2">Sch.10~Sch.160</td></tr>
<tr><td>Grade 4
Alloy steel pipe</td><td>RST 412
RST 422
RST 423
RST 424</td></tr>
</table>

3. Heat treatment

The heat treatment of steel pipes is to comply with the requirements given in **Table 2.1.48.**

Table 2.1.48 Heat treatment

<table>
<tr><th colspan="2" rowspan="2">Grade</th><th colspan="2">Seamless steel pipe</th><th colspan="3">Electric-resistance welded steel pipe</th></tr>
<tr><th>Hot finished</th><th>Cold drawn</th><th>As drawn</th><th>Hot finished</th><th>Cold finished</th></tr>
<tr><td>Grade1</td><td>RST 138
RST 142</td><td rowspan="3">As drawn</td><td>Annealed</td><td>As drawn</td><td>As drawn</td><td>Annealed</td></tr>
<tr><td rowspan="3">Grade2</td><td>RST 238</td><td rowspan="2">Low temperature annealed or</td><td colspan="3" rowspan="3">-</td></tr>
<tr><td>RST 242</td></tr>
<tr><td>RST 249</td><td colspan="2">Normalized</td></tr>
<tr><td rowspan="2">Grade3</td><td>RST 338
RST 342</td><td rowspan="2">As drawn</td><td rowspan="2">Low temperature annealed or Normalized</td><td>Low temper-ature annealed or Normalized</td><td>As drawn</td><td>Low temperature annealed or Normalized</td></tr>
<tr><td>RST 349</td><td colspan="3" rowspan="4">-</td></tr>
<tr><td rowspan="3">Grade4</td><td>RST 412</td><td colspan="2">Low temperature annealed
Isothermal annealed, Full annealed,
Normalized or
Normalized and tempered</td></tr>
<tr><td>RST 422</td><td colspan="2">Low temperature annealed ,
Isothermal annealed, Full annealed
or Normalized and tempered</td></tr>
<tr><td>RST 423
RST 424</td><td colspan="2">Isothermal annealed, Full annealed
or Normalized and tempered at
650℃ and over</td></tr>
</table>

4. Chemical composition

The chemical composition of steel pipes is to comply with the requirements given in **Table 2.1.49.**

Table 2.1.49 Chemical Composition

Grade		Chemical composition (%)						
		C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*
Grade 1	*RST* 138	0.25 max.	0.35 max.	0.30~0.90	0.040 max.	0.040 max.	-	-
	RST 142	0.30 max.		0.30~1.00				
Grade 2	*RST* 238	0.25 max.	0.10~0.35	0.30~1.10	0.035 max.	0.035 max.		
	RST 242	0.30 max.		0.30~1.40				
	RST 249	0.33 max.		0.30~1.50				
Grade 3	*RST* 338	0.25 max.		0.30~0.90				
	RST 342	0.30 max.		0.30~1.00				
	RST 349	0.33 max.						
Grade 4	*RST* 412	0.10~0.20	0.10~0.50	0.30~0.80				0.45~0.65
	RST 422	0.15 max.	0.50 max.	0.30~0.60			0.80~1.25	
	RST 423		0.50~1.00		0.030 max.	0.030 max.	1.00~1.50	
	RST 424		0.50 max.				1.90~2.60	0.87~1.13

5. Mechanical properties

The mechanical properties of steel pipes are to comply with the following requirements.

(1) *Tensile test* : The tensile test of steel pipes are to comply with the requirements given in **Table 2.1.50.**

Table 2.1.50 Mechanical Properties

Grade		Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)($L = 5.65\sqrt{A}$)
Grade 1 Grade 2 Grade 3	*RST* 138 *RST* 238 *RST* 338	215 min.	370 min.	24 (20) min.
Grade 1 Grade 2 Grade 3	*RST* 142 *RST* 242 *RST* 342	245 min.	410 min.	21 (17) min.
Grade 2 Grade 3	*RST* 249 *RST* 349	275 min.	480 min.	19 (15) min.
Grade 4	*RST* 412	205 min.	380 min.	21(17) min.
Grade 4	*RST* 422 *RST* 423 *RST* 424		410 min.	

NOTES:

1. The requirements for elongation given in parentheses in the Table are applied for the case where test specimens are taken transversely. In this case, the test sample is to be stress relieved at the temperature of 600℃ to 650℃ after flattened.
2. In case where test specimen of non-tubular section is taken from electric-resistance welded steel pipes, the test specimen is to be taken from the part that does not include a welded line.

(2) *Flattening test*

(a) *Pipes other than Grade 1 of electric-resistance welded steel pipe*: A tubular section of steel pipe which is taken from the end of the steel pipe, is to stand being flattened between parallel plates, without cracking or showing flaw, until the distance between the plates becomes less than the value of H calculated by the following formula. In this case, the length of test specimen is to comply with the requirements in **401.5** (2). For steel pipes, however, of 15 % of outside diameter and above in thickness, C-type test specimen may be used, having a part of its circumference discarded as shown in **Fig 2.1.9 (b)**

$$H=\frac{(1+e)t}{e+\frac{t}{D}}$$

where:

H = Distance between flattening plates (mm).

t = Thickness of steel pipe (mm).

D = Outside diameter of steel pipe (mm).

e = Constant given in **Table 2.1.51** which varies according to the grade of steel tubes.

Table 2.1.51 value of e

Grade	*RST* 142, *RST* 242, *RST* 249, *RST* 342 *RST* 349	*RST* 138, *RST* 238, *RST* 338, *RST* 412 *RST* 422, *RST* 423, *RST* 424
e	0.07	0.08

(b) *Electric-resistance welded steel pipes Grade 1* :

$H=\frac{2}{3}D$ for welded line,

$H=\frac{1}{3}D$ for elsewhere.

In case of electric-resistance welded steel pipes, the welded line is to be placed at right angle to the direction of the applied force, as in **Fig 2.1.10.**

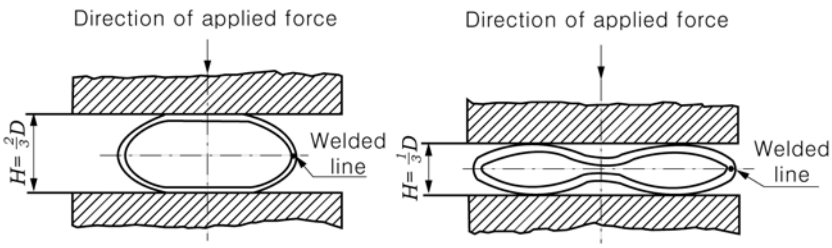


Fig 2.1.10 Flattening test of electric-resistance welded steel pipes Grade 1

(3) *Bend test* : For steel pipes of 50 mm and under in outside diameter, the specimen for flattening test may be substituted for that for bend test. In this case, a test specimen of tubular section which is taken from the end of the steel pipe and has sufficient length is to stand being bent cold, up to the specified value in **Table 2.1.52,** without cracking or showing flaw on the wall. But, for Grade 4, this test need not be carried out.

Table 2.1.52 Bend Test

Grade	Angle of bending	Inside bend radius
1, 2 and 3	90°	6 times the outside diameter of steel pipe
NOTE: Electric-resistance welded steel pipes are to be so bent as the welded line is placed widest.		

(4) *Hydraulic test*

(a) Grade 1 steel pipes are to be hydraulically tested with the pressure specified in **Table 2.1.53.**

(b) In case where the test pressure higher than prescribed in (a) is specified by the purchaser for Grade 2 through 4 steel pipes, the test is to be carried out with the specified pressure. In this case, test pressure need not exceed the pressure calculated by the following formula:

$$P = \frac{2.0St}{D} \text{(Mpa)}$$

where :

P = Hydraulic test pressure (MPa).

D = Outside diameter of steel pipe (mm).

t = Thickness of steel pipe (mm).

S = 60 % of the prescribed minimum yield strength (N/mm^2).

(c) When each steel pipe is hydraulically tested as a regular procedure during the process of manufacturing at the mill which makes a number of steel tubes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(d) A non-destructive inspection deemed appropriate by the Society may be substituted for the hydraulic inspection specified in (a).

6. Selection of test specimen

(1) *Grade 1* : Sampling steel pipes are to be selected as following requirements in connection with the nominal diameter of steel pipes specified in **Table 2.1.53** and each one specimen for tensile test, flattening test or bend test is to be taken from each sampling steel pipe.

(a) *For steel pipes less than 65A in nominal diameter* : One sampling steel pipe is to be selected from each lot of 1000 pipes or fraction thereof.

(b) *For steel pipes which a nominal diameter is 65A or above and less than 150A* : One sampling steel pipe is to be selected from each lot of 500 pipes or fraction thereof.

(c) *For steel pipes which a nominal diameter is 150A or above and less than 350A* : One sampling steel pipe is to be selected from each lot of 250 pipes or fraction thereof.

(d) *For steel pipes more than 350A in nominal diameter* : One sampling steel pipe is to be selected from each lot of 150 pipes or fraction thereof.

(2) *Grade 2* : One sampling steel pipe is to be selected from each lot of 50 pipes or fraction thereof, and each one specimen for tensile test and flattening test or bend test is to be taken from each sampling steel pipe.

(3) *Grade 3*

Selection of test specimen is to comply with the requirements in (2).

(4) *Grade 4* : One sampling steel pipe is to be selected from each lot of 50 pipes or fraction thereof, and each one specimen for tensile test and flattening test or bend test is to be taken from each sampling steel pipe.

Table 2.1.53 Schedule and Hydraulic Test Pressure

Nominal diameter (A)	Outside diameter (mm)	Nominal thickness (mm)									
		Sch.10 (10S)	Sch.20 (20S)	Sch.30	Sch.40	Sch.60	Sch.80	Sch.100	Sch.120	Sch.140	Sch.160
6	10.5	(1.2)	(1.5)	-	1.7	2.2	2.4	-	-	-	-
8	13.8	(1.65)	(2.0)	-	2.2	2.4	3.0	-	-	-	-
10	17.3	(1.65)	(2.0)	-	2.3	2.8	3.2	-	-	-	-
15	21.7	(2.1)	(2.5)	-	2.8	3.2	3.7	-	-	-	4.7
20	27.2	(2.1)	(2.5)	-	2.9	3.4	3.9	-	-	-	5.5
25	34.0	(2.8)	(3.0)	-	3.4	3.9	4.5	-	-	-	6.4
32	42.7	(2.8)	(3.0)	-	3.6	4.5	4.9	-	-	-	6.4
40	48.6	(2.8)	(3.0)	-	3.7	4.5	5.1	-	-	-	7.1
50	60.5	(2.8)	3.2(3.5)	-	3.9	4.9	5.5	-	-	-	8.7
65	76.3	(3.0)	4.5(3.5)	-	5.2	6.0	7.0	-	-	-	9.5
80	89.1	(3.0)	4.5(4.0)	-	5.5	6.6	7.6	-	-	-	11.1
90	101.6	(3.0)	4.5(4.0)	-	5.7	7.0	8.1	-	-	-	12.7
100	114.3	(3.0)	4.9(4.0)	-	6.0	7.1	8.6	-	11.1	-	13.5
125	139.8	(3.4)	5.1(5.0)	-	6.6	8.1	9.5	-	12.7	-	15.9
150	165.2	(3.4)	5.5(5.0)	-	7.1	9.3	11.0	-	14.3	-	18.2
200	216.3	(4.0)	6.4(6.5)	7.0	8.2	10.3	12.7	15.1	18.2	20.6	23.0
250	267.5	(4.0)	6.4(6.5)	7.8	9.3	12.7	15.1	18.1	21.4	25.4	28.6
300	318.5	(4.5)	6.4(6.5)	8.4	10.3	14.3	17.4	21.4	25.4	28.6	33.3
350	355.6	6.4	7.9	9.5	11.1	15.1	19.0	23.8	27.8	31.8	35.7
400	406.4	6.4	7.9	9.5	12.7	16.7	21.4	26.2	30.9	36.5	40.5
450	457.2	6.4	7.9	11.1	14.3	19.0	23.8	29.4	34.9	39.7	45.2
500	508.0	6.4	9.5	12.7	15.1	20.6	26.2	32.5	38.1	44.4	50.0
550	558.8	6.4	9.5	12.7	15.9	22.2	28.6	34.9	41.3	47.6	54.0
600	609.4	6.4	9.5	14.3	17.5	24.6	31.0	38.9	46.0	52.4	59.5
650	660.4	7.9	12.7	-	18.9	26.4	34.0	41.6	49.1	56.6	64.2
Hydraulic test pressure (MPa)	Grade 1	2.0	3.5	5.0	6.0	9.0	12.0	-	-	-	-
	Grade 2	-	-	-	6.0	9.0	12.0	15.0	18.0	20.0	20.0
	Grade 3 and Grade 4	2.0	3.5	5.0	6.0	9.0	12.0	15.0	18.0	20.0	20.0

NOTE:
The values of nominal thickness in parentheses are applicable to stainless steel pipes.

7. Tolerance for dimensions

Tolerances for the outside diameter and the thickness are to comply with the requirements in **Table 2.1.54.**

Table 2.1.54 Tolerance for Dimensions

Kind	Outside diameter of steel pipe D (mm)	Tolerance for outside diameter	Tolerance for wall thickness			
			Grade 1		Grade 2, 3 and 4	
Hot finished seam-less steel pipe	D < 50	± 0.5 mm	Thickness of steel pipe: Less than 4 mm	+ 0.6 mm - 0.5 mm	Thickness of steel pipe: Less than 4 mm	± 0.5 mm
	D ≥ 50	± 1 %	Thickness of steel pipe: 4 mm and over	+ 15 % - 12.5 %	Thickness of steel pipe: 4 mm and over	± 12.5 %
Cold drawn seam-less steel pipe and electric-resistance welded steel pipe	D < 40	± 0.3 mm	Thickness of steel pipe: Less than 3 mm	± 0.3 mm	Thickness of steel pipe: Less than 2 mm	± 0.2 mm
	D ≥ 40	± 0.80 mm	Thickness of steel pipe: 3 mm and over	± 10 %	Thickness of steel pipe: 2 mm and over	± 10 %

NOTE:
For hot finished seamless steel pipes Grades 2, 3 and 4, the tolerance for deviation in wall thickness is to be 20 % and under of the thickness of the pipes. But, for steel pipes less than 5.6 mm in thickness, this note is not applied.

8. Quality

(1) Each steel pipes are hydraulically or non-destructively tested and are free from leakages or harmful defects.
(2) The steel pipes are to be of uniform quality and free from harmful defects.

9. Retest procedures

Where the tensile test, *flattening test* or bend *test* fails to meet the requirements, additional tests may be conducted according to the requirements given in **109.**

10. Marking

(1) The name or brand of the manufacturer, grade of steel tubes, size and symbol of the method of the manufacture relating to (2) below are to be legibly stamped or stenciled before shipment on each length steel tube in case of 60 mm and above in outside diameter and on each bundle or container of steel tubes in case of less than 60 mm in outside diameter. The Society's brand indicating compliance with the requirements is to be in the vicinity of the foregoing marks.
(2) The symbols indicating the method of manufacture are to comply with the requirement in **401. 10** (2).

403. Stainless steel pipes

1. Application

(1) The requirements are to apply to the stainless steel pipes for low temperature service or corrosion-resistance service (hereinafter referred to as "stainless steel pipes").
(2) Stainless steel pipes having characteristics differing from those specified in **403.** are to comply with the requirements in **101. 2.**

2. Kinds

The stainless steel pipes are classified as specified in **Table 2.1.55**.

Table 2.1.55 Grades and Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">solid solution treatment(℃)</th><th colspan="9">Chemical Composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Ni</th><th>Cr</th><th>Mo</th><th>Others</th></tr>
<tr><td>RSTS 304TP</td><td>1010 and over, quenching</td><td>0.080 max.</td><td rowspan="3">1.00 max.</td><td rowspan="10">2.00 max.</td><td rowspan="10">0.040 max.</td><td rowspan="10">0.030 max.</td><td>8.00~11.00</td><td rowspan="2">18.00~20.00</td><td rowspan="4">-</td><td rowspan="8">-</td></tr>
<tr><td>RSTS 304LTP</td><td>1010 and over, quenching</td><td>0.030 max.</td><td>9.00~13.00</td></tr>
<tr><td>RSTS 309STP</td><td>1030 and over, quenching</td><td rowspan="3">0.080 max.</td><td>12.00~15.00</td><td>22.00~24.00</td></tr>
<tr><td>RSTS 310STP</td><td>1030 and over, quenching</td><td>1.50 max.</td><td>19.00~22.00</td><td>24.00~26.00</td></tr>
<tr><td>RSTS 316TP</td><td>1010 and over, quenching</td><td rowspan="6">1.00 max.</td><td>10.00~14.00</td><td rowspan="2">16.00~18.00</td><td rowspan="2">2.00~3.00</td></tr>
<tr><td>RSTS 316LTP</td><td>1010 and over, quenching</td><td>0.030 max.</td><td>12.00~16.00</td></tr>
<tr><td>RSTS 317TP</td><td>1010 and over, quenching</td><td>0.080 max.</td><td rowspan="2">11.00~15.00</td><td rowspan="2">18.00~20.00</td><td rowspan="2">3.00~4.00</td></tr>
<tr><td>RSTS 317LTP</td><td>1010 and over, quenching</td><td>0.030 max.</td></tr>
<tr><td>RSTS 321TP</td><td>920 and over, quenching</td><td rowspan="2">0.080 max.</td><td rowspan="2">9.00~13.00</td><td rowspan="2">17.00~19.00</td><td rowspan="2">-</td><td>Ti≥5×C</td></tr>
<tr><td>RSTS 347TP</td><td>980 and over, quenching</td><td>Nb≥10×C</td></tr>
</table>

3. Heat treatment

The stainless steel pipes are generally to receive a solid solution treatment. For RSTS 321TP and RSTS 347TP, stabilizing treatment may be required. In this case, heat treatment temperature is to be of 850~930℃.

4. Chemical composition

The chemical composition of stainless steel pipes is to comply with the requirements given in **Table 2.1.55.**

5. Mechanical properties

(1) The mechanical properties of stainless steel pipes are to comply with the following requirements.

(a) *Tensile test*
The tensile test of stainless steel pipes is to comply with the requirements given in **Table 2.1.56.**

(b) *Flattening test*
Flattening tests are to be carried out in accordance with the requirements in **402. 5** (2). However, where the requirements are applied, the value of e is to be taken as 0.09.

Table 2.1.56 Tensile Test

Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)($L=5.65\sqrt{A}$)	
			L	T
RSTS 304*TP*	205 min.	520 min.	26 min.	22 min.
RSTS 304*LTP*	175 min.	480 min.		
RSTS 309*STP*	205 min.	520 min.		
RSTS 310*STP*				
RSTS 316*TP*				
RSTS 316*LTP*	175 min.	480 min.		
RSTS 317*TP*	205 min.	520 min.		
RSTS 317*LTP*	175 min.	480 min.		
RSTS 321*TP*	205 min.	520 min.		
RSTS 347*TP*				

NOTES:
1. *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or normal) to the final direction of rolling.
2. Where the nominal diameter of stainless steel pipes is 200 mm and over, tensile test specimens may be taken transversely.
3. Where test specimens of non-tubular section are taken from welded pipes, the test specimens are to be taken from the part that does not include the welded line.

(c) *Hydraulic test*

(i) Stainless steel pipes are to be hydraulically tested with the pressure specified in **Table 2.1.57.**

Table 2.1.57 Hydraulic Test Pressure

Schedule No.	Sch.10S	Sch.20S	Sch.40	Sch.80	Sch.120	Sch.160
Test pressure (MPa)	2.0	3.5	6.0	12.0	18.0	20.0

(ii) In case where the test pressure higher than prescribed in (a) is specified by the purchaser, the test is to be carried out with the specified pressure. In this case, the test pressure need not exceed the pressure calculated by the following formula:

$$P=\frac{2.0St}{D}\ (\text{Mpa})$$

where:

P = Hydraulic test pressure (MPa).

t = Thickness of stainless steel pipe (mm).

D = Outside diameter of stainless steel pipe (mm).

S = 60 % of the prescribed minimum yield strength (N/mm^2).

(iii) When each pipe is hydraulically tested as a regular during the process of manufacturing at the mill which makes a number of tubes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(iv) A non-destructive inspection deemed appropriate by the Society may be substituted for the hydraulic test specified in (i).

(2) The Society may require the impact test or corrosion resistance test according to purposes of stainless steel pipes.

6. Selection of test specimens

One sampling pipe is to be selected from each lot of 50 pipes or fraction thereof which are of the same charge, size and kind and are simultaneously heat treated, and each one specimen for tensile test and flattening test is to be taken from each sample pipe.

7. Tolerance for dimensions

Tolerances for the outside diameter and the thickness are to comply with the requirements in **Table 2.1.58.**

Table 2.1.58 Tolerance for Dimensions

Kind	Outside diameter of stainless steel pipe		Tolerance for wall thickness	
Hot-finished seamless stainless steel pipe	Less than 50	± 0.5 mm	Thickness of pipe: Less than 4 mm	± 0.5 mm
	50 and over	± 1 %	Thickness of pipe: 4 mm and over	± 12.5 %
Cold drawn seamless stainless pipe, automatic arc welded stainless steel pipe and electric-resistance welded stainless steel pipe	Less than 30	± 0.3 mm	Thickness of pipe: Less than 2 mm	± 0.2 mm
	30mm and over	± 1 %	Thickness of pipe: 2 mm and over	± 10 %
NOTE: For hot finished seamless stainless steel pipes, the tolerance for deviation in wall thickness is to be 20 % and under of the thickness of the pipes. But, for stainless steel pipes less than 5.6 mm in thickness, this note is not applied.				

8. Quality

(1) Each steel pipes are hydraulically or non-destructively tested and are free from leakages or harmful defects.
(2) The stainless steel pipes are to be of uniform quality and free from harmful defects.

9. Retest procedures

Where the tensile test or *flattening test* fails to meet the requirements, additional tests may be conducted according to the requirements given in **109.**

10. Marking

Stainless steel pipes which have satisfactorily complied with the required tests are to be marked with identification mark in accordance with the requirements in **402. 10.** However, the symbols indicating the manufacturing method of automatic arc welded steel pipes are to be as specified in the following:

Automatic arc welded steel pipe : *-A*
Automatic arc welded and cold finished steel pipe : *-A-C*
Automatic arc welded and machined steel pipe : *-A-B*

404. Steel pipes for low temperature service

1. Application

(1) These requirements are to apply to the seamless steel pipes and electric resistance welded steel pipes not exceeding 25 mm in thickness, intended to be used at the design temperature lower than 0℃ in liquefied gas carriers (hereinafter referred to as "steel pipes").

(2) Any requirement regarding the steel pipes over 25 mm in thickness is left to the discretion of the Society.
(3) Steel pipes having characteristics differing from those specified in **404.** are to comply with the requirements in **101. 2.**

2. Kinds

The steel pipes are classified as given in **Table 2.1.59.**

3. Deoxidation practice and chemical composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table 2.1.59.**

Table 2.1.59 Grades and Chemical Composition (%)

Grade	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	*Ni*
RLPA	Fully killed fine grain	0.23 max.	0.35 max.	1.60 max.	0.035 max.	0.035 max.	-
RLPB		0.18 max.	0.35 max.	1.60 max.	0.035 max.	0.035 max.	-
RLPC		0.18 max.	0.35 max.	1.60 max.	0.035 max.	0.035 max.	-
RLP 2		0.19 max.	0.10~0.35	0.90 max.	0.035 max.	0.035 max.	2.00~2.60
RLP 3		0.16 max.	0.10~0.35	0.90 max.	0.030 max.	0.030 max.	3.20~3.80
RLP 9		0.10 max.	0.10~0.35	0.90 max.	0.030 max.	0.030 max.	8.40~9.50

4. Heat treatment

The heat treatment of steel pipes is to comply with the requirements given in **Table 2.1.60.**

5. Mechanical properties

(1) The mechanical properties of steel pipes are to comply with the following (a) to (d).
(a) *Tensile test*
The tensile test of steel pipes is to comply with the requirements given in T**able 2.1.60.**
(b) *Impact test*
The impact test of steel pipes is to comply with the requirements given in **Table 2.1.60.**
(c) *Flattening test*
Flattening test is to be carried out in accordance with the requirements given in **402. 5** (2). Where this requirement is applied, the value of e is to be taken as 0.08. For steel pipes of 50 mm and under in outside diameter, the specimen for flattening test may be substituted for that for bend test. In this case, a test specimen of tubular section which is taken from the end of the steel pipe and has sufficient length is to stand being bent cold, up to the specified value in **Table 2.1.60**, without flaw and cracking on the outside of bent portion. Electric resistance welded steel pipes are to be bent at the place where the welded line is on the outside of bent portion.
(d) *Hydraulic test*
All steel pipes are to be subjected to hydraulic test in accordance with the requirements given in **402. 5** (4).
(2) Where deemed necessary by the Society, other tests may be required in addition to the tests specified in (1)

6. Selection of test specimens

(1) One sampling pipe is to be selected from each lot of 50 pipes or fraction thereof which are of the same charge, size and kind and are simultaneously heat treated. Each one specimen for tensile test and flattening test is to be taken from each sample pipe.

(2) One set of three specimens for impact test is to be taken from each sample pipe in accordance with **Fig 2.1.11.** Moreover, for electric resistance welded steel pipes, another set of three specimens is to be taken from the welded zone in accordance with **Fig 2.1.12.**

Table 2.1.60 Heat Treatment and Mechanical Properties

Grade	Heat treatment	Tensile test (1)(2)(3)				Bend test		Impact test	
		Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L=5.65\sqrt{A}$)		Inside radius of bend	Angle of bend (°)	Test temp. (℃)	Average absorbed energy (J)(4)
				L	*T*				
RLPA	Normalized, Normalized and tempered or Quenched and tempered	205 min.	380 min.	26 min.	19 min.	6 times the outside diameter of steel pipe	90	-40(5)	27 min.
RLPB								-50(5)	
RLPC								-60(5)	
RLP 2		245 min.	450 min.	20 min.	14 min.			-70	34 min.
RLP 3								-95	
RLP 9	Double normalized and tempered or Quenched and tempered	520 min.	690 min.	15 min.	11 min.			-196	41 min.

NOTES:
(1) *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or normal) to the final direction of rolling.
(2) Where the nominal diameter of steel pipes is 200 mm and over, the tensile test specimen may be taken transversely.
(3) Where test specimen of non-tubular section is taken from electric resistance welded pipes, the test specimen is to be taken from the portion that does not include the welded line.
(4) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified average absorbed energy, the test is considered to have failed.
(5) Impact test temperature for steel pipes specified in **Pt 7, Ch 5** is to be 5℃ below the design temperature or -20℃, whichever is the lower.

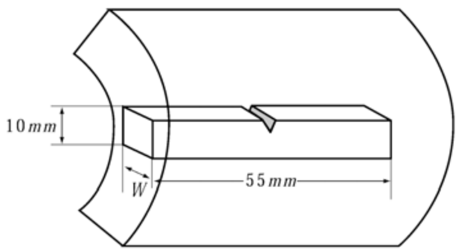


Fig. 2.1.11 The position of selection for impact test specimen taken from the seamless steel pipes and other portions than weld zone of electric-resistance welded steel pipes

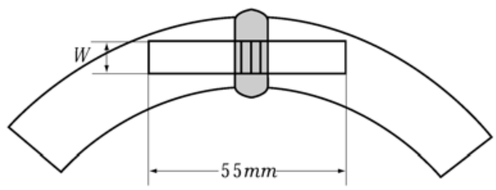


Fig. 2.1.12 The position of selection for impact test specimen taken from the weld zone of electric-resistance welded steel pipes

7. Tolerance for dimensions

The tolerances for outside diameter and wall thickness of steel pipes are to be in accordance with the requirements given in **Table 2.1.61.**

Table 2.1.61 Tolerance for Outside Diameter and Wall Thickness

Kind	Tolerance for outside diameter	Tolerance for wall thickness
Hot-finished seamless steel pipe	D < 50 : ± 0.5 mm 50 ≤ D < 250 : ± 1 % (maximum value 2.0 mm) 250 ≤ D : ± 0.8 %	t < 4 : ± 0.5 mm t ≥ 4 : ± 12.5 %
Cold-drawn seamless steel pipe and Electric-resistance welded steel pipe	± 0.8 % (max. value 0.3 mm)	t < 2 : ± 0.2 mm t ≥ 2 : ± 10 %
NOTE: For hot-finished seamless steel pipes, the tolerance for deviation in wall thickness is to be 20 % or less of wall thickness, but it shall not be applied to the pipes less than 5.6 mm in wall thickness.		

8. Quality

The steel pipes are to be of uniform quality and free from harmful defects.

9. Retest procedures

(1) Where other mechanical tests than impact tests fail to meet the requirements, additional tests may be carried out according to the requirements given in **109.**

(2) Regarding the impact tests, additional tests are to be carried out according to the requirements given in **301. 10** (3).

10. Marking

Marking for steel pipes is generally to comply with the requirements given in **402. 10.** and in case the requirement in Note (5) of **Table 2.1.60** has been applied, "impact test temperature T" is to be suffixed to the marking. (e.g. *RLPA*-25*T*)

405. Header

1. Application

(1) These requirements are to apply to the headers to be used for boilers.

(2) The headers having characteristics differing from those specified in **405.** are to comply with the requirements in **101. 2.**

2. Kinds

The headers are classified as specified in **Table 2.1.62.**

Table 2.1.62 Grades of Headers

Grade	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
	RBH 1	*RBH* 2	*RBH* 3	*RBH* 4	*RBH* 5	*RBH* 6

3. Heat treatment

Headers are to be heat treated by annealing or normalizing.

4. Chemical composition

The chemical composition of headers is to comply with the requirements given in **Table 2.1.63.**

Table 2.1.63 Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th colspan="7">Chemical composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Cr</th><th>Mo</th></tr>
<tr><td>RBH 1</td><td>0.25 max.</td><td rowspan="2">0.10~0.35</td><td rowspan="3">0.30~0.80</td><td rowspan="2">0.040 max.</td><td rowspan="3">0.040 max.</td><td rowspan="3">-</td><td rowspan="2">-</td></tr>
<tr><td>RBH 2</td><td>0.30 max.</td></tr>
<tr><td>RBH 3</td><td rowspan="2">0.10~0.20</td><td rowspan="4">0.10~0.50</td><td rowspan="4">0.030 max.</td><td>0.45~0.65</td></tr>
<tr><td>RBH 4</td><td rowspan="3">0.30~0.60</td><td rowspan="3">0.030 max.</td><td rowspan="2">0.80~1.20</td><td>0.20~0.45</td></tr>
<tr><td>RBH 5</td><td rowspan="2">0.15 max.</td><td>0.45~0.65</td></tr>
<tr><td>RBH 6</td><td>2.00~2.50</td><td>0.90~1.10</td></tr>
</table>

5. Mechanical properties

(1) **Tensile test**: The tensile test of headers is to comply with the requirements given in **Table 2.1.64.**

Table 2.1.64 Mechanical Properties

<table>
<tr><th>Grade</th><th>Yield strength (N/mm^2)</th><th>Tensile strength (N/mm^2)</th><th>Elongation(%) ($L=5.65\sqrt{A}$)</th><th>Reduction of area (%)</th></tr>
<tr><td>RBH 1</td><td>205 min.</td><td>410 min.</td><td>24 min.</td><td>38 min.</td></tr>
<tr><td>RBH 2</td><td>225 min.</td><td>450 min.</td><td>23 min.</td><td rowspan="5">40 min.</td></tr>
<tr><td>RBH 3</td><td rowspan="4">205 min.</td><td>380 min.</td><td>22 min.</td></tr>
<tr><td>RBH 4</td><td rowspan="3">410 min.</td><td rowspan="3">21 min.</td></tr>
<tr><td>RBH 5</td></tr>
<tr><td>RBH 6</td></tr>
<tr><td colspan="5">NOTE:
When test specimens are taken crosswise to the rolled direction, the values of yield strength and tensile strength are to be as given in this Table and the elongation is to take the value reduced by 5 % from the percentage given in this Table. The value of reduction of area may be only remained on records for reference.</td></tr>
</table>

(2) **Bend test**: The test specimen is to stand being bent cold through 180" without flaw and cracking on the outside of bent portion to an inside radius of 12 mm. Where the test specimen of 20 mm in thickness can not be taken, the test specimen may be as original in thickness, in which case, however, the width of test specimen is not to be less than 1.5 times the thickness and the inside radius of bend is to be equal to the thickness.

6. Selection of test specimens

(1) Tensile test specimens are to be taken lengthwise or crosswise to the rolled direction and bend test specimens to be taken crosswise to the rolled direction each from the open ends of headers.

(2) For the headers of the same size made from the same melt and subjected to the heat treatment simultaneously in the same furnace, tensile and bend test specimens are to be selected in accordance with the requirements given in **Table 2.1.65.**

Table 2.1.65 Number of Test Specimens

Grade	Length of test specimens l (mm)	Number of test specimens
RBH 1 *RBH* 2	$3000 \leq l$	1 set for each one length
	$2000 \leq l < 3000$	1 set for each three lengths
	$2000 > l$	1 set for each five lengths
RBH 3 *RBH* 4 *RBH* 5 *RBH* 6	$3000 \leq l$	1 set from each end for each one lengths
	$3000 > l$	1 set for each one length

(3) Where the both ends of header are closed by reforging, the test samples of proper size may be cut from the open ends before reforging.
(4) Where test samples cut from circular headers, etc. are necessary to be flattened, the test samples are to be taken from the body before being subjected to the heat treatment and after flattening the test samples are to be heat treated simultaneously with the body in the same furnace, or the test samples are to be cut from the structures after being subjected to the heat treatment and after flattened cold, they are to be heated to the temperature of 600℃ to 650℃ for the purpose of removing the distortion due to the flattening, and the required test specimens are to be cut from the test samples.

7. Tolerance for thickness

The tolerance for thickness is to be +12.5 %. The tolerance, however, may not apply to the closed portions of circular or square headers, the side corners of square headers and the corrugated headers.

8. Quality

Headers are to be of uniform quality and free from harmful defects.

9. Marking

Headers which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **401. 10.**

SECTION 5 Castings

501. Steel castings

1. Application

(1) The requirements in **501.** are to apply to the steel castings intended to be used for the components specified in the relevant Parts of hull construction equipments and machinery, except that defined in **502., 503.** and **504.**
(2) Steel castings having characteristics differing from those specified in **501.** are to comply with the requirements in **101. 2.**

2. Kinds

The steel castings are classified as specified in **Table 2.1.66.**

Table 2.1.66 Grades and Mechanical Properties

Kind	Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L=5.65\sqrt{A}$)	Reduction of area (%)
Carbon steel castings	*RSC* 410	205 min.	410 min.	24 min.	38 min.
	RSC 450	225 min.	450 min.	22 min.	29 min.
	RSC 480	245 min.	480 min.	20 min.	27 min.
	RSC 520	265 min.	520 min.	18 min.	25 min.
	RSC 560	305 min.	560 min.	15 min.	20 min.
	RSC 600	325 min.	600 min.	13 min.	20 min.
Low alloy steel castings	*RSC* 440*A*	245 min.	440 min.	22 min.	40 min.
	RSC 480*A*	275 min.	480 min.	17 min.	35 min.
	RSC 550*A*	345 min.	550 min.	16 min.	35 min.

NOTES:
1. For intermediate values of the tensile strength, the minimum values for yield strength, elongation and reduction of area may be obtained by interpolation and the value at the first decimal place is to be subjected to the method of counting fractions over 1/2 as one and disregarding the rest.
2. The upper limit of the tensile strength is to be within 150 N/mm^2 from minimum tensile strength of each grade.

3. Manufacture

(1) All flame cutting, scarfing or arc-air gouging to remove the risers and surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.
(2) Where the surface of steel castings is hardened by induction hardening, nitriding, cold rolling or other methods, the proposed methods of manufacture are to be approved by the Society.
(3) When two or more castings are joined by welding to form a composite component, the proposed welding procedure is to be submitted for approval to the Society. If necessary, welding procedure qualification tests may be required.

4. Chemical composition

(1) All castings are to be made from killed steel and the chemical composition is to comply with the overall limits given in **Table 2.1.67.**
(2) The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

Table 2.1.67 Chemical Composition (%)

Steel Type	Application	Chemical composition (%)										
		C	Si	Mn	S	P	Residual elements					Total residuals
							Cu	Cr	Ni	Mo	W	
Carbon steel casting	Casting for non-welded construction	0.40 max.	0.60 max.	0.50-1.60	0.040 max.	0.040 max.	0.30 max.	0.30 max.	0.40 max.	0.15 max.	-	0.80 max.
	Casting for welded construction	0.23 max.(1)	0.60 max.	1.60 max.	0.040 max.	0.040 max.	0.30 max.	0.30 max.	0.40 max.	0.15 max.	-	0.80 max.
Low alloy steel casting		0.25 max.	0.60 max.	0.50 - 0.80	0.030 max.	0.030 max.	0.50 max.	1.50 max.	0.50 max.	1.20 max.	0.10 max.	1.00 max.

NOTES :
(1) The carbon content may be, subject to approval by the Society, increased above this level provided that the carbon equivalent (*Ceq*) is not more than 0.41 %

(3) Unless otherwise required suitable grain refining elements such as aluminium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

5. Heat treatment

(1) Steel castings are to be annealed, normalized, normalized and tempered, or quenched and tempered. No annealed casting is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C. The tempering temperature is to be not less than 550℃.

(2) Steel castings which are locally heated or subjected to any cold work after heat treatment, are to be stress-relieved.

(3) Castings for components such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550℃ followed by furnace cooling to 300℃ or lower.

(4) Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole casting to be uniformly heated to the necessary temperature In the case of very large castings alternative methods for heat treatment will be specially considered by the Society.
Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

(5) The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

6. Mechanical properties

(1) The mechanical properties of the steel castings are to comply with the requirements given in **Table 2.1.66.**

(2) Impact tests should be required on carbon steel castings intended for welded construction such as cast sternframes, rudder horns and shoepieces. The results of impact test is to be in accordance with the Guidance relating to the Rules specified by the Society.

7. Selection of test specimens

(1) At least one test sample is to be provided for each casting. Unless otherwise agreed these test samples are to be either integrally cast or gated to the castings and are to have a thickness of not less than 30 mm. Test material, sufficient for the required tests and for possible retest purposes is to be provided for each casting or batch of castings. One tensile test specimen is to be taken from each test sample.

(2) The test samples are to be heat treated together with the castings which they represent and are not to be detached from the casting until the specified heat treatment has been completed and they have been properly identified.
(3) For castings where the method of manufacture has been specially approved by the Society in accordance with **3** (2), the number and position of test samples is to be agreed with the Society having regard to the method of manufacture employed.
(4) Number of test specimens is to comply with the requirements of **Table 2.1.68.**

Table 2.1.68 Number of Test Specimens

Condition of casting	Number of test specimens
Where the weight of one steel casting is between 1 ton and 10 tons inclusive	1 for each casting(1)
Where the casting is of complex design or where the finished weight exceeds 10 tons	2 for each casting(1)
Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring.	Two or more corresponding to the number of casts involved(1)
Where a number of small castings with a weight of 1 ton or less which are to be of similar type and dimensions, made from one cast and heat-treated in the same furnace charge.	1 for each batch of castings(2)
NOTES: (1) These test samples are to be integrally cast at locations as widely separated as possible. (2) Test sample are to be separately casted and are to have suitable dimensions.	

8. Surface and dimension inspections

(1) When heat treatment and machining are finished and, if necessary, at a proper time during machining, surface inspection is to be carried out. Where applicable, this is to include the examination of internal surfaces. Testing methods and acceptance criteria are to be in accordance with the Guidance relating to the Rules specified by the Society.
(2) All castings are to be cleaned and adequately prepared for examination; suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.
(3) The dimension inspection of the steel castings is to be conducted under the responsibility of the manufacturer, unless otherwise specified.

9. Quality

(1) All castings are to be free from surface or internal defects, which would be prejudicial to their proper application in service.
(2) In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

10. Non-destructive inspection

(1) The steel castings intended for stern frame, rudder post and other important structural members or the steel castings specified in **Pt 5, Ch 2, 201. 1** are to be subjected to ultrasonic tests at an appropriate stage of the manufacturing process and the test reports are to be showed or submitted to the Surveyor. Testing methods and acceptance criteria are to be in accordance with the Guidance relating to the Rules specified by the Society.
(2) The important parts of the following steel castings are to be subjected to magnetic particle tests at an appropriate stage of the manufacturing process. But, machining surfaces may be subjected to liquid penetrant tests. Testing methods and acceptance criteria are to be in accordance with the Guidance relating to the Rules specified by the Society.
(a) Steel castings intended for stern frame, rudder post and other important structural members.
(b) Steel castings specified in **Pt 5, Ch 2, 201. 1.**
(c) Propellers.
(d) Turbine castings.

(3) When required by the relevant construction Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence of the Surveyor and are to be to their satisfaction.
(4) In place of the test methods specified in (1) and (2), the Society may accept the application of other non-destructive inspections considered adequate by the Society.
(5) The Society may require non-destructive inspections by radiographic test, ultrasonic test, magnetic particle test or penetrant test not only for the steel casting specified in (1) and (2) but also for the steel casting deemed necessary by the Society.
(6) The welding parts of steel castings used to welded construction are to be subjected to non-destructive inspections considered adequate by the Society.

11. Repair of defects

(1) *General*
(i) The approval of the Society is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.
(ii) Procedure of removal of defect and weld repair is to be in accordance with the Guidance relating to the Rules specified by the Society.
(iii) Where the defective area is to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by magnetic particle test or liquid penetrant test.
(iv) Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by magnetic particle test or liquid penetrant test.
(v) The manufacturer is to maintain full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs. These records are to be available to the Surveyor and copies provided on request.

(2) *Weld repairs*
When a casting can be repaired by welding, the following requirements apply:
(i) Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatement and subsequent inspection procedures are to be submitted for approval.
(ii) All castings in low alloy steels and all castings for crankshafts are to be suitably pre-heated prior to welding. Castings in carbon steel may also require to be pre-heated depending on their chemical composition, the dimensions and position of the weld repairs.
(iii) Welding is to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the downhand (flat) position.
(iv) The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings.
Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in **5.**
(v) After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of previous **5** (1) or a stress relieving heat treatment at a temperature of not less than 550℃. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs .
(vi) Subject to the prior agreement of the Society, special consideration may be given to the omission of postweld heat treatment or to the acceptance of local stress-relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.
(vii) On completion of heat treatment the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of non-destructive testing used.

12. Retest procedure

(1) Where the tensile test fails to meet the requirements, additional test may be carried out in accordance with the requirements of **109.**

(2) The additional tests are to be taken, preferably from the same, but alternatively from another, test sample representative of the casting or batch of castings.

(3) At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

13. Marking

(1) The grade of material and the manufacturer''s name or trade mark are to be cast or stamped on all steel castings. In addition, the cast number is to be stamped on all steel castings not less than 250 kg in mass. The Society's brand indicating satisfactory compliance with the requirements is to be stamped in the vicinity of the foregoing marks.

(2) For steel castings to which the requirements given in note 1 of the **Table 2.1.66**, the material symbols are specified as *RSC* - (or *RSC* - *A*) and the required tensile strength is to be filled in symbol " - ". (e.g. For carbon steel castings which the required tensile strength is 420 N/mm^2, *RSC* 420)

(3) Where carbon steel castings are intended for welded hull construction specified in **Table 2.1.67**, "W" is to be suffixed to the marking. (e.g, *RSC* 420-*W*)

14. Additional requirements for crank throw

(1) In case where semi-built-up crank throw for diesel engines is made of steel casting, the manufacturing procedure is to be approved by the Society.

(2) Where special manufacturing methods are adopted to reduce the size of crank throw according to the requirements in **Pt 5, Ch 2, 208**, the preliminary test instructed by the Society are to be carried out.

502. Steel castings for chains

1. Application

(1) These requirements are to apply to the steel castings used for anchor chain cables and accessories specified in **Pt 4, Ch 8** (hereinafter referred to as "steel castings").

(2) Steel castings having characteristics differing from those specified in **502.** are to comply with the requirements in **101. 2.**

2. Kinds

The steel castings are classified as specified in **Table 2.1.69**

Table 2.1.69 Grade of Steel Casting

Grade	Application
RSCC 50	Grade 2 chain
RSCC 70	Grade 3 chain
RSCCR 3	Grade *R* 3 chain
RSCCR 3*S*	Grade *R* 3*S* chain
RSCCR 4	Grade *R 4* chain

3. Heat treatment

(1) Steel castings are to be normalized, normalized and tempered, quenched and tempered or heat treated by the process approved by the Society.

(2) Steel castings which are locally heated or subjected to any cold work after heat treatment, are to be stress-relieved by the approved methods.

(3) Flame cutting or scarfing to remove risers and surplus metals is to be completed before final heat treatment of the steel castings.

4. Chemical composition

Chemical composition of steel castings is to be subjected to the special approval by the Society.

5. Mechanical properties

The mechanical properties of steel castings are to comply with the requirements given in **Table 2.1.70.**

Table 2.1.70 Mechanical Properties

Grade	Tensile test				Impact test[1]	
	Yield strength (N/mm^2) [2]	Tensile strength (N/mm^2) [2]	Elongation (%) ($L=5d$)	Reduction of area (%)	Testing temp. (℃)	Average absorbed energy (J)
RSCC 50	295 min.	490~690	22 min.	-	-	-
RSCC 70	410 min.	690 min.	17 min.	40 min.	0	60 min.
RSCCR 3	410 min.	690 min.	17 min.	40 min.	-20[3]	40 min.[3]
RSCCR 3*S*	490 min.	770 min.	15 min.	40 min.	-20[3]	45 min.[3]
RSCCR 4	580 min.	860 min.	12 min.	35 min.	-20	50 min.

NOTE:
(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.
(2) The yield ratio (the aim value of yield to tensile ratio) for grade *RSCCR* 3, *RSCCR* 3*S*, or *RSCCR* 4 is to be maximum 0.92.
(3) Impact test of grade *RSCCR* 3 and *RSCCR* 3*S* may be carried out at the temperature of 0 °*C* where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 60*J* for grade *RSCCR* 3 and 65*J* for grade *RSCCR* 3*S*.

6. Selection of test specimens

(1) One test sample is to be taken from castings of similar dimensions originating from the same heat treatment charge and the same cast of steel. In this case, the test sample may be the test assembly cast with the body of casting and similar area. The tensile and impact test specimens are to be taken from the test sample in the longitudinal direction at a depth of 1/6 diameter from the surface specified in **Fig 2.1.5.**
(2) For *RSCC 50*, one tensile test specimen, and for other grades of chain castings, one tensile test specimen and one set (3 pieces) of impact test specimens are to be taken from the test sample.

7. Surface inspection

Steel castings are to be subjected to the surface inspection after completion of the final heat treatment.

8. Quality

Steel castings are to be of uniform quality and free from harmful defects.

9. Non-destructive inspection

(1) For grades *RSCCR* 3, *RSCCR* 3*S* and *RSCCR* 4, all steel castings are subjected to ultrasonic test at an appropriate stage of the manufacture after heat treatment and it is to be confirmed that there are no harmful defects.
(2) For grades *RSCC* 50 and *RSCC* 70, a suitable non-destructive inspection, such as an ultrasonic test, may be required where deemed necessary by the Society.

10. Repair of defects

The repair of defects for steel castings is generally to be carried out in accordance with the requirements in **501. 11.**

11. Retest procedure

Where the tensile test or impact test on the selected first test specimens fails to meet the requirements, additional tests may be conducted according to the requirements given in **306. 7.**

12. Marking

Steel castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **501. 13** (1).

503. Stainless steel castings

1. Application

(1) The requirements are to apply to the stainless steel castings for valves and pipe fittings in piping systems used at low temperature (-165℃ and over in design temperature) service or corrosion-resisting service (hereinafter referred to as "steel castings").
(2) Steel castings having characteristics differing from those specified in **503.** are to comply with the requirements in **101. 2.**

2. Kinds

The steel castings are classified as specified in **Table 2.1.71.**

3. Heat treatment

Steel castings are generally to receive a solid solution treatment.

4. Chemical composition

The chemical composition of steel castings is to comply with the requirements given in **Table 2.1.71.**

Table 2.1.71 Grades and Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th colspan="9">Chemical composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Ni</th><th>Cr</th><th>Mo</th><th>Other</th></tr>
<tr><td>RSSC 13</td><td rowspan="2">0.08 max.</td><td>2.00 max.</td><td rowspan="7">2.00 max.</td><td rowspan="7">0.040 max.</td><td rowspan="7">0.030 max.</td><td>8.00~11.00</td><td>18.00~21.00</td><td>—</td><td>—</td></tr>
<tr><td>RSSC 14</td><td rowspan="2">1.50 max.</td><td>10.00~14.00</td><td rowspan="2">17.00~22.00</td><td rowspan="2">2.00~3.00</td><td>—</td></tr>
<tr><td>RSSC 16</td><td>0.030 max.</td><td>12.00~16.00</td><td>—</td></tr>
<tr><td>RSSC 17</td><td rowspan="2">0.08 max.</td><td rowspan="4">2.00 max.</td><td>12.00~15.00</td><td>22.00~26.0</td><td>—</td><td>—</td></tr>
<tr><td>RSSC 18</td><td>19.00~22.00</td><td>23.00~27.0</td><td>—</td><td>—</td></tr>
<tr><td>RSSC 19</td><td>0.030 max.</td><td>8.00~12.00</td><td>17.00~21.0</td><td>—</td><td>—</td></tr>
<tr><td>RSSC 21</td><td>0.08 max.</td><td>9.00~12.00</td><td>18.00~21.0</td><td colspan="2">1.35≥Nb+Ta≥10×C</td></tr>
</table>

5. Mechanical properties

(1) The mechanical properties of steel castings are to comply with the requirements give in **Table 2.1.72.**
(2) Where deemed necessary by the Society, impact test or corrosion-resistance test may be required in addition to the specified tests.

Table 2.1.72 Mechanical Properties

<table>
<tr><th rowspan="2">Grade</th><th colspan="3">Tensile test</th><th>Hardness test</th></tr>
<tr><th>Yield strength (N/mm^2)</th><th>Tensile strength (N/mm^2)</th><th>Elongation(%) ($L=5.65\sqrt{A}$)</th><th>Brinell HB</th></tr>
<tr><td>RSSC 13</td><td rowspan="2">185 min.</td><td rowspan="2">440 min.</td><td rowspan="2">26 min.</td><td rowspan="7">183 max.</td></tr>
<tr><td>RSSC 14</td></tr>
<tr><td>RSSC 16</td><td>175 min.</td><td>390 min.</td><td>31 min.</td></tr>
<tr><td>RSSC 17</td><td>205 min.</td><td rowspan="2">440 min.</td><td rowspan="2">26 min.</td></tr>
<tr><td>RSSC 18</td><td rowspan="2">185 min.</td></tr>
<tr><td>RSSC 19</td><td>390 min.</td><td>31 min.</td></tr>
<tr><td>RSSC 21</td><td>205 min.</td><td>440 min.</td><td>26 min.</td></tr>
</table>

6. Selection of test specimens

(1) Where a stainless steel casting is 500 kg and over in weight, one tensile test specimen and one hardness test specimen are to be taken from each casting.
(2) Where a number of stainless steel castings of similar form and size, each of which weight less than 500 kg, are cast from the same charge, two tensile test specimens and two hardness test specimens are to be taken from each group of castings simultaneously heat treated in the same furnace.
(3) Hardness test specimen may be a portion of tensile test specimen.

7. Marking

Steel castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.**

504. Steel castings for low temperature service

1. Application

(1) The requirements are to apply to the steel castings for valves and pipe fittings in piping systems intended to be used at the design temperature lower than 0℃ in liquefied gas carriers (hereinafter referred to as "steel castings").
(2) Steel castings other than specified in **504.** or those used in other parts than specified in (1) are to comply with the requirements given in **101. 2.**

2. Kinds

The steel castings are classified as given in **Table 2.1.73.**

Table 2.1.73 Grades and Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Deoxidation</th><th colspan="7">Chemical composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Ni</th><th>Mo</th></tr>
<tr><td>RLCA</td><td rowspan="4">Fully killed fine grain</td><td>0.30 max.</td><td rowspan="4">0.60 max.</td><td>1.00 max.</td><td rowspan="2">0.035 max.</td><td rowspan="2">0.035 max.</td><td rowspan="2">-</td><td>-</td></tr>
<tr><td>RLCB</td><td>0.25 max.</td><td rowspan="3">0.50~0.80</td><td>0.45~0.65</td></tr>
<tr><td>RLC 2</td><td>0.25 max.</td><td rowspan="2">0.030 max.</td><td rowspan="2">0.030 max.</td><td>2.00~3.00</td><td rowspan="2">-</td></tr>
<tr><td>RLC 3</td><td>0.15 max.</td><td>3.00~4.00</td></tr>
</table>

3. Heat treatment

Steel castings are to be normalized or normalized and tempered.

4. Deoxidation practice and chemical composition

The deoxidation practice and chemical composition of steel castings are to comply with the requirements given in **Table 2.1.73.**

5. Mechanical properties

(1) The mechanical properties of steel castings are to comply with the requirements given in **Table 2.1.74.**
(2) Where deemed necessary by the Society, other tests may be required in addition to the tests specified in (1).

Table 2.1.74 Mechanical Properties

Grade	Tensile test				Impact test (2)	
	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L=5d$)	Reduction of area (%)	Test temp. (℃)	Average absorbed energy (J)
RLCA	245 min.	450 min.	21 min.	35 min.	-40(1)	27 min.
RLCB					-50(1)	
RLC 2	275 min.				-70	34 min.
RLC 3					-95	

NOTES:
(1) Impact test temperature for castings specified in **Pt 7, Ch 5** is to be 5℃ below the design temperature or -20℃, whichever is the lower.
(2) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

6. Selection of test specimens

(1) Where a steel casting is 500 kg and over in weight, one tensile test specimen and one set of three impact test specimens are to be taken from each casting.
(2) Where a number of steel castings of similar form and size, each of which less than 500 kg in weight, are cast from the same charge, two tensile test specimens and two sets of six impact test specimens are to be taken from each group of castings simultaneously heat treated in the same furnace.

7. Retest procedures

(1) Where the tensile tests fail to meet the requirements, additional tests may be carried out according to the requirements given in **109.**
(2) Regarding the impact tests, additional tests are to be carried out according to the requirements given in **304. 9** (2).

8. Marking

Steel castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **501. 13** (1) and in case the requirement in Note (1) of **Table 2.1.74** has been applied, "impact test temperature T" is to be suffixed to the marking. (e.g. *RLCA* - 25*T*)

505. Stainless steel casting for propeller

1. Application

(1) These requirements are applicable to the manufacture of stainless steel casting(hereinafter referred to as "**steel propeller casting**") for propellers, blades and bosses. These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Society.

(2) Steel propeller castings having characteristics differing from those specified in **505.** are to comply with the requirements in **101. 2**.

2. Kinds

Steel propeller castings are classified as specified in **Table 2.1.75**.

3. Chemical composition

Chemical composition is classified as specified in **Table 2.1.75**.

Table 2.1.75 Kinds and Chemical Composition

Alloy type		Chemical composition (%)				
		C	*Mn*	*Cr*	*Mo*(1)	*Ni*
12*Cr* 1*Ni*	Martensitic	0.15 Max.	2.0 Max.	11.5 - 17.0	0.5 Max.	2.0 Max.
13*Cr* 4*Ni*		0.06 Max.	2.0 Max.	11.5 - 17.0	1.0 Max.	3.5 - 5.0
16*Cr* 5*Ni*		0.06 Max.	2.0 Max.	15.0 - 17.5	1.5 Max.	3.5 - 6.0
19*Cr* 11*Ni*	Austenitic	0.12 Max.	1.6 Max.	16.0 - 21.0	4.0 Max.	8.0 - 13.0

NOTE :
(1) Minimum values may be in accordance with recognised national or international standards, subject to prior agreement with the Society.

4. Heat treatment

Martensitic castings are to be austenitized(quenching) and tempered. Austenitic castings should be solution treated.

5. Mechanical properties

(1) The mechanical properties are to meet the requirements in **Table 2.1.76** These values refer to the test specimens machined from integrally cast test bars attached to the hub or on the blade.

Table 2.1.76 Mechanical Properties

Types	Tensile test				Impact test
	Yield strength (1) (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Reduction area (%)	Average absorbed energy (J) (3)
12*Cr* 1*Ni*	440 Min.	590 Min.	15 Min.	30 Min.	20 Min.
13*Cr* 4*Ni*	550 Min.	750 Min.	15 Min.	35 Min.	30 Min.
16*Cr* 5*Ni*	540 Min.	760 Min.	15 Min.	35 Min.	30 Min.
19*Cr* 11Ni	180 Min.(2)	440 Min.	30 Min.	40 Min.	-

NOTES
(1) 0.2 % yield strength
(2) 1.0 % yield strength is min. 205 N/mm^2.
(3) Not required for general service and the lowest Ice class notation(Grade ID). For other Ice class notations, tests are to be made -10℃.

6. Selection of test samples and specimens

(1) Where possible, the test samples attached on blades are to be located in an area between 0.5 to 0.6 R, where R is the radius of the propeller.
(2) The test samples are not to be detached from the casting until the final heat treatment has been carried out. Removal is to be by non-thermal procedures.

(3) Separately cast test samples may be used subject to prior approval of the Society. The test samples are to be cast from the same heat as the castings represented and heat treated with the castings represented.
(4) At least one set of mechanical tests is to be made on material representing each casting. However, where a number of small propellers of about the same size, and less than 1 m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

7. Surface and dimension inspection

(1) Steel propeller castings are to be subjected to the surface inspection by the Society at the final process and other proper processing stages if necessary. The surveyor may require areas to be etched for the purpose of investigating weld repairs.
(2) Steel propeller castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.
(3) The dimensions are the responsibility of the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence.

8. Non-destructive inspection

(1) The important parts of steel propeller casting are to be subjected to the liquid penetrant test in accordance with the Guidance relating to Rules specified by the Society.
(2) The division of severity zones of steel propeller casting is to be in accordance with the Guidance relating to Rules specified by the Society.
(3) Where serious doubt exists that the castings are not free from internal defects, further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. The acceptance criteria are then to be agreed between the manufacturer and the Society.
(4) The foundry is to maintain records of inspections traceable to each propeller casting. These records are to be reviewed by the Surveyor. The foundry is also to provide the Surveyor with a statement confirming that non-destructive tests have been carried out with satisfactory results.

9. Repair of defects

(1) In general the repairs are to be carried out by mechanical means, e.g. by grinding or milling. Where the steel propeller castings from which defects where removed are used in that condition, the steel propeller castings are to be approved by the Surveyor.
(2) The resulting grooves are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by liquid penetrant testing.
(3) Weld repairs are to be undertaken only when they are considered to be necessary and have prior approval of the Surveyor. Welds having an area less than 5 cm^2 are to be avoided.
(4) The repair welding procedures are to have prior approval of the Surveyor in accordance with the Guidance relating to the Rules specified by the Society.
(5) All weld repairs are to be documented by means of sketches or photographs showing the location and major dimensions of the grooves prepared for welding. The documentation is to be presented to the Surveyor prior to repair welding.

10. Retest procedure

Where the results of tensile tests fail to meet the requirements, additional test may be carried out in accordance with the requirements of **109**.

11. Marking

Steel propeller castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110**.

506. Grey iron castings

1. Application

(1) These requirements are to apply to the grey iron castings (hereinafter referred to as "iron castings") intended to be used for propeller or important parts of machinery.
(2) Where deemed necessary by the Society, KS or equivalent thereto may be applied.

(3) Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of the Society.

2. Manufacture

(1) The manufacturer has the necessary manufacturing and testing facilities and the manufacturing processes are to be approved by the Society.
(2) Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.
(3) Where castings of the same type are regularly produced in quantity, the manufacturer, subject to the approval of the Society, is to make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

3. Grade and mechanical properties

Grey iron castings are to comply with the *KS D* 4301. However, the minimum tensile strength is to be not less than 200 N/mm^2

4. Chemical composition

(1) The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.
(2) When required by the Societies the chemical composition of ladle samples is to be reported.

5. Heat treatment

(1) Except as required by (2) castings may be supplied in either the as cast or heat treated condition.
(2) For some applications, such as high temperature service or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment

6. Selection of test samples and specimens

(1) Test material sufficient for the required tests and for possible re-tests is to be provided for each casting or batch of castings.
(2) Separately cast test samples are to be used in principle and are to be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings
(3) Test samples are to be in the form of bars 30 mm in diameter and of a suitable length.
(4) When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart as given in **Fig 2.1.13.**

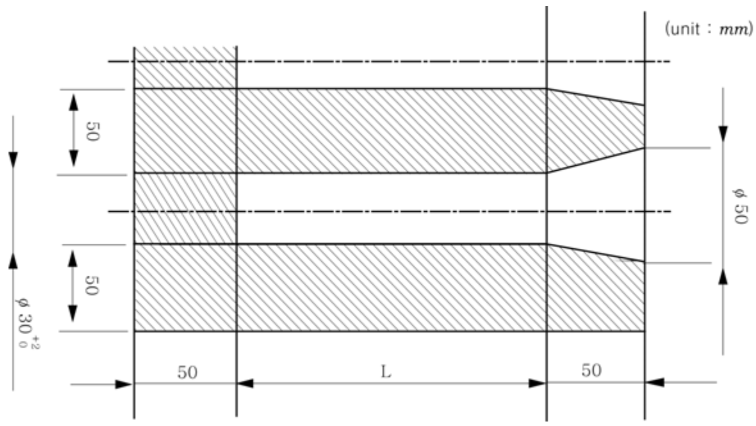


Fig 2.1.13 Sample distance

(5) Cast test samples are not to be stripped from the moulds until the metal temperature is below 500°C.
(6) Integrally cast samples may be used when a casting is more than 20 mm thick and its mass exceeds 200 Kg, subject to agreement between the manufacturer and the purchaser. The type and location of the sample are to be selected to provide approximately the same cooling conditions as for the casting it represents and also subject to agreement.

(7) The numbers of test specimen are as below:
  (a) With the exception of (d) below, at least one test sample is to be cast with each batch.
  (b) With the exception of (c) below, a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed two tonnes of fettled castings and a single casting will constitute a batch is its mass is 2 tonnes or more.
  (c) For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be increased to the output of 2 hours of pouring.
  (d) If one grade of cast iron is melted in large quantities and if production is carefully monitored by systematic checking of the melting process, such as chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals.
(8) All test samples are to be suitably marked to identify them with the castings which they represent.
(9) Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples the sample shall not be cut off from the casting until after the heat treatment.
(10) One tensile test specimen is to be prepared from each test sample. Where test samples of other dimensions are specially required the tensile test specimens are to be machined to agreed dimensions.
(11) All tensile tests are to be carried out using test procedures in accordance with the requirements specified in **203. 1.**

7. Test and inspection

(1) All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.
(2) For grey iron castings, testing and inspection may not require the presence of the Society's surveyors, except where specially specified in connection with the design.
(3) For the steel propeller castings and spheroidal iron castings, testing and inspection may require the presence of the Society''s surveyor.
(4) When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.
(5) Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.
(6) Supplementary examination of castings by suitable nondestructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting.

8. Rectification of defective casting

(1) At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.
(2) Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.
(3) Repairs by welding are generally not permitted.

9. Retest procedure Where the tensile test fails to meet the requirements, additional test may be carried out in accordance with the requirements of **109.**

10. Marking Grey iron castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.**

507. Spheroidal or nodular graphite iron castings

1. Application

(1) These requirements are to apply to the Spheroidal or nodular graphite iron castings (hereinafter referred to as "iron castings") intended to be used for propeller or important parts of machinery.
(2) These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.
(3) Where deemed necessary by the Society, KS or equivalent thereto may be applied.

(4) Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of the Society.

2. Manufacture

(1) The manufacturer has the necessary manufacturing and testing facilities and the manufacturing processes are to be approved by the Society.
(2) Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.
(3) Where castings of the same type are regularly produced in quantity, the manufacturer, subject to the approval of the Society, is to make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

3. Grade and mechanical properties Grade and mechanical properties of castings are to be as specified in **Table 2.1.77.** However, Brinell hardness values are intended for information purposes only.

Table 2.1.77 Grade and mechanical properties

Specified min. tensile strength (N/mm^2)		0.2% proof stress (N/mm^2)	Elongation (%) ($5.65\sqrt{A}$)	Brinell hardness values	Impact energy		Typical structure of matrix
					Test temp.(℃)	kV[(2)] (J) min	
Ordinary qualities	370 min.	230 min.	17 min.	120-180	-	-	Ferrite
	400 min.	250 min.	12 min.	140-200	-	-	Ferrite
	500 min.	320 min.	7 min.	170-240	-	-	Ferrite/Perlite
	600 min.	370 min.	3 min.	190-270	-	-	Ferrite/Perlite
	700 min.	420 min.	2 min.	230-300	-	-	Perlite
	800 min.	480 min.	2 min.	250-350	-	-	Perlite or Tempered
Special qualities	350 min.	220 min.	22 min.[(3)]	110-170	+20	17(14)	Ferrite
	400 min.	250 min.	18 min.[(3)]	140-200	+20	14(11)	Ferrite

NOTE
1. For intermediate values of specified minimum tensile strength, the minimum values for 0,2 % proof and elongation may be obtained by interpolation.
2. The average value measured on 3 Charpy V-notch specimens. One result may be below the average value but not less than the minimum shown in brackets.
3. In the case of integrally cast samples, the elongation may be 2 percentage points less.

4. Chemical composition

(1) The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.
(2) When required by the Societies the chemical composition of ladle samples is to be reported.

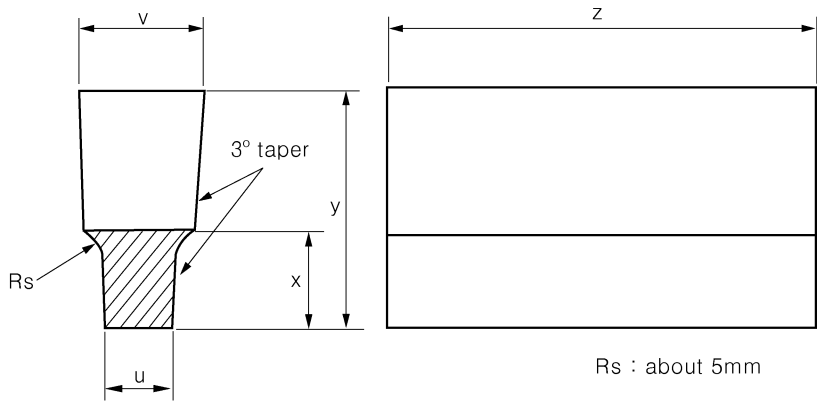
5. Heat treatment

(1) Except as required by (2) castings may be supplied in either the as cast or heat treated condition.
(2) For some applications, such as high temperature service or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment
(3) Heat treatment is to be carried out after any refining heat treatment and before machining. The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test shall undergo a ferritizing heat treatment.
(4) Where it is proposed to locally harden the surfaces of a spheroidal iron castings full details of the proposed procedure and specification are to be submitted for approval by the Society.

6. Selection of test samples and specimens

(1) Test material sufficient for the required tests and for possible re-tests is to be provided for each casting or batch of castings.

(2) The test samples are generally to be one of the standard types detailed in **Figs 2.1.14, 2.1.15** and **2.1.16** with a thickness of 25 mm. Test samples of other dimensions, as detailed in Figs **2.1.14** or **2.1.16** may, however, be specially required for some components.
(3) At least one test sample is to be provided for each casting and unless otherwise required may be either gated to the casting or separately cast. Alternatively test material of other suitable dimensions may be provided integral with the casting.
(4) Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings.
(5) The samples are not to be stripped from the moulds until the temperature is below 500°C.
(6) For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.
(7) As an alternative to (3) above, a batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2,0 tonnes of fettled castings in the batch.
(8) All test samples are to be suitably marked to identify them with the castings which they represent.
(9) Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.
(10) One tensile test specimen is to be prepared from each test sample.
(11) All tensile tests are to be carried out using test procedures in accordance with the requirements specified in **203. 1**. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.
(12) Impact tests may additionally be required and in such cases a set of three test specimens of agreed type is to be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with the requirements specified in **202. 3** and **203. 2**.



	Standard sample	Alternative sample when specially required		
		Case 1	Case 2	Case 3
u(mm)	25	12	50	75
v(mm)	55	41	90	125
x(mm)	40	30	60	65
y(mm)	100	80	150	165
z	To suit testing machine			

Fig 2.1.14 U-type test sample

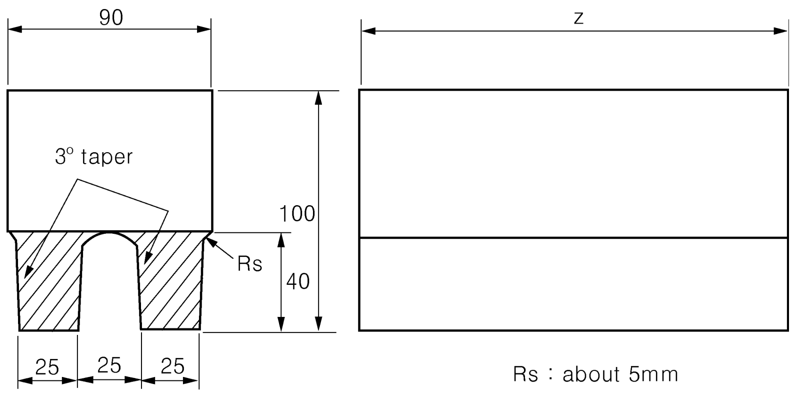
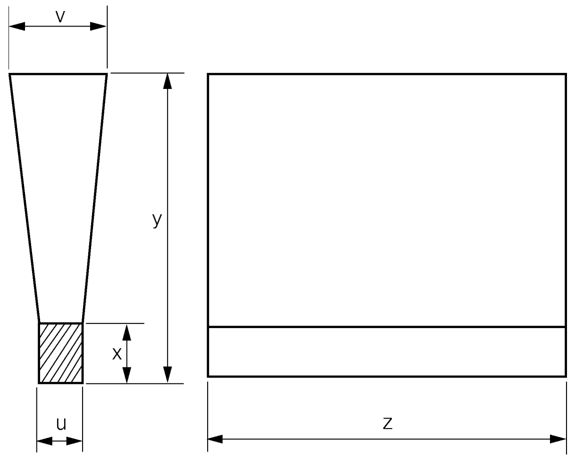


Fig 2.1.15 Double U-type test sample



	Standard sample	Alternative sample when specially required		
		Case 1	Case 2	Case 3
u(mm)	25	12	50	75
v(mm)	55	40	100	125
x(mm)	40	25	50	65
y(mm)	140	135	150	175
z	To suit testing machine			

Fig 2.1.16 Y-type test sample

7. Test and inspection

(1) All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

(2) Before acceptance, all castings are to be visually examined including, where applicable, the examination of internal surfaces. Unless otherwise agreed the verification of dimensions is the responsibility of the manufacturer.

(3) When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

(4) Supplementary examination of castings by suitable nondestructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting. However, cast crankshaft are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

(5) For crankshafts the metallographic examination is to be carried out as followings;

(a) When required, a representative sample from each ladle of treated metal is to be prepared for metallographic examination. These samples may conveniently be taken from the tensile test specimens but alternative arrangements for the provision of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

(b) Examination of the samples is to show that at least 90 % of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in **Table 2.1.77** and are intended for information purposes only.

8. Rectification of defective casting

(1) At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

(2) Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

(3) Repairs by welding are generally not permitted.

9. Retest procedure Where the tensile test fails to meet the requirements, additional test may be carried out in accordance with the requirements of **109.**

10. Marking Spheroidal iron castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.**

SECTION 6 Steel Forgings

601. Steel forgings

1. Application

(1) The requirements in **601.** are to apply to the steel forgings(except those specified in **602., 603.** and **604.**) intended to be used for the components of hull construction, equipments, and machinery specified in each Part, and where relevant, these requirements are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape (hereinafter referred to as the "**steel forgings**").

(2) Steel forgings having characteristics differing from those specified in **601.** are to comply with the requirements in **101. 2.**

2. Kinds The steel forgings are classified as specified in **Table 2.1.81 and 2.1.82.**

3. Manufacturing process

(1) Steel forgings are to be manufactured from the killed steel.

(2) Adequate discards are to be made from the top and bottom of each ingot to ensure freedom from piping and harmful segregation in the finished forgings.

(3) Steel forgings are to be hot worked by press or hammer from ingots, blooms forged or rolled from ingots or blooms made from ingots by a combination of rolling and forging.

(4) Steel forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable, they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service.

(5) The reduction ratio is to comply with the following;

(a) For components where the fibre deformation is mainly longitudinal; the total reduction ratio is to be not less than those shown in **Table 2.1.78.**

Table 2.1.78 Reduction Ratio

Method of manufacture	Description[1]	Total reduction[2][3]
Made directly from ingots or from forged blooms or billets	$L > D$ $L \leq D$	3 : 1 1.5 : 1
Made from rolled products	$L > D$ $L \leq D$	4 : 1 2 : 1

NOTES:
(1) L and D are the length and diameter respectively of the part of the forging under consideration.
(2) The reduction ratio is to be calculated with reference to the average cross-sectional area of the ingot. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.
(3) For rolled bars used as a substitute for forgings the reduction ratio is to be not less than 6:1.

(b) *Disc type forgings such as gear wheels are made by upsetting*

(i) The thickness of any part of the disc is to be not more than one half of the length of the billet from which it was formed provided that this billet has received an initial forging reduction of not less than 1.5:1.

(ii) Where the piece used has been cut directly from an ingot or where the billet has received an initial reduction of less than 1.5:1, the thickness of any part of the disc is to be not more than one third of the length of the original piece.

(6) The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required.

(7) When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval to the Society. Welding procedure qualification tests may be required.

4. Heat treatment

(1) Except as provided in (5), after completion of all hot working operations, forgings are to be supplied in one of the conditions given in **Table 2.1.79.** to refine the grain structure and to obtain the required mechanical properties. No annealed forging is to be removed from the furnace until the temperature of the entire furnace charge has fallen to or below a temperature of 455°C. The tempering temperature is to be not less than 550℃.

Table 2.1.79 Heat Treatment

Kind	Heat treatment
Carbon steels	Annealed Normalized Normalized and tempered Quenched and tempered
Alloy steels	Quenched and tempered

(2) Alternatively, alloy steel forgings may be supplied in the normalized and tempered condition, in which case the specified mechanical properties are to be agreed with the Society.
(3) Steel forgings which are subjected to any hot work after heat treatment, are to be heat treated again.
(4) If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment.
(5) Where induction hardening or nitriding is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.
(6) Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.
(7) Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of the Society. For the purposes of this approval, the manufacture may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.
(8) Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings alternative methods of heat treatment will be specially considered by the Society.
Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.
(9) The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the surveyor on request.

5. Chemical composition

(1) The chemical composition of steel forgings is to comply with the requirements given in **Table 2.1.80.**
(2) The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multi heats are tapped into a common ladle, the ladle analysis shall apply.
(3) At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported in the ladle analysis.

Table 2.1.80 Chemical Composition

Steel type		Chemical composition (%)									
		C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Ni*	*Cu*[3]	Total residual
Hull and General purpose steel forging[5]	Carbon steel	0.23[1][2] max.	0.45 max.	0.30-1.50	0.035 max.	0.035 max.	0.30[3] max.	0.15[3] max.	0.40[3] max.	0.30 max.	0.85 max.
Hull and General purpose steel forging[5]	Low alloy steel	[4]	0.45 max.	[4]	0.035 max.	0.035 max.	[4]	[4]	[4]	0.30 max.	-
Machinery steel forging	Carbon steel	0.65[1] max.	0.45 max.	0.30-1.50	0.035 max.	0.035 max.	0.30[3] max.	0.15[3] max.	0.40[3] max.	0.30 max.	0.85 max.
Machinery steel forging	Low alloy steel[6]	0.45 max.	0.45 max.	0.30-1.00	0.035 max.	0.035 max.	0.40[7] min.	0.15[7] min.	0.40[7] min.	0.30 max.	-

NOTES :
(1) The carbon content of carbon steel forgings intended for welded construction is to be 0.23 % maximum. The carbon content may be increased above this level provided that the carbon equivalent (*Ceq*) is not more than 0.41 %.
(2) The carbon content of carbon steel forgings not intended for welded construction may be 0.65 % maximum.
(3) Elements are considered as residual elements.
(4) Specification is to be submitted for approval.
(5) Rudder stocks and pintles should be of weldable quality.
(6) Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by the Society.
(7) One or more of the elements is to comply with the minimum content.

6. Mechanical properties

(1) The mechanical properties of steel forgings are to comply with the requirements given in **Table 2.1.81.** and **2.1.82.**

(2) At the discretion of this Societies hardness tests may be required on the following: The results of hardness tests are to be reported and, for information purposes, typical Brinell hardness values are given in **Table 2.1.82.**

(i) Gear forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2.5 m, the above number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1.25 m, the hardness is to be determined at eight positions at each end of the forging.

(ii) Small crankshaft and gear forgings which have been batch tested.
In such cases at least one hardness test is to be carried out on each forging.

(3) Hardness tests may also be required on forgings which have been induction hardened, nitrided or carburized. For gear forgings these tests are to be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications.

7. Selection of test specimens

(1) Except as provided in (10) and (11), the test specimens for steel forgings are, after final heat treatment, to be taken lengthwise from prolongations or through bolt holes having a sectional area not less than that of the body of forging. Where batch testing is permitted according to (10), the test material may alternatively be a production part or separately forged. Separately forged test material is to have a reduction ratio similar to that used for the forgings represented.

(2) "One set of test specimens" is to consist of one tensile test specimen and when required, three charpy-V notch impact test specimen.

Table 2.1.81 Kinds and Mechanical Properties for Hull Steel Forgings

Steel type	grades	Tensile test					
		Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation(%) ($L=5.65\sqrt{A}$) (minimum)		Reduction of area(%) (minimum)	
				L	*T*	*L*	*T*
Carbon steel forgings	*RSF* 400*H*	400 min.	200 min.	26	19	50	35
	RSF 440*H*	440 min.	220 min.	24	18	50	35
	RSF 480*H*	480 min.	240 min.	22	16	45	30
	RSF 520*H*	520 min.	260 min.	21	15	45	30
	RSF 560*H*	560 min.	280 min.	20	14	40	27
	RSF 600*H*	600 min.	300 min.	18	13	40	27
Low alloy steel forgings	*RSF* 550*AH*	550 min.	350 min.	20	14	50	35
	RSF 600*AH*	600 min.	400 min.	18	13	50	35
	RSF 650*AH*	650 min.	450 min.	17	12	50	35

Notes ;

(1) Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation and the value at the first decimal place is to be subjected to the method of counting fractions over 1/2 as one and disregarding the rest.

(2) For the upper limit of tensile strength, the following ranges for tensile strength may be additionally specified:

Specified minimum tensile strength (N/mm^2)	Range of upper limit(N/mm^2)
< 600	120
≥ 600	150

(3) In the case of large forgings requiring two tension tests, the range of tensile strength is not to exceed 70 N/mm^2

(4) *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or tangential) to the direction of forging.

Table 2.1.82 Kinds and mechanical properties for machinery steel forgings

Steel type	Grades	Tensile test						Hardness test
		Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation(%) ($L=5.65\sqrt{A}$) (minimum)		Reduction of area(%) (minimum)		Hardness (H_B)
				L	*T*	*L*	*T*	
Carbon steel forgings	*RSF* 400*M*	400 min.	200 min.	26	19	50	35	110 - 150
	RSF 440*M*	440 min.	220 min.	24	18	50	35	125 - 160
	RSF 480*M*	480 min.	240 min.	22	16	45	30	135 - 175
	RSF 520*M*	520 min.	260 min.	21	15	45	30	150 - 185
	RSF 560*M*	560 min.	280 min.	20	14	40	27	160 - 200
	RSF 600*M*	600 min.	300 min.	18	13	40	27	175 - 215
	RSF 640*M*	640 min.	320 min.	17	12	35	27	185 - 230
	RSF 680*M*	680 min.	340 min.	16	12	35	24	200 - 240
	RSF 720*M*	720 min.	360 min.	15	11	35	24	210 - 250
	RSF 760*M*	760 min.	380 min.	14	10	35	24	225 - 265
Low alloy steel forgings	*RSF* 600*AM*	600 min.	360 min.	18	14	50	35	175 - 215
	RSF 700*AM*	700 min.	420 min.	16	12	45	30	205 - 245
	RSF 800*AM*	800 min.	480 min.	14	10	40	27	235 - 275
	RSF 900*AM*	900 min.	630 min.	13	9	40	27	260 - 320
	RSF 1000*AM*	1000 min.	700 min.	12	8	35	24	290 - 365
	RSF 1100*AM*	1100 min.	770 min.	11	7	35	24	320 - 385

NOTES :

(1) Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation and the value at the first decimal place is to be subjected to the method of counting fractions over 1/2 as one and disregarding the rest.

(2) For the upper limit of tensile strength, the following ranges for tensile strength may be additionally specified:

Specified minimum tensile strength (N/mm^2)	Range of upper limit (N/mm^2)
< 900	150
≥ 900	200

(3) *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or tangential) to the direction of forging.

(4) For propeller shafts intended for ships with ice class notation except the lowest one(Grade ID), Charpy V-notch impact testing is to be carried out for all steel types at -10℃ and the average energy value is to be minimum 27 J (longitudinal test). One individual value may be less than the required average value provided that it is not less than 70 % of this average value. and, The impact test for important components for machinery is to be in accordance with the Guidance relating to the Rules specified by the Society.

(5) The hardness values are typical and are given for information purposes only.

(3) Test specimens are normally to be cut with their axes either mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.
(4) Unless otherwise agreed, the longitudinal axis of test specimens is to be positioned as follows. However the axis of transverse specimens may be located close to the surface of the forgings
  (a) for thickness or diameter up to maximum 50 mm, the axis of test specimens is to be at the mid-thickness or the center of the cross section.
  (b) for thickness or diameter greater than 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface.
(5) Except as provided in (10), the number and direction of tests is to be as given in (a) through (h) of the following requirements:
  (a) *Hull components such as rudder stocks, pintles etc. General machinery components such as shafting, connecting rods, etc. :* One set of tests is to be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacture, the alternative directions or positions as shown in **Fig 2.1.17.**, **Fig 2.1.18.** and **Fig 2.1.19** may be used. Where a forging exceeds both 4 tonnes in mass and 3 m in length, one set of tests is to be taken from each end.

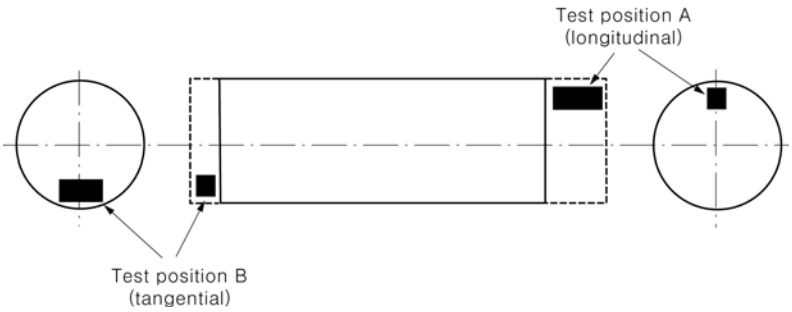


Fig 2.1.17 Plain shaft

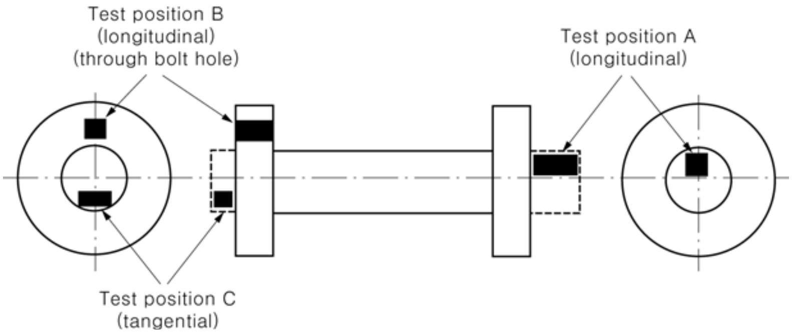


Fig 2.1.18 Flanged shaft

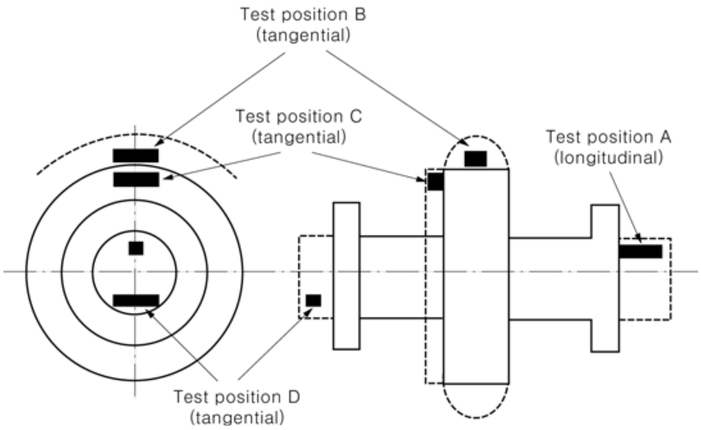


Fig 2.1.19 Flanged shaft with collar

(b) *Pinions* : Where the finished machined diameter of the toothed portion exceeds 200 mm one set of tests is to be taken from each forging in a tangential direction adjacent to the toothed portion (test position B in **Fig 2.1.20**) Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in **Fig 2.1.20**). If however, the journal diameter is 200 mm or less the tests are to be taken in a longitudinal direction (test position A in **Fig 2.1.20**). Where the finished length of the toothed portion exceed 1.25 m, one set of tests is to be taken from each end.

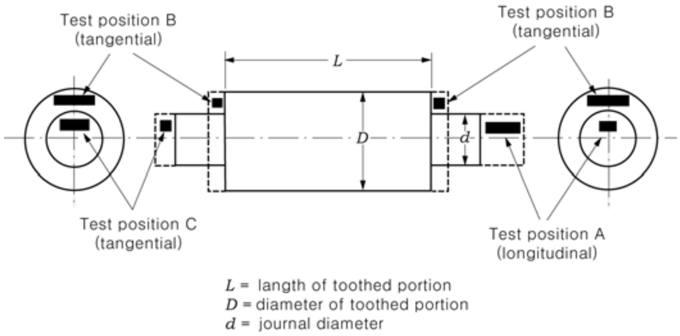


Fig 2.1.20 Pinion

(c) *Small pinions* : Where the finished diameter of the toothed portion is 200 mm or less one set of tests is to be taken in a longitudinal direction (test position A in **Fig 2.1.20**).
(d) *Gear wheels* : One set of tests is to be taken from each forging in a tangential direction (test position A or B in **Fig 2.1.21**).

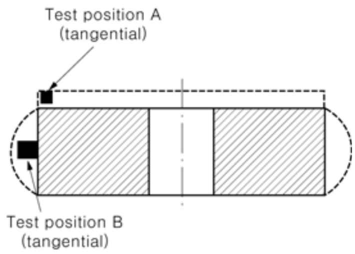


Fig 2.1.21 Gear wheel

(e) Rims intended for reduction gears and for cam shaft driving gears of diesel engine (see **Pt 5, Ch 2 201.1**) are to comply with the following requirements.
  (i) Where the finished diameter exceeds 2.5 m or the mass (as heat treated excluding test material) exceeds 3 tonnes, two sets of tests are to be taken from diametrically opposite positions (test positions A and B in **Fig 2.1.22**). The mechanical properties for longitudinal test are to be applied.

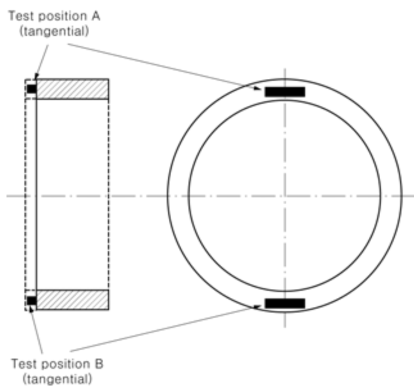


Fig 2.1.22 Gear rim (made by expanding)

(ii) Where the weight and finished diameter are different from those given in (a), one set of test specimens may be taken from one end of the rim.

(f) *Pinion sleeves* : One set of tests is to be taken from each forging in a tangential direction (test position A or B in **Fig 2.1.23**). Where the finished length exceeds 1.25 m one set of tests is to be taken from each end.

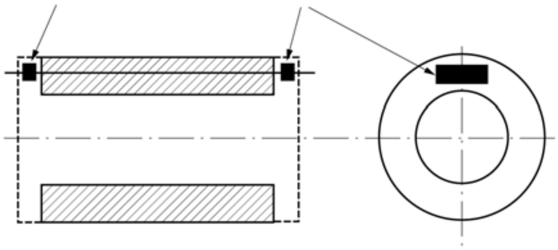


Fig 2.1.23 Pinion sleeve

(g) *Crankwebs* : One set of tests is to be taken from each forging in a tangential direction.

(h) *Solid open die forged crankshafts* : One set of tests is to be taken in a longitudinal direction from the driving shaft end of each forging (test position A in **Fig 2.1.24**). Where the mass (as heat treated but excluding test material) exceeds 3 tonnes tests in a longitudinal direction are to be taken from each end (test positions A and B in **Fig 2.1.24**). Where, however, the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (test position C in **Fig 2.1.24**).

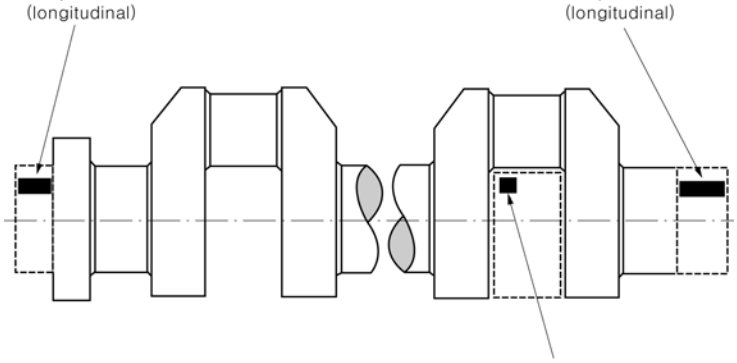


Fig 2.1.24 Solid forged crankshaft

(6) For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been approved by the Society, the number and position of test specimens is to be agreed with the Society having regard to the method of manufacture employed.

(7) When a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging.

(8) The test specimens are not to be separated from the body before the final heat treatment has been completed. In the case of stamp forging or other case of forging requiring the surface hardening process, the test specimens may be prepared at a proper stage before the final heat treatment providing that such is approved by the Surveyor.

(9) When forgings are to be carburized, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing. For this purpose duplicate sets of test material are to be taken from positions as detailed in (5) except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction.

This test material is to be machined to a diameter of D/4 or 60 mm, whichever is less, where D is the finished diameter of the toothed portion. For preliminary tests at the forge one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the second set of test material is to be blank carburized and heat treated along with the forgings which they represent. At the discretion of the forgemaster or gear manufacture test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment. Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the Society.

(10) Normalized forgings with mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively.

(11) A batch testing procedure may also be used for hot rolled bars. A batch is to consist of either:
- (i) material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge, or
- (ii) bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2.5 tonnes.

8. Surface inspection

(1) When heat treatment and final machining are completed and, if necessary, at a proper time during machining, surface inspection is to be carried out. Where applicable, this is to include the examination of internal surfaces and bores. Testing methods and acceptance criteria are to be in accordance with the Guidance relating to the Rules specified by the Society.

(2) Dimension inspection of the steel forgings is to be conducted under the responsibility of the manufacturer, unless otherwise specified.

9. Quality

(1) Steel forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

(2) When required by the conditions of approval for surface hardened forgings referred in **4** (7), additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

(3) In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

10. Non-destructive inspection

(1) The following steel forgings are to be subjected to ultrasonic test at an appropriate stage of the manufacturing process and the test reports are to be showed or submitted to the Surveyor. Testing methods and acceptance criteria are to be in accordance with the Guidance relating to the Rules specified by the Society.
- (a) Rudder stock and pintle.
- (b) Steel forgings given in **Pt 5, Ch 2, 201.1**.
- (c) Thrust shafts, intermediate shafts and propeller shafts.
- (d) Reduction gears and reduction gear shafts.
- (e) Turbine rotors, turbine discs and turbine blades.

(2) The important parts of the following steel forgings are to be subjected to magnetic particle or liquid penetrant test at an appropriate stage of the manufacturing process. Testing methods and acceptance criteria are to be in accordance with the Guidance relating to the Rules specified by the Society.
- (a) Steel forgings given in **Pt 5, Ch 2, 201.1.**
- (b) Propeller shafts.
- (c) Reduction gears.
- (d) Turbine rotors, turbine discs and turbine blades.

(3) The Society may require sulphur print test for the portion of gear teeth.

(4) In place of the test methods given above, the Society may accept the application of other non-destructive inspections considered adequate by the Society.
(5) The Society may require non-destructive inspection or the steel other than those specified in (1) and (2) when such is deemed necessary by the Society.
(6) The welded parts of steel forgings used for welded construction are to be subjected to the non-destructive inspections considered adequate by the Society.

11. Repair of defects

(1) Defects may be removed by grinding or chipping and grinding provided the component dimensions are acceptable.
(2) After removing the defects, adequate non-destructive inspections are to be carried out to ensure that all defects have been completely removed.
(3) The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Where the forgings from which defects where removed are used in that condition, the forgings are to be approved by the Surveyor.
(4) Repair welding of forgings except crankshaft forgings may be permitted subject to prior approval of the Society. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for the approval.
(5) The manufacturer is to maintain full records detailing the extent and location of repairs made to each forging and details of weld procedures and heat treatments applied for repairs. These records are to be available to the Surveyor and copies provided on request.

12. Retest procedures

(1) Where the tensile test or hardness test fails to meet the requirements, additional test may be carried out in accordance with the requirements of **109.**
(2) Regarding the impact tests, additional tests are to be carried out according to the requirements given in **301. 10** (3).
(3) The additional tests are to be taken, preferably from material adjacent to the original tests, but alternatively from another test position or sample representative of the forging or batch of forgings.
(4) At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

13. Marking

(1) Steel forgings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.**
(2) For steel forgings to which the requirements given in note 1. of the **Table 2.1.81 and Table 2.1.82** applied, the material symbols are specified as *RSF* - (or *RSF* - *A*) and the specified tensile strength is to be filled in symbol " - ". (e.g. For Hull and General purpose steel forging which the specified tensile strength is 420 N/mm^2 : *RSF* 420H)
(3) Where carbon steel forgings are intended for welded construction specified in Note (1) of **Table 2.1.80**, "W" is to be suffixed to the marking. (e.g. *RSF* 440H-*W*, *RSF* 440M-*W*)
(4) The grade of Steel bars is to be indicated by suffixing a letter "B" to the symbol "*RSF*". (e.g. For Machinery steel forging which the specified tensile strength is 440 N/mm^2 : *RSFB* 440M)

14. Additional requirements for crank shafts

(1) Where solid crank shafts of 250 mm and over in finished diameter are manufactured by free forging, the heat treatment is normally to be carried out after crank parts are machined as nearly as possible to the finished shape.
(2) Where solid crank shafts, semibuilt-up crank throws and full built up crank arms are manufactured by special manufacturing processes, the preliminary tests instructed by the Society are to be carried out, in connection with the manufacturing processes and the selection of test specimens.
(3) Where special manufacturing processes are adopted to reduce the size of crank shaft (refer to the requirements in **Pt 5, Ch, 208.** the preliminary tests instructed by the Society are to be carried out.

15. Additional requirements for turbine rotors

(1) The test specimens for turbine rotors are to be taken in accordance with the following requirements:

(a) Where the turbine rotor is greater than 3 tons in weight, one set of longitudinal test specimens is to be taken from each end of the shaft portion and one set of transverse test specimens from the body portion respectively. (See **Fig 2.1.25**)
(b) Where the turbine rotor is not exceeding 3 tons in weight, one set of longitudinal test specimens is to be taken from one end of the shaft portion and one set of transverse test specimens from the body portion respectively.

(2) For each turbine disc, one set of transverse test specimens is to be taken from the boss portion. (See **Fig 2.1.26**)

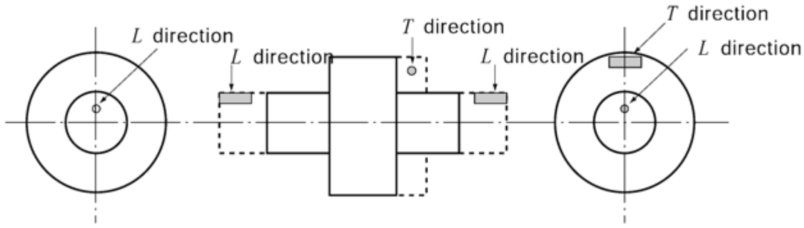


Fig 2.1.25 Selection of test specimen for turbine rotor

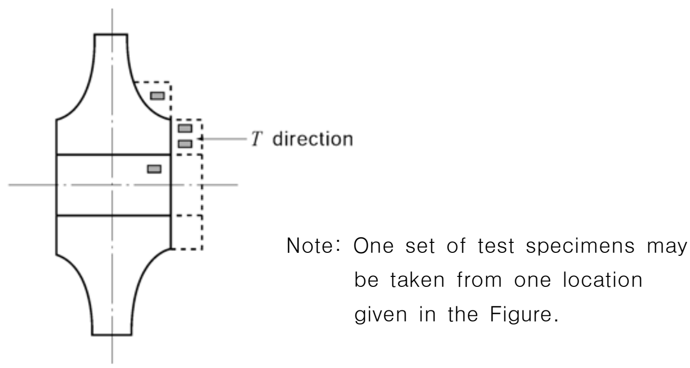


Fig 2.1.26 Selection of test specimen for turbine disc

(3) Solid forged turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400℃ are to be subjected to stability tests at least once at a suitable time after rough machining or heat treatment. This requirement is also applicable to rotors fabricated by welding. The method of stability test is to be approved by the Society prior to the test.

16. Additional requirements for turbine blades Turbine blades are to be tested in accordance with the approved test specification.

602. Stainless steel forgings

1. Application

(1) The requirements are to apply to the stainless steel forgings for valves and pipe fittings in piping systems used at low temperature (-165℃ and over in design temperature) service or corrosion-resisting service (hereinafter referred to as "steel forgings").
(2) Steel forgings having characteristics differing from those specified in **602.** are to comply with the requirements in **101. 2.**

2. Kinds Steel forgings are classified as specified in **Table 2.1.83.**

3. Heat treatment

Steel forgings are generally to receive a solid solution treatment.

4. Chemical composition

The chemical composition of steel forgings is to comply with the requirements given in **Table 2.1.83.**

Table 2.1.83 Grade and Chemical Composition

<table>
<tr><th rowspan="2">Grade</th><th colspan="8">Chemical composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Cr</th><th>Ni</th><th>Others</th></tr>
<tr><td>RSSF 304</td><td>0.08 max.</td><td rowspan="9">1.00 max.</td><td rowspan="9">2.00 max.</td><td rowspan="9">0.040 max.</td><td rowspan="9">0.030 max.</td><td rowspan="2">18.00~20.00</td><td rowspan="2">8.00~12.00</td><td rowspan="4">-</td></tr>
<tr><td>RSSF 304L</td><td>0.030 max.</td></tr>
<tr><td>RSSF 309S</td><td rowspan="3">0.08 max.</td><td>22.00~24.00</td><td>12.00~15.00</td></tr>
<tr><td>RSSF 310S</td><td>24.00~26.00</td><td>19.00~22.00</td></tr>
<tr><td>RSSF 316</td><td rowspan="2">16.00~18.00</td><td rowspan="2">10.00~14.00</td><td>Mo 2.00~3.00</td></tr>
<tr><td>RSSF 316L</td><td>0.030 max.</td><td>Mo 2.00~3.00</td></tr>
<tr><td>RSSF 317</td><td rowspan="3">0.08 max.</td><td>18.00~20.00</td><td>10.00~15.00</td><td>Mo 3.00~4.00</td></tr>
<tr><td>RSSF 321</td><td rowspan="2">17.00~19.00</td><td>9.00~12.00</td><td>Ti≥5×C</td></tr>
<tr><td>RSSF 347</td><td>9.00~13.00</td><td>Nb+Ta≥10×C</td></tr>
</table>

5. Mechanical properties

(1) The mechanical properties of steel forgings are to comply with the requirements given in **Table 2.1.84.**

(2) Where deemed necessary by the Society, impact test or corrosion resistance test may be required in addition to the specified tests.

Table 2.1.84 Mechanical Properties

Grade	Tensile test			
	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) ($L=5.65\sqrt{A}$)	Reduction of area (%)
RSSF 304*L*, *RSSF* 316*L*	175 min.	450 min.	37 min.	50 min.
Other forgings	205 min.	520 min.	37 min.	50 min.

6. Selection of the specimens

(1) The number of tensile test specimens is to be in accordance with the requirements in **601. 7.**

(2) Tensile test specimens are to be taken with their longitudinal axes parallel to the direction of forging, unless otherwise specially provided by the Society.

(3) Where tests are made in accordance with the requirements in **601. 7** (5), (c) and (d), the Surveyor may require hardness test for each forging.

7. Marking

Steel forgings which have satisfactorily complied with the required test are to be marked with the identification mark in accordance with the requirements in **110.**

603. Steel forgings for chains

1. Application

(1) These requirements are to apply to the steel forgings used for anchor chain cables and accessories specified in **Pt 4, Ch 8** (hereinafter referred to as "steel forgings").

(2) Steel forgings having characteristics differing from those specified in (1) are to comply with the requirements in **101. 2.**

(3) In addition to the requirements given in **603.,** general requirements may be considered by the Society.

2. Kinds

The steel forgings are classified as specified in **Table 2.1.85.**

Table 2.1.85 Grades of Steel Forgings

Grade		Application
Steel forging for Grade 2 chain	*RSFC* 50	Grade 2 chain
Steel forging for Grade 3 chain	*RSFC* 70	Grade 3 chain
Steel forging for Grade R3 chain	*RSFCR* 3	Grade *R*3 chain
Steel forging for Grade R3S chain	*RSFCR* 3*S*	Grade *R*3*S* chain
Steel forging for Grade R 4 chain	*RSFCR* 4	Grade *R*4 chain

3. Heat treatment

The steel forgings are to be normalized, normalized and tempered, quenched and tempered or heat treated by the process approved by the Society.

4. Deoxidation practice and chemical composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table 2.1.86.** Elements other than specified in **Table 2.1.86** may be added subject to a special approval by the Society.

Table 2.1.86 Deoxidation Practice and Chemical Composition (%)

Grade	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	*Al*(1)
RSFC 50	Fine-grained killed	0.24 max.	0.15~0.55	1.60 max.	0.035 max.	0.035 max.	0.020 min.
RSFC 70		0.36 max.	0.15~0.55	1.00~1.90	0.035 max.	0.035 max.	0.020 min.
RSFCR 3	Fine-grained killed	(2)(3)					
RSFCR 3*S*							
RSFCR 4							

NOTE:
(1) Al content is to be represented by the total Al content and may be replaced partly by other fine graining elements.
(2) Detailed chemical composition is to be approved by the Society.
(3) For Grade *RSFCR* 4, the steel should contain a minimum of 0.2 % molybdenum.

5. Mechanical properties

The mechanical properties of each grade are to comply with the requirements given in **Table 2.1.87.**

6. Selection of test specimens

(1) One test sample is to be selected from each lot of every 25 steel forgings or fraction thereof, which belong to the same heat. In case of steel forgings having small diameter, the number of test samples may be reduced subject to approval of the Society. Where specially approved by the Society, the test sample may be taken from the representative part of the steel forging at a proper time during manufacturing, or a separate sample forged to the forge ratio equivalent to that of the steel forgings. In this case, the test sample is to be heat treated simultaneously with the steel forgings.
(2) For Grade 1 and Grade 2 chain bars, one tensile test specimen is to be taken from the test sample; for Grade 3 chain bars, one tensile test specimen and one set (3 pieces) of impact test specimens are to be taken from the test sample.

Table 2.1.87 Mechanical Properties

Grade	Tensile test				Impact test (1)	
	Yield strength (N/mm^2) (2)	Tensile strength (N/mm^2) (2)	Elongation (%) ($L=5d$)	Reduction of area (%)	Test temp. (℃)	Average abs-orbed energy(J)
RSFC 50	295 min.	490~690	22 min.	-	-	-
RSFC 70	410 min.	690 min.	17 min.	40 min.	0	60 min.
RSFCR 3	410 min.	690 min.	17 min.	50 min.	-20(3)	40 min.(3)
RSFCR 3*S*	490 min.	770 min.	15 min.	50 min.	-20(3)	45 min.(3)
RSFCR 4	580 min.	860 min.	12 min.	50 min.	-20	50 min.

NOTE:
(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.
(2) The yield ratio (the aim value of yield to tensile ratio) for grade *RSFCR* 3, *RSFCR* 3*S*, or *RSFCR* 4 is to be maximum 0.92.
(3) Impact test of grade *RSFCR* 3 and *RSFCR* 3*S* may be carried out at the temperature of 0°C where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 60J for grade *RSFCR* 3 and 65J for grade *RSFCR* 3*S*.

(3) The tensile and impact test specimens are to be taken from the test sample in the direction of forging at a depth of 1/6 diameter from the surface or as close as possible to this position. (see **Fig 2.1.5**)

7. Surface inspection

Surface inspection for all grades is to be carried out and it is to be confirmed that there are no harmful defects.

8. Non-destructive inspection

For grades *RSFCR* 3, *RSFCR* 3*S* and *RSFCR* 4, all steel forgings are subjected to ultrasonic test at an appropriate stage of the manufacture and it is to be confirmed that there are no harmful defects.

9. Retest procedure

Where the tensile test or impact test on the selected first test specimens fails to meet the requirements, additional tests may be carried out according to the requirements given in **306. 9.**

10. Marking

Steel forgings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirement in **110.**

604. Steel forgings for low temperature service

1. Application

(1) The requirements are to apply to the steel forgings for valves and pipe fittings in piping systems intended to be used at the design temperature lower than 0℃ in liquefied gas carriers (hereinafter referred to as "steel forgings").
(2) Steel forgings other than those specified in **604.** are to comply with the requirements given in **101. 2.**

2. Kinds The steel forgings are classified as given in **Table 2.1.88.**

3. Heat treatment

The steel forgings are to be normalized, normalized and tempered, quenched and tempered or double normalized and tempered.

4. Deoxidation practice and chemical composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table 2.1.88.**

Table 2.1.88 Grades and Chemical Composition

Grade	Deoxidation	Chemical composition (%)								
		C	Si	Mn	P	S	Ni	Cr	Cu	Al
RLFA	Fully killed fine grain	0.23 max.	0.15~0.35	1.10 max.	0.030 max.	0.030 max.	-	-	-	-
RLFB		0.20 max.	0.15~0.35	1.60 max.						
RLFC		0.12 max.	0.10~0.35	0.55~1.00			0.50~0.95	0.50~0.95	0.40~0.75	0.04~0.30
RLF 3		0.20 max.	0.15~0.35	0.90 max.			3.25~3.75	-	-	-
RLF 9		0.10 max.	0.10~0.35	0.90 max.			8.50~9.60			

5. Mechanical properties

(1) The mechanical properties of steel forgings are to comply with the requirements given in **Table 2.1.89.**
(2) Where deemed necessary by the Society, other tests may be required in addition to the tests specified in (1).

Table 2.1.89 Mechanical Properties

Grade	Tensile test				Impact test (2)	
	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)	Reduction of area (%)	Test temp. (℃)	Average absorbed energy (J)
RLFA	205 min.	410 min.	23 min.	40 min.	−40(1)	27 min.
RLFB	275 min.	490 min.	20 min.		−50(1)	
RLFC	205 min.	410 min.	23 min.		−60(1)	
RLF 3	275 min.	490 min.	23 min.	50 min.	−95	34 min.
RLF 9	520 min.	680 min.	19 min.	45 min.	−196	41 min.

NOTES:
(1) Impact test temperature for steel forgings specified in **Pt 7, Ch 5** is to be 5℃ below the design temperature or -20℃, Whichever is the lower.
(2) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

6. Selection of tests specimens

(1) The number of test specimens is to be in accordance with the requirements specified in **601. 7.**
(2) The test specimens for tensile and impact tests are to be cut with their longitudinal axes parallel to the direction of forging except where otherwise specially specified.
(3) Where tests are made in accordance with the requirements in **601. 7** (5), (c) and (d), the Surveyor may require a hardness test for each forging.

7. Retest procedures

(1) Where the tensile tests fail to meet the requirements, additional tests may be carried out according to the requirements given in **109.**

(2) Regarding the impact tests, additional tests are to be carried out according to the requirements given in **304. 9.**

8. Marking

Marking for steel castings is to comply with the requirements given in **601. 13.** (1) and in case the requirement in Note (1) of **Table 2.1.89.** has been applied, "impact test temperature T" is to be suffixed to the marking (e.g. $RLFA$ - 25T)

SECTION 7 Copper and Copper Alloy

701. Copper and copper alloy pipes and tubes

1. Application

(1) The requirements are to apply to the copper and copper alloy pipes and tubes.
(2) Copper and copper alloy pipes and tubes are to comply with the requirements in *KS D* 5301 or equivalent thereto.
(3) Copper and copper alloy pipes and tubes having characteristics differing from those specified in **701.** are to comply with the requirements in **101. 2.**

2. Kinds

Copper and copper alloy pipes and tubes are classified as specified in **Table 2.1.90.**

Table 2.1.90 Kinds and Grades

Kinds		Grades
Copper pipes and tubes.	Phosphorus deoxidized copper seamless pipes and tubes	*C* 1201, *C* 1220
Copper alloy pipes and tubes	Brass seamless pipes and tubes	*C* 2600, *C* 2700, *C* 2800
	Brass seamless pipes and tubes for condenser	*C* 4430, *C* 6870, *C* 6871, *C* 6872
	Cupro-nickel seamless pipes and tubes for condenser	*C* 7060, *C* 7100, *C* 7150

3. Mechanical properties

The mechanical properties of copper and copper alloy pipes and tubes are to comply with the requirements given in **Table 2.1.91.**

Table 2.1.91 Mechanical Properties

Kinds	Grade	Tensile test(1)	
		Tensile strength (N/mm^2)	Elongation (%)
Phosphorus deoxidized copper seamless pipes and tubes.	*C* 1201, *C* 1220	206 min.	40 min.
Brass seamless pipes and tubes	*C* 2600	275 min.	45 min.
	C 2700	294 min.	40 min.
	C 2800	314 min.	35 min.
Brass seamless pipes and tubes for condenser	*C* 4430	314 min.	30 min.
	C 6870, *C* 6871, *C* 6872	373 min.(2)	40 min.
		353 min.(3)	40 min.
Cupro-nickel seamless pipes and tubes for condenser	*C* 7060	275 min.	30 min.
	C 7100	314 min.	30 min.
	C 7150	363 min.	30 min.

NOTES :
(1) These properties are a measure of the mechanical quality of the metal in annealed condition.
(2) It is applicable to those having 5 mm and up to 50 mm in outside diameter.
(3) It is applicable to those having over 50 mm up to 200 mm in outside diameter.

4. Testing and inspection

Testing and inspection of pipes and tubes are to com ply with the requirements specified in *KS D* 5301. Those subjected to the maximum working pressure not exceeding 1 MPa may not require the presence of the Society"s Surveyor.

5. Marking

Copper and copper alloy pipes and tubes which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **110.**

702. Copper alloy castings

1. Application

(1) These requirements are to apply to the copper alloy castings to be used for propellers and propeller blades (hereinafter referred to as "propeller castings"). Also, upon special consideration of the Society, these requirements may also be applied for the repair and inspection of propellers becoming damaged during service.
(2) Copper alloy castings to be used for important parts differing from those specified in **702.** are to comply with the requirements of KS or equivalent thereto. The tests and inspections need in general to be made in the presence of the Surveyor where special requirements are given in connection with the design.
(3) Copper alloy castings characteristics differing from those specified in **702.** are to comply with the requirements in **101. 2.**

2. Kinds Propeller castings are classified as specified in **Table 2.1.92.**

Table 2.1.92 Kinds and Grades

Kinds	Grade
High strength brass casting, Grade 1	*CU* 1
High strength brass casting, Grade 2	*CU* 2
Aluminium bronze casting, Grade 3	*CU* 3
Aluminium bronze casting, Grade 4	*CU* 4

3. Moulding and casting

(1) The pouring must be carried out into dried moulds using degassed liquid metal.
(2) The pouring is to be controlled as to avoid turbulences of flow. Special devices and/or procedures must prevent slag flowing into the mould.
(3) Subsequent stress relieving heat treatment may be performed to reduce the residual stresses. For this purpose, the manufacturer shall submit a specification containing the details of the heat treatment to the Society for approval. The stress relieving temperatures and holding times should be in accordance with the Guidance relating to the Rules specified by the Society.

4. Chemical composition

(1) The chemical composition of propeller castings is to comply with the requirements given in **Table 2.1.93.**

Table 2.1.93 Chemical Composition (%)

Grade	Cu	Al	Mn	Zn	Fe	Sn	Ni	Pb
CU 1	52~62	0.5~3.0	0.5~4.0	35~40	0.5~2.5	0.1~1.5	1.0 max.	0.5 max.
CU 2	50~57	0.5~2.0	1.0~4.0	33~38	0.5~2.5	0.15 max.	3.0~8.0	0.5 max.
CU 3	77~82	7.0~11.0	0.5~4.0	1.0 max.	2.0~6.0	0.1 max.	3.0~6.0	0.03 max.
CU 4	70~80	6.5~9.0	8.0~20.0	6.0 max.	2.0~5.0	1.0 max.	1.5~3.0	0.05 max.

(2) For *CU* 1 and *CU* 2, it is also to comply with the followings:
(a) The zinc equivalent as specified below is not to exceed 45 %

$$\text{Zinc equivalent} = 100 - \frac{100 \times Cu(\%)}{100 + A}$$

Where A : $Sn + 5Al - 0.5Mn - 0.1Fe - 2.3Ni$ (%)

(b) Each tensile test specimen is to be examined metalographically, and the proportion of alpha-phase determined from an average of five counts is not to be less than 25 %.

5. Mechanical properties

(1) The mechanical properties of copper propeller casting are to comply with the requirements given in **Table 2.1.94.**
However, the requirements specified in this Table apply to specimens cut from separately cast samples, where specimens cut from propeller casting itself, the requirements are to be deemed appropriate by the Society

Table 2.1.94 Mechanical Properties

Grade	Yield strength(1) (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5d$)
CU 1	175 min.	440 min.	20 min.
CU 2	175 min.	440 min.	20 min.
CU 3	245 min.	590 min.	16 min.
CU 4	275 min.	630 min.	18 min.

NOTE:
(1) Yield strength is measured as 0.2 % proof stress and is applicable to the case which is specially required considering the design by the Society.
(2) As for the materials of the propellers which used for the ship strengthened for navigation in ice, the elongation of the materials used is not to be less than 19 % for R14A test specimen specified in **Pt 2, Ch 1** and absorbed energy for the Charpy V notch impact test is not to be less than 21 J at -10°C

6. Selection of Test Samples and Specimens

(1) Generally, the specimens shall be taken from separately cast sample pieces. The test samples shall be cast in moulds made of the same material as the mould for the propeller and they must be cooled down under the same conditions as the propeller. If propellers are subjected to a heat treatment, the test samples are to be heat treated together with them.
(2) The shapes and dimensions of the test samples are to comply with those given in **Fig 2.1.27** The shape given by the dotted lines shown in the figure, however, may be acceptable.

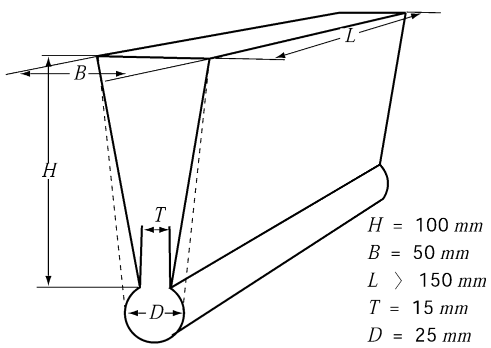


Fig 2.1.27 shapes and dimensions of the Test Samples

(3) One tensile test specimen is to be taken from each casting when integral test samples are provided and one tensile test specimen is to be taken from each ladle when separately-cast test samples are provided.
(4) For determining the proportion of alpha phase of alloy types CU 1 and CU 2. at least one specimen shall be taken from each heat. However tensile test specimen can be substitute for.
(5) When integral test samples are provided, the test samples shall be located on the blades in an area lying between 0,5 to 0,6 R (where R is the radius of the propeller). The test sample material must be removed from the casting by non thermal procedures.

7. Surface and dimension Inspection

(1) Propeller casting is to be subjected to a comprehensive visual inspection by the Surveyor at final process and other proper processing stages if necessary.
(2) The dimensions are to be checked by the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence. Where straightening of a bent blade is carried out, the procedure for the straightening is to be in accordance with the Guidance relating to Rules specified by the Society.
(3) The Surveyor may be require areas to be etched (e.g. by iron chloride) for the purpose of investigating weld repairs.

8. Quality

All castings must have a workman like finish and must be free from defects liable to impair their use. Minor casting defects which may still be visible after machining such as small sand and slag inclusions, small cold shuts and scabs shall be trimmed off by the manufacturer.

9. Non-destructive inspection

(1) The important parts of propeller castings are to be subjected to the liquid penetrant test in accordance with the Guidance relating to Rules specified by the Society.
(2) The division of severity zones of propeller casting is to be in accordance with the Guidance relating to Rules specified by the Society.
(3) Where serious doubts exist that the castings are not free from internal defects, further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. For this purpose, the acceptance criteria are to be agreed between the manufacturer and the Society in accordance with a recognized standard.
(4) All defects requiring welding repair on the propeller castings are to be documented preferably on drawings or special sketches showing their dimensions and locations. Furthermore, the inspection procedure is to be reported. The documentation is to be presented to the Surveyor prior to any repair weldings will be carried out.

10. Repair of defects

(1) In the event of finding defects in the propeller castings, the defects may be removed by grinding, etc. After removing the defects, liquid penetrant tests are to be carried out to ensure that all defects have been completely removed.
(2) Where the propeller castings from which defects where removed are used in that condition or after repaired by welding, the propeller castings are to be approved by the Surveyor.
(3) After weld repairs, the portions repaired by welding are to be subjected to the stress-relieving treatments.
(4) It is to be confirmed that the portions repaired by welding are free from harmful defects by the non-destructive inspections such as liquid penetrant test, etc.
(5) The repair welding procedures are to have prior approval of the Surveyor in accordance with the Guidance relating to the Rules specified by the Society.

11. Retest procedure

Where the results of tensile tests fail to meet the requirements, additional test may be carried out in accordance with the requirements of **109.**

12. Marking

(1) Prior to final inspection by the Surveyor each casting shall be marked by the manufacturer at least with the following symbols:
(a) Grade of cast material or corresponding abbreviated designation
(b) Manufacturer's mark

(c) Heat number, casting number or another mark enabling the manufacturing process to be traced back
(d) Specimen number
(e) Date of final inspection
(f) Number of the Society's test certificate
(g) Ice class symbol, where applicable
(h) Skew angle for high skew propellers.
(i) Manufacturer's certificate

(2) For each propeller the manufacturer must supply to the Surveyor a certificate containing the following details:
(a) Purchaser and order number
(b) Shipbuilding project number, if known
(c) Description of the casting with drawing number
(d) Diameter, number of blades, pitch, direction of turning
(e) Grade of alloy and chemical composition of each heat
(f) Heat or casting number
(g) Final weight
(h) Results of non-destructive tests and details of test procedure where applicable
(i) Portion of alpha-structure for CU 1 and CU 2 alloys
(j) Results of the mechanical tests
(k) Casting identification No.
(l) Skew angle for high skew propellers

SECTION 8 Aluminium Alloys

801. Aluminium alloys

1. Application

(1) These requirements are to apply to the aluminium alloy plates and extruded shapes(hereinafter referred to as "aluminium alloys") intended to be used in the construction of hulls, superstructures, other marine structures and tanks of liquefied gas carriers.

(2) Where aluminium alloys exceeding the maximum value of plate thickness or size specified in **Table 2.1.96** and **Table 2.1.97.** are manufactured, a new approval test is required by the Society.

(3) Aluminium alloys having characteristics differing from those specified in **801.** are to comply with the requirements in **101. 2.**

2. Kinds

The aluminium alloys are classified as specified in **Table 2.1.95.**

Table 2.1.95 Kinds

Product		Grades	Temper condition
Rolled	5000 series	5083*P*, 5086*P*, 5383*P*, 5059*P*, 5754*P*, 5456*P*	*O*, *H*112, *H*116, *H*321
Extruded Shapes	5000 series	5083*S*, 5383*S*, 5059*S*, 5086*S*	*O*, *H*111, *H*112
	6000 series	6005*AS*(1), 6061*S*(1), 6082*S*	*T*5, *T*6

NOTE :
(1) These alloy should not be used in direct contact with sea water unless protected by anodes and/or paint system.

3. Chemical composition

The chemical composition of aluminium alloys is to comply with the requirements given in **Table 2.1.96.**

Table 2.1.96 Chemical Composition

Grades	Chemical composition (%)										
	Si	*Fe*	*Cu*	*Mn*	*Mg*	*Cr*	*Zn*	*Ti*	*Others*(1)		*Al*
									Each	*Total*	
5083*P* 5083*S*	0.40max.	0.40max.	0.10max.	0.40~1.0	4.0~4.9	0.05~0.25	0.25max.	0.15max.	0.05max.	0.15max.	Remainder
5383*P* 5383*S*	0.25max.	0.25max.	0.20max.	0.70~1.0	4.0~5.2	0.25max.	0.40max.	0.15max.	0.05 max.(4)	0.15 max.(4)	
5059*P* 5059*S*	0.45max.	0.50max.	0.25max.	0.60~1.2	5.0~6.0	0.25max.	0.4~0.90	0.20max.	0.05 max.(5)	0.15 max.(5)	
5086*P* 5086*S*	0.40max.	0.50max.	0.10max.	0.20~0.7	3.5~4.5	0.05~0.25	0.25max.	0.15max.	0.05 max.	0.15max.	
5754*P*(2)	0.40max.	0.40max.	0.10max.	0.50max.	2.6~3.6	0.30max.	0.20max.	0.15max.	0.05max.	0.15max.	
5456*P*	0.25max.	0.40max.	0.10max.	0.50~1.0	4.7~5.5	0.05~0.2	0.25max.	0.20max.	0.05max.	0.15max.	
6005*AS*(3)	0.5~0.9	0.35max.	0.30max.	0.50max.	0.40~0.7	0.30max.	0.20max.	0.10max.	0.05max.	0.15max.	
6061*S*	0.4~0.8	0.7max.	0.15~0.40	0.15max.	0.8~1.2	0.04~0.35	0.25max.	0.15max.	0.05max.	0.15max.	
6082*S*	0.7~1.3	0.50max.	0.10max.	0.40~1.0	0.6~1.2	0.25max.	0.20max.	0.10max.	0.05max.	0.15max.	

NOTES :
(1) Includes Ni, Ga, V and listed elements for which no specific limit is shown. When the existence of the other elements is presumed in the course of routine analysis, further analysis thereof is to be conducted.
(2) $0.10 \leq Mn + Cr \leq 0.60$
(3) $0.12 \leq Mn + Cr \leq 0.50$
(4) Zr: maximum 0.20. The total for other elements does not include Zirconium.
(5) Zr: 0.05-0.25. The total for other elements does not include Zirconium.

4. Heat treatment

The heat treatment(hereinafter referred to as "temper condition") of the aluminium alloys is to comply with the requirements given in **Table 2.1.97** and **Table 2.1.98.**

5. Mechanical properties

(1) The mechanical properties in tension tests are to comply with the requirements given in **Tables 2.1.97.** and **2.1.98.**

Table 2.1.97 Mechanical Properties for Rolled Products(1)

Grades	Temper condition(2)	Thickness, t (mm)	Tensile test			
			Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%)	
					($L=5.65\sqrt{A}$)	($L=5d$)
5083*P*	*O*	$3 \le t \le 50$	125 min.	275～350	16 min.	14 min.
	*H*112	$3 \le t \le 50$	125 min.	275 min.	12 min.	10 min.
	*H*116	$3 \le t \le 50$	215 min.	305 min.	10 min.	10 min.
	*H*321	$3 \le t \le 50$	215～295	305～385	12 min.	10 min.
5383*P*	*O*	$3 \le t \le 50$	145 min.	290 min.	-	17 min.
	*H*116 or *H*321	$3 \le t \le 50$	220 min.	305 min.	10 min.	10 min.
5059*P*	*O*	$3 \le t \le 50$	160 min.	330 min.	-	24 min.
	*H*116 or *H*321	$3 \le t \le 20$	270 min.	370 min.	10 min.	10 min.
		$20 < t \le 50$	260 min.	360 min.	10 min.	10 min.
5086*P*	*O*	$3 \le t \le 50$	95 min.	305 min.	16 min.	14 min.
	*H*112	$3 \le t \le 12.5$	125 min.	250 min.	8 min.	-
		$12.5 < t \le 50$	105 min.	240 min.	-	9 min.
	*H*116	$3 \le t \le 50$	195 min.	275 min.	10 min.(3)	9 min.
5754*P*	*O*	$3 \le t \le 50$	80 min.	190～240	18 min.	17 min.
5456*P*	*O*	$3 \le t \le 6.3$	130-205	290-365	16 min.	-
		$6.3 < t \le 50$	125-205	285-360	16 min.	14 min.
	*H*116	$3 \le t \le 30$	230 min.	315 min.	10 min.	10 min.
		$30 < t \le 40$	215 min.	305 min.	-	10 min.
		$40 < t \le 50$	200 min.	285 min.	-	10 min.
	*H*321	$3 \le t \le 12.5$	230-315	315-405	12 min.	-
		$12.5 < t \le 40$	215-305	305-385	-	10 min.
		$40 < t \le 50$	200-295	285-370	-	10 min.

NOTES :

(1) Aluminium alloy may be subject to any other standards in lieu of the requirements given in this Table where they are approved by the Society.

(2) Symbols used in temper condition are as follows :
O : Annealing
*H*112 : Work hardened
*H*116 : Stabilizing treatment after work hardened
*H*321 : Stabilizing treatment after work hardened

(3) 8 % for thicknesses up to and including 6.3 mm.

Table 2.1.98 Mechanical Properties for Extruded Shapes(1)

Grades	Temper condition(2)	Thickness, t (mm)	Tensile test			
			Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%)(3)	
					($L=5.65\sqrt{A}$)	($L=5d$)
5083S	O	$3\le t\le 50$	110 min.	270 ~ 350	14 min.	12 min.
	$H111$	$3\le t\le 50$	165 min.	275 min.	12 min.	10 min.
	$H112$	$3\le t\le 50$	110 min.	270 min.	12 min.	10 min.
5383S	$O/H111$	$3\le t\le 50$	145 min.	290 min.	17 min.	17 min.
	$H112$	$3\le t\le 50$	190 min.	310 min.	-	13 min.
5059S	$H112$	$3\le t\le 50$	200 min.	330 min.	-	10 min.
5086S	O	$3\le t\le 50$	95 min.	240 ~ 315	14 min.	12 min.
	$H111$	$3\le t\le 50$	145 min.	250 min.	12 min.	10 min.
	$H112$	$3\le t\le 50$	95 min.	240 min.	12 min.	10 min.
6005AS	$T5$	$3\le t\le 50$	215 min.	260 min.	9 min.	8 min.
	$T6$	$3\le t\le 10$	215 min.	260 min.	8 min.	6 min.
		$10<t\le 50$	200 min.	250 min.	8 min.	6 min.
6061S	$T6$	$3\le t\le 50$	240 min.	260 min.	10 min.	8 min.
6082S	$T5$	$3\le t\le 50$	230 min.	270 min.	8 min.	6 min.
	$T6$	$3\le t\le 5$	250 min.	290 min.	6 min.	-
		$5<t\le 50$	260 min.	310 min.	10 min.	8 min.

NOTES :

(1) Aluminium alloy may be subject to any other standards in lieu of the requirements given in this Table where they are approved by the Society.
(2) Symbols used in temper condition are as follows :
O : Annealing
$H111$: Work hardened
$H112$: Work hardened
$T5$: Artificial age hardening treatment after elevated temperature working and succeeding cooling
$T6$: Artificial age hardening treatment after solution treatment
(3) The values are applicable for longitudinal and transverse tensile test specimens as well.

(2) Where deemed necessary by the Society, other tests may be required in addition to the specified tests.

6. Selection of test samples

(1) For test samples for rolled products, if the weight of one lot exceeds 2 tonnes, one extra test specimen is to be taken from every 2 tonnes of the product or fraction thereof, in each lot except where specially approved by the Society.
One lot is made up of rolled products of the same alloy and from the same cast, of the same thickness, manufactured by the same process and having been submitted simultaneously to the same temper condition. For single plate or coil weighting more than 2 tonnes each, one lot is made up of a single plate or coil.

(2) For test samples for extruded shapes with a nominal weight of less than 1 kg/m, except where specially approved by the Society, one test specimen is to be taken from each 1 tonne, or fraction thereof, in each lot. For nominal weights between 1 and 5 kg/m, one test specimen is to be taken from each 2 tonnes or fraction hereof, in each lot. If the nominal weight exceeds 5 kg/m, one test specimen is to be taken for each 3 tonnes of the product or fraction thereof, in each lot.
One lot is made up of rolled products of the same alloy and from the same cast, of the same dimension, manufactured by the same process and having been submitted simultaneously to the same temper condition.

(3) Test samples are to be taken out of the place at one third of the width from a longitudinal edge of rolled products, or in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.
(4) After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

7. Selection of test specimens

Tensile test specimens are to be taken according to (1) to (4) below.

(1) One test specimen is to be taken out of each test sample.
(2) For rolled products, the longitudinal axis of the test specimen is to be taken transversely to the rolling direction. If the width is insufficient to obtain transverse test specimen or in the case of strain hardening alloys, however, the longitudinal direction may be taken parallel to the rolling direction.
(3) For extruded shapes, the longitudinal axis of the test specimen is to be taken parallel to the extruding direction.
(4) For thickness of test sample up to and including 40 mm, the longitudinal axis of the test specimen is to be located at a distance from the surface equal to half of the thickness. For thickness of test sample over 40 mm, the longitudinal axis of the test specimen is to be located at a distance from one of the surfaces equal to one quarter of the thickness.

8. Corrosion testing

(1) For aluminium alloys specified in **Tables 2.1.97.** in the $H116$ and $H321$ tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.
(2) For corrosion resistance test sample, one test sample is to be taken from each lot specified in **801. 6** (1). Test samples are to be selected from mid width at one end of a coil or random sheet or plate.
(3) Testing method and acceptance criteria is to be in accordance with the Guidance relating to the Rules specified by the Society.

9. Surface inspection and dimensional tolerance

(1) Surface inspection and verification of dimensions are left to the responsibility of the manufacturer.
(2) The under-thickness tolerances of rolled products are to comply with the requirements given in **2.1.99.**

Table 2.1.99 Under-thickness Tolerance for Rolled Products

Nominal thickness, t (mm)	Nominal width W (mm)		
	$W \leq 1500$	$1500 < W \leq 2000$	$2000 < W \leq 3500$
	Under-thickness tolerance (mm)		
$3 \leq t < 4$	0.10	0.15	0.15
$4 \leq t < 8$	0.20	0.20	0.25
$8 \leq t < 12$	0.25	0.25	0.25
$12 \leq t < 20$	0.35	0.40	0.50
$20 \leq t < 50$	0.45	0.50	0.65

(3) Dimensional tolerance except those specified in (2) above is left to the discretion of the Society.

10. Quality

(1) Aluminium alloys are to be of uniform quality and free from internal and surface harmful defects prejudicial to the use of the concerned material for the intended application.
(2) Slight surface imperfections may be removed by smooth grinding or machining as long as the thickness of the materials remains within the tolerances given in **Table 2.1.99.**

11. Retest procedures

(1) When the tensile test from the first piece selected fails to meet the requirements given in **Table 2.1.97** and **2.1.98,** two further tensile tests may be made from the same piece. If both of these additional tests meet all of the requirements, the piece and the remaining pieces from the same lot may be accepted.

(2) If one or both of the additional tests referred to above (1) are unsatisfactory, the piece is to be rejected. However, the remaining materials from the same lot may be accepted provided that two of the remaining pieces in the lot selected in the same way, are tested with satisfactory results.

12. Marking

(1) Aluminium alloys which have satisfied with the required tests are to be marked with the identification mark in accordance with the requirements in **110. 1.** In this case, the mark of temper conditions is to be put subsequent to the mark of material grade. (ex : 5083 *H*321)

(2) For aluminium alloy, which have satisfied with the corrosion resistance tests specified in 801.8, the mark of [M] is to be put subsequent to the mark of the temper condition (ex : 5083 *H*321 M) ⚓

CHAPTER 2 WELDING

SECTION 1 General

101. Application

1. Welding to be used in hull construction and important equipment is to be in accordance with the requirements in this Chapter unless otherwise specified.

2. The welding in boiler, pressure vessel, main engine, auxiliary engine and pipe arrangement is to be in accordance with the requirements in **Pt 5, Chs 2, 5** and **6** except where prescribed in this Chapter.

102. Matters to be approved

1. The welding is to be carried out in accordance with the procedures previously approved, with the electrodes, the wire and flux (hereinafter referred to as "**welding consumables**") or equivalent materials and by the welders qualified by the Society.

2. Where deemed appropriate by the Society, National Standards, internationally recognized Codes or Standards considered as equivalent for those may be applied instead of requirements of this Chapter.

103. Special weldings

Where special welding and material not complied with the requirements in this Chapter is used, the welding procedures and the welding consumables are to be specially approved by the Society.

104. Terms and definitions

1. The term manual welding is used to describe processes in which the weld is made manually by a welder using a manually fed electrode such as shield metal arc welding, etc.

2. The term semi-automatic is used to describe processes in which the weld is made manually by a welder holding a gun through which the electrode wire is continuously fed such as metal arc welding or flux-cored arc welding, etc.

3. The term automatic welding is used to describe processes in which the weld is made automatically by a welder using a continuously fed electrode wire such as submerged arc welding or electro-slag welding, etc.

SECTION 2 Test Specimens and Testing Procedures

201. General

1. Test specimens and mechanical testing procedures specified in this Chapter for welding procedure qualification tests, welders and qualification tests, approval test and periodical inspection of welding consumables are to comply with the requirements in this Section.

2. Where specimens and mechanical testing procedures differing from those prescribed in this Section are used, they are to be approved by the Society.

202. Selection of test specimens

1. Test specimens are to be selected according to respective requirements in each Section.

2. Except where otherwise specified or agreed with the Surveyor, test specimens are not to be detached from the test assembly until having been stamped by the Surveyor.

3. If test specimens are cut from test assemblies by flame cutting or shearing, a reasonable margine is required to enable sufficient material to be removed from the cut edges during final machining.

4. The preparation of test specimens is to be done in such a manner that test specimens are not subjected to any significant cold straining or heating.

5. If any test specimen shows defective machining or defects having no relation to the substantial nature, it may be discarded and substituted by another test specimen.

203. Size and dimensions of test specimens

1. Tensile test specimens

(1) Tensile test specimens are to be of size and dimensions given in **Table 2.2.1,** and the both ends of the test specimen may be machined to such a shape as to fit the holder of the testing machine.
(2) The upper and lower surfaces of weld are to be filed, ground or machined flush with the surface of plate.
(3) When the capacity of the available testing machine does not permit testing the full thickness specimen, two or more thinner than full thickness specimens may be prepared by cutting the full thickness specimens into section, each of which is to meet the requirements.

2. Bend test specimens

(1) Bend test specimens are to be of size and dimensions given in **Table 2.2.2** according to the kind of test assemblies.
(2) Where the thickness of test assemblies is greater than the thickness of the bend test specimen prescribed in **Table 2.2.2,** the face bend or root bend specimen may be machined on its compression side.
(3) Reinforcements and back straps are to be machined flush with base metal.

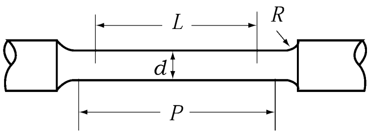
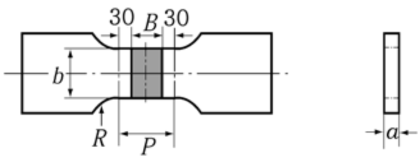
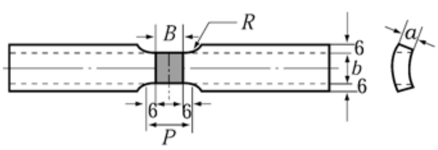
3. Impact test specimens

Impact test specimens are to be charphy V-notch impact test specimens specified in **Ch 1, 202. 3** and to be of size and dimensions given in **Fig 2.1.3, Tables 2.1.3** and **2.1.4.**

4. Confirmation for test specimens

The size and dimensions of test specimens are to be carefully inspected and verified by suitable means before testing

Table 2.2.1 Size and Dimensions of Tensile Test Specimens (Unit : mm)

Type	Size of specimen	Dimensions	Intended for
R 14A		d = 10 L = 50 P = 55 $R \geq$ 10 Alternatively. L = 5 d $P \cong L+0.5d$ R = 12	Deposited metal tensile test Longitudinal tensile test
R 10		t = 12 d = 6.0 L = 24 P = 32 $R \cong$ 6	Deposited metal tensile test(Welding consumables for stainless steel)
		t = 19~25 d = 12.5 L = 50 P = 60 $R \cong$ 15	
R 2A		a = t b = 12 ($t \leq$ 2) b = 25 (t > 2) P = B + 60 R > 25	Butt weld tensile test for plate
R 2B		a = t b = 38 ($t \leq$ 25) b = 25 (t > 25) P = B + 12 $R \geq$ 50	Butt weld tensile test for pipe

NOTE:
The notations used are defined as follows:
d : Diameter
a : Thickness
b : Width
L : Gauge length
P : Parallel test length
B : Width of weld
R : Transition radius
t : Thickness of material

Table 2.2.2 Size and Dimensions of Bend Test Specimens (Unit : mm)

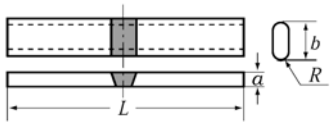
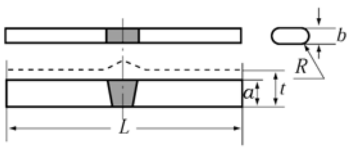
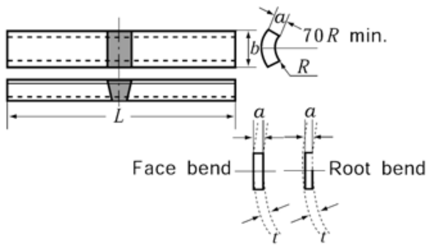
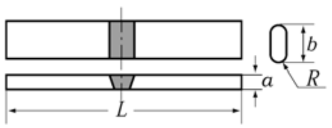
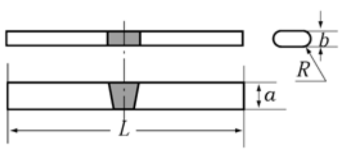
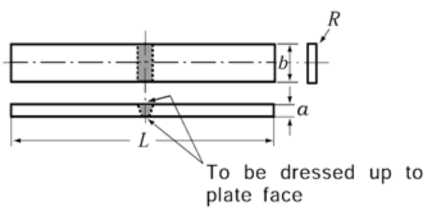
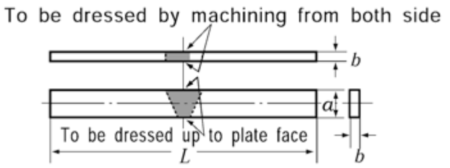
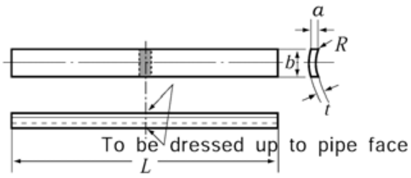
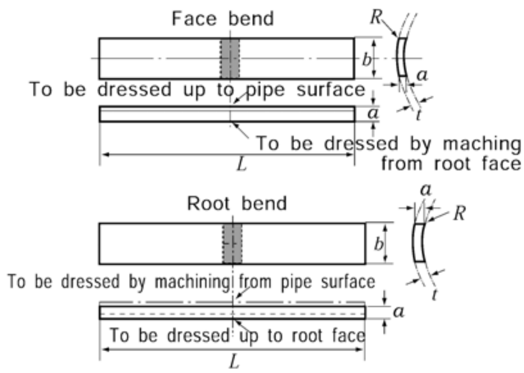
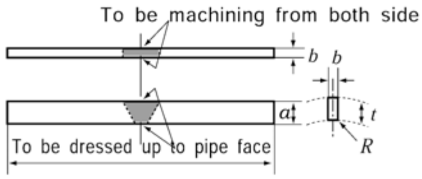
Used for		Type	Size of specimen	Dimensions(1)	Intended for
Welding procedure qualification tests	Face and root bend specimen	*RB* 1		$t \leq 20$ $a = t$ $b = 30$ $L \geq 200$ $R = 1 \sim 2$	Butt weld bend test for plate Longitudinal bend test for plate(2)
	Side bend specimen	*RB* 2		$t > 20$ $a = t$ (3) $b = 10$ $L \geq 200$ $R = 1 \sim 2$	Butt weld bend test for plate or pipe
	Face and root bend specimen	*RB* 3		① $0 < t < 9$ $a = t$ $b = t + D/10$ $L \fallingdotseq 250$ $R \leq a/6$ ② $9 \leq t \leq 20$ $a = 9$ $b = 40$ $L \fallingdotseq 250$ $R \leq 1.5$	Butt weld bend test for pipe
Approval test and periodical inspection for welding consumables	Face and root bend specimen	*RB* 4		$a = t$ $b = 30$ $L \geq 200$ $R \leq 1.5$ Where the thickness of test assemblies exceeds 25 mm, the thickness of test specimen may be reduced to 25 mm with its surface machined on one side only(compression side)	Butt weld bend test
	Side bend specimen	*RB* 5		$a = t$ $b = 10$ $L \geq 200$ $R \leq 1.5$	Butt weld bend test (welding materials for electro-slag and electro-gas)
		RB 6		$a = t$ $b = 9$ $L \geq 200$ $R \leq 1.5$	Butt weld bend test (MIG double side, one layer each, butt welding for aluminium alloy)
Welder's qualification	Face and root bend specimen	*RB* 7		$t < 9.5$ $a = t$ $b = 40$ $L \fallingdotseq 150$ $R \leq 1.5$	Butt weld bend test for pipe

Table 2.2.2 Size and Dimensions of Bend Test Specimens (Continued) (Unit : mm)

Used for		Type	Size of specimen	Dimensions[1]	Intended for
Welder's qualification test	Side bend specimen	*RB*8		$t \geq 9.5$ $a = t^{(3)}$ $b = 9$ $L \fallingdotseq 150$ $R \leq 1.5$	Butt weld bend test for plate
	Face and root bend specimen	*RB*9		$t \leq 9.5$ $a = t$ $L \fallingdotseq 150$ $R \leq 1.5$ $b = 40$ $(D>100)$ or $25(D \leq 100)$	
		*RB*10		$t > 9.5$ $a = 10$ $L \fallingdotseq 150$ $R \leq 1.5$ $b = 40$ $(D>100)$ or $25(D \leq 100)$	Butt weld bend test for pipe
	Side bend specimen	*RB*11		$t \geq 9.5$ $a = t^{(3)}$ $b = 9$ $L \fallingdotseq 150$ $R \leq 1.5$	

NOTES:

(1) The following designations are used.
- a : Thickness
- b : Width
- R : Edge radius
- D : External pipe diameter
- t : Thickness of test assembly
- L : Length

(2) The specimen also applies to longitudinal bend test for welding consumables for 9 % Ni steel. The width of Specimen, b, is to be B+12 where breath of weld, B, is 26 mm and over.

(3) For plates over 40 mm thick, the side bend specimen may be subdivided, each part being at least 20 mm wide and each part may be tested.

204. Mechanical testing procedures

1. Tensile test and impact test

Tensile tests and impact tests are to be carried out in accordance with the procedures prescribed in **Ch 1, 203.**

2. Bend test

(1) Except where guided bend tests are required, bend test is roller bend test carried out by the jig of which the plunger has a bending radius specified in each Section with supporting rollers adjustable for their spans.
(2) Guided bend test jigs are to be as shown in **Figs 2.2.1** and **2.2.2.**
(3) Roller bend test jigs are to be as shown in **Fig 2.2.3.**

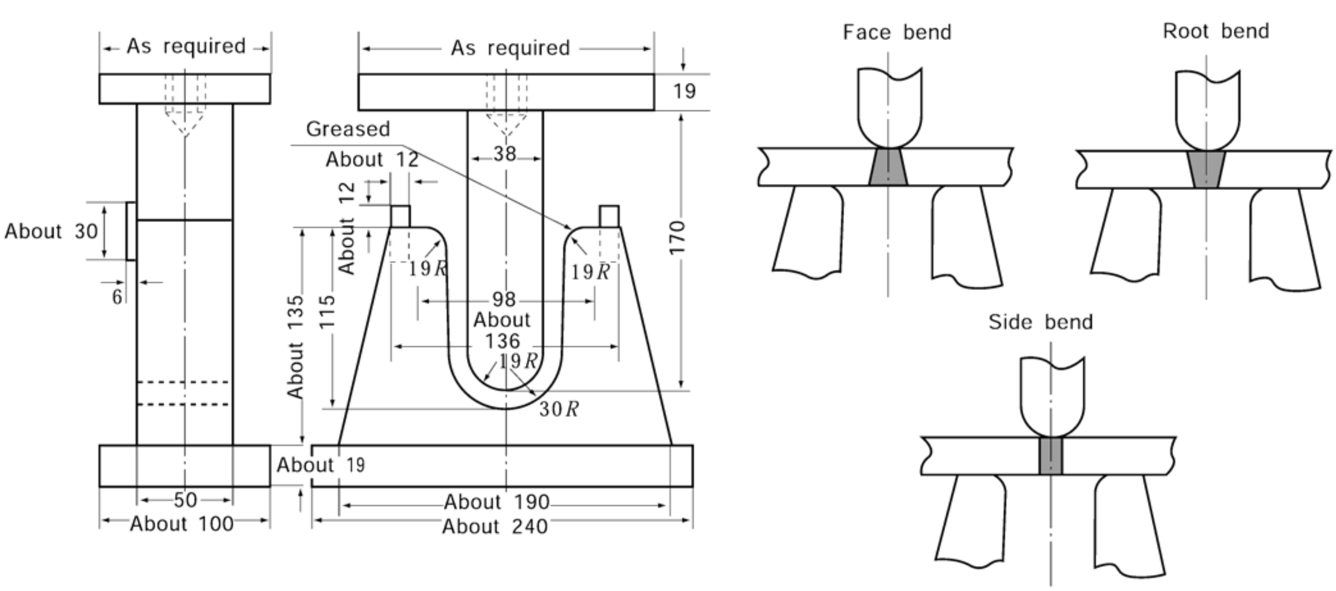


Fig. 2.2.1 Guided Bend Test Jig (For 9 *mm* in thick., Unit : *mm*)

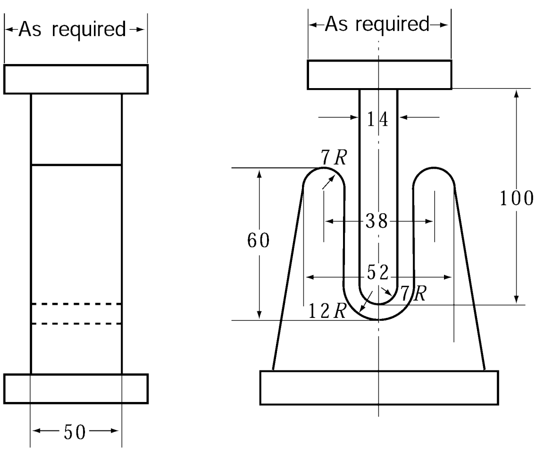
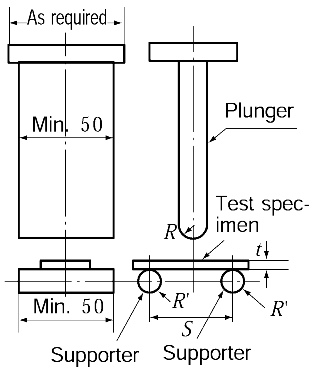


Fig. 2.2.2 Guided Bend Test Jig
(For 3.2 *mm* in thick., Unit : *mm*)



t : Thickness of test specimen
R : Radius of plunger
R' : Radius of supporting roller (not specified)
S : Span between Supports{2 (*R* + *R'* + *t* + 2)}

Fig. 2.2.3 Jigs for Roller Bend Test (Unit: *mm*)

SECTION 3 Welding Work and Inspection

301. Details of joints

1. Application

The details of joints for manual welding are to be in accordance with the following Paragraphs. For other welding procedures such as automatic welding and in case where the specified details of joint are deemed unpracticable, full details of joint are to be submitted for approval.

2. Butt joints

(1) In general, edge preparations of butt welds are to be as shown in **Fig 2.2.4.**

(2) Butt welded joints of plates having difference over 4 mm in thickness are to be properly tapered at the end of thicker plate.

3. Butt joints of thick materials

The groove of thick materials, such as cast steel, is in general to be prepared as shown in **Fig 2.2.5.**

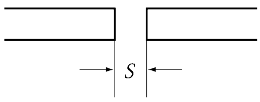
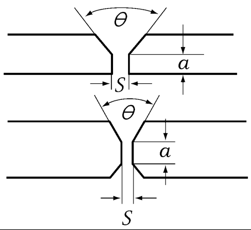
Thickness(*mm*)	Edge preparation	Dimensions
$t \leq 6.0$		$S \leq 3.0$ *mm*
$t > 6.0$		$S \leq 5.0$ *mm* $a \leq 3.0$ *mm* $\theta \geq 50°$

Fig 2.2.4 Edge preparation

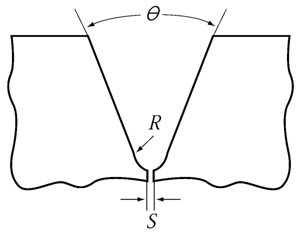


Fig 2.2.5 Butt Joint of Thick Material

4. Lap joints

(1) The breadth of overlap for lap joints which may be subjected to bending is not to be less than obtained from the following formula, but need not exceed 50 mm.

$$b = 2t + 25 \quad \text{(mm)}$$

where:

t = Thickness of the thinner plate (mm)

(2) Where plates are joggled, the breadth of overlap for joints which may be subjected to bending is not to be less than obtained from the following formula, but need not exceed 40 *mm*.

$$b = t + 25 \quad \text{(mm)}$$

where:

t = Thickness of the thinner plate (mm).

302. Welding Practice

1. Welding Practice, which is the detailed statement of the general welding works for hull structure, is to contain welding process, standard of welding and its quality control, application of welding consumables, welding procedures specification(WPS) and welding sequence of main hull structure and be submitted to the Society.

2. The welding procedure specification(WPS) specified above is to be those satisfactorily complying with the welding procedure qualification tests specified in **Sec 4.**

303. Application of welding consumables

Welding consumables used for welded joints of hull structure are to be of the grades as specified in the relevant Articles of **Sec 6** according to the following requirements:

(1) Application of welding consumables for welded joints of various grades of steel is to be as specified in **Table 2.2.3.**

(2) Welding consumables for lower toughness of steel may be used for welded joints of different toughness of steel of the same specified strength.

(3) In case of welding of steels of different specified strength, the welding consumables required for the steel of lower specified strength may be used, provided that adequate means for preventing cracks are considered.

(4) It is recommended that controlled low hydrogen type consumables are to be used when joining higher strength structural steel to the same or lower strength level, except that other consumables may be used at the discretion of the Society when the carbon equivalent is below or equal to 0.41 %. When other than controlled low hydrogen type electrodes are used, appropriate procedure tests for hydrogen cracking may be conducted at the discretion of the Society.

304. Preparation for Welding

1. Edge preparation

(1) The edge preparations are to be in accordance with the plans, and are to be free from moisture, grease, rust and paint which may cause injurious defects in welded joints.

(2) The edges to be welded shall be smooth, uniform and free from notches, laminations, cracks and other discontinuities which would adversely affect the quality or strength of the weld.

(3) Any injurious defects on the edges are to be removed. When weld repairs are required, controlled low hydrogen type welding consumables are to be used as far as practicable and grinding the complete weld smooth and flush with the adjacent surface.

2. Tack welding

(1) Tack welding is to be carried out by the welders qualified by the Society.

(2) Tack welding is to be removed before the main welding for joints of strength deck plating, sheer strakes, shell plating, and other important structural members or is to be carried out by the same procedure as the main welding without injurious defect in welded joints and made with the same or higher grade of welding consumables as intended to use for main welding.

(3) The minimum length and pitch of tack welds should be in accordance with the Guidance in relating to Rules.

(4) Injurious defects or any deviations from groove design due to tack welding to obstruct proceedings of main welding are to be completely removed.

(5) In case of tack welding higher strength steels, high strength quenched and tempered steels or joining under high restraint, preheating is to be taken as necessary prior to tack welding.

3. Fixtures

(1) Setting appliances to be used for welding fabrications are to be so arranged as to give restraint without cracks and other defects in welded joints.

(2) Tack welding for temporary fittings is not to leave any defect on base metal after the tack welds have been removed.

Table 2.2.3 Selection of welding consumables(rolled steel plates)

Kind and grade of steel to be welded			Grade of applicable welding consumables [1]
Rolled steels for hull	Mild steel	*A*	1, 2, 3, 1*Y*, 2*Y*, 3*Y*, 4*Y*, 5*Y*, 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40, *L*1, *L*2, *L*3
		B, *D*	2, 3, 1*Y*, 2*Y*, 3*Y*, 4*Y*, 5*Y*, 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40, *L*1, *L*2, *L*3
		E	3, 3*Y*, 4*Y*, 5*Y*, 3*Y*40, 4*Y*40, 5*Y*40, *L*1, *L*2, *L*3
	Higher strength low alloy steel	*AH*32, *AH*36	1*Y*(2), 2*Y*, 3*Y*, 4*Y*, 5*Y*, 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40, *L*2(3), *L*3, 2*Y*42, 3*Y*42, 4*Y*42, 5*Y*42
		*DH*32, *DH*36	2*Y*, 3*Y*, 4*Y*, 5*Y*, 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40, *L*2(3), *L*3, 3*Y*42, 4*Y*42, 5*Y*42
		*EH*32, *EH*36	3*Y*, 4*Y*, 5*Y*, 3*Y*40, 4*Y*40, 5*Y*40, *L*2(3), *L*3, 4*Y*42, 5*Y*42
		*FH*32, *FH*36	4*Y*, 5*Y*, 4*Y*40, 5*Y*40, *L*2(3), *L*3, 4*Y*42, 5*Y*42
		*AH*40, *DH*40	2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40, 3*Y*42, 4*Y*42, 5*Y*42, 2*Y*46, 3*Y*46, 4*Y*46, 5*Y*46
		*EH*40	3*Y*40, 4*Y*40, 5*Y*40, 3*Y*42, 4*Y*42, 5*Y*42, 3*Y*46, 4*Y*46, 5*Y*46
		*FH*40	4*Y*40, 5*Y*40, 4*Y*42, 5*Y*42, 4*Y*46, 5*Y*46
Rolled steels for low temperature services		*RL*24*A*	4*Y*, 4*Y*40, *L*1, *L*2, *L*3
		*RL*24*B*, *RL*27, *RL*33	5*Y*42, *L*2, *L*3(4)
		*RL*37	5*Y*42, *L*3
		*RL*9*N*53, *RL*9*N*60	*L*91, *L*92
High strength quenched and tempered steels for welded structures		*AH*43	2*Y*42, 3*Y*42, 4*Y*42, 5*Y*42, 2*Y*46, 3*Y*46, 4*Y*46, 5*Y*46, 2*Y*50, 3*Y*50, 4*Y*50, 5*Y*50
		*DH*43	3*Y*42, 4*Y*42, 5*Y*42, 3*Y*46, 4*Y*46, 5*Y*46, 3*Y*50, 4*Y*50, 5*Y*50
		*EH*43	4*Y*42, 5*Y*42, 4*Y*46, 5*Y*46, 4*Y*50, 5*Y*50
		*FH*43	5*Y*42, 5*Y*46, 5*Y*50
		*AH*47	2*Y*46, 3*Y*46, 4*Y*46, 5*Y*46, 2*Y*50, 3*Y*50, 4*Y*50, 5*Y*50
		*DH*47	3*Y*46, 4*Y*46, 5*Y*46, 3*Y*50, 4*Y*50, 5*Y*50
		*EH*47	4*Y*46, 5*Y*46, 4*Y*50, 5*Y*50
		*FH*47	5*Y*46, 5*Y*50
		*AH*51	2*Y*50, 3*Y*50, 4*Y*50, 5*Y*50, 2*Y*55, 3*Y*55, 4*Y*55, 5*Y*55
		*DH*51	3*Y*50, 4*Y*50, 5*Y*50, 3*Y*55, 4*Y*55, 5*Y*55
		*EH*51	4*Y*50, 5*Y*50, 4*Y*55, 5*Y*55
		*FH*51	5*Y*50, 5*Y*55
		*AH*56	2*Y*55, 3*Y*55, 4*Y*55, 5*Y*55, 2*Y*62, 3*Y*62, 4*Y*62, 5*Y*62
		*DH*56	3*Y*55, 4*Y*55, 5*Y*55, 3*Y*62, 4*Y*62, 5*Y*62
		*EH*56	4*Y*55, 5*Y*55, 4*Y*62, 5*Y*62
		*FH*56	5*Y*55, 5*Y*62
		*AH*63	2*Y*62, 3*Y*62, 4*Y*62, 5*Y*62, 2*Y*69, 3*Y*69, 4*Y*69, 5*Y*69
		*DH*63	3*Y*62, 4*Y*62, 5*Y*62, 3*Y*69, 4*Y*69, 5*Y*69
		*EH*63	4*Y*62, 5*Y*62, 4*Y*69, 5*Y*69
		*FH*63	5*Y*62, 5*Y*69
		*AH*70	2*Y*69, 3*Y*69, 4*Y*69, 5*Y*69
		*DH*70	3*Y*69, 4*Y*69, 5*Y*69
		*EH*70	4*Y*69, 5*Y*69
		*FH*70	5*Y*69

NOTES :

(1) The symbol of welding consumables listed above show the materials which are specified in **Table 2.2.16, Table 2.2.25, Table 2.2.33, Table 2.2.39,** and **Table 2.2.67.**

(2) When joining higher strength steels using Grade 1*Y* welding consumables, the material thicknesses should not exceed 25 mm.

(3) Welding consumables of "*L*2" is applicable to steel grade of *AH*32, *DH*32, *EH*32 or *FH*32.

(4) Welding consumables of "*L*3" is applicable to steel grade of *RL*33.

305. Welding sequence and direction of welding

1. Welding sequence and direction of welding are to be so determined as to prevent defects in welded joints and to minimize deformations caused by welding.

2. The joints which may cause excessive contraction by welding are to be welded as far as practicable prior to the joints which cause smaller contraction by welding.

3. Welding is to be proceeded to free ends of the joints as far as practicable and welding with direction of vertical-downward is not to be carried out, except the special approval of the Society.

306. Main welding

1. Welding is to be carried out so that no injurious defects may exist in the joints.

2. Welding is to be carried out under conditions of protection against the deleterious effect of moisture, rain, wind and snow, and is to be preheated in cold weather if found necessary.

3. The ends of important welded joints are to be fitted with run-off tabs or are to have proper extensions, which are to be cut off after finished welding.

4. Butt welded joints are to be back chipped to remove the defects in root of welds before applying the closing bead, except in case of one side welding or other approved procedures.

5. In case of welding under excessive restraint or welding for thick steel plate, cast steel or forged steel, special precaution is to be taken as necessary, such as preheating of the material, use of low hydrogen electrodes, etc. so as to prevent cracks.

6. In the parts subject to excessive stress concentration, the fillet welding is to be carried around the ends of member, but in other parts, the fillet welding may not be carried out around the ends, provided that the craters at the ends of welds are filled up.

7. Excessive gaps in butt joint are to be either deposited with welding on grooves, fitted with backing strips to the joints or partly replaced, and are not to be spanned with welding nor filled by slugging.

8. Where the gap between the members in fillet joints is not greater than 2 mm, the welding may be done with the given size of fillet. Where the gap is not less than 2 mm nor more than 5 mm, the welding is to be done with an increased size of fillet corresponding to the amount of gap. Where the gap exceeds 5 mm, the welding is to be done inserting a liner of suitable size or with a chill strip, or plates to be welded are to be partly renewed.

9. Preheating, intermediate temperature and post heat treatment are to be carried out in accordance with the welding procedure approved beforehand or the special approval of the Society.

307. Automatic welding

1. The grooves for automatic welding are to be finished in specially accurate dimensions.

2. Automatic welding is to be carried out within the inclination approved in the welding procedure qualification test.

3. In the cross but joints of 16 mm or over in thickness, one joint is to be welded after the automatic welding of the other joint has been completed on both sides.

4. Special precaution is to be taken as necessary for the automatic welding of rimmed steel to prevent cracks.

308. Welding for higher strength steel

1. Arc strikes are to be avoided as far as practicable.

2. Short bead, min. length of repair welds and line heating temperature, etc. are to be in accordance with the Shipbuilding Quality Standard recognized by the Society.

309. Quality of welds

1. The weld is to have a regular and uniform surface and it to be reasonably free from excessive reinforcements, injurious defects, such as undercuts, overlaps, etc.

2. Welded structures are to be reasonably free from welding deformation.

3. Non-destructive inspection is to be carried out for welded joints as the Guidance relating to the Rules specified elsewhere.

4. The welding defects found in an appropriate non-destructive inspection including the visual inspection or watertight test are to be removed and corrected by rewelding.

310. Repairs

1. The removal of weld defects shall be done by gouging, grinding, chipping, etc. with such a manner that the remaining weld metal or base metal is not damaged, however oxygen gouging is not to be used in high strength quenched and tempered steels.

2. The removed weld defects parts are to be so machined as not to affect repair welding and repair welding shall be carried out with low hydrogen type welding consumables and an electrode preferably smaller than that used for making the original weld.

3. Members distorted by welding may be straightened by mechanical means or localized heat treatment, however in case of localized heat treatment, the temperature of heated areas is to be so limited as not to affect the mechanical properties of base metal.

SECTION 4 Welding Procedure Qualification Tests

401. General

1. Application

(1) The welding procedures to be applied to hull construction specified in this Chapter as well as cargo tank, secondary barriers and piping arrangements in ships carrying liquefied gases in bulk, are to be those satisfactorily complying with the welding procedure qualification tests specified in this Section.
(2) The welding procedures qualification test for areas other than those specified in (1) is to be in accordance with the Guidance in relating to Rules.

2. Definitions

(1) Welding procedure specification(WPS)
A specification of materials, detailed methods, welding parameters etc. to be applied in the welding of a particular joint.
(2) Welding procedure qualification tests(WPQT)
A test carried out in order to demonstrate that a weld made according to a specific welding procedure specification meets the given requirements.
(3) Welding procedure qualification record(PQR)
The record of the actual parameters employed during welding of the qualification test piece according to the requirement of (2), and results from the non-destructive inspection and mechanical testing.

3. General requirements of WPQT

(1) The manufacturers are to obtain the approval of the welding procedure qualifications before the welding works in the following case specified in (a) through (b)
 (a) Where the welding procedure is first adopted for welding works specified in **1.**
 (b) Where the welding variables specified in **402. 2** (1) through (11) are changed beyond the extent of those described in the approved welding procedure specifications.
(2) For the approval of welding procedure qualification, the preliminary welding procedure specification specified in **402.** is to be reviewed by the Society and the welding procedure qualification test is to be carried out with satisfactory results. Welding procedure specifications are to refer to the test conditions and test results achieved during welding procedure qualification testing.

402. Welding procedure specification

1. A welding procedure specification (WPS) is to be prepared by the shipyard or manufacturer which intends to perform the welding procedure qualification test. This document is also referred to as a preliminary welding procedure specification (pWPS). The shipyard or manufacturer is to submit to the Society a pWPS for review prior to the tests.

2. The pWPS can be modified and amended during procedure tests as deemed necessary however it is to define, at least, the following welding variables.
(1) Kind of base metal
(2) Nominal thickness or diameter range(dimensions)
(3) Welding process
(4) Joint or groove designs with tolerances
(5) Welding position(s) and direction of progression
(6) Welding consumables(grade, shielded gas, backing, flux, etc.)
(7) Electrical characteristics(amperage, voltage and pole nature etc.)
(8) Travel speed and heat input ranges
(9) Preheat and maximum interpass temperature
(10) Post weld heat temperature (if any)
(11) Other conditions necessary for the welding procedure (ex. : welding speed, heat input etc.)

3. Welding consumables used in welding procedure qualification tests should be approved in accordance with the requirements specified in **Sec 6** of the Rules.

4. In case that the test pieces welded according to the pWPS show unacceptable results the pWPS is to be adjusted by the shipyard or manufacturer. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.

5. The WPS is to be used as a basis for the production welds, and upon satisfactory completion of the tests based on the pWPS, the Society may approve it as a WPS. In case that a WPS is approved by the Society the approval range is to be in compliance with the requirements in **407.**

403. Welding procedure qualification tests(WPQT)

1. Where procedure qualification test is required, the test assembly is to be welded in the same or similar environment and the qualification tests are to be carried out under the welding conditions given in the pWPS.

2. Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

3. If tack welds and/or start and stop points are a condition of the weld process they are to be fused into the joint and are to be included in the test assemblies.

4. For qualification tests for stainless clad steels, the requirements specified in **404.** and **405.** are to be complied with. However the impact test may be dispensed with where other welding procedure qualification on the stainless clad steel base metal under the same welding condition has been approved.

5. Where materials other than those specified in this Section are used, the qualification tests are to be carried out in accordance with the testing standard approved by the Society.

6. Tests or test conditions other than those specified in this Section for the welding procedure qualification may be required, where deemed necessary by the Society.

404. Tests for butt welded joints

1. Application

The requirements stated hereunder apply to the butt joints welded by manual welding, semi-automatic welding or automatic welding.

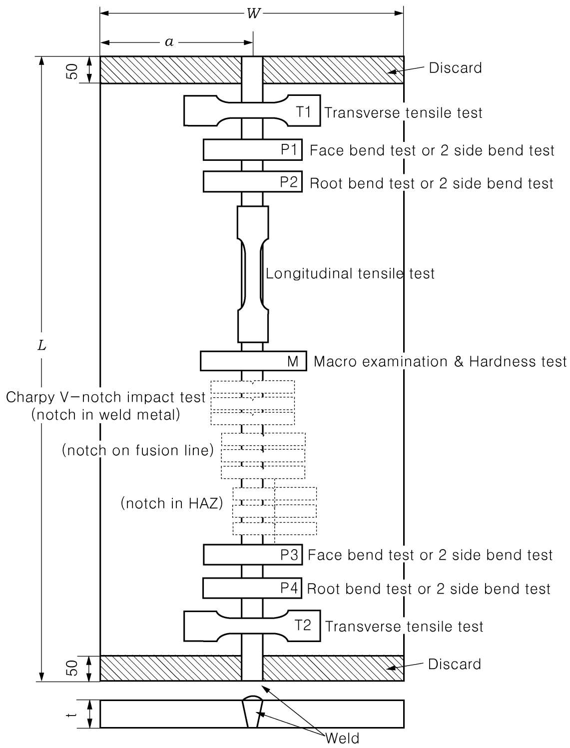
2. Kinds of test

According to the materials to be tested, kinds of test and number of test specimens are to be given in **Table 2.2.4.** Additional test may be required where found necessary by the Society.

3. Test assemblies

(1) Test assemblies are to be prepared with the same or equivalent meterial used in the actual work.

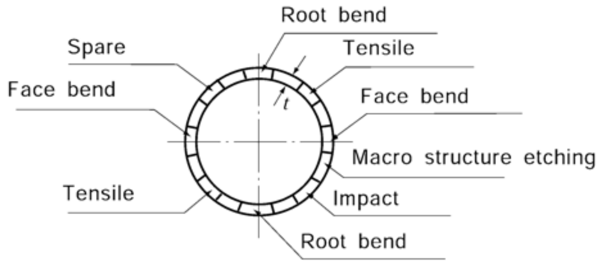
(2) The dimensions and types of test assembly are to be as indicated in **Fig 2.2.6.**



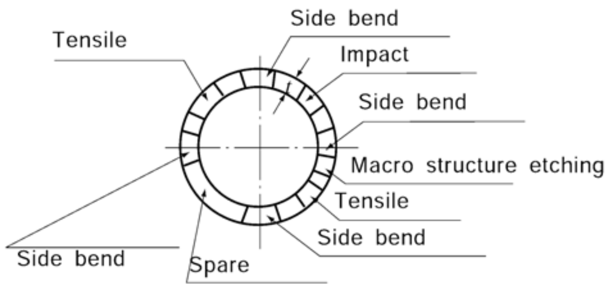
(Note)
The test assembly is to be of a size with the minimum dimensions:
(1) manual or semi-automatic welding:
Width(W) : min. 300mm
Length(L) : min. 350mm
(2) automatic welding
Width(W) : min. 400mm
Length(L) : min. 1,000mm

(A) Test assembly fot Hull Structural Steels, High Strength Quenching and Tempered Steels, Stainless Steels or Aluminium Alloys

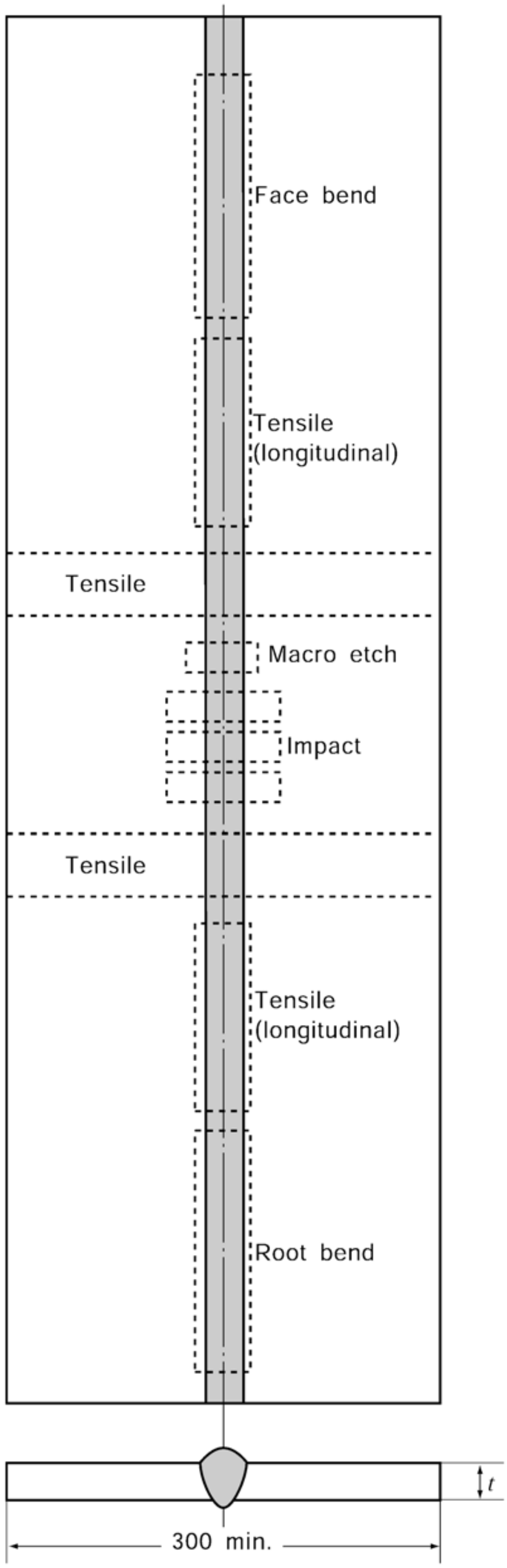
Fig 2.2.6 Welding procedure test assembly (Unit : mm) (cont'd)



(B) Test assembly for pipes up to 20mm in thickness



(C) Test assembly for pipes over 20mm in thickness



(D) Test Assembly for *RL*9*N*53 or *RL*9*N*60

Fig 2.2.6 Welding procedure test assembly (Unit : mm)

Table 2.2.4 Kinds of Test for Butt Welded Joints

Grades and material symbols of test specimens			Kinds and number of specimens for test(1): Visual insp.	Tensile test	Bend test	Impact test	Macro-structure insp.	Hard. test	Non-destructive insp.(3)
Rolled steels for hull structural	Normal strength steel	*A*, *B*, *D*, *E*	Welding positions of whole length	2	4(2)	(3)	1	-	Welding positions of whole length
	Higher strength steel	*AH* 32, *DH* 32, *EH* 32, *FH* 32, *AH* 36, *DH* 36, *EH* 36, *FH* 36, *AH* 40, *DH* 40, *EH* 40, *FH* 40						1(11)	
Rolled steels for low temperature service		*RL* 24*A*, *RL* 24*B*, *RL* 27, *RL* 33, *RL* 37 *RL* 2*N*30, *RL* 3*N*32, *RL* 5*N*43			2			-	
		RL 9*N*53, *RL* 9*N*60		4(5)					
Steel pipes for low temperature service		*RLPA*, *RLPB*, *RLPC*, *RLP* 2, *RLP* 3, *RLP* 9		2	4(2)				
Weldable high strength quenched and tempered steel		*AH* 43, *DH* 43, *EH* 43, *FH* 43, *AH* 47, *DH* 47, *EH* 47, *FH* 47, *AH* 51, *DH* 51, *EH* 51, *FH* 51, *AH* 56, *DH* 56, *EH* 56, *FH* 56, *AH* 63, *DH* 63, *EH* 63, *FH* 63, *AH* 70, *DH* 70, *EH* 70, *FH* 70						1(11)	
Casting for welded construction and Hull steel forging		*RSC* 410, *RSC* 450, *RSC* 480, *RSC* 520, *RSC* 560, *RSC* 600, *RSC* 440*A*, *RSC* 480*A*, *RSC* 550*A*, *RSF* 410*H*, *RSF* 450*H*, *RSF* 480*H*, *RSF* 520*H*, *RSF* 560*H*, *RSF* 600*H*, *RSF* 550*AH*, *RSF* 600*AH*, *RSF* 650*AH*				(3)(10)		-	
Rolled stainless steels		*RSTS* 304, *RSTS* 304*L*, *RSTS* 304*N*1, *RSTS* 304*N*2, *RSTS* 304*LN*, *RSTS* 309*S*, *RSTS* 310*S*, *RSTS* 316, *RSTS* 316*L*, *RSTS* 316*N*, *RSTS* 316*LN*, *RSTS* 317, *RSTS* 317*L*, *RSTS* 317*LN*, *RSTS* 321, *RSTS* 347			2	(6)			
Stainless steel pipes		*RSTS* 304*TP*, *RSTS* 304*LTP*, *RSTS* 309*STP*, *RSTS* 310*STP*, *RSTS* 316*TP*, *RSTS* 316*LTP*, *RSTS* 317*TP*, *RSTS* 317*LTP*, *RSTS* 321*TP*, *RSTS* 347*TP*			4				
Aluminium alloys(7)	5000 series	5083*P*, 5383*P*, 5059*P*, 5086*P*, 5754*P*, 5083*S*, 5383*S*, 5059*S*, 5086*S*(8)			4(2)	-			
	6000 series	6005*AS*, 6061*S*, 6082*S*(9)							

NOTES:
(1) Where found necessary by the Society, microscopic test, hardness test and tests other than these may be required.
(2) Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.
(3) No. of test sets and position of notch are as shown in **Fig 2.2.7**.
(4) Internal inspections by radiographic examination or ultrasonic examination and surface inspections by magnetic particle examination or liquid penetrant examination are to be carried out.
(5) Two specimens are to be taken longitudinally and transversely respectively (See. **Fig 2.2.6**)
(6) Where found necessary by the Society, impact tests up to steels specially used for may be required.
(7) Material symbols of aluminium alloys include the symbols of which is the temper condition.
(8) Rolled products which have the same grade and temp condition may be used.
(9) Other rolled aluminium alloys of 6000 series with minimum tensile strength 260 N/mm^2 may be used.
(10) Where impact test is required.
(11) Hardness test(H_v10) is required for weldable high strength quenched and tempered steel and hull structural steel with specified minimum yield strength of $R_{eH} \geq 355\ N/mm^2$

(3) Test assemblies are to be welded in the same welding positions as the actual work.
(4) Test assemblies for the pipes over 500 mm in diameter at the actual work may be those for the plates.
(5) For butt welded joints of rolled steel plates, the direction of welding according to rolling direction is to be as follows.
  (a) When steel plates impact tested in longitudinal direction are used for test assemblies, the direction of welding of test assembly is perpendicular to the rolling direction of the two plates.
  (b) When steel plates impact tested in transverse direction are used for test assemblies, the direction of welding of test assembly is parallel to the rolling direction of the two plates.

4. Visual inspection

Welding surface is to be regular and uniform surface and is to be free from injurious defects, such as cracks, undercuts, overlaps, etc.

5. Tensile tests

(1) The number of tensile test specimens taken from each test assembly is to be as shown in **Table 2.2.4.**
(2) Tensile tests are to be carried out with the test specimen shown in **Table 2.2.1.** The tensile strength is not to be less than the minimum tensile strength specified for the base metal except for those specified in **Table 2.2.5.** When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirements relating to the steel grade having lower strength.

Table 2.2.5 Tensile Test Requirements for Butt Welded Joint

Kind of testing materials	Grade of testing materials	Tensile strength (N/mm^2)	Yield strength (N/mm^2)
Rolled steels for lower temperature service	*RL* 9*N*53, *RL* 9*N*60	590 min.(1)	315 min.
		630 min.(2)	-
Steel pipes for low temperature service	*RLP* 9	630 min.	-
Aluminium alloys	5754	190 min.	-
	5086	240 min.	-
	5083	275 min.	-
	5383	290 min.	-
	5059	330 min.	-
	6005A, 6061, 6082(3)	170 min.	-

(Notes)
(1) For test specimen in longitudinal direction
(2) For test specimen in transverse direction
(3) See notes (9) of **Table 2.2.4.**

(3) In those cases where the consumables are not unavoidably approved by the Society, it is to be required additionally to prepare a *R* 14A deposited metal tensile test specimen as shown in **Table 2.2.1** in entirely weld metal and the tensile properties recorded for each specimen are not to be less than the minimum required for the approval of the appropriate grade of consumable. Where more than one welding process or type of consumable has been used to make the test weld, test specimens are to be taken from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

6. Bend tests

(1) The number of bend test specimens taken from each test assembly is to be as shown in **Table 2.2.4,** and the position of specimen is to be as shown in **Fig 2.2.6.**

(2) The shape and dimension of face bend specimen, root bend specimen or side bend specimen are to be as indicated in *RB*1, *RB*2 or *RB*3 of **Table 2.2.2.** Bend test procedure and inside bend radius are to be as indicated in **Table 2.2.6.** There is to be no crack nor any other defect greater than 3 mm in length in any direction on the surface of bend specimen.

Table 2.2.6 Bend Test Requirements

Kind of testing materials	Grade of testing materials	Inside bend radius (mm)(1)	Bending angle
Steel pipes for low temperature service	*RLP* 9	$\frac{10}{3}t$	180°
weldable high strength quenched and tempered steel	*AH* 56, *DH* 56, *EH* 56, *FH* 56, *AH* 63, *DH* 63, *EH* 63, *FH* 63, *AH* 70, *DH* 70, *EH*7 0, *FH* 70	$\frac{5}{2}t$	
Aluminium alloys	5754, 5086, 5083, 5383, 5059, 6005*A*, 6061, 6082	(3)	
Other materials		$2t$	

NOTES :
(1) t is the thickness of the test specimen.
(2) See Notes (9) of the **Table 2.2.4.**
(3) The bend test specimens should be bent on a mandrel with maximum diameter as given in the formula below.

$$d = \frac{100 \times t_s}{A} - t_s$$

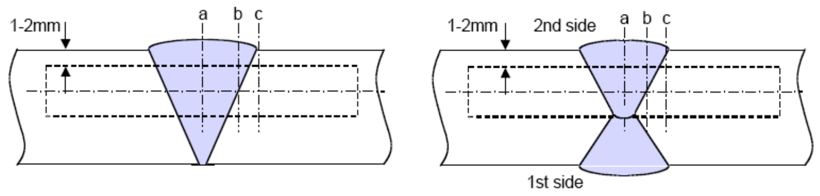
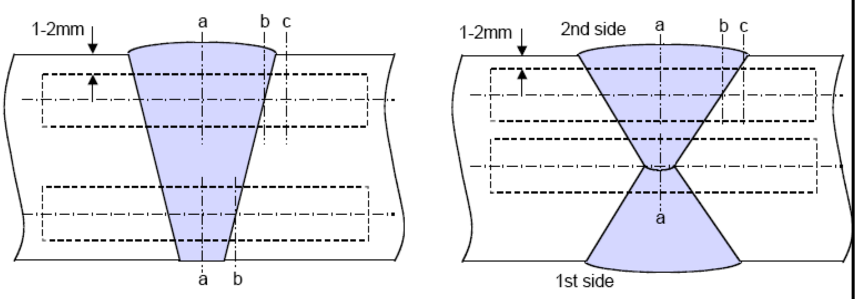
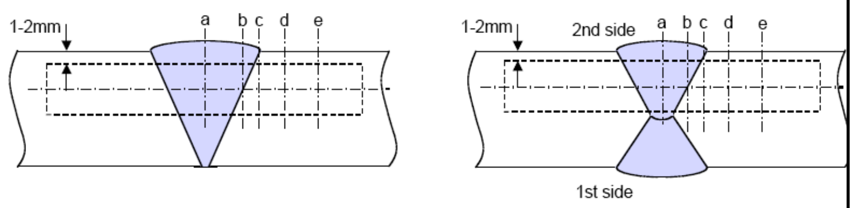
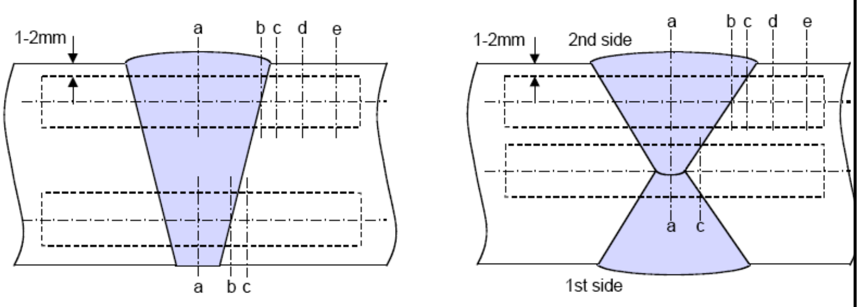
where d is the maximum former diameter
t_s is the thickness of the bend test specimen (this includes side bends)
A is the minimum tensile elongation required by the alloy grade, temper condition and thickness (for combination between different alloys, the lowest individual value should be used).

(3) For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

7. Impact tests

(1) *Normal and higher strength hull structural steels*
(a) The test specimen is to be charphy V-notch impact test specimen as shown in **Table 2.1.3** and to be taken from the position in **Fig 2.2.6.**
(b) The number of test specimens taken from test assemblies and the position of notch for the test specimen are as specified in **Fig 2.2.7.**
(c) Test specimen is to be sampled from 1 to 2 mm below the surface of the base metal, transverse to the weld and on the side containing the last weld run.
(d) Test temperature and absorbed energy are to be in accordance with Table 2.2.7.
(e) When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.
(f) Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.
(g) Where the weld metal cross-section size or shape does not allow the charphy V-notch impact test specimen to be in deposited metal, the requirements in **202. 3** of **Ch 1** are to be applied.

(2) *High strength quenched and tempered steels*
   (a) Impact test is to be performed as described in the above (1).
   (b) Test temperature and absorbed energy are to be in accordance with the requirements of base metal
(3) *Weldable C and C-Mn hull steel castings and forgings*
   For base metal with specified impact values test temperature and absorbed energy are to be in accordance with the requirements of the base metal to be welded.

heat input	thickness	Locations of V-notch[3]
normal heat input $\leq$ 50 kJ/cm	t ≤ 50 mm[1]	
	t > 50 mm	
high heat input > 50 kJ/cm	t ≤ 50 mm[2]	
	t > 50 mm	

Note:
(1) For one side single run welding over 20 mm notch location "a" is to be added on root side.
(2) For one side welding with thickness over 20 mm notch locations "a", "b" and "c" are to be added on root side.
(3) Notch locations:
   a : center of weld "WM"
   b : on fusion line "FL"
   c : in HAZ, 2 mm from fusion line
   d : in HAZ, 5 mm from fusion line
   e : in HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Fig 2.2.7 No. of test sets and locations of V-notch

Table 2.2.7 Impact test requirements for butt joints ($t \leq 50$ mm)[(1),(2)]

<table>
<tr><th rowspan="3">Grade of steel</th><th rowspan="3">Test temp. (℃)</th><th colspan="3">Value of minimum average absorbed energy (J) [(4)]</th></tr>
<tr><th colspan="2">For manually or semi-automatically welded joints</th><th rowspan="2">For automatically welded joints</th></tr>
<tr><th>Downhand, Horizontal, Overhead</th><th>Vertical upward, Vertical downward</th></tr>
<tr><td>A[(3)]</td><td>20</td><td rowspan="11">47 min.</td><td rowspan="7">34 min.</td><td rowspan="7">34 min.</td></tr>
<tr><td>B[(3)], D</td><td>0</td></tr>
<tr><td>E</td><td>-20</td></tr>
<tr><td>AH 32, AH 36</td><td>20</td></tr>
<tr><td>DH 32, DH36</td><td>0</td></tr>
<tr><td>EH 32, EH 36</td><td>-20</td></tr>
<tr><td>FH 32, FH 36</td><td>-40</td></tr>
<tr><td>AH 40</td><td>20</td><td rowspan="4">39 min.</td><td rowspan="4">39 min.</td></tr>
<tr><td>DH 40</td><td>0</td></tr>
<tr><td>EH 40</td><td>-20</td></tr>
<tr><td>FH 40</td><td>-40</td></tr>
</table>

Note:
(1) For thickness above 50 mm impact test requirements are to be agreed by the Society.
(2) These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
(3) For Grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.
(4) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

(4) *Steels for low temperature Service*
(a) The test specimen is to be charphy V-notch impact test specimen as shown in **Table 2.1.3** and to be taken from the position in **Fig 2.2.6.**
(b) The number of test specimens taken from test assemblies, the position of notch for the test specimen, test temperature and absorbed energy are as specified in **Table 2.2.8.**
(5) *Rolled stainless steels and stainless steel pipes*
(a) Where deemed necessary by the Society, impact test may be required.
(b) Test temperature and absorbed energy are to be in accordance with the requirements of base metal

8. Macro-structure inspection

(1) The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, the fusion line and the heat affected zone. Macro examination is to include about 10 mm unaffected base metal.
(2) The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion etc.

9. Non-destructive inspection

(1) Test assemblies are to be examined for the whole length(excepting discard area of test assembly of **Fig 2.2.6**) by visual and by non-destructive testing prior to the cutting of test specimen. Non destructive examinations should be carried out after any required post weld heat treatment, natural or artificial ageing, and prior to the cutting of the test specimens.
(2) For high strength quenched and tempered steels with specified minimum yield strength of 420 N/mm^2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out.

Table 2.2.8 Impact Test Requirements for Butt Welded Joint (Steels for low temperature Service)

<table>
<tr><th rowspan="3">Grade of steel</th><th rowspan="3">Test temp. (℃)[4]</th><th>A[1]</th><th colspan="2">B, C, D, E[1]</th></tr>
<tr><th rowspan="2">Value of average absorbed energy(J)[3]</th><th colspan="2">Value of average absorbed energy(J)[3]</th></tr>
<tr><th>L[2]</th><th>T[2]</th></tr>
<tr><td>RL 24A</td><td>− 40</td><td rowspan="16">27 min.</td><td rowspan="10">41 min.</td><td rowspan="10">27 min.</td></tr>
<tr><td>RL 24B</td><td>− 50</td></tr>
<tr><td>RL 27</td><td>− 60</td></tr>
<tr><td>RL 33</td><td>− 60</td></tr>
<tr><td>RL 37</td><td>− 60</td></tr>
<tr><td>RL 2N30</td><td>− 70</td></tr>
<tr><td>RL 2N32</td><td>− 95</td></tr>
<tr><td>RL 5N43</td><td>− 110</td></tr>
<tr><td>RL 9N53</td><td>− 196</td></tr>
<tr><td>RL 9N60</td><td>− 196</td></tr>
<tr><td>$RLPA$</td><td>− 40</td><td rowspan="3">27 min.</td><td rowspan="6">-</td></tr>
<tr><td>$RLPB$</td><td>− 50</td></tr>
<tr><td>$RLPC$</td><td>− 60</td></tr>
<tr><td>RLP 2</td><td>− 70</td><td rowspan="2">34 min.</td></tr>
<tr><td>RLP 3</td><td>− 95</td></tr>
<tr><td>RLP 9</td><td>− 196</td><td>41 min.</td></tr>
</table>

NOTES:
(1) Position of notch as shown in **Fig 2.2.7.**
(2) L(or T) indicates that the direction of welding is transverse (or parallel) to the rolling direction of test materials.
(3) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified average absorbed energy, the test is considered to have failed.
(4) Where requirements in **Pt 7, Ch 5** apply, the impact test temperature is to be as given as follows:
  (a) Impact test temperature for RL 24A through RL 5N43 is to be the lower of the temperatures given in **Table 2.1.18** specified in **Pt 2, Ch 1.**
  (b) Impact test temperature for $RLPA$ through $RLPC$ is to be either 5℃ below the design temperature or -20℃ whichever is the lower.

(3) NDT procedures are to be agreed with the Society. The results of non-destructive testing are to show that there are no cracks or other injurious defects, and acceptance criteria is to be in accordance with the relevant requirements of the relevant Rules.

10. Hardness test

(1) For weldable high strength quenched and tempered steel and hull structural rolled steels with specified minimum yield strength of ReH ≥ 355 N/mm², hardness test(the vickers method Hv10) is to be carried out in accordance with the Guidance relating to the Rules specified by the Society.

(2) The results from the hardness test are not to exceed the following:
- Steel with a specified minimum yield strength ReH ≤ 420 N/mm² : 350 Hv10
- Steel with a specified minimum yield strength 420 N/mm² < ReH ≤ 690 N/mm² : 420 Hv10

405. Tests for fillet welded joints

1. Application

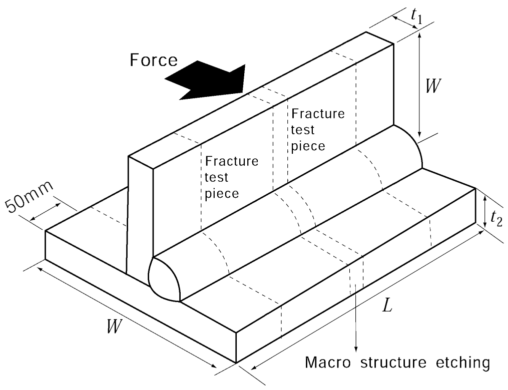
The requirements stated hereunder apply to the fillet joints welded by manual, semi-automatic or automatic welding in any welding position.

2. Kinds of test

Fillet weld joints are to be subjected to visual inspection, surface crack detection, macro-structure inspection, hardness test and fracture test. Additional tests may be required if found necessary by the Society.

3. Test assemblies and welding

(1) Test assembly is to be prepared with the same or equivalent material used in the actual work.
(2) Dimensions and type of test assembly are to be as indicated **Fig 2.2.8.**



NOTES :
1. The length of test specimen is as follows :
   (1) Manual and semi-automatic welding : Width W=3 x t, min.150 *mm*, Length L=6 x t, min.350 *mm*
   (2) Automatic welding : Width W=3 x t, min.150 *mm*, Length L= min.1000 *mm*
2. Thickness of webs and flanges of the test assembly, t_1 and t_2 are to be of ordinary thicknesses used in the actual work.
3. Tack weld may be applied to the test assembly.
4. The fillet length is to be of ordinary length used in the actual work.

Fig 2.2.8 Test assembly for fillet weld joint (unit : mm)

(3) Test assembly is to be welded in the same welding positions as the actual work.
(4) The assembly is to be welded on one side only, except in case deemed necessary by the surveyor.
(5) For single run manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination.

4. Visual inspection

Fillet welding is to have a regular and uniform surface, and is to be free from cracks, undercuts, overlaps and other injurious defects.

5. Non-destructive inspection

(1) Test assemblies are to be examined by visual and by non-destructive testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified non-destructive testing is to be performed after heat treatment.
(2) For weldable high strength quenched and tempered steel with specified minimum yield strength of 420 N/mm^2 and above the non-destructive testing is to be delayed for a minimum of 48 hrs, unless heat treatment has been carried out.
(3) NDT procedures are to be agreed with the Society. The results of non-destructive testing are to show that there are no cracks or other injurious defects, and acceptance criteria is to be in accordance with the relevant requirements of the relevant Rules.

6. Macro-structure inspection

(1) The test specimen is to be taken from the position in **Fig 2.2.8.** However, in case of rolled steels for hull structural, weldable high strength quenched and tempered steel, and aluminium alloy, two specimens are to be taken. For manual welding and semi-automatic welding, one of the macro etched specimens is to be from the stop/restart position, if present.

(2) The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone. Macro examination is to include about 10 mm unaffected base metal.

(3) The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion etc.

7. Hardness test

For weldable high strength quenched and tempered steel and hull structural rolled steels with specified minimum yield strength of ReH ≥ 355 N/mm^2, hardness test(Hv 10) is to be carried out in accordance with the requirement in **404. 10.**

8. Fracture tests

The remaining test assemblies after the macro-structure test specimen has been removed are to be broken by pressing as shown in **Fig 2.2.8** and there shall be no cracks, blow holes, poor penetrations and any other injurious defects in the fractured surface. However, where the sum of lengths having blow holes and poor penetration, except at both ends of the test specimen, is not greater than 10 % of the total welded length, the test may be regarded as satisfactory.

406. Retests and Procedure qualification records(PQR)

1. Retests

(1) Where visual inspection or non-destructive inspection fails to meet the requirements, the new test specimens welded under the same welding condition, are to be subject to retest and all of these test specimens are to pass the test. If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

(2) Where the result of a tensile or bend test does not comply with the requirements, twice as many test specimens as the number of specimens of failed test are to be selected from either the first test material or test materials welded under the same welding conditions, and all of these test specimens are to be satisfactorily tested.

(3) If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

(4) (a) Where the result of the impact test is unsatisfactory, additional tests may be carried out, with the exception of the cases specified in (i) and (ii) below, by taking a set of test specimens out of the same test material from which the above-mentioned test specimens have been taken.

(i) The absorbed energy of all test specimens is under the required average absorbed energy.

(ii) The absorbed energy of two of the test specimens is under 70 % the required average absorbed energy.

(b) In case of the previous (a), the test specimens may be accepted, provided that the average absorbed energy of the six test specimens, including those which have been rejected as unsatisfactory, is not less than the required average absorbed energy, and that not more than two individual results are lower than the required average absorbed energy and of these, not more than one result is below 70 % of the required average absorbed energy.

(5) Where there is insufficient welded assembly remaining to provide additional test specimens, a further assembly is to be welded using the same procedure to provide the additional specimens.

(6) Where the retest fails to meet the requirements, the test may be made over again. In this case, where the whole tests specified on the test assembly are carried out and are complied with requirements, the tests are accepted as successful.

2. Procedure qualification records(PQR)

(1) Three copies of the procedure qualification records showing the welding conditions for test assemblies and test results are to be submitted to the Society for approval. Forms of welding procedure test records are to be at the discretion of the Society.
(2) A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure test. The relevant items listed for the WPS of these requirements are to be included.
(3) A statement that the test piece was made according to the particular welding procedure is to be signed by the Surveyor witnessing the test and is to include the Society´s identification.

407. Validity of qualified welding procedure specification

1. General

(1) Welding procedures qualified at a manufacturer are valid for welding in workshops under the same technical and quality management.
(2) Qualification of a welding procedure remains valid provided the welding variables are kept within the qualified range during production welding. When one or more variables outside the qualified range given in **2.** occur, the welding procedure is to be respecified and requalified by welding procedure qualification tests.
(3) Shop primers may have an influence on the quality of fillet welds and is to be considered. Welding procedure qualification with shop primer will qualify those without but not vice versa.
(4) Validity of welding variables for the welding procedure specification of aluminium alloy is to be in accordance with the Guidance relating to Rules.

2. Validity of variables for qualified WPS is as follows. However, it may be considered as equivalent for the requirements of the standard internationally recognized(*AWS*, *ASME* etc.) are applied.

(1) **Base metal** Kind of base metal and their validity are as follows. Other materials not specified herein is to be in accordance with the requirements of the standard internationally recognized as deemed appropriate by the Society.

(a) **Normal and higher strength hull structural steels**

① Normal strength steel(*A*, *B*, *D* and *E*) or equivalent structural steels with tensile strength 400 ~ 520 N/mm^2.
② Higher strength steels(*AH* 32, *DH* 32, *EH* 32, *FH* 32, *AH* 36, *DH* 36, *EH* 36, *FH* 36, *AH* 40, *DH* 40, *EH* 40 and *FH* 40) or equivalent structural steels with minimum specified yield strength 315 ~ 390 N/mm^2.
③ Weldable high strength quenched and tempered steels (**Pt 2, Ch 1, 308.** of the Rules) or equivalent structural steels with minimum specified yield strength 420~690 N/mm^2.

(i) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.
(ii) For each toughness grade of normal and higher strength hull structural steels, welding procedures are considered applicable to the same and two lower strength levels as that tested.
(iii) For each toughness grade of high strength quenched and tempered steels, welding procedures are considered applicable to the same and one lower strength level as that tested.
(iv) For applying the above (a) and (b) to high heat input processes above 50 kJ/cm, e.g. the two-run technique with either submerged arc or gas shielded metal arc welding, electro slag and electro gas welding, welding procedure is applicable to that toughness grade tested and one strength level below.
(v) The approval of quenched and tempered steels does not quality thermo-mechanically rolled steels (TMCP steels) and vice versa.

(b) **Weldable C and C-Mn hull steel castings** The approval of quenched and tempered hull steel castings does not quality other delivery conditions and vice versa.

(c) **Weldable C and C-Mn hull and general purpose steel forgings** The approval of quenched and tempered hull steel forgings does not quality other delivery conditions and vice versa.
(d) Rolled steels for low temperature service and Steel pipes for low temperature service
(e) Rolled stainless steels and Stainless steel pipes

(2) **Thickness and outer diameter of base metal**

(a) The qualification of a WPS carried out on a plate or pipe test assembly of thickness t is valid for the thickness range given in **Table 2.2.9**

Table 2.2.9 Qualified thickness range for butt, T-joint and fillet welds

Thickness of test piece, t (mm) (1)	Range of approval t(mm)	
	Butt and T-joint welds with single run or single run from both sides	Butt and T-joint welds with multi-run and fillet welds (2)
$t \leq 3$	$0.8t \sim 1.1t$	$t \sim 2t$
$3 < t \leq 12$	$0.7t \sim 1.1t$	$3 \sim 2t$
$12 < t \leq 100$	$0.7t \sim 1.1t$ (3)	$0.5t \sim 2t$ (max.150)
$100 < t$	$0.8t \sim 1.1t$ (3)	$0.5t \sim 1.5t$

Notes ;
(1) For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.
(2) For fillet welds, the range of approval is to be applied to both base metals.
(3) For high heat input processes over 50 kJ/cm, the upper limit of range of approval is to be 1.0 x t.

(b) In addition to the requirements of **Table 2.2.9**, the range of approval of throat thickness "a" for fillet welds is to be as follows:
(i) Single run ; "0.75 x a" to "1.5 x a"
(ii) Multi-run ; as for butt welds with multi-run (i.e. a=t)
(c) The qualification of a WPS carried out on a pipe test assembly is valid for the outer diameter range given in **Table 2.2.10**.

Table 2.2.10 Qualified outer diameter range for pipe welds

Outer diameter D (mm)	Qualified range
$D \leq 168.3$	$0.5D \sim 2D$
$D > 168.3$	$\geq 0.5D$

(d) For the vertical-down welding, the test piece thickness "t" is always taken as the upper limit of the range of application.
(e) For unequal plate thickness of butt welds the lesser thickness is ruling dimension.
(f) Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted, as stated **404. 10** (2) and **405. 7** of the Rules.

(3) **Welding positions**

Approval for a test made in any position is restricted to that position (see **Fig 2.2.9** and **Fig 2.2.10** of the Rules). To qualify a range of positions, test assemblies are to be welded for highest heat input position and lowest heat input position and all applicable tests are to be made on those assemblies.

(4) **Welding process**

(a) The approval is only valid for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run to a single run.

(b) For multi-process procedures the welding procedure approval may be carried out with separate welding procedure tests for each welding process. It is also possible to make the welding procedure test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

(5) **Welding consumables**

(a) Except high heat input processes over 50 kJ/cm, welding consumables cover other approved welding consumables having the same grade mark including all suffixes specified in **Pt 2, Ch 2, Sec 6** of the Rules with the welding consumable tested.

(b) Change in welding consumables specified in **Table 2.2.3**(Application of welding consumables) of **Pt 2, Ch 2** of the Rules.

(c) Change in shielding gas in accordance with **Pt 2, Ch 2, 603. 3** (4) of the Rules.

(6) **Welding condition**

(a) Change from short circuiting transfer to spray arc or pulsed arc or vice versa.

(b) Change of welding voltage, current and/or travel speed are to be at the discretion of the Society.

(c) The minimum preheating temperature is not to be 15℃ less than that used in the qualification. The maximum interpass temperature is not to be 56℃ higher than that used in the qualification

(d) The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

(7) **Heat input**

(a) The upper limit of heat input approved is 25 % greater than that used in welding the test piece or 55 kJ/cm whichever is smaller, except that the upper limit is 10 % greater than that for high heat input processes over 50 kJ/cm.

(b) The lower limit of heat input approved is 25 % lower than that used in welding the test piece.

(8) **Type of joint**

(a) Range of approval depending on type of welded joints for test assembly is to be specified in **Table 2.2.11**

(b) A qualification test performed on a butt weld will also qualify for fillet welding within the thickness ranges specified for fillet welds specified in (2) (a) above.

Table 2.2.11 Range of approval for type of welded joint

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing	A	A, C, D
		Without backing	B	A, B, C, D
	Both side	With gouging	C	C
		Without gouging	D	C, D

(c) Change of specified type of joint which may significantly affect penetration and fusion etc, of the weld. However decrease in the groove angle, decrease in the root opening or increase in root face is to be as deemed appropriate by the Society.

(9) **Others** The Validity relating to the welding variables other than previous (1) to (8) may comply with the requirements of the internationally recognized Code (*AWS, ASME, ISO, EN* etc.)

3. For changes other than previous **2**, the welding procedure qualification test may be dispensed with. In this case, the welding procedure specification to which the related procedure qualification record(PQR) is attached is to be requalified.

SECTION 5 Welders and Welder Performance Qualification Tests

501. General

1. Each welder intended to engage in the manual and semi-automatic welding work specified in this Section is to pass the performance qualification tests required according to the applicable welding process, welding position and kinds of materials to be welded and to have the performance qualification by the Society.

2. Welders engaged in tack welding should be qualified for either butt welds or fillet welds, for the welding process and the position corresponding to the joint to be welded. If requested, the Society may qualify those welders engaged in tack welding works only in accordance with the Guidance in relating to Rules.

3. Welding operators intended to engage in automatic welding work are to be those skillful for the actual welding work in which they will engage. If requested, the Society may qualify those welding operators engaged in automatic welding works only in accordance with the Guidance in relating to Rules.

4. The performance qualification test of welder intended to engage in the special material and welding work not prescribed in this Section are to be at the discretion of the Society.

5. The application of more suitable requirements instead of the requirements of this Section is left to the discretion of the Society.

502. Grades, and range of qualification

1. A welder should be qualified in relation to the variables such as base material, welding process, type of welded joint, plate thickness and welding position.

2. Welding processes

(1) The welding processes for welder''s qualification are to be classified in **Table 2.2.12-1.**

Table 2.2.12-1 Welding processes for welder''s qualification

Symbol	Welding process in actual welding works	
M	Manual welding	Shield Metal Arc Welding(SMAW)
S	Semi-automatic welding	(1) Flux Cored Arc Welding(FCAW) (2) Gas Metal Arc Welding(GMAW)
T	TIG welding	Gas Tungsten Arc Welding(GTAW)

(2) A welder intended to engage in the multi-process welding work is to pass the separate performance qualification tests for each welding process.

3. Types of welded joint

(1) The types of welded joint for welder's qualification are to be classified as shown in **Table 2.2.12-2** in accordance with the qualification test.
(2) A qualification test performed using butt welds automatically qualifies fillet welding.
(3) The Society may qualify the welders who are employed to perform fillet welding only. However, where such welders are engaged to weld fillet with groove they are to be qualified for butt welds.

Table 2.2.12-2. Types of welded joint for welder's qualification

Type of welded joint used in the test assembly for the qualification test(1)				Type of welded joint qualified
Butt weld	Single sided weld(2)	With backing	WB	WB, FW
		Without backing	NB	WB, NB, FW
Fillet weld		-	FW	FW

NOTES:
(1) A qualification test performed using butt weld test assembly for pipes automatically qualifies butt weld test for plates.
(2) A qualification test performed using single sided weld automatically qualifies double sided weld.

4. Base materials

(1) Base materials for qualification tests are grouped as follows;
  (a) Carbon and low alloy rolled steels, tubes and pipes, castings and forgings
  (b) Stainless rolled steels, tubes and pipes, castings and forgings
  (c) Aluminium alloy
  (d) Copper alloy castings
(2) A welder passed the qualification test with certain material in specific material group may be accepted to weld other materials in same material group.
(3) For welding with materials in different material groups, qualification approval may be carried out with separate qualification test for each material.

5. Thickness and outer diameter of base metal

(1) The welder qualification carried out on a plate or pipe test assembly of thickness T is valid for the thickness range given in **Table 2.2.13-1**

Table 2.2.13-1 Qualified thickness range for welder qualification

Grade	Thickness of test assembly, T(mm)	Qualified thickness range t(mm)
1	$T \leq 3$	$T \leq t < 2T$
2	$3 < T \leq 20$	$3 < t \leq 2T$
3(1)	$20 < T$	$5 < t$
3R	$12.5 < T$	$5 < t$

Note
(1) For aluminium alloy, the upper limit of qualified thickness range is to be 40mm. For aluminium alloy with thickness over 40mm, additional tests may be carried out as deemed necessary by the Society.

(2) The welder qualification carried out on a pipe test assembly is valid for the outer diameter range given in **Table 2.2.13-2.**

Table 2.2.13-2 Qualified outer diameter range for pipe welds

Grade	Outer diameter *D* (mm)	Qualified range
1	$D \leq 25$	D～2D
2	$25 < D \leq 150$	0.5D～2D(Min. 25mm)
3	$150 < D$	$\geq 0.5D$
3R(T, K and Y Joint)	$150 < D$	≥ 100mm

Note;
(1) Test assemblies for the pipes over 500 mm in diameter may be those for the plates.

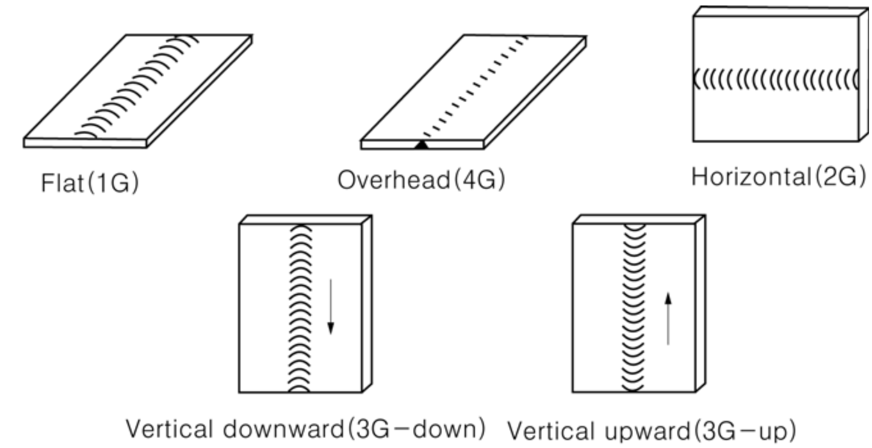
6 Positions

The positions for qualification test and positions qualified for actual welding work are to comply with the **Table 2.2.14.**

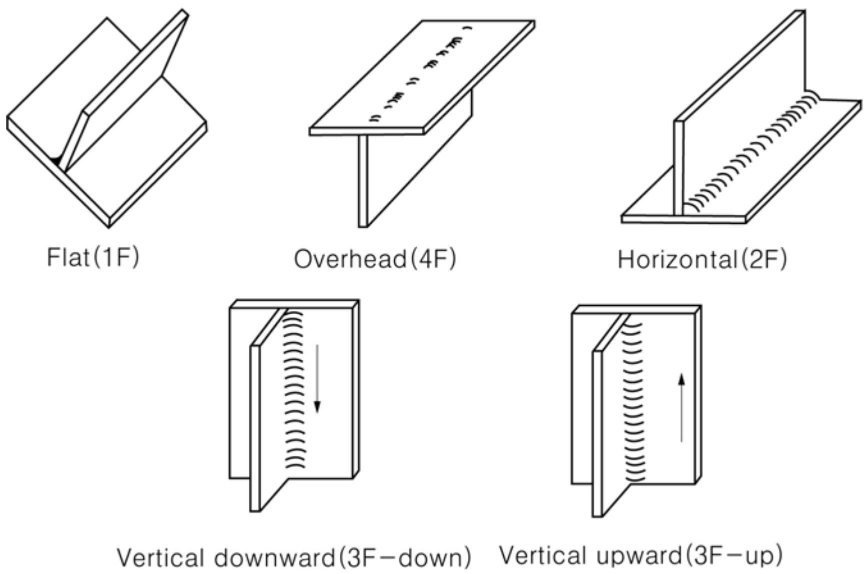
Table 2.2.14 Welding Positions for Welder Qualification

Grade	Test Positions(1)		Welding positions in actual welding work(2)			
			Plates		Pipes	
			Butt joint	Fillet joint	Butt joint	Fillet joint
For each grade of plates	Flat	1G	F	F, H	F(3)	F, H
		1F	-	F	-	F
	Horizontal	2G	F, H	F, H	F, H(3)	F, H
		2F	-	F, H	-	F, H
	Vertical-upward	3G-up	F, H, VU	F, H, VU	F, H, VU(3)	F, H, VU
		3F-up	-	F, H, VU	-	F, H, VU
	Vertical-downward	3G-down	F, VD	F, VD	-	-
		3F-down	-	F, VD	-	-
	Overhead	4G	F, H, OH	F, H, OH	F, OH(3)	F, H, OH
		4F	-	F, H, OH	-	F, H, OH
	3G-up+4G		All	All	All(3)	All
For each grade of pipes(7)	Horizontal-rolled	1G-P	F	F	F	F, H
		1F-P	-	F	-	F
	Vertical-fixed	2G-P	F, H	F, H	F, H	F, H
		2F-P	-	F, H	-	F, H
	Horizontal-fixed	5G-P	F, V, OH	F, V, OH	F, V, OH	F, V, OH
		5F-P	-	F, V, OH	-	F, V, OH
	Vertical-fixed+Horizontal-fixed (2G-P)+(5G-P)		All	All	All	All
	Inclined-fixed	6G-P	All	All	All	All
		6F-P	-	All	-	All
	Inclined-fixed with restriction ring (6GR-P)(4)		All	All	All	All

NOTES:
(1) Test positions are to comply with **Fig 2.2.9** and **Fig 2.2.10.**
(2) F=Flat, VU=Vertical-Up, VD=Vertical-Down, H=Horizontal, OH=Overhead
(3) Only qualified for pipe over 600 mm in diameter with backing strips or back gouging.
(4) Test in the 6GR-P position qualify welding in T, K & Y connection(Grade 3R) and welds with restricted access.



(a) Butt welds



(b) Fillet welds

Fig 2.2.9 Welding position of plates

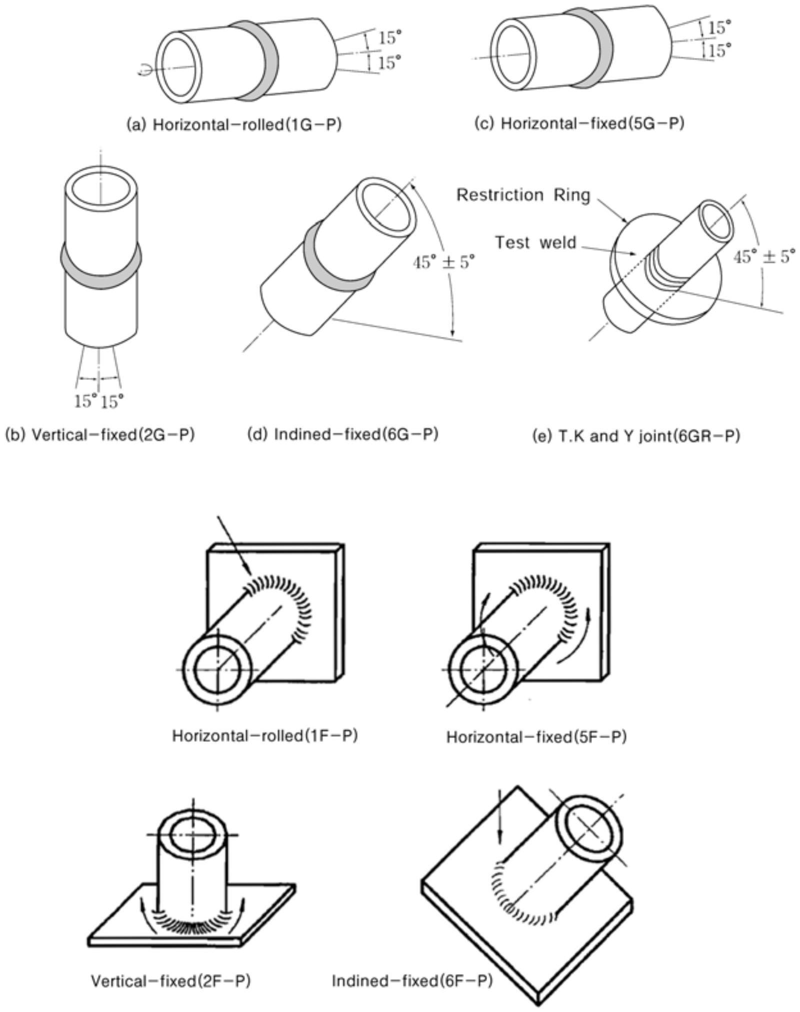


Fig 2.2.10 Welding position of pipes

503. Testing procedure

1. General

(1) Test assemblies may be welded with either alternating current or direct current.
(2) The test assemblies are not to be changed their up-and-down or right-and-left position throughout the welding operation.
(3) The welding is to be carried out only on one side and the back welding is not to be carried out unless specified otherwise.
(4) In general, the test assemblies for plates are to be so restrained or prestrained that the warping due to the welding does not exceed an angular distortion of 5 degrees.
(5) The test assemblies are not to be subjected to peening or heat treatment throughout the period before, during and after the welding.
(6) The backing strips of the test assemblies may be used steel plates, copper plate, ceramic or similar materials to obtain the enough penetration.
(7) Welding of the test assemblies and testing of test specimens should be witnessed by the Surveyor.

2. Test assemblies

(1) Test assemblies for butt welds and for fillet welds are to be prepared as shown in **Fig 2.2.11** to **Fig 2.2.15** in each qualification test.
(2) Materials used for tests are to be those specified in **502. 4** or those which are considered

equivalent by the Society.

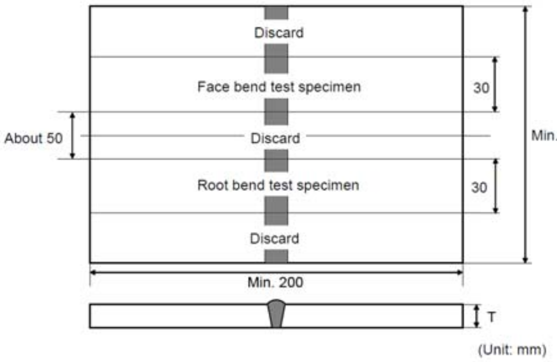


Fig 2.2.11 Dimensions and types of test assembly for butt welds

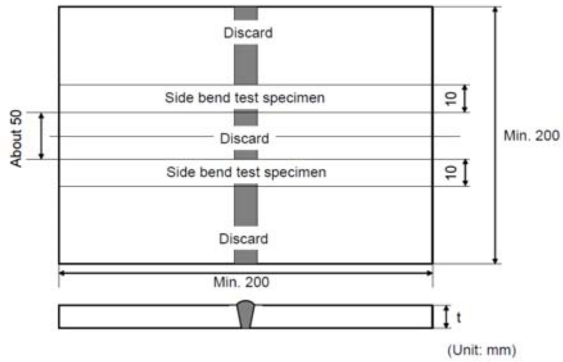


Fig 2.2.12 Dimensions and types of test assembly for butt welds(T≧12mm)

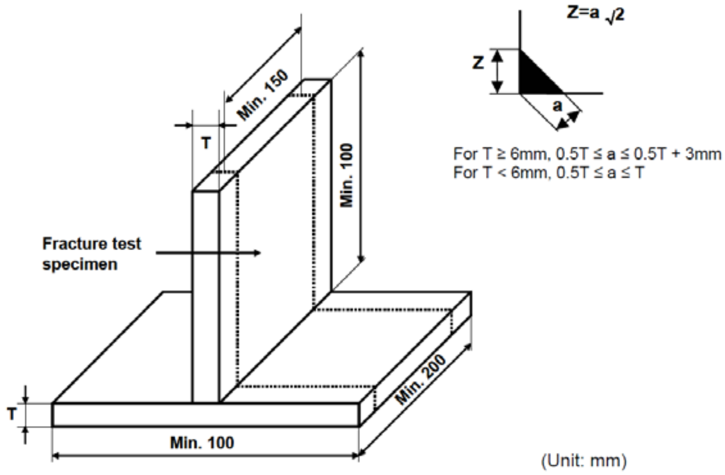


Fig 2.2.13 Dimensions and types of test assembly for fillet welds

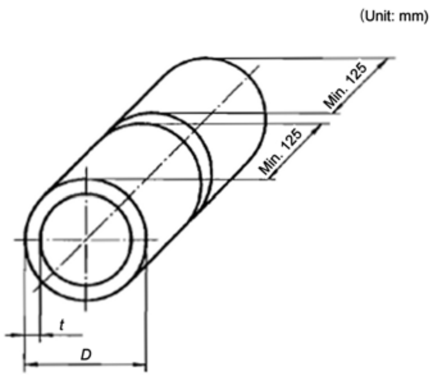


Fig 2.2.14 Dimensions and types of test assembly for pipe butt welds

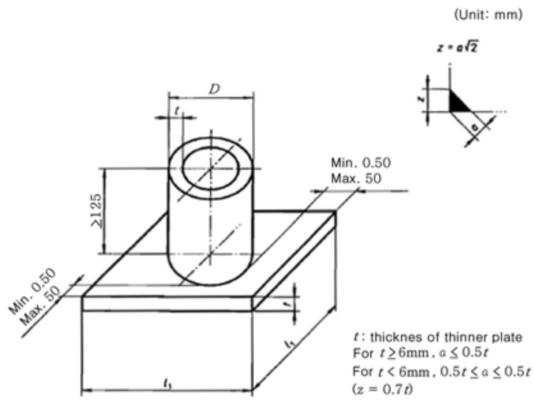


Fig 2.2.15 Dimensions and types of test assembly for pipe fillet welds

(3) The dimensions and types of welded joint are to be as indicated in **Fig 2.2.16** and **Fig 2.2.17** or those which are considered equivalent by the Society.

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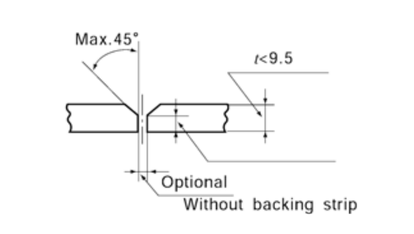
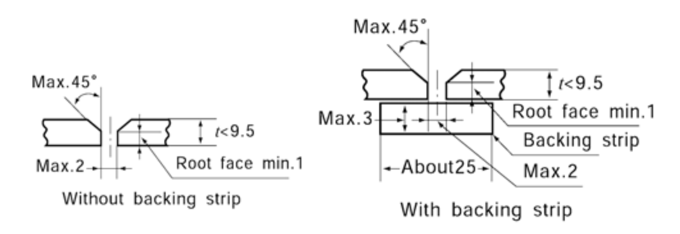
<tr><td>Grade 1</td><td>
</td><td>
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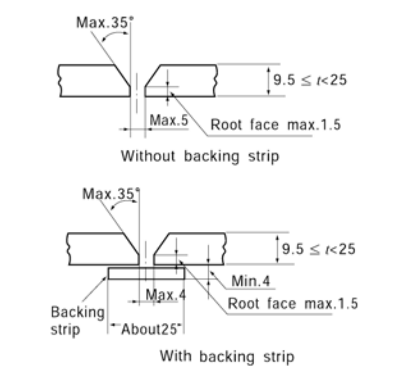
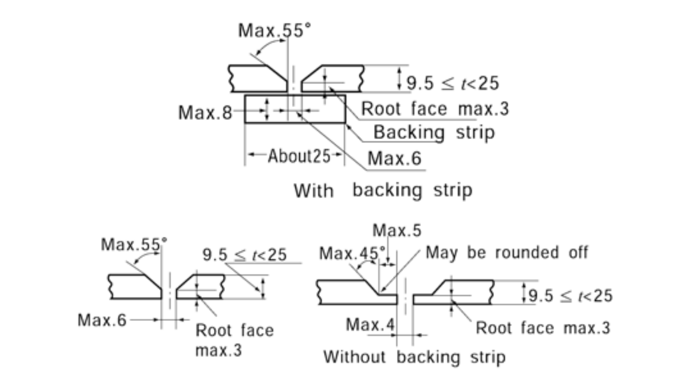
<tr><td>Grade 2</td><td>
</td><td>
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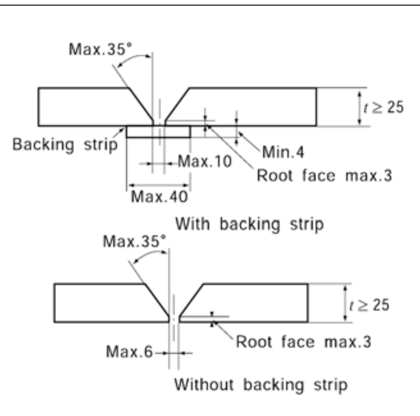
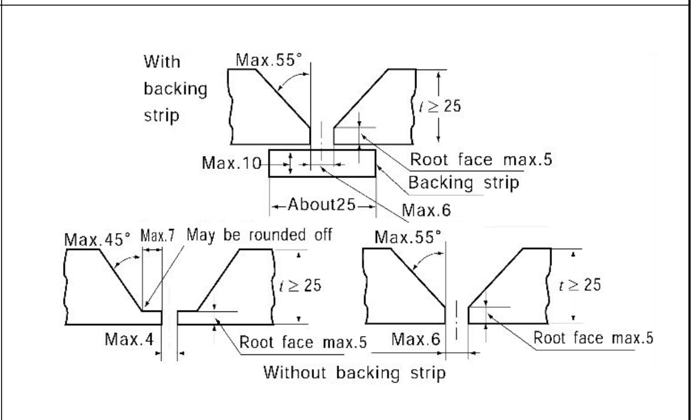
<tr><td>Grade 3</td><td>
</td><td>
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Fig 2.2.16 Dimensions and types of welded joint-plates

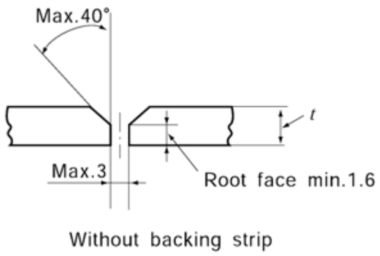
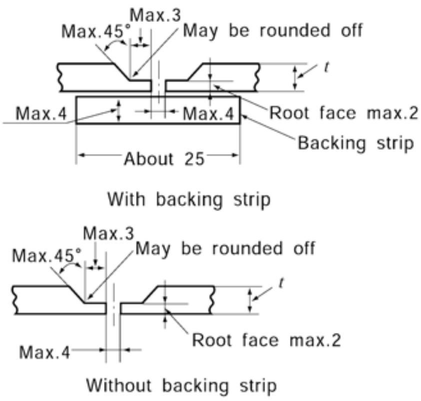
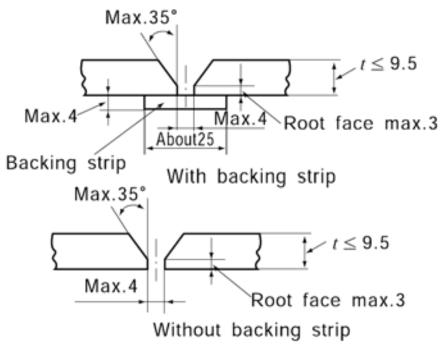
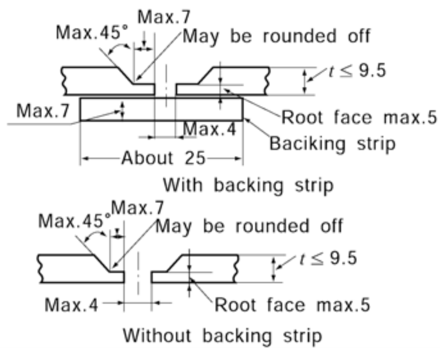
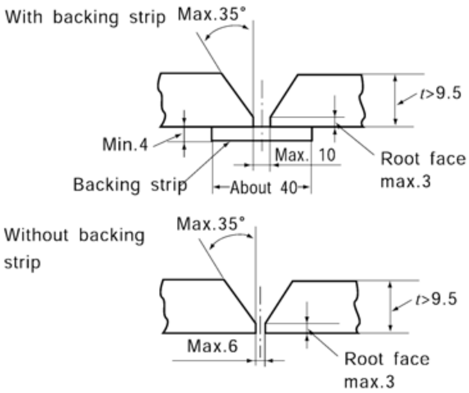
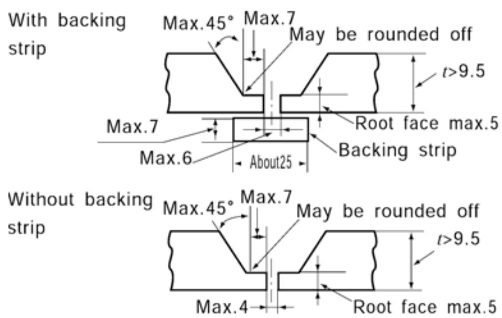
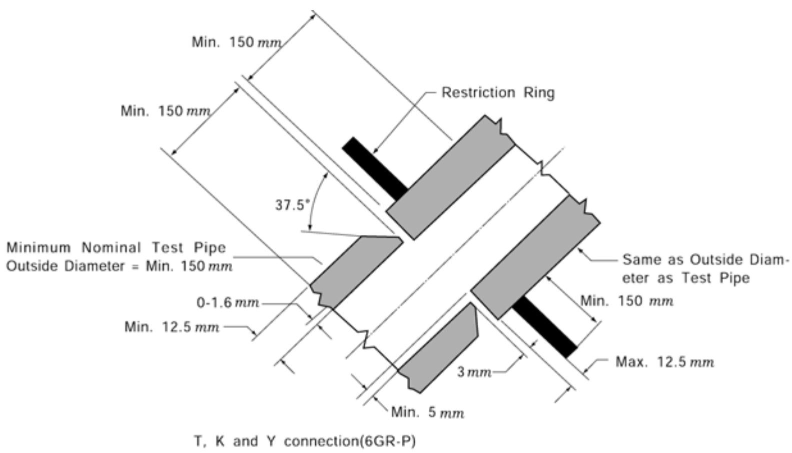
Materials	Mild steel and stainless steel	Aluminium alloy
Grade 1		
Grade 2		
Grade 3		
Grade 3R		

Fig 2.2.17 Dimensions and types of welded joint-pipes

(4) Welding consumables used in qualification tests should be type approved one or those which are considered equivalent by the Society.

3. Examination and test

(1) Examination and test are as specified in **Table 2.2.15.**

Table 2.2.15. Examination and test for Welder Qualification

Kinds	Examination and test(3)
Butt welds	Visual inspection, Bend test(1)
Fillet welds	Visual inspection, Fracture test(2)

NOTES
(1) Radiographic test may be carried out in lieu of bend test.
(2) Two macro sections may be taken in lieu of the fracture test.
(3) Additional tests may be required, at the discretion of the Society

(2) **Visual examination**
(a) The welds should be visually examined prior to the cutting of the test specimen for the bend test.
(b) The result of the examination is to show the absence of cracks or other serious imperfections. Imperfections detected are to be assessed in accordance with quality **level B** in **KS B ISO 5817**, except for imperfection typea such as excess weld metal, excess penetration, excessive convexity and excessive throat thickness for which level C applies

(3) **Bend test**
(a) One face bend test and root bend test specimen are to be tested. For thickness 12 mm and over, two side specimens may be tested as an alternative.
(b) Bend test specimens are to be of size and dimensions given in **Table 2.2.2** according to the kind of test assemblies.
(c) The mandrel diameter to thickness ratio (i.e. D/t) is to be that specified in each article of **Pt 2, Ch 2, Sec 6** of the Rules +1 except for aluminium alloy for which requirements in **Table 2.2.64** of **Pt 2, Ch 2, 608** of the Rules applies
(d) The test specimens are to be bent through 180 degrees. After the test, the test specimens should not reveal any open defects in any direction greater than 3mm. Defects appearing at the corners of a test specimen during testing should be investigated case by case.

(4) **Radiographic test**
When radiographic testing is used in lieu of bend test, test procedures and acceptance criteria are to be in accordance with the Guidance in relating to Rules.

(5) **Fracture test (Fillet welds)**
(a) The fracture test of fillet welds is to be carried out in accordance with the requirements specified in **Pt 2, Ch 2, 405. 8** of the Rules
(b) Evaluation should concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected should be assessed in accordance with **KS B ISO5817**, class B.

(6) **Macro examination**
When macro examination is used for fillet welds, examination procedures and acceptance criteria are to be as follows;
(a) The macro examination of fillet welds is to be carried out in accordance with the requirements specified in **Pt 2, Ch 2, 405. 6** of the Rules
(b) The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone.
(c) Macro sections should include about 10mm of unaffected base metal.
(d) The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion etc.

4. Retest

(1) When a welder fails a qualification test, the following should apply.

(a) For the welder who fails to meet the requirements in a part of the tests, the retests as to the failed tests may be made on duplicate test specimens from the test assemblies welded within 1 month from the date of the failure and the welder may be treated to have passed the requirements where all test specimens fully comply with the test requirements.
(b) In cases where the welder fails to meet the requirements in all parts of the required tests or in the retest prescribed in (a) above, the welder should undertake further training and practice.

(2) Where any test specimen does not comply with dimensional specifications due to poor machining, a replacement test assembly should be welded and tested.

5. Certification

(1) Qualification certificates are normally issued to the applicants(shipbuilder or manufacturer) when the welder has passed the qualification test by the Society.
(2) The following items should be specified in the certificate:
(a) Range of qualification for materials, welding processes, types of welded joint, plate thicknesses and welding positions;
(b) Expiry date of the validity of the qualification;
(c) Name, date of birth, identification and the photograph of the welder;
(d) Name of shipbuilder / manufacturer.

6. General requirements for qualification validity

(1) Each shipyard and manufacturer should be responsible for the employment, training, testing, control of the validity of the certificate and the range of the approval of the welders.
(2) Where welder has not engaged in a particular process and equipment for a period exceeding six months, his qualification is automatically withdrawn. All the following conditions are fullfilled for maintaining welder's qualification.
(a) The welder should be engaged with reasonable continuity on welding work within the current range of approval. The welder's work should in general be in accordance with the technical conditions under which the approval test is carried out.
(b) The qualification validity of welder is to be confirmed at six-month intervals by the shipyards/manufacturers responsible for weld quality.
(c) The status of approvals of each individual qualification is to be demonstrated to the Classification Society when requested.

(3) The welder failed to meet the required qualify of the Society in welding work may be suspended his qualification.

SECTION 6 Welding Consumables

601. General

1. Application

(1) The covered electrodes for manual welding and gravity welding, wire/flux combinations for two run or multirun submerged arc welding, solid wire/gas combinations for arc welding, flux cored wires with or without gas for arc welding and consumables for use in electroslag and electrogas vertical welding specified in the Rules are to be approved by the Society in accordance with the requirements in this Section.
(2) The welding consumables which are used in welding processes differing from those specified in (1) or where it is considered impracticable to apply the requirements in this Section are to be of the type approved by the Society.
(3) The approval test for welding consumables which are not covered by this Section is to be left to the discretion of the Society.

2. Process of manufacture

The approved welding consumables are to be manufactured of uniform quality, under the manufacturer's responsibility, by the process approved by the Society, at works approved by the Society.

3. Test assemblies

(1) The test assemblies are to be prepared under the supervision of the Surveyor, and all tests are to be carried out in his presence.
(2) When a welded joint is performed, the edges of the plates are to be bevelled either by mechanical machining or by oxygen cutting; in the later case, a descaling of the bevelled edges is necessary.
(3) The welding conditions used such as amperage, voltage, travel speed, etc are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler material is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.

4. Approval test

(1) The approved welding consumables are subject to the approval tests and inspections specified in **602.** to **609.** in this Section.
(2) Welding consumables are to be approved at each manufacturing plant and for each brand. However, where are specified in (a) and/or (b) below, a reduced test programme at least equivalent to annual tests is permitted if the manufacturer can certify that the materials used and the fabrication process are identical with those used in the main works. However, should there be any doubt, complete test-series may be required.
   (a) Where welding consumables which have been approved are intended to manufacture at manufacturing plants other than those of the manufacturers who manufacture the said welding consumables.
   (b) Where welding consumables which have been approved are intended to manufacture according to technical licensing agreements with those parties who manufacture the said welding consumables.
(3) Wire flux combination for submerged arc welding. If a unique powder flux is combined with different wires coming from several factories belonging to the same firm, it may be admitted to perform only one test-series if the different wires are conformable to the same technical specification, after approval of the Society.
(4) Where deemed necessary by the Society, tests other than those specified in this Section may be required.

5. Periodical inspection

The manufacturer of welding materials is to be subjected to the periodical inspection in the presence of Surveyor for each brands of the welding materials at each manufacturing plant in a period not exceeding 12 months.

6. Alterations to approved consumables

(1) In case when the particulars of the welding materials which being mentioned in the certificate

of approval, such as grade, welding position, maximum diameter of welding materials or shield gas, are changed, the manufacturer is to submit a copy of application form for change to the Society, and necessary additional approval tests are to be carried out accordingly.

(2) When the significant changes in compositions or manufacturing process of the wire and flux or removal of manufacturing plant is made, the manufacturer is to submit a single copy of notification of alternation in any preferred form to the Society, and necessary confirmation survey and test may be carried out accordingly.

(3) Upgrading and uprating of welding consumables will be considered only at manufacturer's request, preferably at the time of annual testing. Generally, for this purpose, tests from butt weld assemblies will be required in addition to the normal annual approval tests..

7. Retests

(1) *Tensile test and bend test*

(a) Where the tensile test and bend test fail to meet the requirements, twice as many test specimens as the number of specimens of failed test are to be selected from the first test material or from a test material welded under the same welding conditions, and if all of test specimens pass the tests, then the tests are considered to be successful.

(b) Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch.

(c) If the new assembly is made with the same procedure (particularly the number of runs) as the original assembly, only the duplicate re-test specimens needs to be prepared and tested. Otherwise, all test specimens should be prepared as for re-testing.

(2) *Impact test*

(a) Where the result of the impact test is unsatisfactory, additional tests may be carried out, with the exception of the cases specified in (i) and (ii) below, by taking a set of test specimens out of the same test material from which the above-mentioned test specimens have been taken.

(i) The absorbed energy of all test specimens is under the required average absorbed energy.

(ii) The absorbed energy of two of the test specimens is under 70 % the required average absorbed energy.

(b) In case of the previous (a), the test specimens may be accepted, provided that the average absorbed energy of the six test specimens, including those which have been rejected as unsatisfactory, is not less than the required average absorbed energy, and that not more than two individual results are lower than the required average absorb energy and of these, not more than one result is below 70 % of the required average absorbed energy.

(3) Where the retest fails to meet the requirements, the test may be made over again with changed welding conditions. In this case, if the whole tests specified for the test assembly are carried out and are in compliance with the requirements, the test is accepted as successful.

8. Revocation of approval

In the following cases, the approval of welding consumables by the Society shall be revoked, after notice is given to the manufacturer:

(1) When the Society has recognized that the quality is remarkably worse than that approved or is not uniform.

(2) When the welding consumables have failed the requirements in the annual inspections.

(3) When the welding consumables are not inspected annually as required by the Rules.

9. Data

The Society may require the submission of the data with respect to the properties of welding consumables if necessary.

10. Packings and markings

(1) The approved welding consumables are to be packed throughly to keep the quality during their transportation and storage.

(2) All packages of approved welding consumables are to clearly marked with the following descriptions together with the approved mark of the Society.

(a) Brand

(b) Name of manufacturer

(c) Kind of gas if used
(d) Grade or mark of welding consumables
(e) Electric current and its polarity
(f) Welding positions
(g) Date and number of production
(h) Sizes (diameter of core wire, length of elect rode, grain size of flux for submerged arc welding, etc.)
(i) Special notices on the treatment

602. Electrodes for manual arc welding for normal strength steels, higher strength steels and steels for low temperature service

1. Application

(1) Electrodes for manual arc welding for normal strength steels, higther strength steels and steels for low temperature service given in the following (a) and (b) (hereinafter referred to as "electrodes") are to be subjected to the approval test and annual inspections in accordance with the requirements in **602.**
(a) Electrodes for manual welding
(i) For butt welds
(ii) For fillet welds
(iii) For both butt welds and fillet welds
(b) Electrodes used in gravity welding or similar set-ups
(i) For fillet welds
(ii) For both butt welds and fillet welds
(2) Any requirements regarding one side welding without backing are left to the discretion of the Society.

2. Grades and marks of electrode

(1) Electrodes are classified as specified in **Table 2.2.16.**

Table 2.2.16 Grades and Marks

For normal strength steel	For higher strength steel	For steel for low temperature service
1, 2, 3	2*Y*, 3*Y*, 4*Y*, 5*Y*, 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40	*L* 1, *L* 2, *L* 3, *L* 91, *L* 92

(2) For low hydrogen electrodes which have passed the hydrogen test specified in **Par 6,** the suffixes given in **Table 2.2.22** are to be added to the grade marks of the said electrodes. (e.g. 2*Y H*5)

3. General provisions for tests

(1) Kinds of test, number, thickness and dimension of test assemblies, diameter of electrodes used for welding, welding positions, grades and number of test specimens to be taken from each test assembly for electrodes given in **Par 1** (1) (a) (i) and (iii) are to be as given in **Table 2.2.17.** However, where deemed necessary by the Society, hot cracking tests may be required by the Society in addition to tests specified in this Table.
(2) Kinds of test, number, thickness and dimension of test assemblies, diameter of electrodes used for welding and welding positions, together with grades and number of test specimens to be taken from each test assembly for electrodes given in **Par 1** (1) (a) (ii), are to be as given in **Table 2.2.18.**
(3) Tests for electrodes given in **Par 1** (1) (b) are to be in accordance with the requirements in the following (a) and (b):
(a) For electrodes given in **Par 1** (1) (b) (i), tests given in **Table 2.2.18** specified in the preceding (2) are to be conducted.
(b) For electrodes given in **Par 1** (1) (b) (ii), tests specified in the preceding (a) and butt weld test given in **Table 2.2.17** specified in the preceding (1) are to be conducted.

Table 2.2.17 Kinds of Test for Electrode

Kind of test	Test assembly					Kind and No. of test specimens taken from test assembly
	Welding position	Diameter of electrode (mm)	No. of test assemblies	Dimensions of test assembly	Thickness (mm)	
Deposited metal test	Flat	4	1(1)	**Fig 2.2.18**	20	Tensile test specimen : 1 Impact test specimen : 3
		max. diameter	1(1)			
Butt weld test	Flat	First run. 4; Subsequent runs:5 or over; Last two runs. max. dia.	1	**Fig 2.2.20**	15~20	Tensile test specimen : 1 Face bend specimen : 1 Root bend specimen : 1 Impact test specimen : 3(5)
		First run. 4; Second run,5 or 6; Subsequent runs. max. dia.	1(2)			
	Horizontal (4)	First run. 4 or 5 Subsequent runs, 5	1			
	Vertical upward	First run. 3.2; Subsequent runs. 4 or 5	1			
	Vertical downward	(3)	1			
	Overhead	First run. 3.2; Subsequent runs. 4 or 5	1			
Fillet weld test(6)	Horizontal -Vertical	One side; max. dia. The other side; min. dia.	1	**Fig 2.2.21**	20	Macro structure test specimen : 3(8) Hardness test specimen : 3(8) Fracture test specimen : 2
Hydrogen test(7)	Flat	4	4	(9)	12	Hydrogen test specimen : 1

NOTES:
(1) Where the diameter of the manufactured electrodes is of one type, there is to be one test assembly.
(2) Where the tests are conducted solely in the downhand position, this test assembly has been added.
(3) Electrodes with diameters specified by the manufacturers are to be used.
(4) For electrodes which have passed butt weld tests in the downhand and vertical upward positions, test in the horizontal position may be omitted subject to approval by the Society.
(5) Impact tests are not to conduct for overhead welds.
(6) This test is added solely for electrodes used in both butt welds and fillet welds.
(7) This test is to conduct solely for low hydrogen electrodes.
(8) Test specimens used in macro structure test and hardness tests are considered to be the same.
(9) Dimensions of test assembly are to be as specified in **602. 6**.

(4) Where electrodes are intended to be used for both items specified in **Par 1** (1) (a) and (b), approval tests required for each electrode are to be conducted. However, deposited metal tests may be omitted for electrodes given in **Par 1** (1) (b).
(5) Steel plates to be used in preparation of test assemblies are to be as given in **Table 2.2.19** according to the grades of electrode.
(6) The welding conditions used such as amperage, voltage, travel speed, etc. are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.
(7) For the approval of electrodes, the tests specified in the preceding (1) to (4) are to be conducted for each brand of electrodes.
(8) After welding, the test assemblies are not to be subjected to any heat treatment.

Table 2.2.18 Kinds of Test for Electrode

<table>
<tr><th rowspan="2">Kind of test</th><th colspan="5">Test assembly</th><th rowspan="2">Kind and No. of test specimens taken from test assembly</th></tr>
<tr><th>Welding position</th><th>Diameter of electrode (mm)</th><th>No. of test assemblies</th><th>Dimensions of test assembly</th><th>Thickness (mm)</th></tr>
<tr><td rowspan="2">Deposited metal test</td><td rowspan="2">Flat</td><td>4</td><td>1</td><td rowspan="2">Fig 2.2.18</td><td rowspan="2">20</td><td rowspan="2">Tensile test specimen : 1
Impact test specimen : 3</td></tr>
<tr><td>max. diameter</td><td>1</td></tr>
<tr><td rowspan="5">Fillet weld test</td><td>Flat</td><td rowspan="5">One side; max. dia. The other side; min. dia.</td><td>1</td><td rowspan="5">Fig 2.2.20</td><td rowspan="5">20</td><td rowspan="5">Macro structure test specimen : 3(1)
Hardness test specimen : 3(1)
Fracture test specimen : 2</td></tr>
<tr><td>Horizontal-vertical</td><td>1</td></tr>
<tr><td>Vertical upward</td><td>1</td></tr>
<tr><td>Vertical downward</td><td>1</td></tr>
<tr><td>Overhead</td><td>1</td></tr>
<tr><td>Hydrogen test(2)</td><td>Flat</td><td>4</td><td>4</td><td>(3)</td><td>12</td><td>Hydrogen test specimen : 1</td></tr>
<tr><td colspan="7">NOTES:
(1) Test specimens used in macro tests and hardness tests are considered to be the same.
(2) This test is to conduct solely for low hydrogen electrodes.
(3) Dimensions of test assembly are to be as specified in 602. 2. 6.</td></tr>
</table>

Table 2.2.19 Grade of Steels used for Test Assembly

Grade of electrode	Grade of steels used for test assembly(1)(2)
1	*A*
2	*A*, *B* or *D*
3	*A*, *B*, *D* or *E*
2*Y*	*AH* 32, *AH* 36, *DH* 32 or *DH* 36
3*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32 or *EH* 36
4*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
5*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
2*Y*40	*AH* 40 or *DH* 40
3*Y*40	*AH* 40, *DH* 40 or *EH* 40
4*Y*40	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
5*Y*40	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
L 1	*E* or *RL* 24*A*
L 2	*E*, *RL* 24*A*, *RL* 24*B*, *RL* 27 or *RL* 33
L 3	*RL* 27, *RL* 33 or *RL* 37
L 91	*RL* 9*N*53 or *RL* 9*N*60
L 92	*RL* 9*N*53 or *RL* 9*N*60

NOTES:
(1) Notwithstanding the requirements in this Table normal strength or higher strength steel may be used for the deposited metal test assembly. In this case, test assemblies of grade *L* 91 and *L* 92 are to be appropriately buttered.
(2) The tensile strength of higher strength steels *AH* 32, *DH* 32 *EH* 32, and *FH* 32 used in butt weld test assemblies is to be greater than 490 N/mm^2.

(9) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

4. Deposited metal test

(1) *Welding of deposited metal test assemblies*
  (a) Test assembly as shown in **Fig 2.2.18** is to be welded in the downhand position according to the normal practice.
  (b) The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of each run is to alternate from each end of the plate, each run of weld metal being not less than 2 mm but not more than 4 mm thick.
  (c) After each run, the test assembly is to be left in still air until it has cooled to less than 250℃ but not below 100℃, the temperature being taken at the centre of the weld on the surface of seam.

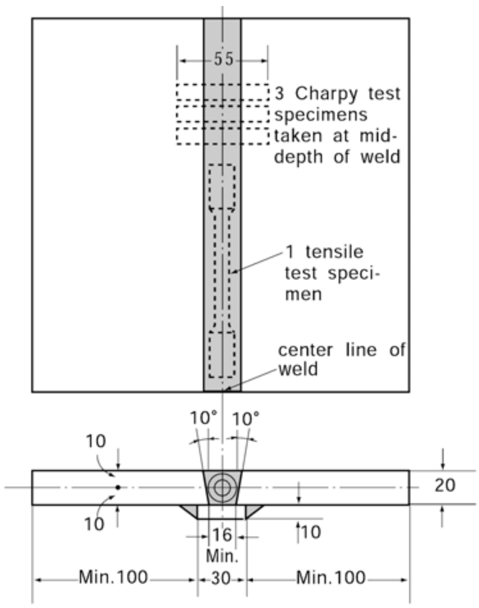


Fig. 2.2.18 Deposited Metal Test Assembly for Electrode for Manual Arc Welding (unit : *mm*)

(2) *Chemical analysis*
The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying element.

(3) *Deposited metal tensile test*
  (a) The tensile test specimen, one from each test assembly, is to be machined to dimensions R14A test specimen as shown in **Table 2.2.1**, care being taken that the longitudinal axis coincides with the centre of weld and the mid-thickness of plates.
  (b) The tensile test specimen may be subjected to a temperature not exceeding 250 ℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.
  (c) The tensile strength, yield strength and elongation of each test specimen are to comply with the requirements given in **Table 2.2.20**, where the upper limit of tensile strength is exceeded, special consideration will be given to the approval of the electrode, taking into consideration of the other mechanical properties shown in the test results and the chemical composition of deposited metal.

(4) *Deposited metal impact tests*
  (a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions charphy V-notch impact test specimen as shown in **Table 2.1.3.** The test specimen is to be cut with its longitudinal axis transverse to the direction of welding, and the test specimen is to coincide with the mid-thickness of the plate shown in Fig **2.2.19.**
  (b) The notch is to be positioned in the centre of weld and is to be cut in the face of test specimens perpendicular to the surface of plate.

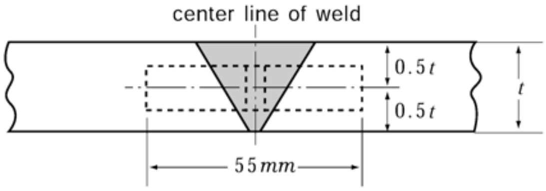


Fig 2.2.19 Position of Butt Weld Impact Test Specimen
(Unit : mm, t : plate thickness)

(c) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.20.**

Table 2.2.20 Tensile and impact Test Requirements for Deposited Metal

Grade of electrode	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)	Impact test	
				Test temp. (℃)	Average absorbed energy(J)
1	400 ~ 560	305 min.	22 min.	20	47 min.
2				0	
3				-20	
2*Y*	490 ~ 660	375 min.	22 min.	0	
3*Y*				-20	
4*Y*				-40	
5*Y*				-60	
2*Y*40	510 ~ 690	400 min.	22 min.	0	
3*Y*40				-20	
4*Y*40				-40	
5*Y*40				-60	
L 1	400 ~ 560	305 min.	22 min.	-40	34 min.
L 2	440 ~ 610	345 min.	22 min.	-60	
L 3	490 ~ 660	375 min.	21 min.	-60	
L 91	590 min.	375 min.(1)	25 min.	-196	27 min.
L 92	660 min.	410 min.(1)	25 min.	-196	

NOTE:
(1) 0.2 % Yield strength

(d) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

5. Butt weld test

(1) *Welding of butt weld test assemblies*

(a) Test assembly as shown in **Fig 2.2.20** is to be welded in each welding position (flat, horizontal-vertical, vertical-upward, vertical downward and overhead) which is recommended by the manufacturer, according to the normal practice.

(b) Test assembly is to be left in still air until it has cooled to less than 250℃ but not below 100℃, the temperature being taken at the centre of the weld on the surface of seam.

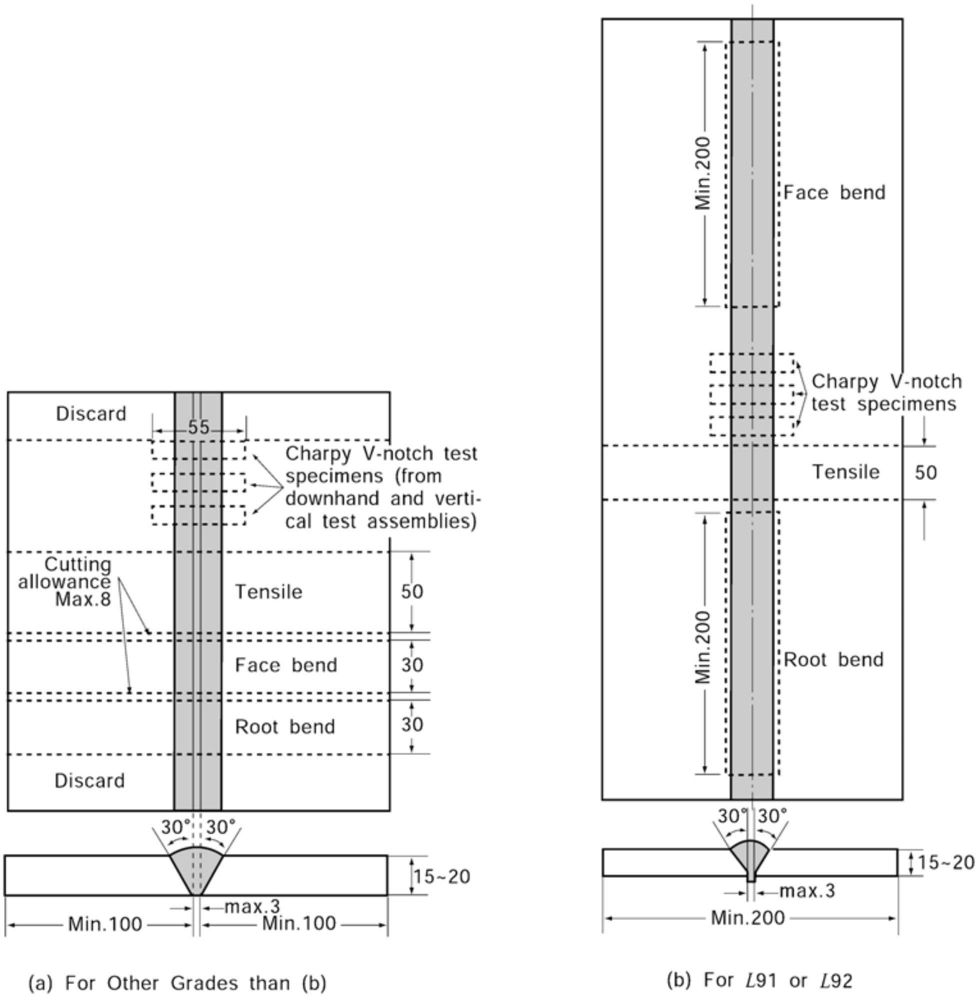


Fig 2.2.20 Butt weld Test Assembly for Electrode for Manual Arc Welding (Unit: mm)

(c) In all cases, the back sealing runs are to be made with 4 mm electrode in the welding position appropriate to each test assembly, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

(2) *Butt weld tensile tests*

(a) The tensile test specimen is to be R 2A specimen shown in **Table 2.2.1** and the test specimen is to be taken from each test assembly.

(b) The surface of weld is to be machined flush with the surface of plate.

(c) The tensile strength of test specimen is to comply with the requirements given in **Table 2.2.21.**

(3) *Butt weld bend test*

(a) The face and root bend test specimens are to be *RB* 4 specimen shown in **Table 2.2.2,** and test specimens are to be taken from each test assembly. However, for *L* 91 or *L* 92, the face and root bend specimens are to be *RB* 1 specimen shown in **Table 2.2.2,** and test specimens are to be taken longitudinally from each test assembly.

(b) The upper and lower surfaces of the weld are to be filed, ground or machined flush with the Surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm.

(c) The test specimens are to be capable of withstanding, without crack exceeding 3 mm long on the outer surface of other defects, being bent through an angle of 120 degrees over a former having a radius of 1.5 times the thickness of test specimen. The radius and angle of the former for *L* 91 and *L* 92, however, are to be 2 times the thickness of the specimen and 180 degrees respectively.

Table 2.2.21 Tensile and impact Test Requirements for butt weld

Grade of electrode	Tensile strength (N/mm^2)	Impact test		
		Test temp. (℃)	Average absorbed energy (J)	
			Flat, Horizontal, Overhead	Vertical upward Vertical downward
1	400 min.	20	47 min.	34 min.
2		0		
3		-20		
2*Y*	490 min.	0		
3*Y*		-20		
4*Y*		-40		
5*Y*		-60		
2*Y*40	510 min.	0		39 min.
3*Y*40		-20		
4*Y*40		-40		
5*Y*40		-60		
L 1	400 min.	-40	27 min.	27 min.
L 2	440 min.	-60		
L 3	490 min.	-60		
L 91	630 min.	-196		
L 92	670 min.	-196		

(4) *Butt weld impact tests*
(a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions charphy V-notch impact test specimens as shown in **Table 2.1.3.**
(b) The test specimens are to be prepared as shown in **Fig 2.2.19** and the dimensions, form, position and direction of notches are to be as specified in **Par 4.** (4)
(c) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.21,** appropriate to the grades of the electrode and welding position.
(d) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

6. Hydrogen test

The hydrogen test to be carried out by the mercury method or gas chromatographic method. The use of the glycerine method may be admitted at the Society discretion.

(1) The mercury method to be as specified in the Standard *KS B ISO* 3690
(2) The gas chromatographic method to be as specified in the Standard KS D0064(Method of Measurement for Hydrogen Evolved from Steel Welds)
(3) Glycerin method
(a) *Welding of test assemblies*
(i) As a rule, mild and high tensile steels are to be used for the test assembly, and four test specimens are to be prepared measuring 12 mm by 25 mm in cross section by about 125 mm in length. Before welding, the specimens are to be weighed to the nearest 0.1 *gram*. On the 25 mm surface of each test specimen, a single bead of welding is to be deposited, about 100 mm in length, by a 4 mm electrode, using about 150 mm of the electrode. The welding is to be carried out with as short an arc as possible and with a current of about 150 *amp*.
(ii) The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer.

(b) After welding, each test specimen prepared to the hydrogen test specified in (a) above is to be quenched in water at a temperature of approximately 20℃ for 30 sec, after removing the slag within a period of 30 sec. Subsequently, the test specimens are to be cleaned and be sealed into a hydrogen collector by means of the glycerin replacement method.
The glycerin is to be kept at a temperature of approximately 45℃ during the test. The test time required for all the four test specimens from welding to the enclosure in the hydrogen collector is to be within 30 min. After immersing into glycerin for 48 hours, the test specimens are to be cleaned with water and alcohol and weighed with an accuracy of 0.1 g after being dried to measure the weight of the deposited metal. The volume of hydrogen gas collected is to be measured with an accuracy of 0.05 cm^3 and converted into that under the conditions 20℃ and 1 atmospheric pressure (760 mm Hg).

(4) Average diffusible hydrogen contents of the four specimens is to comply with the requirements given in **Table 2.2.22** according to the test procedures specified in preceding articles or the type of suffixes to be added to the grade marks.

Table 2.2.22 Requirements for Hydrogen Contents ($ml/100g$)

Mark	Mercury method	gas chromatographic method	Glycerine method
$H15$	15 max.	15 max.	10 max.
$H10$	10 max.	10 max.	5 max.
$H5$	5 max.	5 max.	-

7. Fillet weld test

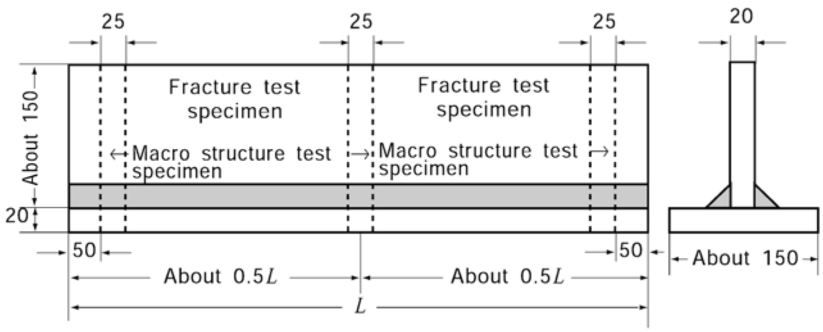
(1) *Welding of fillet weld test assemblies*

(a) Test assembly as shown in **Fig 2.2.21** is to be welded in each welding position (flat, horizon-vertical, vertical-up ward, vertical-downward and overhead) which is recommended by the manufacturer.

(b) The first side is to be welded using the maximum size of electrode manufactured and the second side is to be welded using the minimum size of electrode manufactured.

(c) The leg length of fillet welds may will in general be determined by the electrode size and the welding current employed during testing.

(d) In case of fillet welds using gravity or similar contact welding method, the fillet welding is to be carried out with electrodes of maximum length. Where approval is requested for the welding of both normal strength and higher strength steel, the assemblies are to be prepared using higher strength steel.



(The length of the test assemblies L is to be sufficient to allow at least the deposition of the entire length of the electrode being tested.)

Fig 2.2.21 Fillet Weld Test Assembly (Unit : mm)

(2) *Fillet weld macro-structure test*

(a) For macro-structure test specimens, those with breadths of 25 mm are selected from three places shown in **Fig 2.2.21.**

(b) The macro-etching test is conducted on the transverse section of fillet weld joint and welded joints are to be free from excessive difference of leg length between upper and lower, cracks and other injurious defects.

(3) *Fillet weld hardness test* The hardness of weld metal, heat affected zone and base metal are to be measured at places given in **Fig 2.2.22** for each test specimen which underwent the macro-etching test specified in preceding (1) and the respective hardnesses are to be in accordance with those deemed appropriate by the Society.

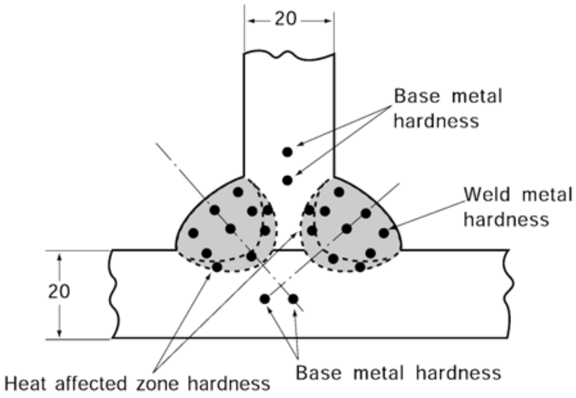


Fig 2.2.22 Hardness Test (Unit : mm)

(4) Fillet weld fracture test

(a) One of the remaining sections of the fillet weld is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld as shown in Fig **2.2.23**, on the second side by closing the two plates together, submitting the root of the weld to tension. On the other remaining section the weld on the second side is to be gouged or machined and the section fractured using the same procedure.

(b) The fractured surfaces are to be examined and there should be no evidence of incomplete penetration, or internal cracking and they should be reasonably free from porosity.

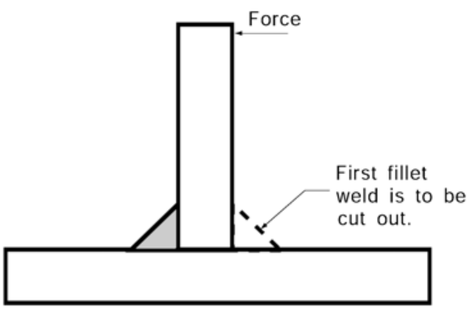


Fig 2.2.23 Fracture Test

8. Annual inspections

(1) In the annual inspections, tests specified in the following (2) and (3) are to be conducted for each brand of the approved electrodes and they are to be passed satisfactorily.

(2) The kinds of test, etc. in the annual inspections for manual arc welding electrodes are to be as given in **Table 2.2.23.**

(3) The kinds of test, etc. in the annual inspections of electrodes used in gravity welding or other welding using similar welding devices are to be as given in **Table 2.2.24.**

(4) The welding procedures and requirements for test assemblies of tests specified in the preceding (2) and (3) are to be as specified in **Par 4.**

Table 2.2.23 Kind of Test for Annual Inspection

Kind of test[2]	Test assembly					Kind and no. of test specimens taken from test assembly
	Welding position	Diameter of electrode (mm)	Number	Dimensions	Thickness (mm)	
Deposited metal test	Flat	4[1]	1	**Fig 2.2.18**	20	Tensile test specimen : 1 Impact test specimen : 3
		exceeding 4, 8 max.	1			

NOTES:
(1) Where deemed necessary by the Society, butt weld tests in the downhand or vertical (either upward or downward) welding position specified in **Table 2.2.17** may be requested in place of deposited metal tests of 4 mm diameter electrodes. In this case, impact test specimens (one set of three) are to be selected.
(2) For low hydrogen electrodes, an hydrogen test can also be required at the discretion of the Society.

Table 2.2.24 Kind of Test for Annual Inspection

Kind of test	Test assembly					Kind and no. of test specimens taken from test assembly
	Welding position	Diameter of electrode (mm)	Number	Dimensions	Thickness (mm)	
Deposited metal test	Flat	4 min.	1	**Fig 2.2.18**	20	Tensile test specimen : 1 Impact test specimen : 3

9. Changes in grades

(1) Where changes in the grades relating to the strength or toughness of electrodes approved are to be made, tests specified in the following (2) and (3) are to be carried out and satisfactorily passed in accordance with the requirements in **601. 5** (2).
(2) For changes in the grades relating to strength, the butt weld tests, specified in the annual inspection of **Par 8** and in the requirements of **Par 3** (1), are to be conducted.
(3) For changes in the grades relating to toughness, the butt weld impact tests, specified in the annual inspection of **Par 8** and in the requirements of **Par 3** (1), are to be conducted.

603. Automatic welding consumables for normal strength steels, higher strength steels and steels for low temperature service

1. Application

(1) Welding consumables for normal strength steels, higher strength steels and steels for low temperature service given in the following (a) through (c) (hereinafter referred to as "automatic welding consumables") are to be subjected to the approval tests and annual inspections in accordance with the requirements in **603.**
  (a) Submerged arc automatic welding consumables (Wire flux combinations)
  (b) Gas shielded arc automatic welding consumables(Flux cored wire and solid wire automatic welding consumables with shielding gas)
  (c) Self-shielded arc automatic welding consumables (flux-cored or flux-coated wires without a shielding gas)
(2) Wire-flux combinations for multiple electrode submerged arc welding will be subject to separate approval tests. They are to be carried out generally in accordance with the requirements in **603**.
(3) At the discretion of the Society, wires or wire-gas combinations approved for semi-automatic multirun welding may also be approved, without additional tests, for automatic multirun welding approval. This is generally the case when automatic multirun welding is performed in the same conditions of welding current and energy as semi automatic welding with the concerned wire-gas combination.

2. Grades and marks

(1) The automatic welding consumables are classified as specified in **Table 2.2.25.**

Table 2.2.25 Grade and Marks

For normal strength steel	For higher strength steel	For steel for low temperature service
1, 2, 3	1*Y*, 2*Y*, 3*Y*, 4*Y*, 5*Y* 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40	*L* 1, *L* 2, *L* 3, *L* 91, *L* 92

(2) Automatic welding materials which have passed the tests for each welding process given in **Table 2.2.28** are to be appended with the suffixes shown in **Table 2.2.26** at the end of their marks.

(3) In the preceding (2), a suffix G will be added to the grade mark for gas shielded arc automatic welding consumables, and a suffix N will be added for self-shielded wire automatic welding consumables Further, the type of gas used is to be as specified in **Table 2.2.27,** and the suffix given in **Table 2.2.27** will be added after the suffix G. (e.g. 3*YTM* *G*(*M*1))

Table 2.2.26 Marks

Welding technique	Mark
Multi-run technique(1)	*M*
Two-run technique(2)	*T*
Multi-run and two-run technique	*TM*

NOTES:
(1) Multi-run technique refers to a welding process involving multiple passes.
(2) Two-run technique refers to a welding process involving a single pass on both sides.

Table 2.2.27 Kinds of Gas

Group	Type	Gas composition (*Vol*.%)			
		CO_2	O_2	H_2	*Ar*(1)(2)
M 1	*M* 11	1～5	−	1～5	Rest
	M 12	1～5	−	−	Rest
	M 13	−	1～3	−	Rest
	M 14	1～5	1～3	−	Rest
M 2	*M* 21	6～25	−	−	Rest
	M 22	−	4～10	−	Rest
	M 23	6～25	1～8	−	Rest
M 3	*M* 31	26～50	−	−	Rest
	M 32	−	11～15	−	Rest
	M 33	6～50	9～15	−	Rest
C	*C* 1	100	−	−	−
	C 2	Rest	1～30	−	−
I	*I* 1	−	−	−	100
E	*E* 1	Except above			

NOTE:
(1) Argon may be substituted by Helium up to 95 % of the Argon content.
(2) Approval covers gas mixtures with equal or higher Helium contents only.

3. General provisions for tests

(1) Steel plates to be used for test assemblies are to be as given in **Table 2.2.28,** appropriate to the kind of automatic welding consumables.
(2) Kinds of test, number, thickness and dimensions of test assemblies, grades and number of test specimens to be taken from each test assembly for automatic welding consumables are to be as given in **Table 2.2.29.**
(3) For the approval of automatic welding consumables, the tests specified in the preceding (2) are to be conducted for each brand of automatic welding consumables.
(4) For gas shielded arc automatic welding consumables, the test in the preceding (3) is to be performed for each type of gas given in **Table 2.2.27.** When the manufacturer of the material recommends gas types of the group of $M1$, $M2$, $M3$ or C in **Table 2.2.27** and the test is satisfactorily conducted in accordance with the preceding (3) on one of the gas type, the test on the other gas types belonging to the same group is allowed to be dispensed with at the discretion of the Society.
(5) Unless otherwise agreed by the Society, additional approval tests are required when a shielding gas is used other than that used for the original approval tests.
(6) The welding conditions used such as amperage, voltage, travel speed, etc. are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.

Table 2.2.28 Grades of Steel used for Test Assembly

Grade of welding consumable	Grade of steel used for test assembly(1)(2)
1	*A*
2	*A*, *B* or *D*
3	*A*, *B*, *D* or *E*
1*Y*	*AH* 32 or *AH* 36
2*Y*	*AH* 32, *AH* 36, *DH* 32 or *DH* 36
3*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32 or *EH* 36
4*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
5*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
2*Y*40	*AH* 40 or *DH* 40
3*Y*40	*AH* 40, *DH* 40 or *EH* 40
4*Y*40	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
5*Y*40	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
L 1	*E or RL* 24*A*
L 2	*E*, *RL* 24*A*, *RL* 24*B*, *RL* 27 or *RL* 33
L 3	*RL* 27, *RL* 33 or *RL* 37
L 91	*RL* 9*N*53 or *RL* 9*N*60
L 92	*RL* 9*N*53 or *RL* 9*N*60

NOTES:
(1) Notwithstanding the requirements in this Table, normal strength steel or higher strength steels may be used for deposited metal test assembly In this case, test assemblies of grade *L* 91 and *L* 92 are to be appropriately buttered.
(2) The tensile strength of higher strength steels *AH* 32, *DH* 32, *EH* 32 and *FH* 32 used in butt weld test assemblies is to be greater than 490 N/mm^2

Table 2.2.29 Kinds of Test of Automatic Welding Consumables

Welding technique(7)	Kind of test(8)		Grade of welding consumables	Test assembly: Number	Test assembly: Dimen-sions	Test assembly: Thickness (mm)(3)	Kinds and no. of test specimens taken from test assembly
Multi-run technique	Deposited metal test		1, 2, 3 1*Y*, 2*Y*, 3*Y*, 4*Y*, 5*Y* 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40 *L*1, *L*2, *L*3, *L*91, *L*92	1	**Fig 2.2.24**	20	Tensile test specimen: 2 Impact test specimen: 3
	Butt weld test			1(4)	**Fig 2.2.25**	20~25	Tensile test specimen: 2(4) Face bend test specimen: 2(4)(6) Root bend test specimen: 2(4)(6) Impact test specimen: 3
Two-run technique	Butt weld test	Submerged arc welding	1, 1*Y*	1	**Fig 2.2.26**	12~15	Tensile test specimen: 2 Longitudinal tensile test speci-men: 1(5) Face bend test specimen: 1 Root bend test specimen: 1 Impact test specimen: 3
				1		20~25	
			2, 3 2*Y*, 3*Y*, 4*Y*, 5*Y* 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40	1		20~25	Tensile test specimen: 2 Longitudinal tensile test speci-men: 1(5) Face bend test specimen: 1 Root bend test specimen: 1 Impact test specimen: 3
				1		30~35	
		Gas shielded and self-shielded arc welding	1, 2, 3 1*Y*, 2*Y*, 3*Y*, 4*Y*, 5*Y* 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40	1		12~15(1) 20(2)	Tensile test specimen: 2 Longitudinal tensile test speci-men: 1(5) Face bend test specimen: 1 Root bend test specimen: 1 Impact test specimen: 3
				1		20~25(1) acceptable maximum thickness(2)	
	Butt weld test		*L*1, *L*2, *L*3, *L*91, *L*92	1		12~15	Tensile test specimen: 2 Longitudinal tensile test speci-men: 1(5) Face bend test specimen: 1 Root bend test specimen: 1 Impact test specimen: 3
				1		20 or acceptable maximum thickness	

NOTES:

(1) Thickness of test assemblies where applied maximum plate thickness is not more than 25 mm.

(2) Thickness of test assemblies where applied maximum plate thickness is more than 25 mm.

(3) Where thickness is restricted by welding process, thickness of test assemblies may be changed upon approval of the Society. Test assemblies shall then be welded using plates of 12 to 15 mm and 20 to 25 mm irrespective of the grade for which the approval is requested.

(4) The number of butt weld test assemblies for multi-run gas shielded and self-shielded arc welding techniques is to be one for each welding position. However, where there is more than one welding position, the number of tensile test specimens and bend test specimens selected from the test assemblies for each welding position may be half of the specified number.

(5) Test specimens are to be selected from only the thicker of two test assemblies.

(6) The number of face bend and root bend test specimens selected from the butt weld test assemblies for *L* 91 and *L* 92 is to be one each.

(7) Tests on both multi-run and two-run technique are to be conducted for multi-run and two-run welding respectively, and the number, dimensions and thickness of test assemblies, along with the grades and number of test specimens selected from each test assembly are to be according to each of the welding processes. However, the number of tensile test specimens in the deposited metal test for the multi-pass welding technique is to be one.

(8) The hydrogen test may be applied by request of the manufacturer.

(9) Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of the Society.

(7) After welding, the test assemblies are not to be subjected to any heat treatment.
(8) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

4. Deposited metal test with multi-run technique

(1) *Welding of deposited metal test assemblies*
(a) Test assemblies as shown in **Fig 2.2.24** are to be welded in the flat position by multirun technique according to the normal practice. The direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag is to be removed.
(b) The thickness of layer is not to be less than the diameter of wire nor less than 4 mm whichever is the greater for submerged arc automatic welding consumables. For gas shield and self-shielded are automatic welding consumables the thickness of layer is not to be less than 3 mm.
(b) After each run, the test assembly is to be left in still air until it has cooled to less than 250℃ but not below 100℃, the temperature being taken at the centre of the weld on the surface of seam.
(2) *Chemical analysis*
The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying element.

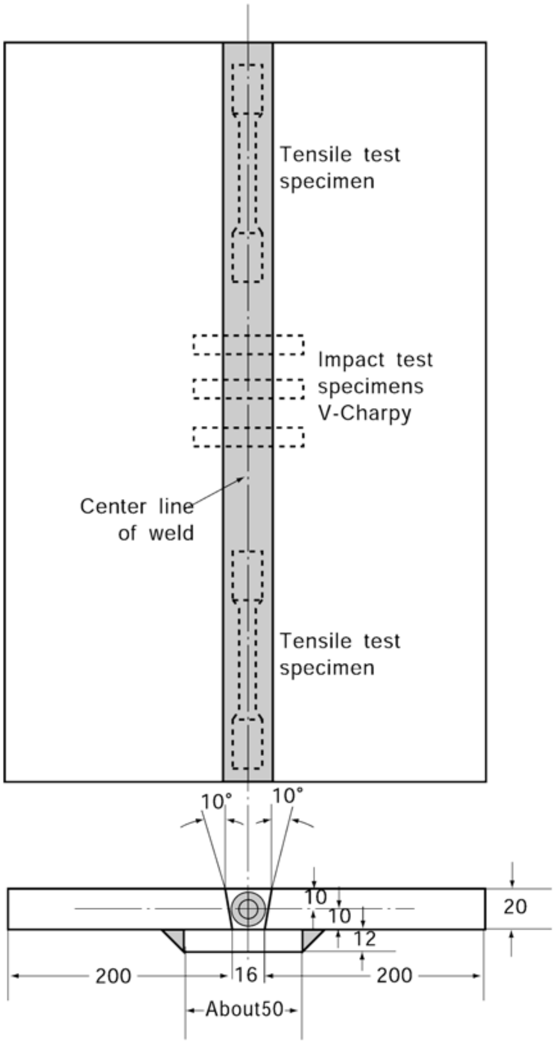


Fig. 2.2.24 Deposited Metal Test Assembly with Multi-run Technique (Automatic Welding, Unit : *mm*)

(3) *Deposited metal tensile test with multi-run technique*
(a) The tensile test specimens, two from each test assembly, are to be machined to dimensions R14A test specimen as shown in **Table 2.2.1**, care being taken that the longitudinal axis coincides with the centre of weld and the mid-thickness of plates.
(b) The tensile strength, yield point and elongation of each test specimen are to comply with the requirements given in **Table 2.2.30**, where the upper limit of tensile strength is exceeded, special consideration will be given to the approval of the electrode, taking into consideration of the other mechanical properties shown in the test results and the chemical composition of deposited metal.
(c) The tensile test specimens may be subjected to a temperature not exceeding 250 ℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.
(4) *Deposited metal impact test with multi-run technique*
(a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions *R* 4 test specimen as shown in **Table 2.1.3.** The test specimen is to be cut with its longitudinal axis transverse to the direction of welding, and the test specimen is to coincide with the mid-thickness of the plate shown in Fig **2.2.19.**
(b) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.30**.

Table 2.2.30 Tensile and Impact Test Requirements for Deposited Metal test

Grade of welding material	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)	Impact test	
				Test temp. (℃)	Average absorbed energy (J)
1	400 ~ 560	305 min.	22 min.	20	34 min.
2				0	
3				-20	
1*Y*	490 ~ 660	375 min.	22 min.	20	
2*Y*				0	
3*Y*				-20	
4*Y*				-40	
5*Y*				-60	
2*Y*40	510 ~ 690	400 min.	22 min.	0	39 min.
3*Y*40				-20	
4*Y*40				-40	
5*Y*40				-60	
L 1	400 ~ 560	305 min.	22 min.	-40	27 min.
L 2	440 ~ 610	345 min.	22 min.	-60	
L 3	490 ~ 660	375 min.	21 min.	-60	
L 91	590 min.	375 min.(1)	25 min.	-196	
L 92	660 min.	410 min.(1)	25 min.	-196	

NOTE:
(1) 0.2 % yield stress

(c) The notch is to be positioned in the centre of weld and is to be cut in the face of test specimens perpendicular to the surface of plate.
(d) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

5. Butt weld test with multi-run technique

(1) *Welding of butt weld test assemblies with multi-run technique*

(a) The face side of the test assemblies as shown in **Fig 2.2.25** is to be multi-pass welded in flat position, and the corresponding welding procedure is to follow the requirements of the preceding **4.** (1). However, for gas shield arc and self shielded arc wire automatic welding consumables, the welding position is to be as specified by the manufacturer.

(b) After completing the face welding in downhand position, back welding is performed. In this instance, back chipping may be carried out to expose sound deposited metal at the root.

(2) *Butt weld tensile test with multi-run technique*

(a) The tensile test specimens are to be prepared to *R* 2*A* specimen shown in **Table 2.2.1** and two test specimens are to be taken from each test assembly.

(b) The surface of weld is to be machined flush with the surface of plate.

(c) The tensile strength of test specimen is to comply with the requirements given in **Table 2.2.31.**

(3) *Butt weld bend test with multi-run technique*

(a) The face bend and root bend test specimens are to be *RB* 4 specimen shown in **Table 2.2.2,** and two test specimens are to be taken from each test assembly. However, for *L* 91 or *L* 92, the face bend and root bend specimens are to be *RB* 1 specimen shown in **Table 2.2.2,** and test specimens are to be taken longitudinally from each test assembly.

(b) The test specimens are to be capable of withstanding, without crack exceeding 3 mm long on the outer surface of other defects, being bent through an angle of 120 *degrees* over a former having a radius of 1.5 times the thickness of test specimen. The radius and angle of the former for *L* 91 and *L* 92, however, are to be 2 *times* the thickness of the specimen and 180 degrees respectively.

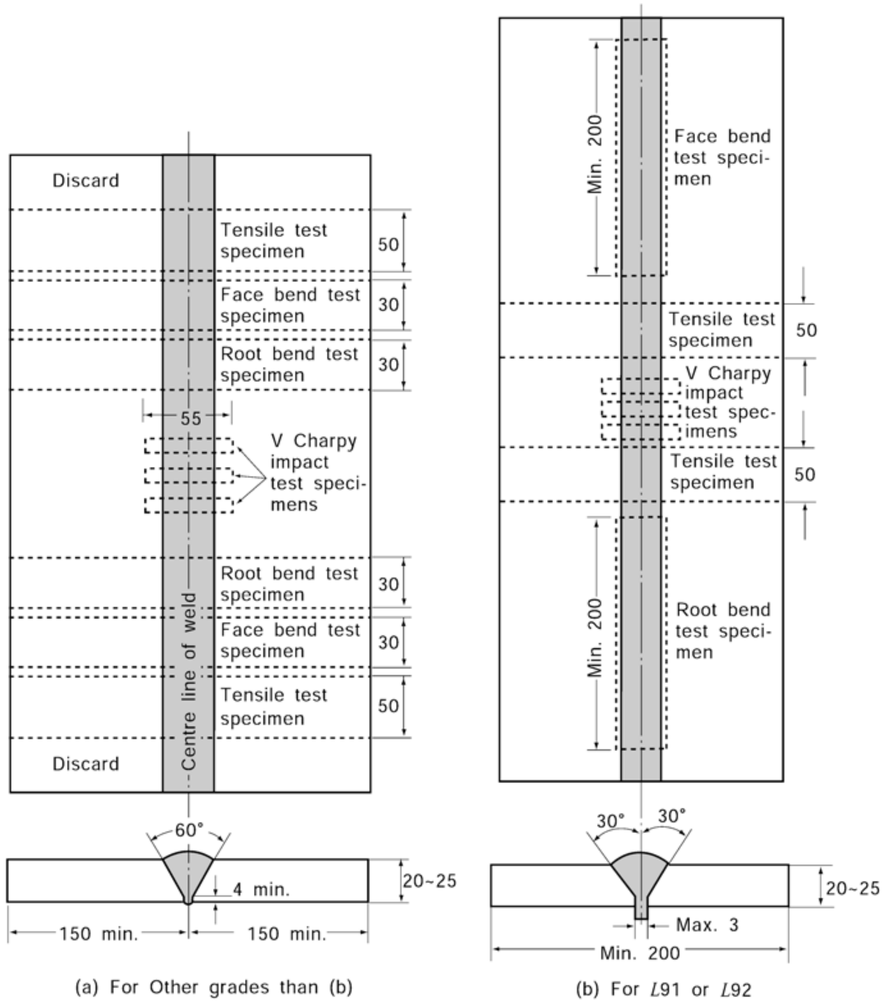


Fig 2.2.25 Butt Weld Test Assembly with Multi-run Technique (Automatic welding, Unit : *mm*)

Table 2.2.31 Tensile and Impact Test Requirements for butt weld test with multi-run technique

Grade of welding material	Tensile strength(N/mm^2)	Impact test	
		Test temp. (℃)	Average absorbed energy (J)
1	400 min.	20	34 min.
2		0	
3		− 20	
1*Y*	490 min.	20	
2*Y*		0	
3*Y*		− 20	
4*Y*		− 40	
5*Y*		− 60	
2*Y*40	510 min.	0	39 min.
3*Y*40		− 20	
4*Y*40		− 40	
5*Y*40		− 60	
L 1	400 min.	− 40	27 min.
L 2	440 min.	− 60	
L 3	490 min.	− 60	
L 91	630 min.	− 196	
L 92	670 min.	− 196	

(4) *Butt weld impact test with multi-run technique*

(a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions *R* 4 test specimens as shown in **Fig 2.1.3.** The test specimen is to be cut with its longitudinal axis perpendicular to the direction of welding, and the test specimen is to coincide with the mid-thickness of the plate shown in **Fig 2.2.19.**

(b) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.31.**

(c) The requirements in **Par 4.** (4), (c) and (d) are to correspondingly apply to this Paragraph.

6. Butt weld test with two-run technique

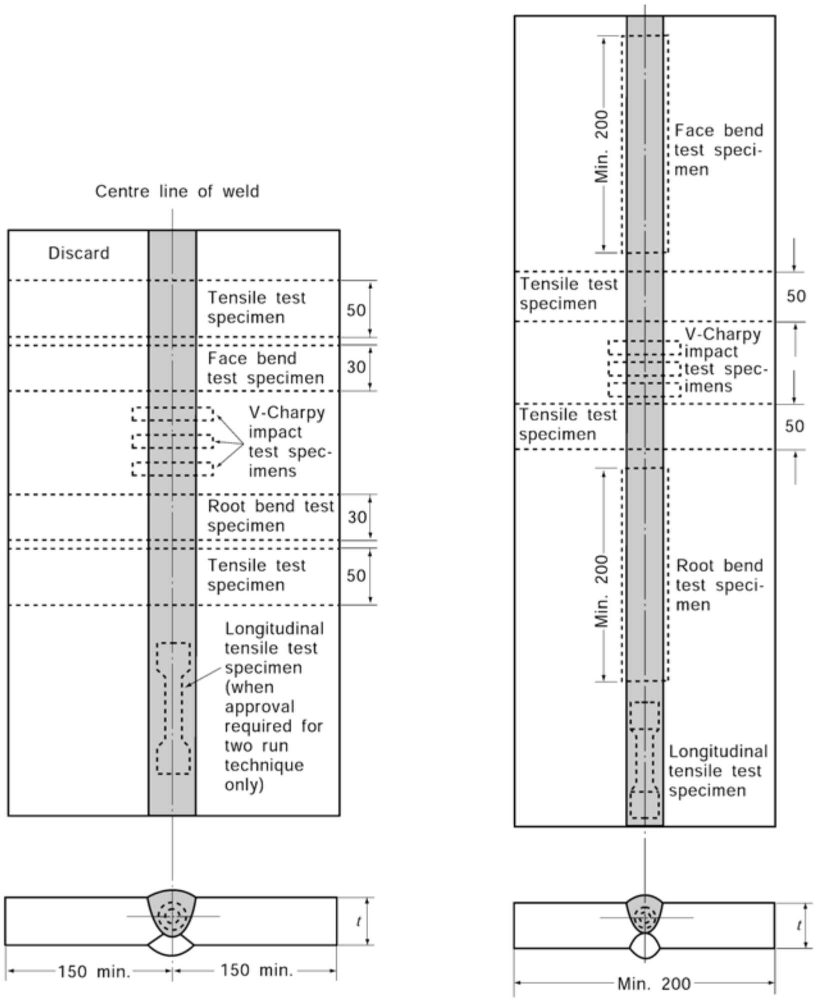
(1) *Welding of Butt weld test assemblies with two-run technique*

(a) Test assemblies are to be prepared as shown in **Fig 2.2.26,** and the diameter of wire and edge preparation are to be as shown in **Fig 2.2.27,** but some deviation may be allowed where accepted by the Society.

(b) Test assemblies are to be welded according to the normal practice in downhand position by two-run technique where each run is to be started alternately from each end of the plate. After completing the first run, the assembly is to be left in still air until it has cooled to 100℃ or below, the temperature being taken at the centre of weld on the surface of seam.

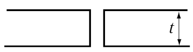
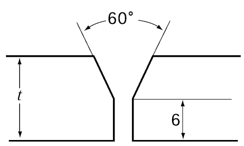
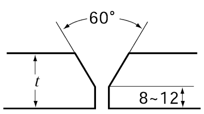
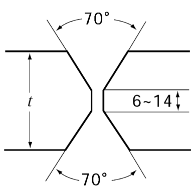
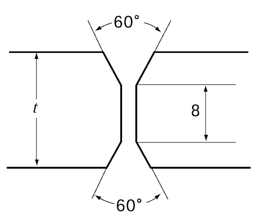
(2) *Chemical analysis*

The chemical analysis of the weld metal is to be supplied by the manufacturer, and is to include the content of all significant alloying elements.



(a) For Grades Other than (b)　　　(b) For L91 or L92

Fig. 2.2.26 Butt Weld Test Assembly with Two-run Technique (Automatic welding, Unit : *mm*, *t* : plate thickness)

(A) Submerged arc welding consumables			(B) Gas shielded arc and self shielded arc welding consumables		
Thickness of test assembly	Edge preparation(1)	Max. dia. of core	Thickness of test assembly	Edge preparation(2)	Max. dia. of wire
12~15		5	12~15		Maximum diameter of wire used is to be reported for information by manufacturer.
20~25		6			
30~35		7	20~25		

NOTES:
(1) Root gap is not to be greater than 1.0 *mm*.
(2) For assemblies using plate over 25 *mm* in thickness, the edge preparation used is to be specified by the manufacturer and the thickness of assembly is to comply with **Table 2.2.28.** (2).

Fig. 2.2.27 Edge Preparation of Butt Weld Test Assembly with Two-run Technique (*t* : plate thickness. Unit: *mm*)

(3) *Butt weld tensile tests with two-run technique*

(a) The tensile test specimens are to be R2A specimen shown in **Table 2.2.1** and two test specimens are to be taken from each welded assembly.

(b) The surface of weld is to be machined flush with the surface of plate.

(c) The tensile strength of test specimen is to comply with the requirements given in **Table 2.2.31.**

(d) One longitudinal tensile test specimen of R14A shown in **Table 2.2.1** is to be machined from the thicker of the test assembly specified in **Table 2.2.28** and the longitudinal direction of the test specimen is to be parallel to the weld line and the centre line of the test specimen is to coincide with the centre of second layer.

(e) The longitudinal tensile test specimen in the preceding (4) may be subjected to a temperature not exceeding 250℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.

(f) The requirements of tensile test specified in the preceding (d) and (e) are to be as given in **Table 2.2.30.** Where the upper limit of tensile strength is exceeded, special consideration will be given to the approval of the welding consumables, taking into consideration of the other mechanical properties shown in the test results and the chemical composition of deposited metal.

(4) *Butt weld bend test with two-run technique*

(a) The face and root bend test specimens are to be RB4 or RB5 specimen shown in **Table 2.2.2** and test specimens are to be taken from each test assembly. However, for L91 and L92, the face and root bend test specimens are to be RB1 test specimens and test specimens shown in **Table 2.2.2** are to be taken longitudinally from each test assembly.

(b) The requirements in **Par 5.** (3), (b) are to correspondingly apply to this Paragraph.

(5) *Butt weld impact test with two-run technique*

(a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions charphy V-notch impact test specimens as shown in **Table 2.1.3,** and the longitudinal direction of the test specimen is to be perpendicular to the weld line and the surface of weld about 2 mm apart is to coincide with the surface of specimen as shown in **Fig 2.2.28.**

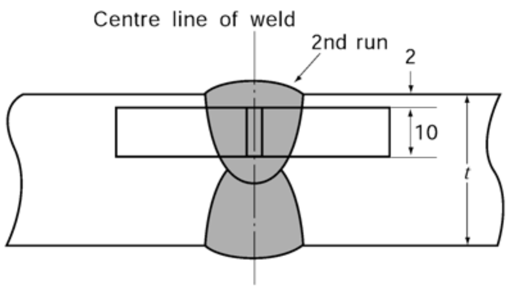


Fig 2.2.28 Position of impact Test Specimen for Butt Weld Test Assembly with Two-Run Technique (Unit : mm, t : plate thickness)

(b) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.31.**

(c) The requirements in **Par 4.** (4), (c) and (d) are to correspondingly apply to this Paragraph.

7. Hydrogen test

The hydrogen test is to be in accordance with **602. 6** of the Rules

8. Annual inspections

(1) In the annual inspection, tests specified in the following (2) are to be conducted for each brand of the approved consumables, and they are to be passed satisfactorily.

(2) The kinds of test, etc. involved in the annual inspections are to be as given in **Table 2.2.32.**

(3) The welding procedures and requirements for test assemblies of tests specified in the preceding (2) are to be as specified in **Pars 4** through **6.**

Table 2.2.32 Kinds of Test for Annual Inspection

Grade of welding consumables	Welding technique[(1)]	Kind of test		Test assembly: Number	Test assembly: Dimensions	Test assembly: Thickness (mm)	Kinds and no. of test specimens taken from test assembly
1, 2, 3 1Y, 2Y, 3Y, 4Y, 5Y 2Y40, 3Y40, 4Y40, 5Y40 L1, L2, L3, L91, L92	Multi-run technique	Deposited metal test		1	**Fig 2.2.24**	20	Tensile test specimen: 1 Impact test specimen: 3
	Two-run technique	Butt weld test	Submerged arc welding	1	**Fig 2.2.26**	20	Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend test specimen: 1 Root bend test specimen: 1 Impact test specimen: 3
			Gas shielded and self shielded arc welding	1		20~25	Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend test specimen: 1 Root bend test specimen: 1 Impact test specimen: 3

NOTE:
(1) Tests on both multi-run and two run technique are to be conducted for multi-run and two run welding respectively. However, longitudinal tensile test of two run technique are not required.

9. Changes in grades

(1) Where changes in the grades relating to the strength or toughness of automatic welding consumables approved are to be made, tests specified in the following (2), (3) and (4) are to be carried out and satisfactorily passed in accordance with the requirements in **601. 3** (3).

(2) Changes in grades relating to the strength or toughness of multi-run automatic welding consumables are to be in accordance with the requirements in the following (a) and (b).

(a) For changes in the grades relating to strength, the butt weld tests, specified in the annual inspection of **Par 8** and in the requirements of **Par 3** (1), are to be conducted.

(b) For changes in the grades relating to toughness, the butt weld impact tests, specified in the annual inspection of **Par 8** and in the requirements of **Par 3** (1), are to be conducted.

(3) Changes in grades relating to the strength or toughness of two-run automatic welding consumables are to be in accordance with the requirements in the following (a) and (b).

(a) For changes in the grades relating to strength, all tests specified in **Par 3** (1) are to be conducted.

(b) For changes in the grades relating to toughness, the butt weld impact tests, specified in the annual inspections of **Par 8** and in the requirements of the preceding (a), are to be conducted.

(4) Changes in the grades relating to the strength or toughness of automatic welding consumables for multi-run and two-run use are to be as specified in the preceding (2) and (3).

604. Semi-automatic welding consumables for normal strength steels, higher strength steels and steels for low temperature service

1. Application

Welding consumables for semi-automatic welding for normal strength steels, higher strength steels and steels for low temperature service given in the following (a) and (b) (hereinafter referred to as "semi-automatic welding consumables") are to be subjected to the approval test and annual inspections in accordance with the requirements in **604.**

(a) Gas shielded arc semi-automatic welding consumables(flux cored wire and solid wire semi-automatic welding consumables with shielding gas)

(b) Self-shielded arc semi-automatic welding consumables(solid wire and flux cored wire semi-automatic welding consumables without shielding gas).

2. Grades and marks

(1) The semi-automatic welding consumables are classified as specified in **Table 2.2.33.**

Table 2.2.33 Grades and Marks

For normal strength steel	For higher strength steel	For steel for low temperature service
1, 2, 3	1*Y*, 2*Y*, 3*Y*, 4*Y* 5*Y* 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40	*L*1, *L*2, *L*3, *L*91, *L*92

(2) A suffix "S" will be added after the grade mark to indicate approval for semi-automatic multi-run welding. For wires intended for both semi-automatic and automatic welding, the suffixes will be added in combination.(eg. 3*YSM*)
(3) A suffix G will be added to the grade marks for semi-automatic welding consumables which use shield gas, and a suffix N will be added for semi-automatic welding consumables which do not use shield gas. Further, the type of shield gas used is to be as specified in **Table 2.2.24,** and the suffix given in **Table 2.2.24** will be added after the suffix G. (e.g. 3*YS G*(*M*1))
(4) For low hydrogen electrodes, which have passed the hydrogen test specified in **602. 6,** the suffixes given in **Table 2.2.22** are to be added to the end of the grade marks of the said electrode. (e.g. 3*YS H*5)

3. General provisions for tests

(1) Kinds of test, number, thickness and dimensions of test assemblies, diameter of wire used for welding, welding position, grades and number of test specimens to be taken from each test assembly, position for semi-automatic welding consumables used in butt welds or in both butt and fillet welds are to be as given in **Table 2.2.34.**
(2) Kinds of test, number, thickness and dimensions of test assemblies, diameter of wire used for welding, welding position, grades and number of test specimens to be taken from each test assembly for semi-automatic welding materials used in fillet welds only are to be as given in **Table 2.2.18.**
(3) Steel plates to be used for test assemblies are to be as given in **Table 2.2.35,** appropriate to the kind of semi-automatic welding consumables.
(4) For the approval of semi-automatic welding consumables, the test specified in the preceding (1) and (2) are to be conducted for each brand of semi-automatic welding consumables.
(5) For semi-automatic welding consumables, the test in the preceding (4) is to be performed for each type of gas given in **Table 2.2.27.** When the manufacturer of the material recommends gas types of the group of *M* 1, *M* 2, *M* 3 or C in **Table 2.2.27** and the test is satisfactorily conducted in accordance with the preceding (3) on one of the gas type, the test on the other gas types belonging to the same group is allowed to be dispensed with at the discretion of the Society.
(6) The welding conditions used such as amperage, voltage, travel speed, etc. are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.
(7) After welding, the test assemblies are not to be subjected to any heat treatment.
(8) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

Table 2.2.34 Kinds of Test for Semi-automatic Welding Consumables

Kind of test[8]	Test assembly					Kinds and no. of test specimens taken from test assembly
	Welding position	Wire diameter (mm)	Number	Dimen-sions	Thickness (mm)	
Deposited metal test	Flat	maximum diameter	1[1]	**Fig 2.2.18**	20	Tensile test specimen: 1 Impact test specimen: 3
		minimum diameter	1[1]			
Butt weld test	Flat	First-run: minimum diameter Remaining-run: maximum diameter[4]	1[2]	**Fig 2.2.19**	15~20	Tensile test specimen: 1 Face bend test specimen :1 Root bend test specimen: 1 Impact test specimen: 3[3]
	Horizontal[5]		1			
	Vertical upward		1			
	Vertical downward		1			
	Overhead		1			
Fillet weld test[6]	Horizontal-vertical	One side: maximum diameter The other side: minimum diameter	1	**Fig 2.2.20**	20	Macro test specimen: 3[7] Hardness test specimen: 3[7] Fracture test specimen: 2

NOTES:

(1) Where the core diameter to be manufactured is of single variety, the number of test assembly is to be one.
(2) Where tests are conducted solely in the Flat position. one test assembly welded with wire of different diameters is to be added. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.
(3) Impact tests are not required for welding in overhead position.
(4) The butt weld assemblies in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and, for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.
(5) For semi-automatic welding consumables which have passed butt weld tests in the downhand and vertical upward positions, the horizontal butt weld test may be omitted. at the discretion of the Society.
(6) This test is to be added solely against welding consumables for use in both butt and fillet weld.
(7) The test specimens used in the macro-etching test and hardness test are to be the same.
(8) For low hydrogen welding consumables, an hydrogen test may be conducted by the application of the manufacturer, and test assembly is to be as specified in **602. 6** (1).

Table 2.2.35 Grades of Steel for Test Assembly

Grade of welding consumables	Grade of steel for test assembly(1)(2)
1*S*	*A*
2*S*	*A*, *B* or *D*
3*S*	*A*, *B*, *D* or *E*
1*YS*	*AH* 32 or *AH* 36
2*YS*	*AH* 32, *AH* 36, *DH* 32 or *DH* 36
3*YS*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32 or *EH* 36
4*YS*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
5*YS*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
2*Y*40*S*	*AH* 40 or *DH* 40
3*Y*40*S*	*AH* 40, *DH* 40 or *EH* 40
4*Y*40*S*	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
5*Y*40*S*	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
L 1*S*	*E* or *RL* 24*A*
L 2*S*	*E*, *RL* 24*A*, *RL* 24*B*, *RL* 27 or *RL* 33
L 3*S*	*RL* 27, *RL* 33 or *RL* 37
L 91*S*	*RL* 9*N*53 or *RL* 9*N*60
L 92*S*	*RL* 9*N*53 or *RL* 9*N*60

NOTES;
(1) Notwithstanding the requirements in this Table, normal or higher strength steels may be used for deposited metal test assembly. In this case, test assemblies of grade *L* 91 and *L* 92 are to be appropriately buttered.
(2) The tensile strength of higher strength steels *AH* 32, *DH* 32, *EH* 32 and *FH* 32 used in butt weld test assemblies is to be greater than 490 N/mm^2.

4. Deposited metal test

(1) *Welding of Deposited metal test assemblies*
 (a) Test assembly as shown in **Fig 2.2.18** is to be welded in the flat position according to the normal practice.
 (b) Test assembly is to be welded in single or multi-run layers, and the direction of deposition of each run is to alternate from each end of the plate, each run of weld metal being not less than 2 mm but not more than 6 mm thick.
 (c) After each run, the test assembly is to be left in still air until it has cooled to less than 250℃ but not below 100℃, the temperature being taken at the centre of the weld on the surface of seam.

(2) *Chemical analysis*
The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying element.

(3) *Deposited metal tensile test*
 (a) The tensile test specimen, one from each test assembly, is to be machined to dimensions R14A test specimen as shown in **Table 2.2.1,** care being taken that the longitudinal axis coincides with the centre of weld and the mid-thickness of plates.
 (b) The tensile test specimen may be subjected to a temperature not exceeding 250℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.

(c) The tensile strength, yield strength and elongation of each test specimen are to comply with the requirements given in **Table 2.2.36,** where the upper limit of tensile strength is exceeded, special consideration will be given to the approval of the electrode, taking into consideration of the other mechanical properties shown in the test results and the chemical composition of deposited metal.

Table 2.2.36 Tensile and Impact Test Requirements for Deposited Metal test

Grade of welding consumables	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)	Impact test	
				Test temp. (℃)	Average absorbed energy (J)
1*S*	400 ~ 560	305 min.	22 min.	20	47 min.
2*S*				0	
3*S*				− 20	
1*YS*	490 ~ 660	375 min.	22 min.	20	
2*YS*				0	
3*YS*				− 20	
4*YS*				− 40	
5*YS*				− 60	
2*Y*40*S*	510 ~ 690	400 min.	22 min.	0	
3*Y*40*S*				− 20	
4*Y*40*S*				− 40	
5*Y*40*S*				− 60	
L 1*S*	400 ~ 560	305 min.	22 min.	− 40	34 min.
L 2*S*	440 ~ 610	345 min.	22 min.	− 60	
L 3*S*	490 ~ 660	375 min.	21 min.	− 60	
L 91*S*	590 min	375 min.(1)	25 min.	− 196	27 min.
L 92*S*	660 min	410 min.(1)	25 min.	− 196	

NOTE:
(1) 0.2 % yield stress

(4) *Deposited metal impact tests*

(a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions charphy V-notch impact test specimens as shown in **Table 2.1.3.** The test specimen is to be cut with its longitudinal axis transverse to the direction of welding, and the test specimen is to coincide with the mid-thickness of the plate shown in **Fig 2.2.21.**

(b) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.36.**

(c) The notch is to be positioned in the centre of weld and is to be cut in the face of test specimens perpendicular to the surface of plate.

(d) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

5. Butt weld test

(1) *Welding of butt weld test assemblies*

(a) Test assembly as shown in **Fig 2.2.20** is to be welded in each welding position (flat, horizontal-vertical, vertical-upward, vertical-downward and overhead) which is recommended by the manufacturer.

(b) After each run, the test assembly is to be left in still air until it has cooled to less than 250℃ but not below 100℃, the temperature being taken at the centre of the weld on the surface of seam.

(2) *Butt weld tensile tests*

(a) The tensile test specimen is to be *R* 2*A* test specimen shown in **Table 2.2.1** and the test specimen is to be taken from each test assembly.

(b) The surface of weld is to be machined flush with the surface of plate.

(c) The tensile strength of test specimen is to comply with the requirements given in **Table 2.2.37.**

Table 2.2.37 Tensile and Impact Test Requirements for Butt weld test

<table>
<tr><th rowspan="3">Grade of welding consumables</th><th rowspan="3">Tensile strength (N/mm²)</th><th colspan="3">Impact test</th></tr>
<tr><th rowspan="2">Test temp. (℃)</th><th colspan="2">Average absorbed energy (J)</th></tr>
<tr><th>Flat, Horizontal Overhead</th><th>Vertical upward, Vertical downward</th></tr>
<tr><td>1S</td><td rowspan="3">400 min.</td><td>20</td><td rowspan="12">47 min.</td><td rowspan="8">34 min.</td></tr>
<tr><td>2S</td><td>0</td></tr>
<tr><td>3S</td><td>− 20</td></tr>
<tr><td>1YS</td><td rowspan="5">490 min.</td><td>20</td></tr>
<tr><td>2YS</td><td>0</td></tr>
<tr><td>3YS</td><td>− 20</td></tr>
<tr><td>4YS</td><td>− 40</td></tr>
<tr><td>5YS</td><td>− 60</td></tr>
<tr><td>2Y40S</td><td rowspan="4">510 min.</td><td>0</td><td rowspan="4">39 min.</td></tr>
<tr><td>3Y40S</td><td>− 20</td></tr>
<tr><td>4Y40S</td><td>− 40</td></tr>
<tr><td>5Y40S</td><td>− 60</td></tr>
<tr><td>L 1S</td><td>400 min.</td><td>− 40</td><td rowspan="5">27 min.</td><td rowspan="5">27 min.</td></tr>
<tr><td>L 2S</td><td>440 min.</td><td>− 60</td></tr>
<tr><td>L 3S</td><td>490 min.</td><td>− 60</td></tr>
<tr><td>L 91S</td><td>630 min.</td><td>− 196</td></tr>
<tr><td>L 92S</td><td>670 min.</td><td>− 196</td></tr>
</table>

(3) *Butt weld bend test*

(a) The face and root bend test specimens are to be RB4 specimen shown in **Table 2.2.2,** and test specimens are to be taken from each test assembly. However, for *L* 91 or *L* 92, the face and root bend specimens are to be RB1 specimen shown in **Table 2.2.2,** and test specimens are to be taken longitudinally from each test assembly.

(b) The test specimens are to be capable of withstanding, without crack exceeding 3 mm long on the outer surface of other defects, being bent through an angle of 120 degrees over a former having a radius of 1.5 times the thickness of test specimen. The radius and angle of the former for *L* 91 and *L* 92, however, are to be 2 times the thickness of the specimen and 180 degrees respectively.

(4) *Butt weld Impact test*
(a) One set of three impact test specimens, from each test assembly, are to be machined to dimensions charphy V-notch impact test specimens as shown in **Table 2.1.3.** The test specimen is to be cut with its longitudinal axis transverse to the direction of welding, and the test specimen is to coincide with the mid-thickness of the plate shown in **Fig 2.2.19.**
(b) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.37.**
(c) The requirements in **Par 4** (4), (c) and (d) are to correspondingly apply to this Paragraph.

6. Fillet weld test assemblies

(1) *Welding of fillet weld test assemblies* The test assemblies are to be in accordance with the requirements in **602. 7** (1).
(2) *Fillet weld macro-structure test* The macro-structure test is to be correspondingly in accordance with the requirements in **602. 7** (2).
(3) *Fillet weld hardness test* The hardness test is to be correspondingly in accordance with the requirements in **602. 7** (3).
(4) *Fillet weld fracture test* The fracture test is to be correspondingly in accordance with the requirements in **602. 7** (4).

7. Hydrogen test

Flux-cored or flux-coated wires which have satisfied the requirements for Grades 2*S*, 2*YS*, 2*Y*40*S*, 3*S*, 3*YS*, 3*Y*40*S*, 4*YS* or 4*Y*40*S* may, at manufacturer's option, be submitted to the hydrogen test as detailed in **602. 6.** using the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weight of weld deposit per sample similar to that deposited when using manual electrodes.

8. Annual inspections

(1) In the annual inspections, tests specified in the following (2) are to be conducted for each brand of the approved consumables, and they are to be passed satisfactorily.
(2) The kinds of test, etc. in the annual inspection are to be as given in **Table 2.2.38.**

Table 2.2.38 Kind of Test for Annual Inspection

Kind of test	Test assembly					Kind and no. of test specimens taken from test assembly
	Welding position	Diameter of wire (mm)	Number	Dimension	Thickness (mm)	
Deposited metal test	Flat	(1)	1	**Fig 2.2.18**	20	Tensile test specimen : 1 Impact test specimen : 3

NOTE:
(1) The diameters of the wire are to be within the range specified by the manufacturers.

(3) The welding procedures and requirements for test assemblies of tests specified in the preceding (2) are to be as specified in **Par 4.**

9. Changes in grades

(1) Where changes in the grades relating to the strength or toughness of welding consumables approved are to be made, tests specified in the following (2) and (3) are to be carried out and satisfactorily passed in accordance with the requirements in **601. 5** (2).
(2) For changes in the grades relating to strength, the butt weld tests, specified in the annual inspection of **Par 8** and in the requirements of **Par 3** (1), are to be conducted.
(3) For changes in the grades relating to toughness, the butt weld impact tests, specified in the annual inspection of **Par 8** and in the requirements of **Par 3** (1), are to be conducted.

605. Electro-slag and electro-gas welding consumables

1. Application

Electro-slag and electro-gas welding consumables for normal strength and higher strength steels (hereinafter referred to as "welding consumables") are to be in accordance with the requirements in 605.

2. Grades and marks

Welding consumables are classified as specified in **Table 2.2.39.**

Table 2.2.39 Grades and Marks

For normal strength steel	For higher strength steel
1*V*, 2*V*, 3*V*	1*YV*, 2*YV*, 3*YV*, 4*YV*, 5*YV* 2*Y*40*V*, 3*Y*40*V*, 4*Y*40*V*, 5*Y*40*V*

3. General provisions for tests

(1) Kinds of test, number, thickness and dimensions of test assemblies, grades and number of test specimens to be taken from each test assembly for welding consumables are to be as given in **Table 2.2.40.**

Table 2.2.40 Kinds of Test for Electro-Slag and Electro-Gas Welding Consumables

Kind of test	Test assembly(1)			Kinds and no. of test specimens taken from test assembly
	Number	Dimensions	Thickness (mm)(2)	
Butt weld test	1	**Fig 2.2.29**	20 ~ 25	Tensile test specimen: 2 Longitudinal tensile test specimen: 2 Side bend test specimen: 2 Impact test specimen: 6 Macro structure test specimen: 2
	1		35 ~ 40	

NOTE:
(1) Where approval is requested for welding of both normal strength and higher strength steel two assemblies are to be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of each Classification Society.
(2) Where thickness is restricted by welding process, thickness of test assemblies may be changed upon approval of the Society. In this case, the maximum test thickness is to be taken as the maximum applicable thickness.

(2) Steel plates to be used for test assemblies are to be as given in **Table 2.2.41,** appropriate to the kind of welding consumables.
(3) For the approval of welding consumables, the tests specified in the preceding (1) are to be conducted for each brand of welding consumables.
(4) The welding conditions used such as amperage, voltage, travel speed, etc. are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.
(5) After welding, the test assemblies are not to be subjected to any heat treatment.
(6) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

Table 2.2.41 Grades of Steel used for Test Assembly

Grade of welding material	Grade of steel used for test assembly(1)(2)
1*V*	*A*
2*V*	*A*, *B* or *D*
3*V*	*A*, *B*, *D* or *E*
1*YV*	*AH* 32 or *AH* 36
2*YV*	*AH* 32, *AH* 36, *DH* 32 or *DH* 36
3*YV*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32 or *EH* 36
4*YV*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
5*YV*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
2*Y*40*V*	*AH* 40 or *DH* 40
3*Y*40*V*	*AH* 40, *DH* 40 or *EH* 40
4*Y*40*V*	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
5*Y*40*V*	*AH* 40, *DH* 40, *EH* 40 or *FH* 40

NOTE:
(1) The tensile strength of higher strength steels of *AH* 32, *DH* 32, *EH* 32 and *FH* 32 used in the test assemblies is to be greater than 490 N/mm^2.
(2) This is in respect of the content of grain refining elements, and if general approval is required, a niobium treated steel is to be used for the approval tests.

4. Butt weld test

(1) *Welding of butt weld test assemblies*

(a) Test assemblies as shown in **Fig 2.2.29** are to be welded upward in vertical position in one Pass.

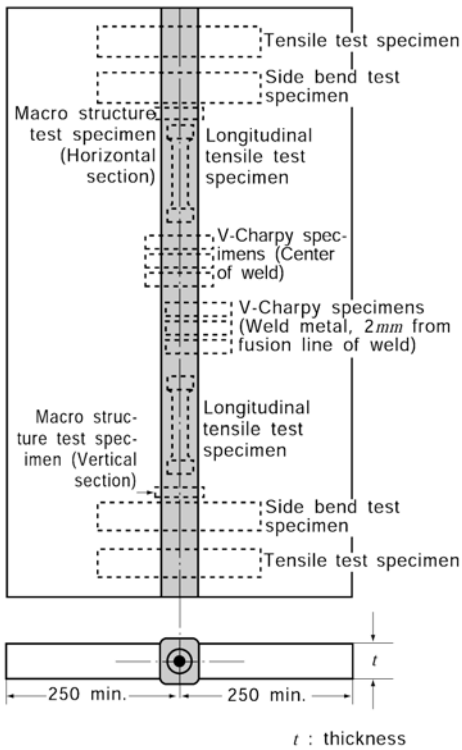


Fig. 2.2.29 Butt Weld Assembly (Electro-slag and electrod-gas welding, Unit :mm)

(b) The welding conditions and edge preparation are to be within the range recommended by the manufacturer.

(2) *Tensile test*

(a) Two tensile test specimens to be R2A specimen and two longitudinal tensile test specimens to be R14A specimen as shown in **Table 2.2.1** are to be taken from each test assembly. The longitudinal axis of test specimen coincides with the centre of weld and the mid-thickness of plates.

(b) The longitudinal tensile test specimens may be subjected to the heat treatment not exceeding 250℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.

(c) Tensile strength of each test specimen R2A and tensile strength, yield strength and elongation of each longitudinal test specimen R14A are to comply with the requirements in **Table 2.2.42.** Where the upper limit of tensile strength is exceeded, special consideration will be given to the approval of the welding consumables, taking into consideration of the other mechanical properties shown in the test results and chemical composition of deposited metal.

Table 2.2.42 Tensile and Impact Test Requirements for Butt weld test

Grade of welding consumables	Tensile strength (N/mm^2)	Longitudinal Tensile Test			Impact test	
		Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)	Test temp. (℃)	Average absorbed energy (J)
1*V*	400 min.	400 ~ 560	305 min.	22 min.	20	34 min.
2*V*					0	
3*V*					-20	
1*YV*	490 min.	490 ~ 660	375 min.	22 min.	20	
2*YV*					0	
3*YV*					-20	
4*YV*					-40	
5*YV*					-60	
2*Y*40*V*	510 min.	510 ~ 690	400 min.	22 min.	0	39 min.
3*Y*40*V*					-20	
4*Y*40*V*					-40	
5*Y*40*V*					-60	

(3) *Bend test*

(a) Bend test specimens are to be *RB* 6 specimens shown in **Table 2.2.2** and two side bend test specimens are to be taken from each test assembly.

(b) The test specimens are to be capable of withstanding, without crack exceeding 3 mm long on the outer surface of other defects, being bent through an angle of 180 degrees over a former having a radius of two times the thickness of test specimen.

(4) *Impact test*

(a) Two sets of six impact test specimens, from each test assembly, are to be machined to dimensions charphy V-notch impact test specimens as shown in **Table 2.1.3** and the longitudinal direction of the test specimen is to be perpendicular to the weld line and the surface of weld about 2 mm apart is to coincide with the surface of specimen as shown in **Fig 2.2.30.**

(b) The position of the notch is to be in accordance with **Fig 2.2.30** (a) and (b) respectively, and its longitudinal direction is to be perpendicular to the surface of the test assembly.

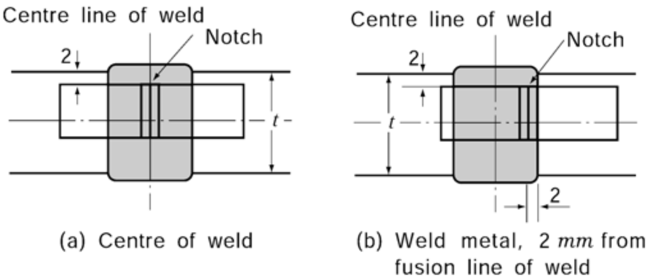


Fig 2.2.30 Position of Impact Specimen (Unit : mm, t = Plate thickness)

(c) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.42.**

(d) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

(5) *Macro-structure test*

(a) Two macro-structure test specimens are to be taken from the position shown in **Fig 2.2.29.** As for the surface to be tested, one is to be normal to the assembly surface and the other parallel to the assembly surface.

(b) Both the welded parts and the weld boundaries are to show complete fusion, penetration and sound metallurgical structure.

5. Annual inspections

(1) In the annual inspection, tests specified in the following (2) are to be conducted for each brand of the approved materials, and they are to be passed satisfactorily.

(2) The kinds of test, etc. in the annual inspections are to be as given in **Table 2.2.43.**

(3) The welding procedures and requirements for test assemblies of tests specified in the preceding (2) are to be as specified in **Par 4.**

Table 2.2.43 Kind of Test for Annual Inspection

Kind of test	Test assembly			Kinds and no. of test specimens taken from test assembly
	Number	Dimensions	Thickness (mm)(1)	
Butt weld test	1	**Fig 2.2.29**	20 ~ 25	Tensile test specimen: 1 Longitudinal Tensile test specimen: 1 Side bend test specimen: 2 Impact test specimen: 6(1)

NOTE:
(1) One set of three impact test specimens may be taken from the centre of welded part. where approved by the Society.

6. Changes in grades

Where changes in the grades relating to the strength or toughness of welding consumables approved are to be made, tests specified in **Par 3** (1) are to be conducted and satisfactorily passed in accordance with the requirements in **601. 5** (2).

606. One side welding consumables for normal strength steels, higher strength steels and steels for low temperature service.

1. Application

(1) Welding consumables for normal strength steels, higher strength steels and steels for low temperature service given in the following (a) through (c) (hereinafter referred to as "one side automatic welding consumables") are to be subjected to the approval tests and annual inspections in accordance with the requirements in **606**.
(a) Submerged arc one side automatic welding consumables
(b) Gas shielded arc one side automatic welding consumables (solid wire or flux cored wire with shielding gas)
(c) Self-shielded arc one side automatic welding consumables (flux cored wire or flux coated wire without shielding gas)
(2) Approval tests and annual inspections of one side covered electrodes for normal strength steels, higher strength steels and steels for low temperature service, and one side semi-automatic welding consumables are to be as deemed appropriate by the Society.
(3) Approval tests and annual inspections for one side automatic welding consumables of muitiple electrodes are to be as deemed appropriate by the Society.

2. Grades and marks

(1) One side automatic welding consumables are classified as specified in **603. 2.** Further, one side automatic welding consumables which have passed the tests for each welding procedure given in **Table 2.2.45** are to be appended with the suffixes given in **Table 2.2.44** at the end of their marks.
(2) In the preceding (1), a suffix G will be added to the grade mark for gas shielded arc one side automatic welding consumables, and a suffix N will be added for self-shielded wire one side automatic welding consumables. Further, the type of gas used is to be as specified in **Table 2.2.27** and the suffix given in **Table 2.2.27** will be added after the suffix G. (e.g. $3Y\ SMR\ G(M1)$)

Table 2.2.44 Marks

Welding technique[(1)]	Marks
One-run technique	SR
Multi-run technique	MR
One-run and multi-run technique	SMR

NOTE:
(1) One-run or multi-run technique refers to a welding process which performed in one pass or multiple passes respectively regardless of the number of electrodes.

3. General provisions for tests

(1) Kinds of test, number, thickness and dimensions of test assemblies, grades and number of test specimens to be taken from each test assembly for one side automatic welding consumables are to be as given in **Table 2.2.45.**
(2) Steel plates to be used for test assemblies are to be as given in **Table 2.2.46.**
(3) For the approval of one side automatic welding consumables, the tests specified in the preceding (1) are to be conducted for each brand of one side automatic welding consumables.
(4) For gas shield arc one side automatic welding consumables, the test in the preceding (3) is to be performed for each type of gas given in **Table 2.2.27.** When the manufacturer of the material recommends gas types of the group of $M1$, $M2$, $M3$ or C in **Table 2.2.27** and the test is satisfactorily conducted in accordance with the preceding (3) on one of the gas type, the test on the other gas types belonging to the same group is allowed to be dispensed with at the discretion of the Society.

Table 2.2.45 Kinds of Test for One-side Automatic Welding Consumables

Grade of welding consumables	Welding technique	Kind of test(4)	Test assembly			Kind and number of test specimens taken from test assembly
			Number	Thickness (mm)(1)	Dimension	
1, 2, 3, 1*Y*, 2*Y*, 3*Y*, 4*Y*, 5*Y*, 2*Y*40, 3*Y*40, 4*Y*40, 5*Y*40, *L*1, *L*2, *L*3, *L*91, *L*92	One-run technique	Butt weld test	1	12 ~ 15	**Fig 2.2.31**	Tensile test specimen: 2 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1 Impact test specimen: 6 Macro-structure test specimen: 1
			1	Maximum thickness		
	Multi-run technique		1	15 ~ 25		Tensile test specimen: 2 Longitudinal tensile test specimen: 1 Face bend specimen :1 Root bend Specimen: 1 Impact test specimen: 6 Macro-structure test specimen: 1
			1	35		
	One-run and Multi-run technique		1	Maximum thickness(2)		Tensile test specimen: 2 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1 Impact test specimen: 6 Macro-structure test specimen: 1
			1	35(3)		

NOTES:
(1) Where thickness is restricted by welding process, thickness of test assemblies may be changed upon approval of the Society. In this case, the maximum test thickness is to be taken as the maximum applicable thickness.
(2) Thickness of test assembly for one run technique.
(3) Thickness of test assembly for multi-run technique.
(4) The hydrogen test may be carried out according to the manufacturer's request.

Table 2.2.46 Grades of Steel used for Test Assembly

Grade of welding consumables	Grade of steel used for test assembly(1)
1	*A*
2	*A*, *B* or *D*
3	*A*, *B*, *D* or *E*
1*Y*	*AH* 32 or *AH* 36
2*Y*	*AH* 32, *AH* 36, *DH* 32 or *DH* 36
3*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32 or *EH* 36
4*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
5*Y*	*AH* 32, *AH* 36, *DH* 32, *DH* 36, *EH* 32, *EH* 36, *FH* 32 or *FH* 36
2*Y*40	*AH* 40 or *DH* 40
3*Y*40	*AH* 40, *DH* 40 or *EH* 40
4*Y*40	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
5*Y*40	*AH* 40, *DH* 40, *EH* 40 or *FH* 40
L 1	*E* or *RL* 24*A*
L 2	*E*, *RL* 24*A*, *RL* 24*B*, *RL* 27 or *RL* 33
L 3	*RL* 27, *RL* 33 or *RL* 37
L 91	*RL* 9*N*53 or *RL* 9*N*60
L 92	*RL* 9*N*53 or *RL* 9*N*60

NOTE:
(1) The tensile strength of higher strength steels *AH* 32, *DH* 32, *EH* 32 and *FH* 32 used in the test assemblies is to be greater than 490 N/mm^2

(5) The combination of one side automatic welding materials are classified as given in **Table 2.2.47,** appropriate to the welding procedure.

Table 2.2.47 Combinations of One Side Automatic Welding Consumables

Welding technique	Combinations of welding consumables
Submerged one side automatic welding	Wire + Flux + Iron powder + Backing
Gas shielded arc one side automatic welding	Wire + Gas + Iron powder + Backing
Self-shielded arc one side automatic welding	Wire + Iron powder + Backing

NOTE: Where iron powder is not used, iron powder is excluded in this Table.

(6) The welding conditions used such as amperage, voltage, travel speed, etc. are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.
(7) After welding, the test assemblies are not to be subjected to any heat treatment.
(8) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

4. Butt weld test assemblies with one-run and multi-run technique

(1) *Welding of butt weld test assemblies with one-run and multi-run technique*

(a) Test assemblies are to be prepared as shown in **Fig 2.2.31,** and the diameter of wire, root gap and edge preparation are to be within the range specified by the manufacturer.

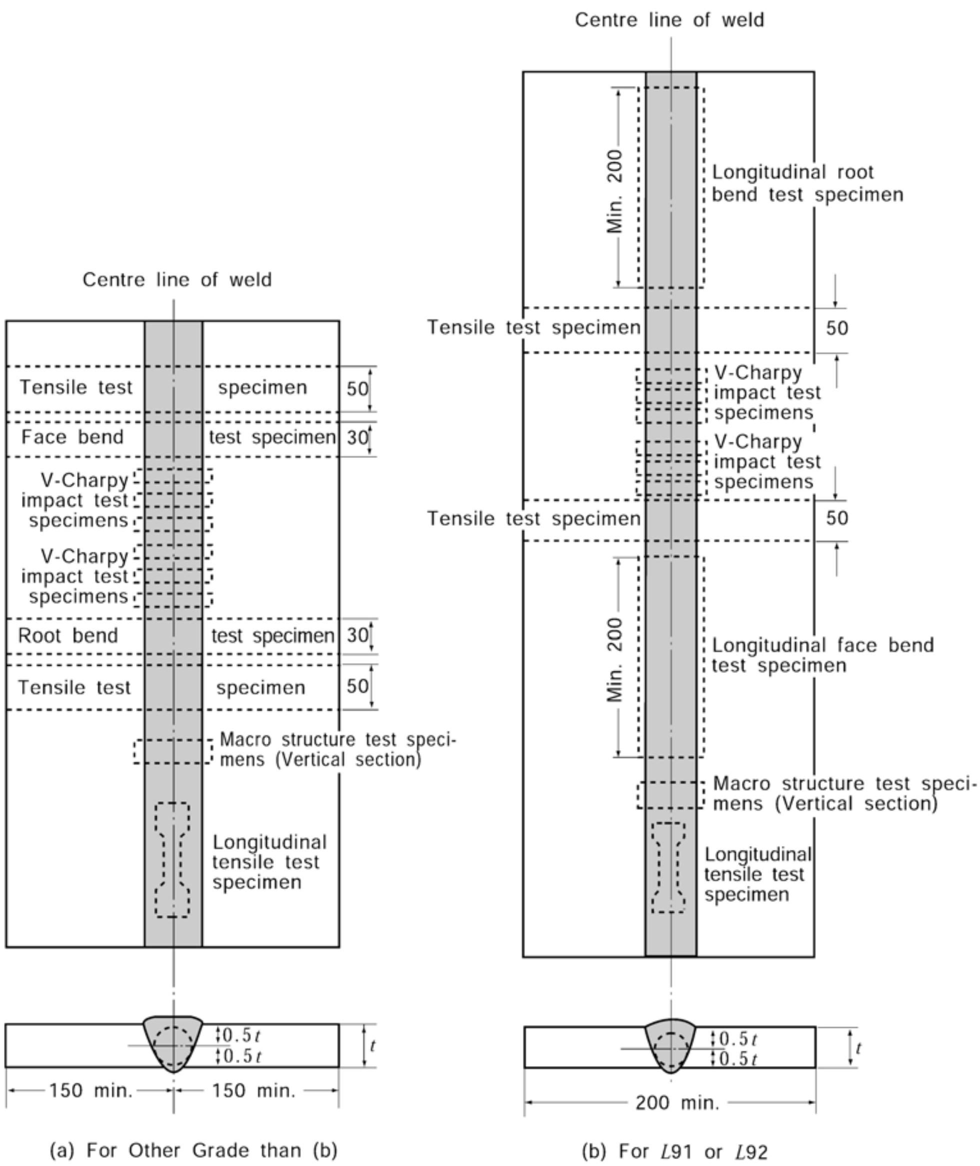


Fig. 2.2.31 Butt Weld Test Assembly with One-run and Multi-run Technique (Unit : *mm*, *t* = Plate thickness)

(b) Test assemblies are to be welded in downhand position by one-run technique or multi-run technique according to the procedures specified by the manufacturer. However, for gas shield and self-shielded arc one side automatic welding consumables, the welding position is to be specified by the manufacturer.

(c) After completing each run the test assembly is to be left in still air until it has cooled to less than 250℃ but not below 100℃, the temperature being taken at the centre of weld on the surface of seam.

(2) *Butt weld tensile test with one-run and multi-run technique*

(a) Tow tensile test specimens to be *R* 2*A* specimen and one longitudinal tensile test specimen to be *R*14*A* specimen as shown in **Table 2.2.1** are to be taken from each test assembly.
The longitudinal axis of test specimen coincides with the centre of weld and the mid-thick-

ness of plate.

(b) The longitudinal tensile test specimen may be subjected to a temperature not exceeding 250℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.

(c) Tensile strength of each test specimen *R* 2*A* is to comply with the requirements in **Table 2.2.31.** Tensile strength, yield strength and elongation of longitudinal tensile test specimens *R* 14 are to comply with the requirements given in **Table 2.2.30.** Where the upper limit of tensile strength is exceeded, special consideration will be given to the approval of the welding consumables, taking into consideration of the other mechanical properties shown in the test results and chemical composition of deposited metal.

(3) *Butt weld bend test with one-run and multi-run technique* The bend tests are to comply with the requirements in **603. 6.** (3).

(4) *Butt weld impact test with one-run and multi-run technique*

(a) Two sets of impact test specimens, from each test assembly, are to be machined to dimensions *R* 4 test specimen as shown in **Table 2.1.3.** Longitudinal direction of the test specimen is to be perpendicular to the weld line as shown in **Fig 2.2.32.**

(b) Test temperature and average absorbed energy are to comply with the requirements given in **Table 2.2.31.**

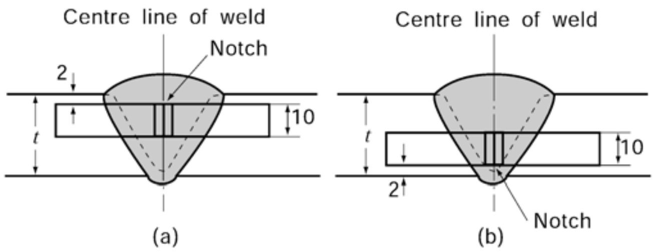


Fig. 2.2.32 Position of Impact Test Specimen for Butt Weld with One-run and Multi-run Technique
(Unit: mm, t = Plate thickness)

(c) The notch is to be positioned in the centre of weld and is to be cut in the face of test specimens perpendicular to the surface of plate.

(d) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified average absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified average absorbed energy, the test is considered to have failed.

(5) *Butt weld macro-structure test with one-run and multirun technique*

(a) Macro-structure test specimens are to be taken from the position shown in **Fig 2.2.31.** The surface to be tested is to be perpendicular to the surface of the test assembly.

(b) Both the welded parts and the weld boundaries are to show complete fusion, penetration and sound metallurgical structure.

5. Hydrogen test

The hydrogen test is to be in accordance with **602. 6** of the Rules

6. Annual inspections

(1) In the annual inspection, tests specified in the following (2) are to be conducted for each brand of the approved consumables, and they are to be passed satisfactorily.

(2) The kinds of test, etc. in the annual inspection are to be as given in **Table 2.2.48.**

Table 2.2.48 Kinds of Test for Annual Inspection

Grade of welding consumables	Welding technique	Kind of test	Test assembly			Kind and number of test specimens taken from test assembly
			Number	Dimension	Thickness (mm)(1)	
1, 2, 3, 1Y, 2Y, 3Y, 4Y, 5Y, 2Y40, 3Y40, 4Y40, 5Y40, L1, L2, L3, L91, L92	One-run technique	Butt weld test(2)	1	**Fig 2.2.31**	20	Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1 Impact test specimen: 3(3)
	Multi-run technique		1		20~25	Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1 Impact test specimen: 3(3)
	One-run and Multi-run technique		1		20~25	Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1 Impact test Specimen: 3(3)

NOTES:
(1) Where the thickness of test assemblies is changed according to Note (1) of **Table 2.2.45**, the maximum test thickness for approval test is to be applied.
(2) The butt weld tests for one-run and multi-run technique are to be carried out by one-run technique.
(3) The positions of notch and selection of impact test specimens are to be as given in **Fig2.2.32** (b).

(3) The welding procedures and requirements of test assemblies for tests in the preceding (2) are to be as specified in **Par 4.**

7. Changes in grades

Where changes in the grades relating to the strength or toughness of one side automatic welding consumables approved are to be made, all the tests specified in **Par 3** (1) are to be carried out and satisfactorily passed in accordance with the requirements in **601. 5** (2).

607. Welding consumables for stainless steel

1. Application

Welding consumables for stainless steels specified in **Ch 1, Sec 3** (hereinafter referred to as "welding consumables") are to be subjected to the approval tests and annual inspections in accordance with the requirements in **607.**

2. Grades and marks

(1) Welding consumables are classified as specified in **Table 2.2.49.**
(2) Submerged arc welding consumables which have passed the tests for each welding process given in **Table 2.2.51** are to be appended with the suffixes shown in **Table 2.2.50** at the end of their marks.
(3) For flux cored wire semi-automatic welding consumables in the preceding (1), a suffix G will be added to the grade mark for welding consumables which use shield gas, and a suffix N will be added to the grade markes for welding consumables which do not used shield gas. Further, the type of shield gas used is to be as specified in **Table 2.2.27** and the suffix given in **Table 2.2.27** will be added after the suffix G. (e.g. *RW* 308*G* (C))

Table 2.2.49 Grades and Marks of Welding Consumables

Electrode for manual arc welding	Material for TIG and MIG welding	Flux cored wire semi-automatic welding	Consumables for submerged welding
RD 308	*RY* 308	*RW* 308	*RU* 308
RD 308*L*	*RY* 308*L*	*RW* 308*L*	*RU* 308*L*
RD 309	*RY* 309	*RW* 309	*RU* 309
RD 309*L*	*RY* 309*L*	*RW* 309*L*	-
RD 309*Mo*	*RY* 309*Mo*	*RW* 309*Mo*	*RU* 309*Mo*
RD 309*MoL*	-	*RW* 309*MoL*	-
RD 310	*RY* 310	*RW* 310	*RU* 310
-	*RY* 310*S*	-	-
RD 310*Mo*	-	-	-
RD 316	*RY* 316	*RW* 316	*RU* 316
RD 316*L*	*RY* 316*L*	*RW* 316*L*	*RU* 316*L*
RD 317	*RY* 317	*RW* 317	*RU* 317
RD 317*L*	*RY* 317*L*	*RW* 317*L*	*RU* 317*L*
-	*RY* 321	-	-
RD 347	*RY* 347	*RW* 347	*RU* 347

Table 2.2.50 Marks

Welding technique	Marks
Multi-run technique	*M*
Two-run technique	*T*
Multi-run and Two-run technique	*TM*

3. General provisions for tests

(1) Kinds of test, number, thickness and dimensions of test assemblies, diameter of wire used for welding, grades and number of test specimens to be taken from each test assembly in each welding position for welding consumables are to be as given in **Table 2.2.51.** However, additional tests appropriate to steels, such as test on corrosion-resistance test, impact test, macro etching test, etc., except the test given in **Table 2.2.51** may be required where deemed necessary by the Society.
(2) Steel plates to be used for test assemblies are to be as given in **Table 2.2.52** according to the grades of welding consumables.
(3) For the approval of welding consumables, the tests specified in the preceding (1) are to be conducted for each brand of welding consumables.
(4) For flux cored wire semi-automatic welding materials, which use shield gas, the test in the preceding (3) is to be performed for each type of gas given in **Table 2.2.27.** When the manufacturer of the consumables recommends gas types of the group of *M* 1, *M* 2, *M* 3 or C in **Table 2.2.27** and the test is satisfactorily conducted in accordance with the preceding (3) on one of the gas type, the test on the other gas types belonging to the same group is allowed to be dispensed with at the discretion of the Society.
(5) The welding conditions used such as amperage, voltage, travel speed, etc. are to be within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.

Table 2.2.51 Kinds of Test of Welding Consumables for Stainless Steel

Kind of welding consumables	Kind of test	Test assembly: Thick-ness (mm)	No.	Welding position	Dia. of electrode or wire (1) (mm)	Dimen-sion	Kind and number of test specimens taken from test assembly
Electrode for manual arc welding	Deposited metal test	12	1	Flat	3.2	**Fig 2.2.33**	Tensile test specimen: 1
		19	1		4.0		
	Butt weld test	9~12	1	Flat	3.2 or 4.0	**Fig 2.2.34**	Tensile test specimen: 1 Face bend Specimen: 1 Root bend specimen: 1
			1	Horizontal			
			1	Vertical upward			
			1	Vertical downward			
			1	Overhead			
Consumables for TIG welding	Deposited metal test	12	1	Flat	2.4	**Fig 2.2.33**	Tensile test specimen: 1
		19	1		3.2		
	Butt weld test	9~12	1	Flat	2.0~3.2	**Fig 2.2.34**	Tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1
			1	Horizontal			
			1	Vertical upward			
			1	Vertical downward			
			1	Overhead			
Consumables for MIG welding	Deposited metal test	12	1	Flat	1.2	**Fig 2.2.33**	Tensile test specimen: 1
		19	1		1.6		
	Butt weld test	9~12	1	Flat Horizontal Vertical upward Vertical downward Overhead	1.2~2.0	**Fig 2.2.34**	Tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1
Flux cored wire for semi-automatic welding	Deposited metal test	12	1	Flat	1.2~2.4	**Fig 2.2.33**	Tensile test specimen: 1
		19	1		3.2 or max. dia		
	Butt weld test	9~12	1	Flat Horizontal Vertical upward Vertical downward Overhead	1.2~3.2	**Fig 2.2.34**	Tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1
Consumables for submerged arc welding (2) — Multi-run technique	Deposited metal test	19~25	1	Flat	1.2~4.0	**Fig 2.2.33**	Tensile test specimen: 1
	Butt weld test	19	1	Flat	1.2~4.0	**Fig 2.2.35 (a)**	Tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1
Consumables for submerged arc welding (2) — Two-run technique	Butt weld test	12	1	Flat	1.2~2.4	**Fig 2.2.35 (b)**	Tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1
		19	1	Flat	4.0		Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1

NOTES:
(1) Where approved by the Society, the diameter of electrodes or wires may be changed.
(2) Tests on both multi-run and two run technique are to be conducted for multi-run and two run welding respectively and the number, dimensions and thickness of test assemblies, along with the grades and number of test specimens selected from each test assembly are to be according to each of the welding processes. However, longitudinal tensile test of two run technique are not required.

Table 2.2.52 Grades of Steel for Test Assembly

Grade of welding consumables	Grade of steel for test assembly(1)
RD 308, *RY* 308, *RW* 308, *RU* 308	*RSTS* 304
RD 308*L*, *RY* 308*L*, *RW* 308*L*, *RU* 308*L*	*RSTS* 304*L*
RD 309, *RY* 309, *RW* 309, *RU* 309	*RSTS* 309*S*
RD 309*L*, *RY* 309*L*, *RW* 309*L*	
RD 309*Mo*, *RY* 309*Mo*, *RW* 309*Mo*, *RU* 309*Mo*	
RD 309*MoL*, *RW* 309*MoL*	
RD 310, *RY* 310, *RW* 310, *RU* 310	*RSTS* 310*S*
RY 310*S*	
RD 310*Mo*	
RD 316, *RY* 316, *RW* 316, *RU* 316	*RSTS* 316
RD 316*L*, *RY* 316*L*, *RW* 316*L*, *RU* 316*L*	*RSTS* 316L
RD 317, *RY* 317, *RW* 317, *RU* 317	*RSTS* 317
RD 317*L*, *RY* 317*L*, *RW* 317*L*, *RU* 317*L*	*RSTS* 317, *RSTS* 317*L*
RY 321	*RSTS* 321
RD 347, *RY* 347, *RW* 347, *RU* 347	*RSTS* 321, *RSTS* 347

NOTE:
(1) Notwithstanding the requirements in this table, mild steel or higher strength steel may be used for deposited metal test assembly. In this case, test assemblies are to be appropriately buttered.

(6) After welding, the test assemblies are not to be subjected to any heat treatment.
(7) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

4. Deposited metal test

(1) *Welding of deposited metal test assemblies*
 (a) Test assemblies as shown in **Fig 2.2.33** are to be welded in the flat position according to the welding procedure recommended by the manufacturer.
 (b) After each run, the test assembly is to be left in still air until it has cooled to less than 150℃ but not below 15℃, the temperature being taken at the centre of the weld on the surface of seam.
(2) *Chemical composition*
 (a) Deposited metals of electrodes for manual arc welding and of welding consumables for flux cored wire semi-automatic welding and submerged arc welding are to have the chemical composition given in **Tables 2.2.53, 2.2.55** and **2.2.56** respectively.
 (b) TIG and MIG welding consumables are to have the chemical composition of ladle analysis value complied with the requirements as given in **Table 2.2.54.**
(3) *Deposited metal tensile test*
 (a) One tensile test specimens to be R10 shown in **Table 2.2.1** is to be taken from each test assembly. Further, where approved by the Society, one R14A tensile test specimen may be taken, the longitudinal axis of test specimen coincides with the centre of weld and the mid-thickness of plate.
 (b) The tensile test specimens may be subjected to a temperature not exceeding 250℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.
 (c) Deposited metal tensile tests are to comply with the requirements in **Table 2.2.57.**

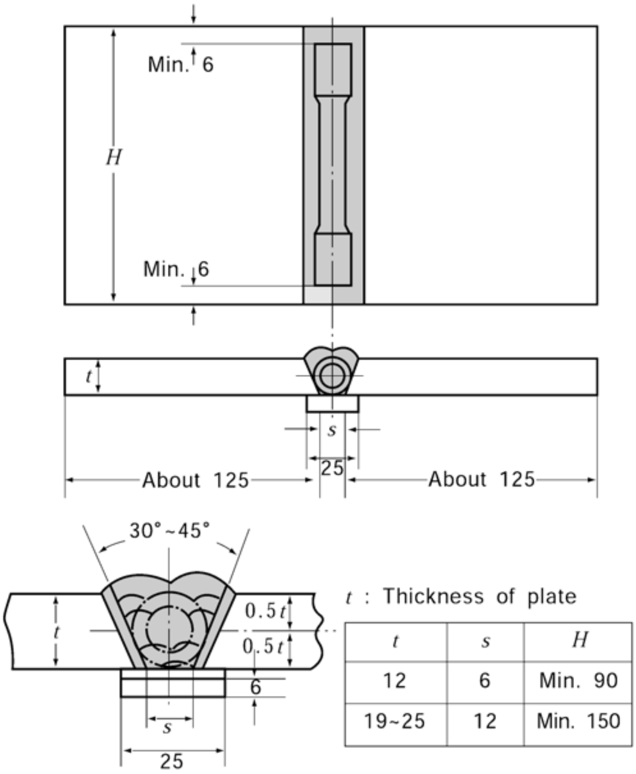


Fig. 2.2.33 Deposited Metal Test Assembly for Stainless Steel (Unit : *mm*)

Table 2.2.53 Chemical Composition of Deposited Metal for Electrodes

Grade	Chemical composition (%)								
	C(max.)	Si(max.)	Mn(max.)	P(max.)	S(max.)	Ni	Cr	Mo	Others
RD 308	0.08	0.90	2.50	0.04	0.03	9.0 ~ 11.0	18.0 ~ 21.0	–	–
RD 308L	0.04	0.90	2.50	0.04	0.03	9.0 ~ 12.0	18.0 ~ 21.0	–	–
RD 309	0.15	0.90	2.50	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	–	–
RD 309*L*	0.04	0.90	2.50	0.04	0.03	12.0 ~ 16.0	22.0 ~ 25.0	–	–
RD 309*Mo*	0.12	0.90	2.50	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	–
RD 309*MoL*	0.04	0.90	2.50	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	–
RD 310	0.20	0.75	2.50	0.03	0.03	20.0 ~ 22.0	25.0 ~ 28.0	–	–
RD 310*Mo*	0.12	0.75	2.50	0.03	0.03	20.0 ~ 22.0	25.0 ~ 28.0	2.0 ~ 3.0	–
RD 316	0.08	0.90	2.50	0.04	0.03	11.0 ~ 14.0	17.0 ~ 20.0	2.0 ~ 2.75	–
RD 316*L*	0.04	0.90	2.50	0.04	0.03	11.0 ~ 16.0	17.0 ~ 20.0	2.0 ~ 2.75	–
RD 317	0.08	0.90	2.50	0.04	0.03	12.0 ~ 14.0	18.0 ~ 21.0	3.0 ~ 4.0	–
RD 317*L*	0.04	0.90	2.50	0.04	0.03	12.0 ~ 16.0	18.0 ~ 21.0	3.0 ~ 4.0	–
RD 347	0.08	0.90	2.50	0.04	0.03	9.0 ~ 11.0	18.0 ~ 21.0	–	Nb8×C (%)~1.0

Table 2.2.54 Chemical Composition of Deposited Metal for TIG Electrodes or MIG Wires

Grade	Chemical composition (%)								
	C(max.)	Si(max.)	Mn	P(max.)	S(max.)	Ni	Cr	Mo	Others
RY 308	0.08	0.65	1.0 ~ 2.5	0.03	0.03	9.0 ~ 11.0	19.0 ~ 22.0	–	–
RY 308*L*	0.03	0.65	1.0 ~ 2.5	0.03	0.03	9.0 ~ 11.0	19.0 ~ 22.0	–	–
RY 309	0.12	0.65	1.0 ~ 2.5	0.03	0.03	12.0 ~ 14.0	23.0 ~ 25.0	–	–
RY 309*L*	0.03	0.65	1.0 ~ 2.5	0.03	0.03	12.0 ~ 14.0	23.0 ~ 25.0	–	–
RY 309*Mo*	0.12	0.65	1.0 ~ 2.5	0.03	0.03	12.0 ~ 14.0	23.0 ~ 25.0	2.0 ~ 3.0	–
RY 310	0.15	0.65	1.0 ~ 2.5	0.03	0.03	20.0 ~ 22.5	25.0 ~ 28.0	–	–
RY 310*S*	0.08	0.65	1.0 ~ 2.5	0.03	0.03	20.0 ~ 22.5	25.0 ~ 28.0	–	–
RY 316	0.08	0.65	1.0 ~ 2.5	0.03	0.03	11.0 ~ 14.0	18.0 ~ 20.0	2.0 ~ 3.0	–
RY 316*L*	0.03	0.65	1.0 ~ 2.5	0.03	0.03	11.0 ~ 14.0	18.0 ~ 20.0	2.0 ~ 3.0	–
RY 317	0.08	0.65	1.0 ~ 2.5	0.03	0.03	13.0 ~ 15.0	18.5 ~ 20.5	3.0 ~ 4.0	–
RY 317*L*	0.03	0.65	1.0 ~ 2.5	0.03	0.03	13.0 ~ 15.0	18.5 ~ 20.5	3.0 ~ 4.0	–
RY 321	0.08	0.65	1.0 ~ 2.5	0.03	0.03	9.0 ~ 10.5	18.5 ~ 20.5	–	Ti9×C (%) ~ 1.0
RY 347	0.08	0.65	1.0 ~ 2.5	0.03	0.03	9.0 ~ 11.0	19.0 ~ 21.5	–	Nb10×C (%) ~ 1.0

Table 2.2.55 Chemical Composition of Deposited Metal for Flux Cored Wire Semi-automatic Welding

(a) With Gas

Grade	Chemical composition (%)								
	C(max.)	Si(max.)	Mn	P(max.)	S(max.)	Ni	Cr	Mo	Others
RW 308	0.08	1.0	0.5 ~ 2.5	0.04	0.03	9.0 ~ 11.0	18.0 ~ 21.0	–	–
RW 308*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	9.0 ~ 12.0	18.0 ~ 21.0	–	–
RW 309	0.10	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	–	–
RW 309*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	–	–
RW 309*Mo*	0.12	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	–
RW 309*MoL*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	–
RW 310	0.20	1.0	0.5 ~ 2.5	0.04	0.03	20.0 ~ 22.0	25.0 ~ 28.0	–	–
RW 316	0.08	1.0	0.5 ~ 2.5	0.04	0.03	11.0 ~ 14.0	17.0 ~ 20.0	2.0 ~ 3.0	–
RW 316*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	11.0 ~ 14.0	17.0 ~ 20.0	2.0 ~ 3.0	–
RW 317	0.08	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	18.0 ~ 21.0	3.0 ~ 4.0	–
RW 317*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 16.0	18.0 ~ 21.0	3.0 ~ 4.0	–
RW 347	0.08	1.0	0.5 ~ 2.5	0.04	0.03	9.0 ~ 11.0	18.0 ~ 21.0	–	Nb8×C (%) ~ 1.0

Table 2.2.55 Chemical Composition of Deposited Metal for Flux Cored Wire Semi-automatic Welding

(b) Without Gas

Grade	Chemical composition (%)								
	C(max.)	Si(max.)	Mn	P(max.)	S(max.)	Ni	Cr	Mo	Others
RW 308	0.08	1.0	0.5 ~ 2.5	0.04	0.03	9.0 ~ 11.0	19.5 ~ 22.0	−	−
RW 308*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	9.0 ~ 12.0	19.5 ~ 22.0	−	−
RW 309	0.10	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	23.0 ~ 25.5	−	−
RW 309*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	23.0 ~ 25.5	−	−
RW 309*Mo*	0.12	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	−
RW 309*MoL*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	−
RW 310	0.20	1.0	0.5 ~ 2.5	0.04	0.03	20.0 ~ 22.0	25.0 ~ 28.0	−	−
RW 316	0.08	1.0	0.5 ~ 2.5	0.04	0.03	11.0 ~ 14.0	18.0 ~ 20.5	2.0 ~ 3.0	−
RW 316*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	11.0 ~ 14.0	18.0 ~ 20.5	2.0 ~ 3.0	−
RW 317	0.08	1.0	0.5 ~ 2.5	0.04	0.03	13.0 ~ 15.0	18.5 ~ 21.0	3.0 ~ 4.0	−
RW 317*L*	0.04	1.0	0.5 ~ 2.5	0.04	0.03	13.0 ~ 15.0	18.5 ~ 21.0	3.0 ~ 4.0	−
RW 347	0.08	1.0	0.5 ~ 2.5	0.04	0.03	9.0 ~ 11.0	19.0 ~ 21.5	−	Nb8×C (%) ~ 1.0

Table 2.2.56 Chemical Composition of Deposited Metal for Submerged Arc Welding

Grade	Chemical composition (%)								
	C(max.)	Si(max.)	Mn(max.)	P(max.)	S(max.)	Ni	Cr	Mo	Others
RU 308	0.08	1.0	2.5	0.04	0.03	9.0 ~ 11.0	18.0 ~ 21.0	−	−
RU 308*L*	0.04	1.0	2.5	0.04	0.03	9.0 ~ 12.0	18.0 ~ 21.0	−	−
RU 309	0.15	1.0	2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	−	−
RU 309*Mo*	0.12	1.0	2.5	0.04	0.03	12.0 ~ 14.0	22.0 ~ 25.0	2.0 ~ 3.0	−
RU 310	0.20	1.0	2.5	0.04	0.03	20.0 ~ 22.0	25.0 ~ 28.0	−	−
RU 316	0.08	1.0	2.5	0.04	0.03	11.0 ~ 14.0	17.0 ~ 20.0	2.0 ~ 2.75	−
RU 316*L*	0.04	1.0	2.5	0.04	0.03	11.0 ~ 16.0	17.0 ~ 20.0	2.0 ~ 2.75	−
RU 317	0.08	1.0	2.5	0.04	0.03	12.0 ~ 14.0	18.0 ~ 21.0	3.0 ~ 4.0	−
RU 317*L*	0.04	1.0	2.5	0.04	0.03	12.0 ~ 16.0	18.0 ~ 21.0	3.0 ~ 4.0	−
RU 347	0.08	1.0	2.5	0.04	0.03	9.0 ~ 11.0	18.0 ~ 21.0	−	Nb8×C (%) ~ 1.0

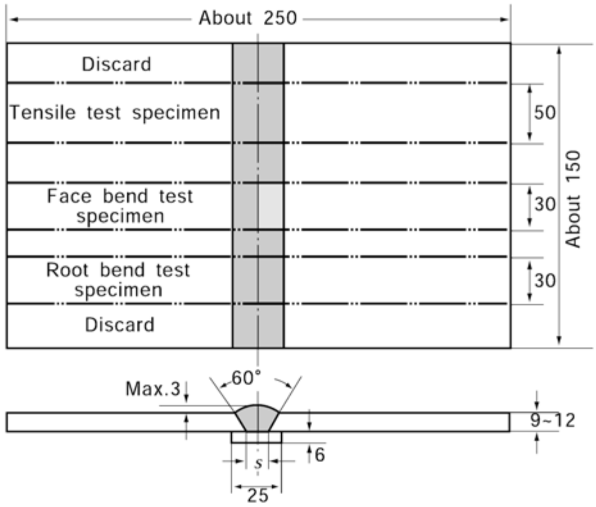
Table 2.2.57 Tensile Test Requirements for Deposited Metal

Electrode for manual arc welding	Consumables for TIG and MIG welding	Flux cored wire for semi-automatic welding	Consumables for submerged arc welding	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation (%)
RD 308	*RY* 308	*RW* 308	*RU* 308	550 min.	225 min.	35 min.
RD 308L	*RY* 308*L*	*RW* 308*L*	*RU* 308*L*	510 min.	205 min.	35 min.
RD 309	*RY* 309	*RW* 309	*RU* 309	550 min.	225 min.	30 min.
RD 309*L*	*RY* 309*L*	*RW* 309*L*	–	510 min.	205 min.	30 min.
RD 309*Mo*	*RY* 309*Mo*	*RW* 309*Mo*	*RU* 309*Mo*	550 min.	225 min.	30 min.
RD 309*MoL*	–	*RW* 309*MoL*	–	510 min.	205 min.	30 min.(1)
RD 310	*RY* 310	*RW* 310	*RU* 310	550 min.	225 min.	30 min.
–	*RY* 310*S*	–	–	550 min.	225 min.	30 min.
RD 310*Mo*	–	–	–	550 min.	225 min.	30 min.
RD 316	*RY* 316	*RW* 316	*RU* 316	550 min.	225 min.	30 min.
RD 316*L*	*RY* 316*L*	*RW* 316*L*	*RU* 316*L*	510 min.	205 min.	35 min.
RD 317	*RY* 317	*RW* 317	*RU* 317	550 min.	225 min.	30 min.
RD 317*L*	*RY* 317*L*	*RW* 317*L*	*RU* 317*L*	510 min.	205 min.	30 min.
–	*RY* 321	–	–	550 min.	225 min.	30 min.
RD 347	*RY* 347	*RW* 347	*RU* 347	550 min.	225 min.	30 min.

NOTE:
(1) Elongation of *RW* 309*MoL* is to be not less than 20 (%).

5. Butt weld test

(1) *Welding of butt weld test assemblies*
(a) Test assemblies as shown in **Figs 2.2.34** and **2.2.35** are to be welded in each welding position (flat, horizontal, vertical upward, vertical downward and overhead) which is recommended by the manufacturer.
(b) After each run, the test assembly is to be left in still air until it has cooled to less than 150℃ but not below 15℃, the temperature being taken at the centre of the weld on the surface of seam.
(2) *Butt weld tensile test*
(a) One tensile test specimens to be R2A shown in **Table 2.2.1** is to be taken from each test assembly.
(b) The tensile strength of each test specimen is to comply with the requirements given in **Table 2.2.58.**
(c) Submerged arc welding materials used only in the two-run technique are to be selected as one R14A tensile test specimen of **Table 2.2.1,** such that the longitudinal centre line of the test specimen coincides with the weld centre line of the test assemblies and centre of thickness.
(d) The longitudinal tensile test specimens specified in the preceding (3) may be subjected to the heat treatment not exceeding 250℃ for a period not exceeding 16 hours for hydrogen removal prior to testing.
(e) The tensile strength, yield point and elongation of the test specimens specified in the preceding (c) and (d) are to comply with the requirements given in **Table 2.2.57.**
(3) *Butt weld bend test*
(a) The face and root bend test specimens are to be RB4 specimen shown in **Table 2.2.2,** and test specimens are to be taken from each test assembly.
(b) The test specimens are to be capable of withstanding, without crack exceeding 3 mm long on the outer surface of the specimen or other defects, being bent through an angle of 120 degrees over a former having a radius of 1.5 times the thickness of test specimen.



Kind of welding consum-ables	Electrode for manual arc welding	Elec-trode for TIG welding	Wire for MIG welding	Flux cored wire for semi-auto-matic welding
$s(mm)$	Max. dia. of electrode	Max.5	Max.5	Max.6

Fig. 2.2.34 Butt Weld Test Assembly for Stainless Steel
(Except for Submerged arc welding, Unit : mm)

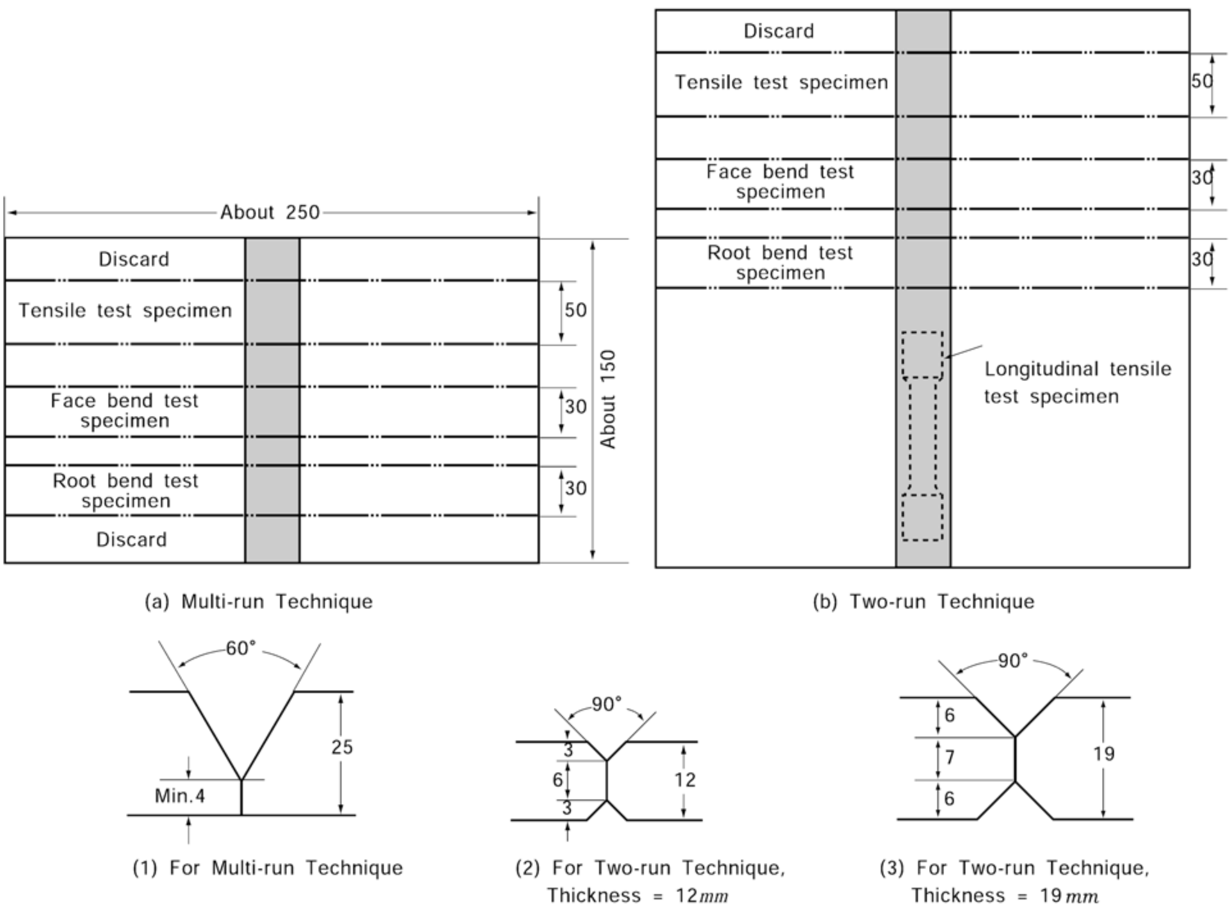


Fig. 2.2.35 Butt Weld Test Assembly for Stainless Steel (Submerged arc welding, Unit : mm)

Table 2.2.58 Tensile Test Requirements for Butt Weld

Electrode for manual arc welding	Consumables for TIG and MIG welding	Flux cored wire for semi-automatic welding	Consumables for submerged arc welding	Tensile strength (N/mm^2)
RD 308	*RY* 308	*RW* 308	*RU* 308	520 min.
RD 308*L*	*RY* 308*L*	*RW* 308*L*	*RU* 308*L*	480 min.
RD 309	*RY* 309	*RW* 309	*RU* 309	520 min.
RD 309*L*	*RY* 309*L*	*RW* 309*L*	–	520 min.
RD 309*Mo*	*RY* 309*Mo*	*RW* 309*Mo*	*RU* 309*Mo*	520 min.
RD 309*MoL*	–	*RW* 309*MoL*	–	520 min.
RD 310	*RY* 310	*RW* 310	*RU* 310	520 min.
–	*RY* 310*S*	–	–	520 min.
RD 310*Mo*	–	–	–	520 min.
RD 316	*RY* 316	*RW* 316	*RU* 316	520 min.
RD 316*L*	*RY* 316*L*	*RW* 316*L*	*RU* 316*L*	480 min.
RD 317	*RY* 317	*RW* 317	*RU* 317	520 min.(1)
RD 317*L*	*RY* 317*L*	*RW* 317*L*	*RU* 317*L*	520 min.(1)
–	*RY* 321	–	–	520 min.
RD 347	*RY* 347	*RW* 347	*RU* 347	520 min.

NOTE:
(1) Where the test assembly is made of *RSTS* 317*L*, the tensile strength is not to be less than 480 N/mm^2.

6. Annual inspections

(1) In the annual inspections, tests specified in the following (2) are to be conducted for each brand of approved consumables, and they are to be passed satisfactorily.
(2) The kinds of test, etc. in the annual inspections are to be as given in **Table 2.2.59.**
(3) The welding procedures and requirements of test assemblies for tests in the preceding (2) are to be as specified in **Pars 4** through **5.**

Table 2.2.59 Kinds of Test at Annual Inspection

Kind of welding consumables		Kind of test	Welding procedure for test assembly					Kind and number of test specimens taken from test assembly
			Welding position	Dia. of electrode or wire (mm)	Number	Dimension	Thickness (mm)	
Electrode for manual arc welding		Deposited metal test	Flat	3.2 ~ 4.0	1	**Fig 2.2.33**	12 ~ 19	Tensile test specimen: 1
Consumables for TIG welding				2.4 ~ 3.2				
Consumables for MIG welding				1.2 ~ 1.6				
Flux cored wire for semi-automatic welding				1.2 ~ 3.2				
Consumables for submerged arc welding (1)	Multi-run technique	Deposited metal test	Flat	1.2 ~ 4.0	1	**Fig 2.2.33**	19 ~ 25	Tensile test specimen: 1
	Two-run technique	Butt weld test	Flat	2.4 ~ 4.0	1	**Fig 2.2.35**(b)	12 ~ 19	Tensile test specimen: 1 Longitudinal tensile test specimen: 1 Face bend specimen: 1 Root bend specimen: 1

NOTE:
(1) Tests on both multi-run and two run technique are to be conducted for multi-run and two run welding respectively and the number, dimensions and thickness of test assemblies, along with the grades and number of test specimens selected from each test assembly are to be according to each of the welding processes. However, longitudinal tensile test of two run technique are not required.

608. Welding consumables for aluminium alloys

1. Application

(1) Welding consumables used for aluminium alloys mentioned in the following (a) and (b)(hereinafter referred to as "welding consumables") are to be subjected to the approval tests and annual inspections in accordance with these requirements.

(a) Rod-gas combinations for tungsten inert gas arc welding (TIG welding) or plasma arc welding

(b) Wire electrode and wire-gas combinations for metal arc inert gas welding (MIG welding), tungsten inert gas arc welding(TIG welding) or plasma arc welding

(2) Where no special requirements are given herein, e.g. for the approval procedure or for the welding of test assemblies and testing, those as specified in **601.** through **605.** apply in analogous manner.

2. Grades and marks of welding consumables

(1) Grades and marks of welding consumables are classified as given in **Table 2.2.60.**

Table 2.2.60 Grades and Marks

Kind of welding consumables	Grade and Mark
Electrode	*RA, RB, RC, RD*
Wire	*WA, WB, WC, WD*

(2) Approval of a wire or a rod will be granted in conjunction with a specific shielding gas according to Table 2.2.58 with suffixed mark “G”(e.g. *RBG*(*I*-3)). or defined in terms of composition and purity of “special” gas to be designated with group sign “*S*”(eg. *RBS*(CO_2 100%). The composition of the shielding gas is to be reported. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in **Table 2.2.61**, subject to the agreement of the Society.

Table 2.2.61 Kind of Gas

Group	Kinds	Gas composition(%)	
		He	Ar
I	I-1 I-2 I-3 I-4 I-5	- 100 > 0 - 33 > 33 - 66 > 66 - 95	100 - Rest Rest Rest
S		Others	

3. General provisions of tests

(1) Kinds of test, number, thickness and dimensions of test assemblies, kind and number of test specimen taken from each test assembly for welding consumables are to be as given in **Table 2.2.62.**

(2) The aluminium alloys used in preparation for test assembly corresponding to welding consumables are to be as given in **Table 2.2.63.**

(3) For the approval of welding consumables, the tests specified in (1) are to be successfully conducted for each brand of welding consumables.

(4) For welding consumables using a shielding gas, the tests specified in (1) are to be conducted for each kind of gas designated among **Table 2.2.61** by the manufacturer. However, where the manufacturer designates several kinds of gas which are classified into the group l in **Table 2.2.61** and the tests specified in (1) are to be conducted for any one kind of gas, the tests for the other kind of gas may be dispensed with subject to the approval of the Society.

Table 2.2.62 Kinds of Test for Welding Consumables

Kinds of test	Test assembly				Kinds and number of test specimens taken from test assembly
	Welding position	Number	Dimension	Thickness (mm)	
Deposited metal test (Chemical composition test)	Flat	1	**Fig 2.2.36**	-	-
Butt weld test	Flat	1	**Fig 2.2.37**	10 ~ 12	Tensile test specimen : 2 Face bend test specimen : 2 Root bend test specimen : 2 Macro structure test specimen : 1
	Horizontal	1[(1)]			
	Vertical upward	1			
	Overhead	1			
	Flat	1	**Fig 2.2.38**	20 ~ 25	Tensile test specimen : 2 Face bend test specimen : 2 Root bend test specimen : 2 Macro structure test specimen : 1

Note
(1) Welding consumables satisfying the requirements for flat and vertical upward positions may be dispensed with the tests for horizontal position subject to the approval of the Society.

Table 2.2.63 Grade of Aluminium Alloys used for Test Assembly

Grade of welding consumables	Grade of aluminium alloys used for test assembly	
RA, *WA*	5000 series	5754
RB, *WB*		5086
RC, *WC*		5083, 5383, 5456, 5059
RD, *WD*	6000 series	6005*A*, 6061, 6082

Note:
Approval on higher strength *AlMg* base materials(5000 series) covers also the lower strength *AlMg* grades and their combination with *AlSi* grades

(5) When the manufacturer designated the gas classified into the group "*S*" in the tests specified in (4), the composition of the shielding gas is to be reported to the Society.
(6) After welding, the test assemblies are not to be subjected to any heat treatment or peening.
(7) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

4. Deposited metal test

(1) *Welding of deposited metal test assembly*
(a) The test assemblies as shown in **Fig 2.2.36** are to be welded in flat position in accordance with the welding process designated by the manufacturer.

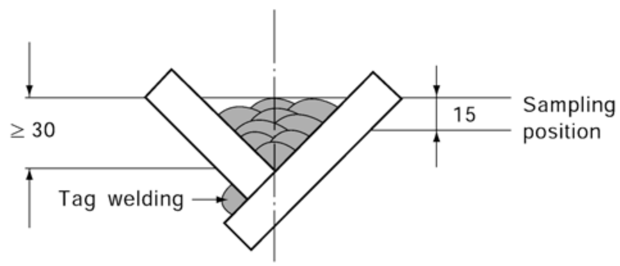


Fig. 2.2.36 Deposited Weld Metal Test Assembly
(Unit : *mm*)

(b) The size of test assembly corresponding to the welding consumables and welding process is to be taken a sufficient amount of pure weld metal for chemical analysis.

(2) *Chemical composition* The chemical composition of the welding consumables is to be determined by the analysis of the deposited weld metal specified in **Fig 2.2.36** and the results of the analysis are to comply with the limit value specified by the manufacturer.

5. Butt weld test

(1) *Welding of butt weld test assemblies*

(a) The test assemblies as shown in **Fig 2.2.37** are to be welded in each welding position designated by the manufacturer (downhand, horizontal, vertical-upward and overhead). The test assembly as shown by **Fig 2.2.38** is to be welded in the downhand position.

(b) On completion of each run, the test assemblies are to be allowed to cool naturally in air until the temperature measured at the surface of the centre of the welding joint is ambient temperature. However, the test assemblies for *RD* and *WD* are to be allowed to naturally ageing for a minimum period of 72 hours from the completion of welding before testing.

(2) *Butt weld tensile test*

(a) The tensile test specimens are to be *R* 2*A* specimen shown in **Table 2.2.1** and two test specimens are to be taken from each test assembly.

(b) The tensile strength is to comply with the requirements as given in **Table 2.2.64.**

Table 2.2.64 Requirements for the transverse tensile and bend tests

Grade of welding consumables	Base material used for the test	Tensile strength (N/mm^2)	Bend test	
			Former diameter (mm)	Bending angle
RA/WA	5754	190 min.	3 *t*(1)	180°
RB/WB	5086	240 min.	6 *t*(1)	
RC/WC	5083	275 min.		
	5383, 5456	290 min.		
	5059	330 min.		
RD/WD	6061, 6005A, 6082	170 min.		

Note
(1) *t* : Thickness of the test specimen

(3) *Butt Weld Bend Test*

(a) The face bend and root bend test specimens are to be *RB* 4 specimen shown in **Table 2.2.**2 and two test specimens are to be taken from each assembly.

(b) The test specimens are to sustain the face and root bend tests over 180" using a former having a diameter in accordance with **Table 2.2.64,** without cracks exceeding 3 mm in length and other any defects on the outer surface.

(4) *Butt weld macro structure test*

(a) One macro structure test specimen as shown in **Fig 2.2.37** and Fig **2.2.38** is to be taken from the butt weld test assembly.

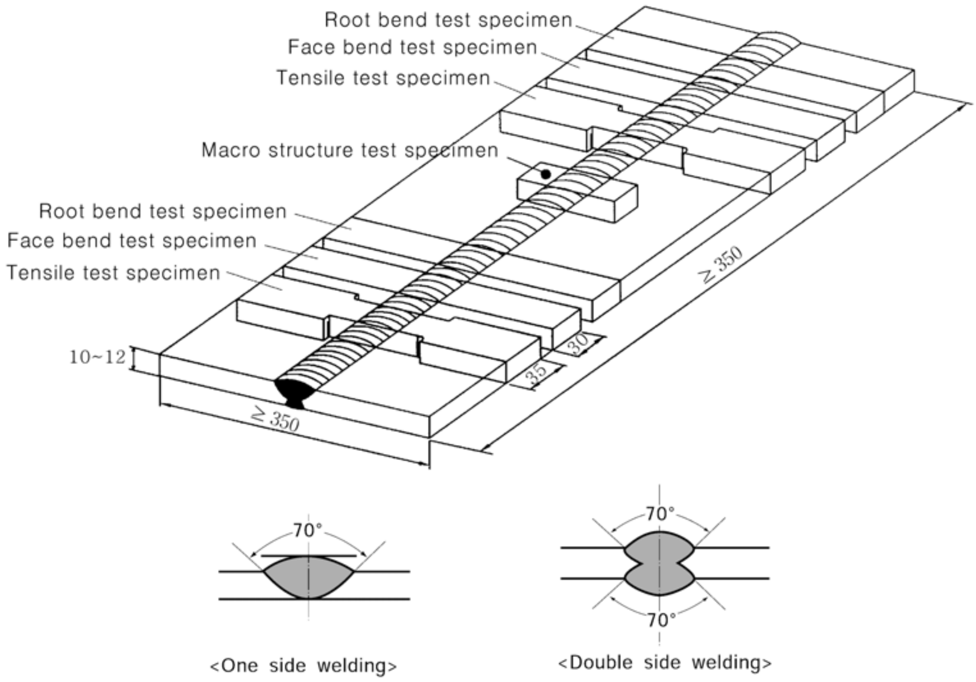
(b) The macro structure test specimen is to be examined that there are not any imperfections such as lack of fusion, poor penetration or cracks.

6. Annual inspections

(1) In the annual inspections, every approved welding consumables are to be subjected to the tests provided in (2) and are to be successfully examined.

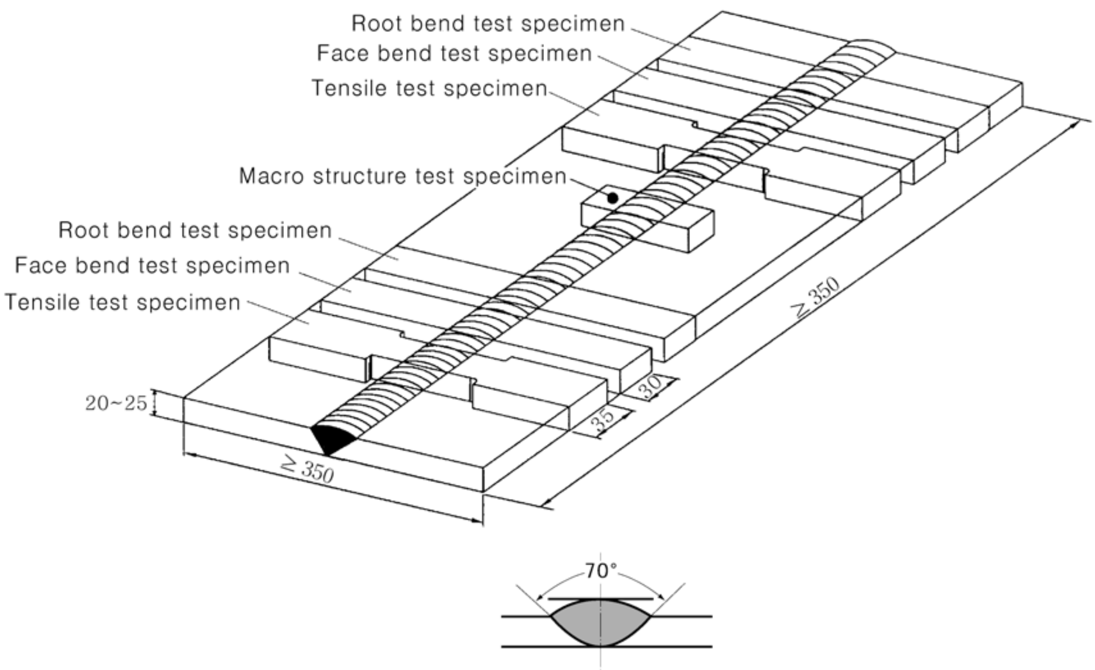
(2) Kinds of tests in the annual inspections are to be as given in **Table 2.2.65.**

(3) The welding procedure and requirements for test assemblies specified in (2) are to be in accordance with the requirements in **4.** to **5.**



(Note)
(1) Back sealing runs are allowed in single V weld assembly.
(2) In case of double V assembly both sides are to be welded in the same welding position.

Fig.2.2.37 Butt Weld Test Assembly for Aluminium Alloys
(A thickness of 10 to 12, unit : *mm*)



(NOTE)
(1) Back sealing runs are allowed.

Fig. 2.2.38 Butt Weld Test Assembly for Aluminium Alloys
(A thickness of 20 to 25, unit : *mm*)

Table 2.2.65 Kinds of Tests in Annual Inspections

Kinds of test	Test assembly				Kind and number of test specimens taken from test assembly
	Welding position	Number	Dimensions	Thickness (mm)	
Deposited weld metal test(Chemical composition Analysis)	Flat	1	**Fig 2.2.36**	-	-
Butt weld test	Flat	1	**Fig 2.2.37**	10 - 12	Tensile test specimen : 2 Face bend test specimen : 2 Root bend test specimen : 2 Macro structure test specimen : 1

609. Welding consumables for high strength quenched and tempered steels

1. Application

Welding consumables for high strength quenched and tempered steels, which are given in following (1) through (3) (hereinafter referred to as "welding consumables" in **609.**) the approval test and annual inspections are to be in accordance with the requirements specified in **609.**

(1) Electrodes for manual arc welding(specified in **602. 1** (1) and (2))
(2) Automatic welding consumables(specified in **603. 1** (1) and (2). However, in this case, used only for multi-run technique in principle.)
(3) Semi-automatic welding consumables

2. Grade and marks of welding consumables

(1) Grades and marks of welding consumables are classified as given in **Table 2.2.67.**
(2) Where the welding consumables have passed the test specified in **3** (1) below, the suffixes are to be added to the grade marks with the same methods as specified in **603. 2** (2) and (3) or **604. 2** (2) and (3) according to the grade of welding consumables.
(3) For low hydrogen electrodes which have passed the hydrogen test specified in **6.** the suffixes given in **Table 2.2.70** are to be added to the grade marks (eg. $3Y46S\ H5$).

3. General provisions for tests

(1) Kinds of test, number, thickness, and dimensions of test assembles, diameters of electrodes or wires used for welding and welding positions, together with kinds and number of test specimens taken from each test assembly for welding consumables are to be in accordance with the requirements specified in **602. 3., 603. 3.** or **604. 3.** However, note (4) of **Table 2.2.17** and note (5) of **Table 2.2.34** are not to be required. Provisions for automatic welding consumables are to be the requirements specified in multi run technique.
(2) The grades of steels used for tests are to be those given in **Table 2.2.66** corresponding to the grades of welding consumables, or those which are considered equivalent by the Society.

Table 2.2.66 Grade of Steels for Test Assembly

Grade of welding consumables	Grade of steel for assembly
2Y42, 2Y46, 2Y50, 2Y55, 2Y62, 2Y69	AH 43～AH 70
3Y42, 3Y46, 3Y50, 3Y55, 3Y62, 3Y69	AH 43～AH 70, DH 43～DH 70
4Y42, 4Y46, 4Y50, 4Y55, 4Y62, 4Y69	AH43～AH70, DH 43～DH 70, EH 43～EH 70
5Y42, 5Y46, 5Y50, 5Y55, 5Y62, 5Y69	AH 43～AH 70, DH 43～DH 70, EH 43～EH 70, FH 43～FH 70

NOTES:
Notwithstanding the requirements in this table, normal and higher strength steels may be used for deposited metal test assembly. In this case, appropriate buttering is to be carried out.

(3) For the approval of welding consumables, the tests specified in **602., 603.** or **604.** are to be conducted for each brand of welding consumables.
(4) After welding, the test assemblies are not to be subjected to any heat treatment or peening.
(5) It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain that there are any defects in the weld prior to the preparation of test specimens.

4. Deposited metal test

(1) *Welding of deposited metal test assembly*
Welding sequence of test assemblies are to be in accordance with the requirements specified in **602. 4** (1)**, 603. 4** (1) or **604. 4** (1) appropriate to the grade of the welding consumables.
(2) *Chemical composition*
(a) The chemical composition of the deposited weld metal shall be determined by the manufacturer and reported the results of the analysis to the Society. The report is also to include the main alloy elements.
(b) The results of the analysis shall not exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.
(3) *Deposited metal tensile test*
(a) Kinds, numbers and selection methods of the deposited metal tensile test specimens being taken from each test assembly are to comply with the requirements specified in **602. 4** (3), **603. 4** (3) or **604. 4** (3) according to the grade of the welding consumables.
(b) The tensile strength, yield strength and elongation of each test specimen are to comply with the requirements specified in **Table 2.2.67** according to the grade of the welding consumables.
(c) The provisions specified in the preceding **602. 4** (3) (b) may be applied to the tensile test specimens.
(4) *Deposited metal impact test*
(a) Kinds, numbers and selection methods of the deposited metal impact test specimens being taken from each test assembly are to comply with the requirements specified in **602. 4** (4), **603. 4** (4) or **604. 4** (4) according to the grade of the welding consumables.
(b) The test temperature and minimum mean absorbed energy are to comply with the requirements specified given in **Table 2.2.67** according to the grade of the welding consumables.
(c) The requirements specified in the preceding **602. 4** (4), (b) and (d) are to be applied to this test.

5. Butt weld test

(1) *Welding of butt weld test assembly*
Welding sequence of test assemblies are to be in accordance with the requirements specified in **602. 5** (1)**, 603. 5** (1) or **604. 5** (1) appropriate to the grade of the welding consumables.
(2) *Butt weld tensile test*
(a) Kinds and numbers of the butt weld tensile test specimens being taken from each test assembly are to comply with the requirements specified in **602. 5** (2), **603. 5** (2) or **604. 5** (2) according to the grade of the welding consumables.
(b) The tensile strength of each test specimen is to meet the requirements given in **Table 2.2.68** according to the grade of the welding consumables.

Table 2.2.68 Tensile Test Requirements for butt weld test

Grade of welding consumables	Tensile strength (N/mm^2)
2*Y*42, 3*Y*42, 4*Y*42, 5*Y*42	530 min.
2*Y*46, 3*Y*46, 4*Y*46, 5*Y*46	570 min.
2*Y*50, 3*Y*50, 4*Y*50, 5*Y*50	610 min.
2*Y*55, 3*Y*55, 4*Y*55, 5*Y*55	670 min.
2*Y*62, 3*Y*62, 4*Y*62, 5*Y*62	720 min.
2*Y*69, 3*Y*69, 4*Y*69, 5*Y*69	770 min.

Table 2.2.67 Test Requirements for Deposited Metal

Grade of welding consumables	Tensile test			Impact test	
	Tensile strength (N/mm²)(1)	Yield strength (N/mm²)	Elongation (%)	Test temp (℃)	Minimum mean absorbed energy(J)
2Y42	530 ~ 680	420 min.	20 min.	0	47 min.
3Y42				-20	
4Y42				-40	
5Y42				-60	
2Y46	570 ~ 720	460 min.	20 min.	0	
3Y46				-20	
4Y46				-40	
5Y46				-60	
2Y50	610 ~ 770	500 min.	18 min.	0	50 min.
3Y50				-20	
4Y50				-40	
5Y50				-60	
2Y55	670 ~ 830	550 min.	18 min.	0	55 min.
3Y55				-20	
4Y55				-40	
5Y55				-60	
2Y62	720 ~ 890	620 min.	18 min.	0	62 min.
3Y62				-20	
4Y62				-40	
5Y62				-60	
2Y69	770 ~ 940	690 min.	17 min.	0	69 min.
3Y69				-20	
4Y69				-40	
5Y69				-60	

Note
Tensile strength specified in the table may be alerted where deemed appropriate by the Society.

(3) *Butt weld bend test*

(a) Kinds and numbers of the butt weld face bend and root bend test specimens being taken hom each test assembly are to comply with the requirements specified in **602. 5** (3), **603. 5** (3) or **604. 5** (3) according to the grade of the welding consumables.

(b) The test specimens are to be subjected to face bend and root bend tests by using former having a radius given in **Table 2.2.69.** Outer surface of the specimens is to be free from any cracks exceeding 3 mm long or other defects when they are bent to the angle of 120 degrees.

Table 2.2.69 Bend Radius for Butt Weld Bend Test

Grade of welding consumable	Radius of plunger
2Y42～50, 3Y42～50, 4Y42～50, 5Y42～50	2.0 t
2Y55～69, 3Y55～69, 4Y55～69, 5Y55～69	2.5 t

(c) Where the bending angle 120° is not achieved, the specimen may be considered as fulfilling the requirements, if the bending elongation on a gauge length Lo shown in **Fig 2.2.39** fulfills the minimum elongation requirements stated in **Table 2.2.67** of the Rules

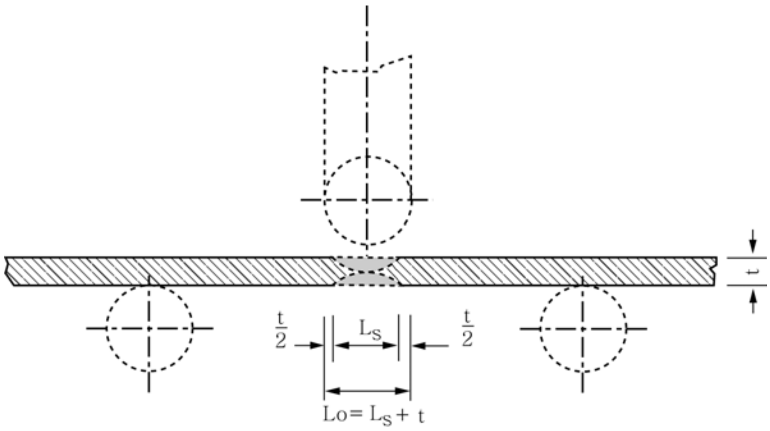


Fig 2.2.39 gauge length *Lo*

(4) *Butt weld impact test*
   (a) Kinds, numbers and selection method of the butt weld impact test specimens being taken from each test assembly are to comply with the requirements specified in **602. 5** (4), **603. 5** (4) or **604. 5** (4) according to the grade of the welding consumables.
   (b) Testing temperature and minimum mean absorbed energy are to comply with the requirements specified in **Table 2.2.67** according to the grade of the welding consumables.
   (c) The requirements specified in the preceding **602. 5** (4), (b) and (d) are to be applied to these tests.

6. Hydrogen test

(1) Hydrogen Test is to be carried out for welding consumables except gas shielded arc solid wire by the glycerine method, mercury method, gas chromatographic method or other methods deemed appropriate by the Society.
(2) The average volume of hydrogen is to comply with the requirements specified in **Table 2.2.70** according to the test procedures specified in preceding (1) or the type of suffixes to be added to the grade marks.

Table 2.2.70 Requirements for hydrogen Contents

Grade of welding consumable	Suffixes	Requirements for Hydrogen Contents (cm^3/g)		
		Glycerine method	Mercury method	Gas chromatographic method
2*Y*42～50, 3*Y*42～50, 4*Y*42～50, 5*Y*42～50	*H* 10	0.05 max.	0.10 max.	0.10 max.
2*Y*55～69, 3*Y*55～69, 4*Y*55～69, 5*Y*55～69	*H* 5	-	0.05 max.	0.05 max.

7. Fillet weld test assemblies

(1) *Welding of fillet weld test assemblies* The test assemblies are to be in accordance with the requirements in **602. 7** (1).
(2) *Fillet weld macro-structure test* The macro-structure test is to be correspondingly in accordance with the requirements in **602. 7** (2).
(3) *Fillet weld hardness test* The hardness test is to be correspondingly in accordance with the requirements in **602. 7** (3).
(4) *Fillet weld fracture test* The fracture test is to be correspondingly in accordance with the requirements in **602. 7** (4).

8. Annual inspections

Annual inspections are to comply with the requirements specified in **602. 8, 603. 8** or **604. 8** according to the grade of the welding consumables. However, in general, annual inspections for automatic welding consumables are to comply with the requirements specified for multi run technique.

9. Change in grades

The changes in grades relating to the strength or toughness of approved welding consumables are to comply with the requirements specified in **602. 9, 603. 9** or **604. 9** according to the grade of the welding consumables. ⚓

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 2

Materials and Welding

GA-02-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidance as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

Amendments to the Guidance Relating to the Rules for the Classification of Steel Ships
(PART 2 MATERIALS AND WELDING, 2010 Edition)

Effective Date 1 July 2011

CHAPTER 1 MATERIALS

Section 1 General

- 101. 2. has been newly established.

CHAPTER 2 WELDING

Section 6 Welding Consumables

- 602. 2. has been deleted.
- 603. has been deleted.

ANNEX

Annex 2-7 Guidance for Non-destructive Testing of ship hull steel welds

- 1. (2), (E), (d) has been newly established.
- 1. (2), (F) has been amended.
- 3. (4) has been fully amended.

Annex 2-8 Reinforced plastic materials

- newly established.

CONTENTS

CHAPTER 1 MATERIALS

SECTION 1 General

101. Application

1. Seamless shells of boilers made of steel forgings are to comply with the **Annex 2-1.**

2. Reinforced plastic materials used for construction or repair of plastic pipes, FRP ships or composite vessel are to comply with the **Annex 2-8.**

102. Approval of manufacturing process and manufacturing control

"control imperfection" referred in **102. 2** (2) of the Rules includes the deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures.

103. Chemical composition

1. The application to **103. 1** of the Rules is to be in accordance with the followings:

(1) The chemical composition analyses from each ladle are to be applied to steel.
(2) The chemical composition analyses from each cast are to be applied to non-ferrous metals.

2. The application to **103. 2** of the Rules is to be in accordance with the followings :

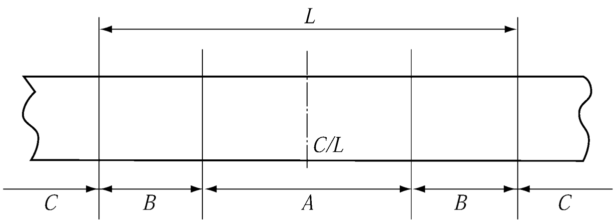
(1) Selection of samples for the check analyses
Samples for the check analyses are to be taken from specimens for mechanical tests or from the portion of the body adjacent to the part where mechanical specimens had been taken.
(2) Production analysis and its tolerance for steel
Production analysis and its tolerance for steel is to comply with *KS D*0228 (Production Analysis and its Tolerance for Wrought Steel).

104. Testing and inspection

"The approval of quality assurance scheme specially specified by the Society" referred in **104. 4** of the Rules means where the quality assurance scheme of material manufacturer has been already approved according to the requirements of **Ch 5** of "*Guidance for Approval of Manufacturing Process and Type approval etc*." by the Society.

109. Retest procedure

"Any part of fracture is outside the one-fourth of the gauge length from the centre of gauge length" specified in **109. 4** of the Rules means the parts of "B" and "C" as shown in **Fig 2.1.1** of the Guidance.



L : Gauge length
A : Inside the one-fourth of the gauge length from the centre of gauge length
B : Between outside the one-fourth of the gauge length from the centre of gauge length and inside gauge length
C : Over gauge length

Fig 2.1.1 Divisions for Fracture Parts of Tensile Specimen

SECTION 2 Test Specimens and Testing Procedures

201. General

1. Application

In case where test specimens or test procedures specified in the requirements of *ISO* or *KS* are adopted, the approvals by the Society may be dispensed with, notwithstanding the requirement in **201. 1** (2) of the Rules.

2. Selection of test specimens

"Where otherwise specified or agreed with the Surveyor" referred in **201. 3** (2) of the Rules means only where manufacturing process of the material has been already approved according to the requirements of **Ch 2** of *"Guidance for Approval of Manufacturing Process and Type Approval, etc"* by the Society

202. Form and dimension of test specimen

1. Tensile test specimen

(1) The gauge length of the *R* 14*B* tensile test specimens specified in **Fig 2.1.1** of the Rules may be used as given in **Table 2.1.1** of Guidance in accordance with **201. 1** (2) of the Rules.

Table 2.1.1 Rounding of Gauge Length

Thickness of test specimen t (mm)	Width of test specimen W (mm)	Gauge length L (mm)
$3 \leq t \leq 4$	25	50
$4 < t \leq 5$		60
$5 < t \leq 7$		70
$7 < t \leq 10$		80
$10 < t \leq 15$		100
$15 < t \leq 20$		120
$20 < t \leq 30$		140
$30 < t \leq 40$		160

(2) In application to **202. 1** (4) of the Rules, corrections for elongation are to be in accordance with the followings :

(A) Stainless steel and aluminium alloys are to be considered as Material 1 in **Table 2.1.1** of the Rules. However, corrections for elongation specified in **202. 1** (4) of the Rules may not be required in the case of copper alloy.

(B) In case where the corrections by the requirements of **202. 1** (4) of the Rules are deemed troublesome because of a great number of test specimens, the value of specified elongation may be corrected by using the following formula. In such case, the corrected specified elongation is to be recorded in the certificates of the material test.

$$E = n \cdot F$$

where

E = Elongation equivalent to where the proportional specimens ($L = 5.65\sqrt{A}$) specified in **Fig 2.1.1** of the Rules are used.

n = Elongation where optional test specimens are used.

F = Coefficient of correction for elongation are shown in **Table 2.1.2** of the Guidance according to the gauge length.

Table 2.1.2 Values of F

Gauge length (L)	Material 1	Material 2
$8D$	1.21	1.29
$8\sqrt{A}$	1.15	1.21
$4D$	0.91	0.88
$4\sqrt{A}$	0.87	0.82
D : Diameter of the test specimen A : Sectional area of the test specimen		

2. Impact test specimen

(1) In application to **202. 3** (3) of the Rules, the sub-size specimens permitted according to thickness of the steels are to be as follows;

Steel thickness	Width of the sub-size specimen
$6\text{mm} \le t < 9\text{mm}$	5 mm
$9\text{mm} \le t < 12\text{mm}$	7.5 mm

(2) In application to **202. 3** (5) of the Rules, in case where the capacity of impact tester limits the use of normal impact test specimens, sub-size specimens can be used provided that the test results using sub-size specimens are to comply with the requirements specified for the normal impact test specimens.

SECTION 3 Rolled Steels

301. Rolled steels for hull

1. Manufacturing process

(1) The term of "thermo-mechanical controlled processing($TMCP$)" in **301. 3** of the Rules is defined in the following **2** of this Guidance.

(2) The carbon equivalent value of higher strength steels supplied in $TMCP$ condition in Remarks (13) to **Table 2.1.6** of **301. 3** of the Rules is to comply with the requirements of **Table 2.1.3** of the Guidance.

Table 2.1.3 Carbon Equivalent of Higher Strength Steels supplied in TMCP Condition

Grade	Carbon Equivalent(%)	
	$t \leq$ 50 mm	50 $<$ t $\leq$ 100 mm
AH 32, DH 32, EH 32, FH 32	0.36 max.	0.38 max.
AH 36, DH 36, EH 36, FH 36	0.38 max.	0.40 max.
AH 40, DH 40, EH 40, FH 40	0.40 max.	0.42 max

(3) The cold cracking susceptibility (P_{cm}) calculated by following a formula instead of carbon equivalent of previous (2) may be required to be submitted when deemed necessary by the Society.

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

2. Heat treatment

The definition of heat treatment mentioned in Remarks (1) to **Table 2.1.8** and **Table 2.1.9** of **301. 4** of the Rules are as follows : (Refer to **Fig 2.1.2**)

(1) **As rolled, *AR***
This procedure involves the rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

(2) **Normalising, *N***
Normalising involves heating rolled steel above the critical temperature, A_{C3}, and in the lower end of the austenite recrystallization region followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the grain size.

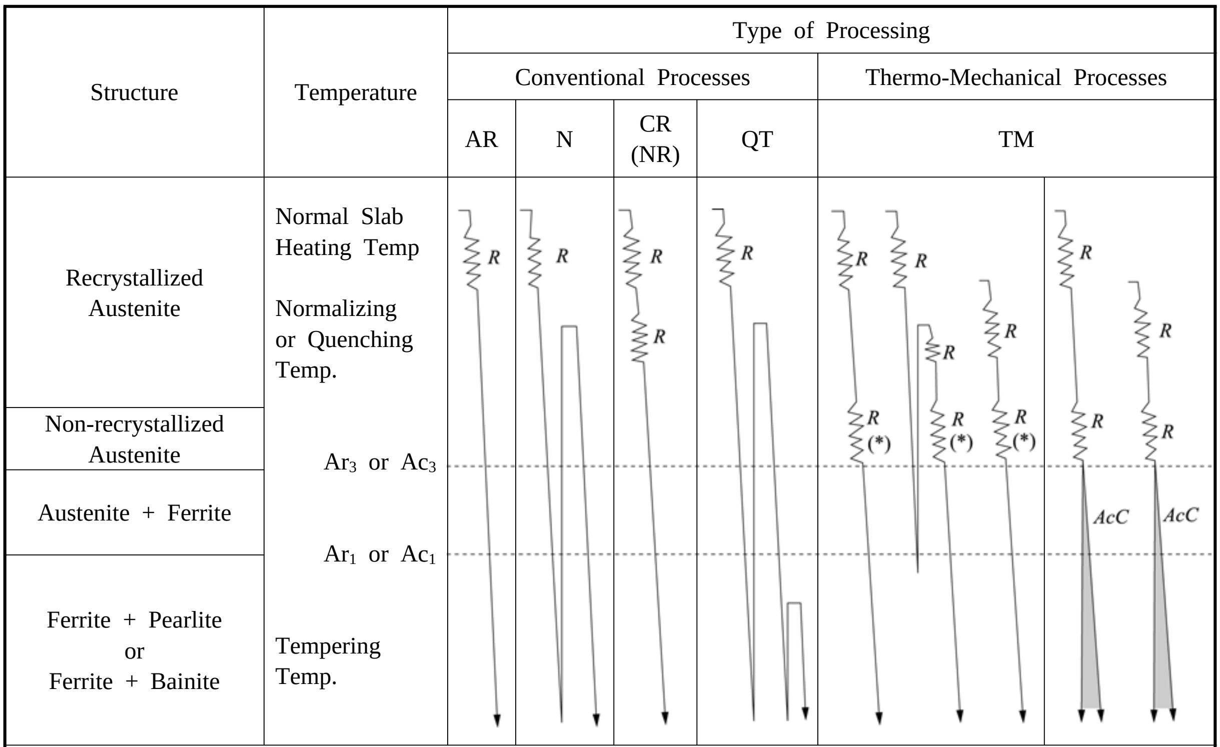
(3) **Controlled Rolling(Normalising Rolling), *CR*(*NR*)**
A rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(4) **Quenching and Tempering, *QT***
Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the A_{C3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the A_{C1} to restore toughness properties by improving the microstructure.

(5) **Thermo-mechanical Rolling(Thermo-mechanical Controlled Processing), *TM*(*TMCP*)**
This is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike controlled rolled (normalised rolling) the properties conferred by $TM(TMCP)$ cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM-rolling may also be accepted subject to the special approval of the Society.

(6) **Accelerated Cooling Processing, *AcC***

Accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling in the range of Ar_3 temperature or below. However, direct quenching is excluded from accelerated cooling.



(Note)
R : Reduction AR : As rolled
N : Normalising CR(NR) : Controlled Rolling(Normalising Rolling)
AcC : Accelerated cooling
TM(TMCP) : Thermal-mechanical rolling (Thermal-Mechanical Controlled Process))
(*) : Where final rolling is carried out in austenite-ferrite duplex.

Fig 2.1.2 Rolled Processes for Rolled Steels for Hull

3. Selection of test samples

"Where specially approved by the Society" specified in **301. 6** (3) of the Rules may be dealt with as follows :

(A) Impact tests for *AH* 32 and *AH* 36 may be dispensed with as far as periodical examinations are carried out in the presence of the Society's Surveyor, except otherwise specially specified on the approval of the manufacturing process.

(B) “Periodical” in (A) above means once a month. In this case, impact tests specified are carried out for a set (3 pieces) of specimens and the results of which are to be confirmed in compliance with the specifications.

(C) In case where the result does not comply with the specifications, retests for the lot of steel material to which the failed specimens are belonging may be carried out in accordance with the requirements in **301. 10** of the Rules.

(D) Where the result of the retest does not comply with the requirements, impact tests provided in **Table 2.1.8** and **2.1.9** of **301. 6** of the Rules are to be carried out for all the steels manufactured thereafter. Where the test results during 6 months are confirmed as being satisfactory, the procedure specified in (B) above may be applied again.

(E) Every manufacturer is to submit the annual report compiling the results of the impact tests to the Society.

4. Surface inspection and verification of dimensions

The application to **301. 8** of the Rules is to be in accordance with the follows :

(1) The Society may require the surface inspection of rolled steels to confirm in compliance with the quality same as that of those days of approval of the manufacturing process.

(2) Criteria of surface inspection for flaw, pin hole and blow hole of steel plate is to comply with *KS D*0208 (Method of macro-streak-flaw test for steel).

(3) Tolerance for rolled steel other than under thickness tolerance for plate is to comply with *KS D* 3051(Dimensions weight and permissible variations of hot rolled steel bar in coil), *KS D* 3052(Shape, dimensions, weight and tolerance of hot rolled steel flats), *KS D*3500 (Dimensions weight and permissible variations of hot rolled steel plates, sheets and strips) and *KS D*3502 (Dimensions, weight and tolerances of hot rolled steel sections).

5. Quality and repair of defects

(1) Ultrasonic test procedures and acceptance criteria, specified in **301. 9** (2) of the Rules, are to be in accordance with either *EN* 10160 *Level S1/E1*, *ASTM A* 578 *Level C* or accepted standard at the discretion of the Society.

(2) The application to **301. 9** (3) of the Rules is to be in accordance with the followings:

(A) The surface defects may be removed by local grinding, in the presence of the Surveyor, provided:

(a) the nominal product thickness will not be reduced by more than 7 % or 3 mm, whichever is the less

(b) each single ground area does not exceed 0,25 m^2 and all ground areas do not exceed 2 % of the total surface in question.

(c) Ground areas lying opposite each other on both surfaces must not decrease the product thickness by values exceeding the limits as stated above (a)

(d) Complete elimination of the defects may be verified by a magnetic particle or dye penetrant test procedure at the Surveyor's discretion.

(e) Where necessary, the entire surface may be ground to a depth as given by the under thickness tolerances of the product. Ground areas lying in a distance less than their average breadth to each other are to be regarded as one single area.

(B) Local defects which cannot be repaired by grinding as stated above may be repaired with the Surveyor's consent by chipping and/or grinding followed by welding subject to the following conditions:

(a) Any single welded area shall not exceed 0,125 m^2 and the sum of all areas shall not exceed 2 % of the surface side in question. The distance between two welded areas shall not be less than their average width.

(b) The weld preparation must not reduce the thickness of the product below 80 % of the nominal thickness.

(c) the welding is to be carried out by an approved procedure, by the welder qualified by the Society, with approved electrodes, And the electrodes shall be of low hydrogen type and must be dried in accordance with the manufacturer's requirements and protected against rehumidification before and during welding.

(d) All weldings are to be of reasonable length and must have at least 3 parallel welding beads. Weld metal is to have at least 1.6 mm reinforcement, which is to be removed by grinding or chipping and grinding flush with the rolled surface, and is to present a workmanlike finish.

(e) The deposited metal must be sound without any lack of fusion, undercut, cracks and other defects which could impair the workability or use of the product. The finished products are to be presented to the Surveyor for acceptance. The soundness of the repair may be verified by ultrasonic, magnetic particle or dye penetrant methods at the Surveyor's discretion.

(f) Products which are to be supplied in a heat treated condition are to be welded prior to the heat treatment; otherwise, a new heat treatment may be required. Products supplied in the controlled rolled (*CR*) or as rolled (*AS*) condition may require a suitable heat treatment after welding. However, the post weld heat treatment may be omitted provided the manufacturer has demonstrated by a procedure test that the required properties will be maintained without heat treatment.

(g) For every welding repair the manufacturer must provide the Surveyor with a written report and a sketch showing sizes and location of the defects and full details of the repair procedure including the welding consumables, post weld heat treatment and non-destructive testing.

(C) Shapes may be conditioned by the manufacturer for the removal of surface defects in accordance with the following limitations.

(a) For material less than 9.5 mm thickness, in which the defects are not more than 0.8 mm in depth, the defects may be removed by grinding or chipping.

(b) For material 9.5 mm and over in thickness, in which the defects are not more than 1.6 mm in depth, the defects may be removed by grinding or chipping.

(c) Surface defects which are greater in depth than the limits shown above (a) and (b) may be removed by chipping or grinding and then depositing weld metal, in the presence of the Surveyor, subject to the following conditions.

(i) The total area of the chipped or ground surface of any piece is not to exceed 2 % of the total surface area of that piece.

(ii) After removal of any defect preparatory to welding, the thickness of the shape is not to be reduced by more than 30 % of the nominal thickness, nor is the depth of depression prior to welding to exceed 12.5 mm in any case.

(D) Before repair works prescribed in above (B) or (C) (c), the following documents are to be submitted to the Society for approval.

(a) Specifications of repairing procedure which state about kind of surface defects, the way of chipping, grinding and welding, etc.

(b) Reports on results of tensile test, bend test, impact test, macro-structure inspection and hardness test on test samples repaired according to the procedure specified in above (a).

302. Rolled steel plates for boilers

1. Selection of test samples

In application to **302. 6** of the Rules, selections of test samples in case that where the purchasers carry out normalizing specified in **302. 3** (2) of the Rules at their factories are to comply with the following requirements :

(1) The manufacturer is to carry out normalizing of the test sample conforming to the requirements by the purchaser. Where no requirements have been given by the purchaser, the manufacturer may carry out normalizing as considered preferable. In this case, the manufacturer is to inform the purchaser the conditions of normalizing which had been carried out.

(2) The test samples is taken from the steel plates normalized at purchasers factory or normalized together with the steel plates simultaneously.

(3) The mechanical properties obtained by the test specimens specified in (1) and (2) above are to comply with the provisions in **Table 2.1.12** of the Rules.

2. Marking

The markings related to the heat treatment of the steel plates provided in **302. 1** of the Rules are to be "*TN*" showing the case where normalizing is carried out for test samples only.

303. Rolled steel plates for pressure vessels

1. Selection of test samples

In application to **303. 6** of the Rules, selections of test samples in case that where the purchasers carry out normalizing specified in **303. 3** (2) of the Rules at their factories are to comply with the following requirements :

(1) The manufacturer is to carry out normalizing of the test sample conforming to the requirements by the purchaser. Where no requirements have been given by the purchaser, the manufacturer may carry out normalizing as considered preferable. In this case, the manufacturer is to inform the purchaser the conditions of normalizing which had been carried out.

(2) The test samples is taken from the steel plates normalized at purchasers factory or normalized together with the steel plates simultaneously.

(3) The mechanical properties obtained by the test specimens specified in (1) and (2) above are to comply with the provisions in **Table 2.1.15** of the Rules.

2. In **303. 7** (2) of the Rules, the application to "deemed necessary by the Society" is to be in accordance with the follows :

(1) Where the steel plates are used for spherical tanks or end plates, etc. of cylindrical tanks to contain cold liquefied gas at normal temperature, the impact test specimens are to be taken with their longitudinal axis normal (T direction) to the final direction of rolling.

(2) In previous (1), the specified values of the impact tests are to be in accordance with **Table 2.1.15** of the Rules.

3. Marking

The markings related to heat treatments of the steel plates provided in **303. 1** of the Guidance are to be "*TN*" showing case where normalising is carried out for test samples only.

304. Rolled steels for low temperature service

1. Mechanical properties

Minimum elongation where the *R*5 specimen instead of *R* 1*B* specimen mentioned in Remarks (2) to **Table 2.1.17** of the Rules is used may apply to the values of **Table 2.1.4** of the Guidance.

Table 2.1.4 Minimum Elongation (%)

Grade \ Thickness t (mm)	$t \le 5$	$5 < t \le 10$	$10 < t \le 15$	$15 < t \le 20$	$20 < t \le 25$
RL 24*A*, *RL* 24*B*, *RL* 27	22	24	26	28	30
RL 33	23	26	29	32	35
RL 37	21	24	27	30	33
RL 2*N*30, *RL* 3*N*32, *RL* 5*N*43		23	25	27	29
RL 9*N*53, *RL* 9*N*60	19	22		28	31

305. Rolled stainless steels

1. Application

In application to **305. 1** (3) of the Rules, the grade, chemical composition and mechanical properties of austenitic-ferritic stainless steel (hereinafter referred to as "duplex stainless steels") not exceeding 75 mm in thickness are to be as specified on the followings.

(1) **Grades and chemical composition**
The grade and chemical composition of duplex stainless steels are to comply with the provisions in **Table 2.1.5** of the Guidance.

Table 2.1.5 Grades and chemical composition

Grade	Chemical composition(%)								
	C	*Si*	*Mn*	*P*	*S*	*Ni*	*Cr*	*Mo*	*N*
*S*31803	0.030 max.	1.00 max.	2.00 max.	0.035 max.	0.015 max.	4.5～6.5	21.0～23.0	2.5～3.5	0.10～0.22
*S*32750						6.0～8.0	24.0～26.0	3.0～4.5	0.24～0.35

(2) **Mechanical properties**
The mechanical properties of duplex stainless steels are to comply with the provisions in **Table 2.1.6** of the Guidance.

Table 2.1.6 Mechanical properties

Grade	Tensile test			Impact test		
	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) ($L=5.65\sqrt{A}$)	Test temp. (℃)	Average absorbed energy(J)	
					L	T
*S*31803	460 min.	640 min	25 min	- 20	41	-
*S*32750	530 min	730 min	25 min		-	27

2. Mechanical properties

In application to **305. 5** (1) of the Rules, the minimum yield strength specified in **Table 2.1.20** of the Rules may be altered to other values subject to the approval of the Society. In this case, minimum yield strength and indication symbol of heat treatment specified in **301. 2** of the Guidance will be added after the steel grade mark.(eg. : *RSTS* 316*LN* - 400*TM*)

308. High Strength Quenched and Tempered Steels for Welded Structures

1. Deoxidation practice and chemical composition

(1) In application to **308. 3** (3) of the Rules, the cold cracking susceptibility(P_{cm}) for evaluating weldability is to be calculated from the ladle analysis in accordance with the formula specified in **301. 1** (3) of the Guidance.

(2) The maximum P_{cm} for high strength quenched and tempered steels is to comply with the requirements of **Table 2.1.7** of the Guidance.

Table 2.1.7 Grades and Cold Cracking Susceptibility

Grades	Cold Cracking Susceptibility (P_{cm})(%)	
	Thickness t (mm)	
	$t \leq 50$	$50 < t \leq 70$
AH 43, *DH* 43, *EH* 43, *FH* 43	0.25 max.	0.27 max.
AH 47, *DH* 47, *EH* 47, *FH* 47	0.26 max.	0.28 max.
AH 51, *DH* 51, *EH* 51, *FH* 51	0.26 max.	0.28 max.
AH 56, *DH* 56, *EH* 56, *FH* 56	0.28 max.	0.30 max.
AH 63, *DH* 63, *EH* 63, *FH* 63	0.29 max.	0.31 max.
AH 70, *DH* 70, *EH* 70, *FH* 70	0.30 max.	0.32 max.

309. Stainless clad steel plates

1. Mechanical properties

Shearing strength test method complies with *KS D*0234.(Testing methods for clad steel)

2. Quality and repair of defects

Ultrasonic test generally complies with *KS D*3693 (Stainless-clad steel) and *KS D*0234.(Testing methods for clad steel)

310. Additional requirements for through thickness properties

1. Ultrasonic tests

(1) Ultrasonic test procedures and acceptance criteria, specified in **310. 7** (2) of the Rules, are to be in accordance with either *EN* 10160 *Level S1/E1*, *ASTM A* 578 *Level C* or accepted standard at the discretion of the Society

SECTION 4 Steel Tubes and Pipes

401. Steel tubes for boilers and heat exchangers

1. The definition of heat treatment mentioned in **Table 2.1.40** of **401. 3** of the Rules are as follows

(1) **Low temperature annealing** : An annealing treatment which is performed to eliminate internal stress or reduce quenching strain .

(2) **Normalizing** : Heating a ferrous alloy to a suitable temperature above A_3 or A_{cm} and then cooling in still air to a temperature substantially below A_1. Is performed to refine the crystal structure and eliminate internal stress.

(3) **Full Annealing** : An annealing treatment in which a steel is austenitized by heating to a temperature above the upper critical temperature (A_3 or A_{cm}) and then cooled slowly to room temperature.

(4) **Isothermal Annealing** : A process in which a ferrous alloy is heated to produce a structure partly or wholly austenitic, and is then cooled to and held at a temperature that causes transformation of the austenite to a relatively soft ferrite-carbide aggregate.

2. Chemical composition

The chemical composition of *RSTH*33 is to comply with the requirements given in **Table 2.1.8.**

Table 2.1.8. Chemical composition

Grade	chemical composition (%)				
	C	*Si*	*Mn*	*P*	*S*
RSTH 33	0.18max.	0.35max	0.25～0.60	0.035max	0.035max

3. Heat treatment and mechanical properties

(1) The heat treatment of *RSTH*33 is to be same as the requirement for *RSTH*35

(2) The mechanical properties of *RSTH*33 are to comply with the following requirements.

(a) *Tensile test* : The tensile test of *RSTH*33 is to comply with the requirements given in **Table 2.1.9.**

Table 2.1.9 Mechanical properties

Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L=5.65\sqrt{A}$)
RSTH 33	175 min	325 min	26(22) min

NOTES:
1. The values of elongation in parenthesis are applicable to the test specimens taken transversely. In this case, the sampling material is to be heated 600℃ to 650℃ after flattened and annealed in order to make it free from strain.
2. In case where test specimen of non-tubular section is taken from an electric-resistance welded steel tube, the test specimen is to be taken from the parts that do not include the welded line.

(b) *Flattening test* : The flattening test of *RSTH*33 is to comply with the requirements given in **401. 5** (2) of the Rules. However, the value of e is to be 0.09

(c) *Flanging test* : A section of steel tube which is taken from its end is to be turned over cold so as to have a flange, the outside diameter of which is not less than specified in **Table 2.1.10,** at right angle to the axis without cracking or showing flaw. In this case, the flanging test specimen is to be of length L such that after testing the remaining cylindrical portion is not less than 0.5D. But, this test is to be made only for *RSTH* 33 tubes having wall thickness not more than 1/10 of its outside diameter and not more than 5 mm.

Table 2.1.10 Outside Diameter of Flange after Flanging

Outside diameter of steel tube	Outside diameter of flange
Less than 63 mm	1.3 times the outside diameter of steel tube
63 mm and over	Outside diameter of steel tube + 20 mm

(d) *Crushing test* : Where required by the Surveyor, a crushing test is to be made on a section of steel tube of 65 mm in length which is to stand crushing longitudinally without cracking or splitting to the height specified in **Table 2.1.11.**

Table 2.1.11 Height of Section after Crushing

Thickness of steel tube t (mm)	Height of section after crushing
$t \leq 3.4$	19 mm or until outside folds are in contact
$t > 3.4$	32 mm

(e) *Reverse flattening test* : The reverse flattening test of *RSTH*33 is to comply with the requirements given in **401. 5** (4) of the Rules.
(f) *Hydraulic test* : The hydraulic test of *RSTH*33 is to comply with the requirements given in **401. 5** (5) of the Rules.

(3) The non-destructive inspection, substituted for the hydraulic tests, specified in **401. 5** (5), (d) of the Rules are to be either ultrasonic tests or eddy current tests.
(a) Ultrasonic test is to comply with *KS D* 0250 (Ultrasonic examination for steel pipes and tubes). Steel tubes and pipes not to be detected the signal equivalent to that to be detected at artificial holes of reference block from detection sensitivity UD are accepted.
(b) Eddy current test is to comply with *KS D* 0251 (Eddy current examination for steel pipes and tubes). Steel tubes and pipes not to be detected the signal equivalent to that to be detected at artificial holes of reference block from detection sensitivity EY are accepted.

4. Selection of test specimen

The test specimens of *RSTH*33 are to be taken in accordance with the following requirements, from each grade and each size which has been heat treated at the same time in the same heating furnace for heat-treated tubes and from each grade and each size for non-heat-treated steel tubes respectively.

(1) *Seamless steel tubes* : One sampling steel tube is to be selected from each lot of 100 tubes or fraction thereof, and one tension, one flattening and one flanging or flaring test specimens are to be taken from each of the sampling steel tubes.
(2) *Electric-resistance welded steel tubes* : In addition to the requirements in (1), one sampling steel tube is to be selected from each lot of 50 tubes or fraction thereof for 100 and less steel tubes, and each lot of 100 tubes or fraction thereof for 100 over steel tubes, and one reverse flattening test specimen is to be taken from each of the sampling steel tubes.

402. Steel pipes for pressure piping

1. Mechanical properties

“The non-destructive inspection deemed appropriate by the Society" specified in **402. 5** (4), (d) of the Rules are dealt with according to the provisions in **401. 3** (3) of the Guidance.

SECTION 5 Castings

501. Steel castings

1. Chemical composition

(1) In application to **501. 4** of the Rules, the chemical composition of special carbon steel casting with higher toughness requirements such as high holding power anchors etc. is to comply with the requirements of **Table 2.1.12** of the Guidance.
The suitable grain refining elements such as aluminium etc. are to be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

Table 2.1.12 Chemical Composition

Materials	Chemical composition (%)						
	C	*Si*	*Mn*	*P*	*S*	*Al*	others
Special carbon steel casting	0.23 max.	0.60 max.	1.60 max.	0.035 max.	0.035 max.	0.015～0.08	to comply with **Table 2.1.67** of the Rules

(2) "Subject to approval by the Society," referred in note (1), **Table 2.1.67** of **501. 4** of the Rules means only where welding procedure qualification test of the casting for welded construction with same chemical composition has been satisfied by the Society

2. Mechanical properties

In application to **501. 6** (2) of the Rules, the results of impact test is to comply with the requirements of **Table 2.1.13** of the Guidance.

Table 2.1.13 Impact Test Requirements

Grade	Impact test	
	Test temp.(℃)	Average absorbed energy(J)
RSC 410, *RSC* 450, *RSC* 480, *RSC* 560, *RSC* 600	0	27 min.

3. Surface and dimension inspection

The surface inspection of stern frames, rudder frames and crank shaft specified in **501. 8** of the Rules are to be dealt with as follows :

(1) The surface inspection of stern frame and rudder frame are to comply with the **Annex 2-2.**
(2) The surface inspection of crank shafts made of steel castings are to comply with the **Annex 2-3.**

4. Non-destructive inspection

The non-destructive inspection for steel castings specified in **501. 10** (1) and (2) of the Rules are to be dealt with as follows :

(1) The non-destructive inspection of stern frame and rudder frame are to comply with the **Annex 2-2.**
(2) The non-destructive inspection of crank shafts made of steel castings are to comply with the **Annex 2-3.**

5. Repair of defects

Repairs by welding for steel casting specified in **501. 11** (1), (b) of the Rules are to be dealt with as follows :

(1) Repairs by welding of crank throws made of steel castings are to comply with the **Annex 2-4.**
(2) Repairs by welding of steel alloy castings are to comply with **7.** (the preparatory tests) of the **Annex 2-4.**
(3) Repairs of steel castings such as stern frame, rudder frame and others intended for important parts of hull structure are to comply with the **Annex 2-2, 8.**

505. Stainless steel casting for propeller

1. Non-destructive inspection

(1) The liquid penetrant test of steel propeller casting specified in **505. 8** (1) of the Rules is to comply with **Annex 2-6.**
(2) The division of severity zones of steel propeller casting specified in **505. 8** (2) is to comply with the **Figs. 1** and **2** of **Annex 2-6.**

2. Repair of defects

In application to **505. 9** (4) of the Rules, the repair welding procedure is to comply with the followings

(1) The limits of repair welding are to comply with **Annex 2-6, 3** (2) to (4).
(2) **Repair welding procedure**
When steel propeller casting is repaired by welding in accordance with the previous (1), the following requirements apply.
(A) Before welding is started, a detailed welding procedure specification is to be submitted covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures to the Society. The welding procedure qualification tests are to carried out in accordance with following (3).
(B) All weld repairs are to be made by welders qualified as deemed appropriate by the Society.
(C) Welding is to be done under controlled conditions free from draughts and adverse weather.
(D) The welding consumables used in the welding procedure qualification tests are to be used. The welding consumables are to be stored and handled in accordance with the manufacturer's recommendations.
(E) The martensitic steels are to be furnace re-tempered after weld repair. Subject to prior approval of the Society, however, local stress relieving may be considered for minor repairs.
(F) On completion of heat treatment the weld repairs and adjacent material are to be ground smooth. All weld repairs are to be liquid penetrant tested.
(G) The foundry is to maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. These records are to be reviewed by the Surveyor.
(3) **Welding procedure qualification test**
(A) *Preparation of test sample*
The test sample is to be as shown **Fig 2.1.3** of the Guidance. The edge preparation, in principle, to be V-shape and bevel angle is to be not less than 60°.
(B) *Non-destructive testing*
The test sample is to be visually inspected and liquid penetrant tested.
(C) *Macro-structure examination*
Two macro-sections shall be prepared. No pores greater than 3 mm and cracks in welded sections is permitted.

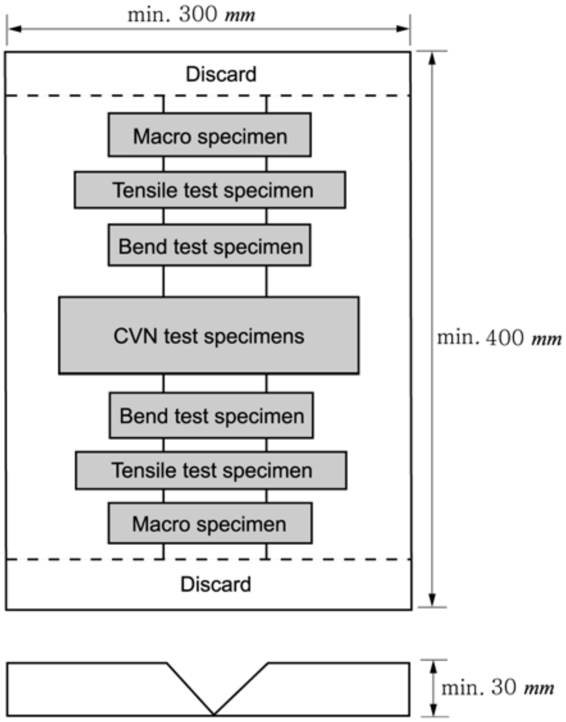


Fig 2.1.3 Test Sample for Butt Welding Test

(D) *Tensile testing*

Two flat transverse tensile test specimens shall be prepared. The tensile strength shall meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

(E) *Bend testing*

Two transverse side bend test specimens shall be prepared . The former diameter shall be 4 x thickness except for austenitic steels, in which case the former diameter shall be 3 x thickness.

The test specimen, when visually inspected after bending, shall show no surface imperfections greater than 2 mm in length.

(F) *Impact testing*

Impact test is not required, except where the base material is impact tested. Two sets shall be taken, one set with the notch positioned in the center of the weld and one set with the notch positioned in the fusion line, respectively. The test temperature, and impact energy shall comply with the requirement specified for the base material.

(G) *Hardness testing*

One of the macro-sections shall be used for Hv5 hardness testing. At least three individual indentations in the weld metal, the HAZ (both sides) and in the base material. The values are to be reported for information.

506. Grey iron casting

1. Test samples

The chill test specified in **506. 6** (7), (d) of the Rules is to comply with *ASTM A*367-60(Standard test methods of chill tests of cast iron

SECTION 6 Steel Forgings

601. Steel Forgings

1. Manufacturing process

(1) The application to the requirements of **601. 3** (5), (a) of the Rules is to be in accordance with the following :
For crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by the Society. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

(2) The application to the requirements of **601. 3** (6) of the Rules is to be in accordance with the following :
These requirements apply to where gas workings are being carried out on the parts subjected to high stress such as mass removal of crankshaft. The data related to the processes (including preheating) and change of material due to working are to be submitted approval of the Society.

2. Heat treatment

The application to **601. 4** (1) of the Rules is to be in accordance with the following :

(1) Overall length of the product is not afforded to be heat treated simultaneously, it is requested that an approval of the surveyor be obtained beforehand. In this case, one set of test specimens is to be taken from each end of the product. Degree of heterogeneity in micro structure at the boundary zone caused by such a heat treatment is to be examined by the method deemed appropriate by the Society and ultrasonic test.

3. Mechanical properties

In application to **601. 6** Note (4) of **Table 2.1.82** of the Rules, the kinds and average absorbed energy for low alloys steel forgings intended to be used for important parts of machinery which the impact test may be required are to comply with the requirements of **Table 2.1.14** of the Guidance.

Table 2.1.14 Kinds and Average Absorbed Energy for Low Alloys Steel Forgings

Grades	Low Alloys Steel forging applied	Charpy V notch Impact test Average absorbed energy(J)	
		L	T
RSF 600AM	- Crankshaft - Forgings for gears	41 min.	24 min.
RSF 700AM		32 min.	22 min.
RSF 800AM		32 min.	20 min.
RSF1000AM		25 min.	16 min.
RSF1100AM		21 min.	13 min.
(Note) Impact tests are to be carried out at ambient temperature (18~25 $^\circ c$).			

4. Selection of test specimen

Selection of the test specimens for forgings subjected to surface hardening, except for carburizing, specified in **601. 7** (9) of the Rules and hardness test are to comply with the following requirements.

(1) **Induction hardened or nitrized gears**
(A) *Tensile and impact test specimens*
The test specimens are to be taken from the product after the final heat treatment and before the surface hardening in accordance with the requirements specified in **601. 7** (3), (b) through (e) of the Rules
(B) *Depth of the hardened layer*
(a) In case of induction hardening
The depth of the hardened layer of the product is to be measured when the gear is produced for the first time, and tests thereafter may be dispensed with.
(b) In case of nitrization
(i) Selection of test samples
Test samples are to be made of the same material as the product having been processed under the same conditions.
(ii) Size of test samples
The size of the test samples may be optional.
(iii)Heat treatments of test samples
The test samples are to be heat treated and nitrized simultaneously together with the product.
(iv)Measurements of depth of hardened layer
The depth of hardened layer is to be measured every lot of same nitrization.
(2) The hardness tests of the surface hardened gears are to be dealt with as follows :
(A) The requirements for the measurement of hardness after surface hardening processes have been required related to the Shafting and Power Transmission Systems in **Pt 5, Ch 3** of the Rules, and the measured hardness value is to be approved by the Society in relation of the approval of the manufacturing processes.
(B) In case where the measurements of hardness for every forged products are difficult owing to their sizes and shapes, the hardness may be measured at appropriate locations considered to be representative in respect to the value of hardness resulted from the approval tests for the manufacturing processes referred to in (A) above.

5. Surface inspection

The requirements specified in **601. 8** of the Rules are to be dealt with as follows :
(1) The surface inspection of steel forgings is to comply with the **Annex 2-5, 2.**

6. Non-destructive inspection

(1) Non-destructive inspection of steel forgings specified in **601. 10** (1) and (2) of the Rules are to be dealt with as follows:
(A) The non-destructive inspection of steel forgings are to comply with the **Annex 2-5, 2** and **3.**
(2) Operator intended to engage in the ultrasonic test is to have sufficient technique and experience for the testing of the forgings prescribed in **601. 10** (1), (C) of the Rules means the operators of ultrasonic tests who correspond to either of the following (A) or (B).
(A) Those who belong to the manufacturing factory of the steel forgings, occupied in ultrasonic test operation of steel forgings under the system of manufacturing schedule control and quality considered appropriate by the Society and deemed to have sufficient understanding of characteristics and nature of steel forgings.
(B) Those having official qualification considered appropriate by the Society.

7. Repair of defects

The application to **601. 11** (4) of the Rules is to be accordance with the following:
(1) Repair by welding in order of correct shapes for the portions not subjected to high stress may be accepted.

8. Additional requirements for crank shafts

(1) In **601. 14** (1) of the Rules, where the heat treatments of the crank throws of solid crank shafts are carried out without mass removal, one set of test specimens are to be taken from the removed mass of the central crank throw at the part neighboring the pin, as shown in **Fig 2.1.4** of the Guidance after the heat treatment.

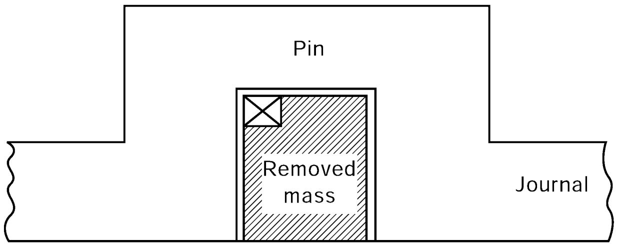


Fig 2.1.4 Location of Test Specimens

(2) In relation to the tests for semibuilt-up crank throws specified in **601. 14** (2) of the Rules, following requirements are to be complied with.

(A) Test specimens are to be taken, in general, one set from each arm in the longitudinal direction.

(B) In case where either the process of manufacturing those approved are intended to be changed or cranks larger than ever approved are intended to be manufactured, the tests instructed by the Society are to be newly carried out.

SECTION 7 Copper and Copper Alloys

702. Copper alloy castings

1. Manufacturing process

In application to **702. 3** (3) of the Rules, the stress relieving temperatures and holding times are to comply with the **Annex 2-6.**

2. Mechanical properties

The wording " specially required considering the design by the Society" in **Table 2.1.94,** Note 1 of **702. 5** of the Rules means in case where the requirements specified in **Pt 5, Ch 3, 305. 2** (1) (g) of the Guidance are applied.

3. Surface and dimension inspection

In application to **702. 7** (2) of the Rules, procedure for straightening of propeller casting is to comply with **Annex 2-6.**

4. Non-destructive inspection

(1) The liquid penetrant test of steel propeller casting specified in **702. 9** (1) of the Rules is to comply with **Annex 2-6.**
(2) The division of severity zones of steel propeller casting specified in **702. 9** (2) is to comply with the **Fig 1** and **2** of **Annex 2-6.**

5. Repair of Defects

In application to **702. 10** (5) of the Rules, repair welding of propeller castings is to comply with **Annex 2-6.**

SECTION 8 Aluminium Alloys

801. Aluminium alloys

1. Mechanical properties

(1) In connection with the **801. 5** (2) of the Rule, for verification of proper fusion of press welds for closed profiles, the Manufacturer has to demonstrate by drift expansion tests of closed as follows;

(a) Batches of five profiles or less shall be sampled one profile. Each profile sampled will have two samples cut from the front and back end of the production profile. The test specimens are to be cut with the ends perpendicular to the axis of the profile.

(b) Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production. The number of tests may be reduced to every fifth profile if the results from the first 3-5 profiles are found acceptable.

(c) The size of the specimen and testing procedure are to be in accordance with the requirements in **401. 5** (3) of the Rule.

(d) The sample is considered to be unacceptable if the sample fails with a clean split along the weld line which confirms lack of fusion.

2. Heat treatment

In application to **801. 4,** Note (2) of **Table 2.1.97** and **Table 2.1.98** of the Rules, definitions of the symbols used in temper condition are to comply with the requirements in **Table 2.1.19** of the Guidance.

Table 2.1.19 Definition of the symbols used in temper condition

Symbols	Definition (1)	Application(1)
O	Annealing	Applies to wrought alloys which are annealed to obtain the softest temper
H111, H112 and H116	Work hardened only.	Applies to products which are strain-hardened to achieve the strength desired without additional thermal treatment
H321	Stabilizing treatment after work hardened(2)	Applies to alloys that are strain-hardened and whose mechanical properties are stabilized by a low temperature thermal treatment that results in slightly lowered tensile strength and improved ductility.
T5	Artificial age hardening only(3)	Applies to alloys which are not cold worked after cooling from an elevated temperature shaping process
T6	Artificial age hardening treatment(3) after solution treatment(4)	Applies to alloys which are not cold worked after solution heat-treatment

Note
(1) Refer to KS D0049(Ferrous products－Heat treatments－Vocabulary) and KS D0004(Temper Designation for Aluminium and Aluminium Alloys)
(2) Stabilising is the relief of residual internal stresses by heating to a predetermined temperature, usually in the region of 250ºC, then cooling slowly.
(3) Age hardening is the increasing the hardness of an alloy by a relatively low-temperature heat treatment that causes precipitation of components or phases of the alloy from the supersaturated solid solution.
(4) Solution treatment is the heating and holding an alloy at a temperature at which one (or more) constituent enters into solid solution, then cooling the alloy rapidly to prevent the constituent from precipitating

3. Corrosion testing

In connection with the **801. 8** (3) of the Rule, corrosion testing methods and acceptance criteria are to be in accordance with the followings:

(1) **Micro-structure test**
Micro-structure test is to be in accordance with *ASTM B928* or equivalent standards agreed by the Society.

(2) **Corrosion tests**
(a) Corrosion tests with respect to exfoliation and intergranular corrosion resistance are to be in accordance with *ASTM G66* and *G67* or equivalent standards agreed by the Society.
(b) The samples have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better when subjected to the test described in *ASTM G66*.
(c) The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in *ASTM G67*.

4. Surface inspection and dimensional tolerance

"Dimension tolerance except those specified in previous (2)" given in requirements of **801. 8** (3) of the Rules may comply with a recognized national or international standard accepted by the Society. ⚓

CHAPTER 2 WELDING

SECTION 1 General

103. Special weldings

Production weld test for tanks of ships carrying liquefied gases in bulk, and tank circumference hull construction units.

1. Application

When welding is made for independent tanks of ships carrying liquefied gases in bulk, the production weld tests are to be carried out for each position of welding in accordance with the following requirements, in addition to the welding procedure qualification tests specified in **Ch 2, Sec. 4** of the Rules.

(1) For Type A independent tanks, the production weld test is to be carried out on at least one test sample for every 50 m of welding length of butt joints of principal structural members.
However, consideration may be given for reduction of the number of test sample or omission of the production weld test by taking into account the past records and the actual state of quality control system of the manufacturer.

(2) For Type B independent type tanks, the production weld tests are to be carried out on at least one test sample for every 50 m of welding length of butt joints of principal structural members. However, the number of test sample may be reduced to one test sample for every 100 m of welding length by taking into account the past records and the actual state of quality control system of the manufacturer. In this case, however, at least one or more test specimens are to be selected for one tank.

(3) For Type C independent type tanks, the production weld tests are to be carried out on at least one test sample for every 30 m of welding length of butt joints of principal structural members. However, the number of test sample may be reduced to one test sample for every 50 m of welding length by taking into account the past records and the actual state of quality control system of the manufacturer.
Remark : The definitions of type A, B and C independent tank comply with the requirements in the **Pt 7, Ch 5, 402. 4** of the Rules.

2. Test procedure

(1) The production weld tests are to be carried out for every welding length specified in the above **1.** for welded joints made under the same welding procedure, position of welding and welding conditions.

(2) Test samples are, in principle, to be located on the same line as the welded joints of the body and to be welded at the same time of welding of the body.

3. Kind of test

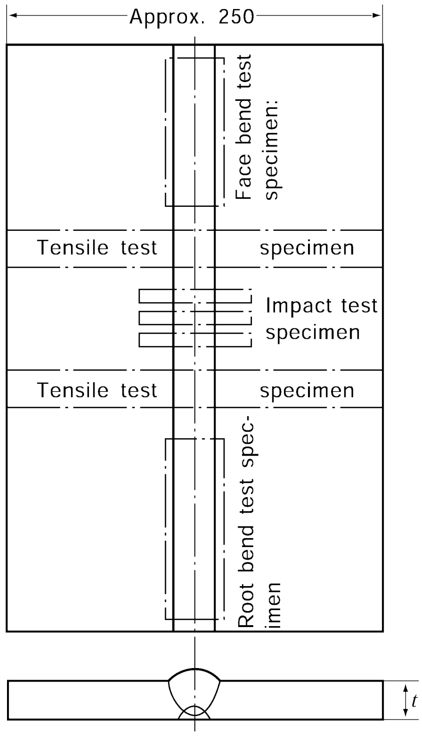
Kinds of the test are to be as given in **Table 2.2.1** of the Guidance.

Table 2.2.1 Kind of Test

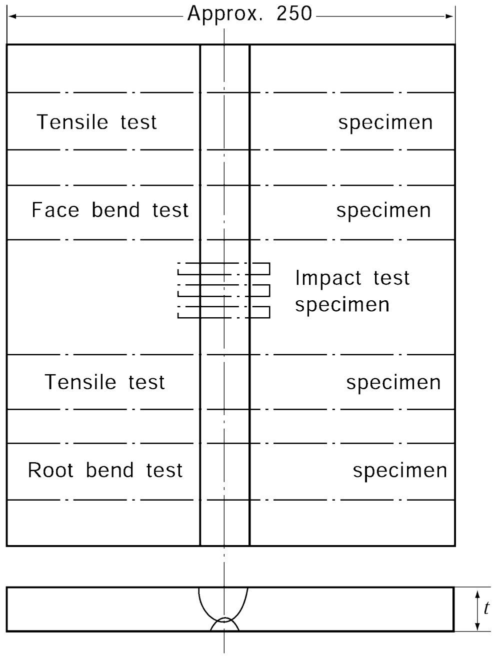
Material	Kind of Test
9 % Ni steel	Tensile test, bend test and impact test
Stainless steel	Tensile test and bend test
Aluminium alloys	Tensile test and bend test
Steel for low temperature service (excluding 9 % Ni steel)	Tensile test, bend test and impact test

4. Test assemblies

The shape and size of test assemblies are to be as shown in **Fig 2.2.1** of the Guidance. In cases of Type A and Type B independent tanks, tensile test may not be required.



(a) Test specimen of 9% *Ni* steel



(b) Test specimens of materials other than (a)

Fig 2.2.1 Test Specimens for Production Weld Test (Units : *mm*, thickness *t*)

5. Test specimens

(1) The shape and size of tensile test specimens are to be of the *R* 2*A* test specimen specified in **Table 2.2.1** of the Rules.
(2) The shape and size of bend test specimens are to be of the *RB* 1 or *RB* 2 test specimens specified in **Table 2.2.2** of the Rules. For test specimens with a thickness exceeding 19 mm, side bend test specimens are to be substituted for face bend and root bend test specimens.
(3) Impact test specimens are to be the R4 test specimen specified in **Table 2.1.3** of the Rules. In the impact test, one set of test specimens comprising three pieces are to be taken from every test assembly. The test specimens are to be taken alternately from the position "a" and from a position among "b" through "e" where the lowest value is recorded in the welding procedure qualification test, shows in **Fig 2.2.7** of the Rules. This means that one set of three test specimens are taken from a test assembly at the position "a", hence other set of three test specimens are taken in the subsequent test assembly from the position among "b" through "e" where the lowest value is recorded, and this procedure is repeated. No impact test specimens is required in cases of stainless steel and aluminium alloy.

6. Tensile test

(1) The tensile strength of 9 % Ni steels is to be 630 N/mm^2 or more.
(2) The tensile strength of stainless steels, aluminium alloys and steels for low temperature service (excluding 9 % Ni steels) is to be more than the specified value of the base metal.

7. Bend test

(1) The bend test specimen is to be bent up to an angle of 180° by a test jig with an inner radius of double (three and a third times for aluminium alloys) the thickness of the test specimen.
(2) The results of the bend test are to be as free from cracks exceeding 3 mm in length in any direction on the outer bent surface and from other significant defects.

8. Impact test

The specified values for the impact test are as given in **Table 2.2.8** of the Rules.

SECTION 3 Welding Works and Inspection

303. Application of welding consumables

Hydrogen cracking test specified in **303.** (4) of the Rules is to comply with *KS B* 0870 or equivalent.

304. Preparation for Welding

1. Tack welding

(1) The application to **304. 2.** (3) of the Rules is to be in accordance with the followings:

(A) The bead length of tack welds is to comply with **Table 2.2.2** of the Guidance.

Table 2.2.2 Bead length of tack welds

Steel grade	Kinds	Required Bead length	Remark
Higher strength- low alloy steel Steel casting	Ceq>0.36%	≥ 50 mm	including TMCP
	Ceq≤0.36%	≥ 30 mm	
grade E mild steel		≥ 30 mm	

(B) The pitch of tack welds should generally be approximately 400 mm or shorter.

305. Welding sequence and direction of welding

1. "The special approval of the Society" specified in **305. 3** of the Rules means the fillet weld to satisfy the following.

(1) The welding procedure qualification tests specified in **Sec. 4** of the Rules are accepted as successful.

(2) The welding consumables are to be those for welding with direction of vertical-downward approved by the Society.

(3) The joints of steels which welding with direction of vertical- downward is restricted, in general, is to comply with **Table 2.2.3-1** of the Guidance.

Table 2.2.3-1 Joints of Steels which Welding with Direction of Vertical Downward is restricted

Grade of steels	Welded joints
Rolled steels for hull	Joints of any E grade to any E grade(E, EH32 and EH36)
Rolled steels for low temperature services	Joints of any steels for low temperature service to any steels for low temperature service, Joints of any steels for low temperature service to any grade of steels
High Strength Quenched and Tempered Steels for Welded Structures	Joints of any high strength quenched and tempered steels to any high strength quenched and tempered steels, Joints of any high strength quenched and tempered steels to any grade of steels
Stainless clad steel plates	Joints of any stainless clad steel plates to any stainless clad steel plates, Joints of any stainless clad steel plates to any grade of steels
Rolled stainless steels	Joints of any rolled stainless steels to any rolled stainless steels, Joints of any rolled stainless steels to any grade of steels

(4) The zones where welding with direction of vertical- downward is restricted to hull structure, in general, is to comply with **Table 2.2.3-2** of the Guidance.

2. Notwithstanding the provisions of **1** (3) and (4), the other plans presented by shipbuilder or manufacturer may be accepted provided that the quality control system of shipbuilder and the importance of the welds are considered and deemed appropriate by the Society.

Table 2.2.3 Zones where Welding with Direction of Vertical Downward is restricted

Divisions	Locations and members
Fillet welded joints of primary strength member	- The welds of BHD(See **Fig 2.2.2,** (a) of the Guidance) - Cross hatching areas of **Fig 2.2.2,** (c) of the Guidance within connection areas of solid floor and girder - Connection areas of primary strength member and bottom shell, side shell, upper deck and double bottom tank top
Areas where water, oil and air tightness are required	- Boundary line where water, oil and air tightness are required - The area whose distance from the end of tight collar plate shall be at least 50mm (See **Fig 2.2.2,** (d) of the Guidance)
Areas where structural continuity is required or where high concentrated stress is expected	- The end of heavy bracket (See **Fig 2.2.2,** (b) of the Guidance) - Longitudinal strength members (See **Fig 2.2.2**, (e) of the Guidance)
Areas where high concentrated loads is expected	- The lower part of crane post - The lower part of crane pedestal
Specified areas	- The lower part of main engine : Connection areas of main engine girder and follr - Hatch cover : Connection area of side plate and end plate - Hatch coaming : Connection areas of main plate and top plate, Connection areas of main plate main plate - Shaft bed - Rudder horn : Connection areas of casting steels and normal strength steels - Rudder : Connection areas of rudder main pieces and rudder stocks, Connection areas of casting forging steels and normal strength steels - Bracket toe
(Note) Harmful defects such as cracks may, if necessary, be inspected by magnetic particle inspection or liquid penetrant inspection and, where the condition of the quality is serious, the welding work is to discontinue until measures for importance are planned.	

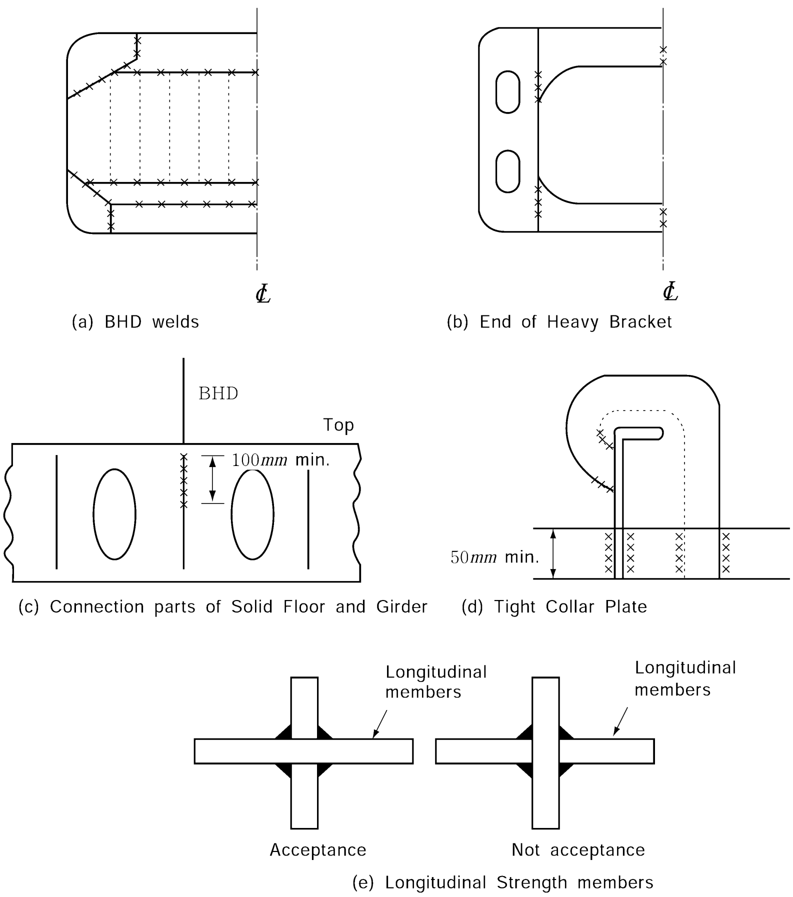


Fig 2.2.2 Zones where Welding with Direction of Vertical Downward is restricted (Cross hatching zone of Fig)

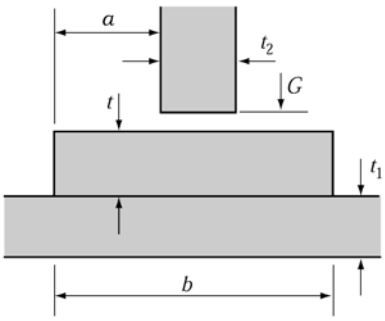
306. Main welding

1. In application of **306. 2** of the Rules, minimum preheating temperature for welding hull steels at low temperature is to comply with **Table 2.2.4** of the Guidance.

Table 2.2.4 Preheating for Welding Hull Steels at Low Temperature

Grades	Standard	
	Base metal temperature needed preheating	Minimum preheating temperature
Normal strength steels (*A*, *B*, *D*, *E*)	below 0℃	20℃ or over (1)
Higher strength steels (*AH* 32, *DH* 32, *EH* 32, *AH* 36, *DH* 36, *EH* 36)		
Note : (1) This level of preheat is to be applied unless the approved welding procedure specifies a higher level		

2. "The welding inserting a liner of suitable size" in **306. 8** of the Rules complies with the **Fig 2.2.3** of the Guidance.



(Notes)

1. Welding size is to comply with the following:
   $t_2 \leq t \leq t_1$
   $G \leq 2mm$
   $a = 5mm$ + fillet leg length
2. Not to be used in cargo area or areas of tensile stress perpendicular to liner

Fig 2.2.3 Fillet Welding inserting a Liner

309. Quality of welds

In **309. 3** of the Rules, the application to the non-destructive inspection specified elsewhere is to comply with **Annex 2-7.**

SECTION 4 Welding Procedure Qualification Tests(WPQT)

401. General

1. Application

In application to **401. 1** (2) of the Rules, the welding procedure qualification tests on materials for machinery installations are to be as follows.

(1) **Application**
(A) The requirements are to apply to the welding procedure qualification tests for boiler, pressure vessels and piping system.
(B) The requirements, other than this requirement, are to be in accordance with **Ch 2, Sec 4** of the Rules,

(2) **General requirements of WPQT**
(A) The manufacturers are to conduct the welding procedure qualification tests, if they plan to carry out for the first time the welding word as follows.
(i) Welding work for boiler, Class 1 and Class 2 pressure vessels
(ii) Welding work for principal components of machinery (the principal components specified in **Table 5.2.1** of **Pt 5, Ch 2** and **Ch 3** of the Rules) and piping system
(iii)Welding work using special materials
(iv)Welding work using special welding process
(B) Where the procedure qualification test is required, the following data and information in connection with the welding procedure qualification tests are, in general, to be submitted and reviewed. :
(i) Outline of plant facilities and equipment (outline of plant installations, type and number of important welding machines, outline of facilities for heat treatment and installations for test and inspection)
(ii) Qualification and number of welders
(iii) Production records of welded constructions
(iv) Data covering the welding quality control system and working process standards
(v) Welding procedure intended to be tested, and type or name of product to which the welding procedure is to be applied
(vi) Maximum plate thickness of above product, kind and specification of material
(vii)Draft proposal for welding procedure qualification tests(type of test, sampling procedure of test specimens and dimensions of test specimens etc, are to be specified)

(3) **Welding procedure qualification tests**
(A) Where procedure qualification test is required, the test assembly is to be welded in the same or similar environment and the qualification tests are to be carried out under the welding conditions given in the welding procedure specifications.
(B) The qualification test is to be carried out in the presence of the Society's surveyor.

(4) **Tests for butt and fillet welded joints**
(A) Kinds of test and number of specimens taken from test assembles
The kinds of test and number of specimens are to comply with **Table 2.2.5** of the Guidance.
(B) Test assemblies, test specimens and testing procedure
The dimensions and types of test assemblies and test specimens, and testing procedure are to comply with **Pt 2, Ch 2, Sec 4** of the Rules.

404. Butt welded joints

1. Tensile test

(1) In application to **404. 7** (1) (e) of the Rules, "lower toughness grade of steel" means grade *D* of **Fig 2.2.4**, (1) of the Guidance.
(2) In application to **404. 5** (2) of the Rules, "lower strength grade of steel" means grade *E* of **Fig 2.2.4**, (2) of the Guidance.
(3) "Where the consumables are avoidably applied" of **404. 5** (3) of the Rules means as follows.
(a) For the urgency of the corresponding work schedule
(b) For a small quantity of welding consumables with the rare frequency of the survey in future

Table 2.2.5 Kinds of Test and Number of Specimens taken from Test Assemblies

Divisions		Kinds of test and number of specimens taken from test assembles (1)(2)										
		Butt welded joints								Fillet welded joints		
		Visual inspection	radiographic examination	Macro-structure inspection	Hard-ness test	Tensile test	Bend test(4)	Impact test(5)(6) No. of sets	Impact test(5)(6) Position of notch	Macro-structure inspection	Visual insp.	Fracture test
Welding of boiler and pressure vessel	Boiler and class 1 pressure vessel	welding position	welding position	1	1	2	4	3	a, b, c	1	welding position	2
	Class 2 pressure vessel			1	1	2	4	-	-			
	Class 3 pressure vessel	The tests may be omitted according to the discretion of the Surveyor.										
Welding of piping(8)	The pipes for ordinary piping	welding position	welding position(3)	1	1	2	4	-	-	-	-	-
	The pipes used for high temperature and high pressure(7)			1	1	2	4	1	a			

Notes :

(1) In a case where special materials are used, special welding procedure is employed or where deemed necessary by the Society, the other tests or test conditions than those specified in this Section for the welding procedure qualification may be required

(2) For the welding procedure qualification tests on materials used at high temperature, the Society may require a creep test or high temperature tensile test.

(3) For those with an outer diameter of 130 mm or above, and with a design working pressure 30 kgf/cm^2 or above, and further with maximum design temperature over 400℃. However, even for the pipes having an outer diameter of less than 130 mm, radiographic examination depending on material and working condition may be required.

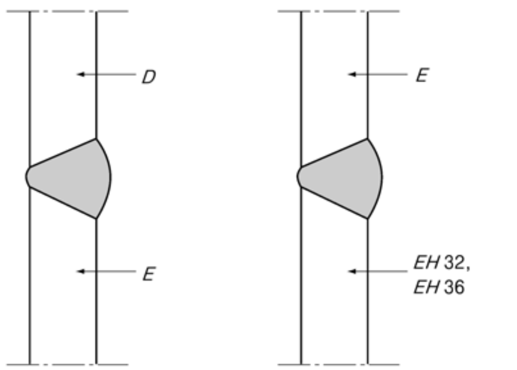
(4) Where preparation of the above test specimens is not possible depending on pipe's diameter, test specimens for face bend test and root bend test may be reduced to one set each for those of 19 mm thickness or less, and for side bend test may be reduced to one set for those of over 19 mm.

(5) Position of notch is as shown in **Fig 2.2.7** of the Rules.

(6) In a case where preparation of impact test specimens is not possible depending on pipe's dimensions or in case where welding is made with a base metal having no impact value required, impact test may be omitted subject to the approval of the Society.

(7) For steam pipes and flanges to be used in the place where the design pressure is not less than 30 kgf/cm^2 and the design temperature exceeds 400℃.

(8) Regardless of the above, as for those of less than 50 mm in outer diameter, test assemblies are to be prepared by two sets, one for tensile test, the other for macro, micro structure and hardness distribution examinations to be carried out respectively.



(1) Welded jonts of steels of same specified strength

(2) Welded joint of steels of same specified toughness(same specified impact test temperature)

Fig 2.2.4 Butt Welds between Different Steel Grades

2. Non-destructive inspection

In application to **404. 9** of the Rules, the relevant Rules for the acceptance criteria of non-destructive inspection are to be in accordance with the following. However, if agreed by the Society, imperfections detected by visual or non-destructive testing may be assessed in accordance with *ISO* 5817, class B.

(1) Rolled steels for hull - **Annex 2-7**
(2) High strength quenched and tempered steels for welded structures - **Annex 2-7** or **Pt 7, Ch 5** of the Rules
(3) Rolled steels for low temperature service - **Pt 7, Ch 5** of the Rules
(4) Materials for machinery installation(boilers, pressure vessel and piping system) - **Pt 5, Ch 5** or **Ch 6** of the Rules

3. Hardness test

The hardness test specified in **404. 10** of the Rules is to be as follows.

(1) Hardness distribution at positions shown in **Fig 2.2.5** of the Guidance is to be measured.

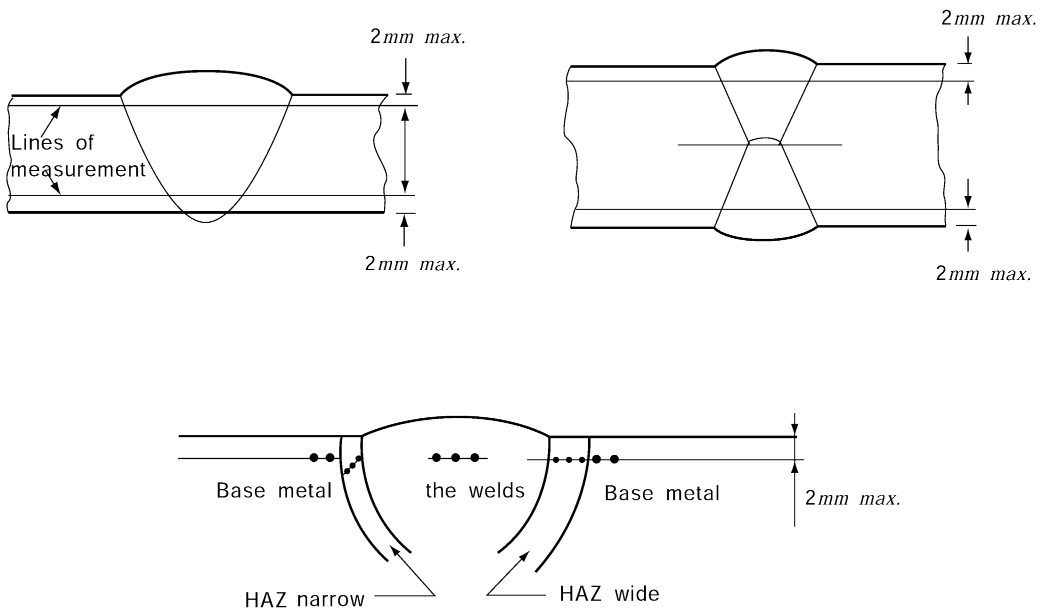


Fig 2.2.5 Hardness Test (Units : mm)

(2) Hardness test is required for steel for low temperature service(*Ni* steels).
(3) Measuring load is to be 10 kg vickers and measuring intervals are to be 1 mm.

405. Test for fillet welded joints

1. Hardness test

In application to **405. 7** of the Rules, hardness test, if required, is to comply with the following requirements :

(1) Hardness test is to be carried out in accordance with **Fig 2.2.6** of the Guidance.
(2) Hardness test is required for steel for low temperature service(*Ni* steels).
(3) Measuring load is to be 10 kg vickers and measuring intervals are to be 1 mm.

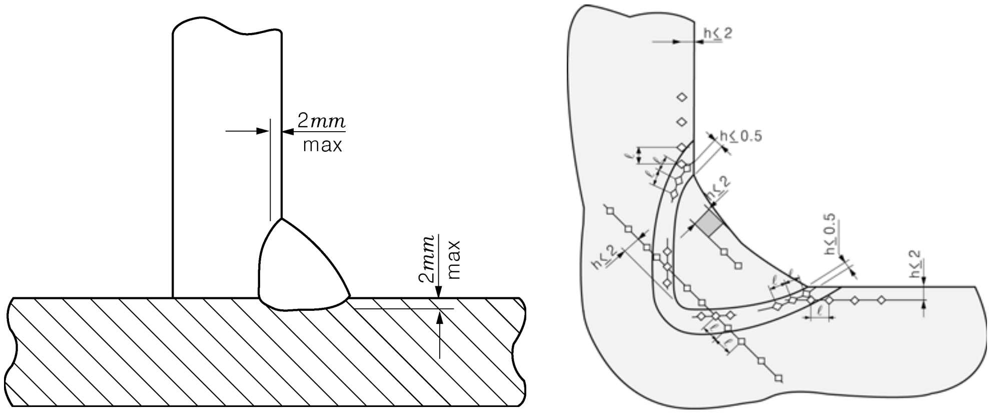


Fig 2.2.6 Hardness test for fillet welded joint (unit : mm)

407. Validity of qualified welding procedure specification

1. Validity of qualified welding procedure specification for aluminium alloy

In application to **407. 1** (3) of the Rules, the validity of qualified welding procedure specification for aluminium alloy is to comply with the followings:

(1) **General**

(a) The approval of the WPS obtained by a shipyard or a manufacturer is valid for welding in all its workshops under the same technical and quality control.

(b) All the conditions of validity stated below should be met independently of each other. Changes outside of the ranges specified may require a new welding procedure test.

(2) **Base metal**

(a) The aluminium alloys are grouped into three groups:

(i) Group A: aluminium-magnesium alloys with *Mg* content = 3.5 % (alloy 5754)

(ii) Group B: aluminium-magnesium alloys with 4% = *Mg* = 5.6 % (alloys 5059, 5083, 5086, 5383 and 5456)

(iii) Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082)

(b) For each Group, the qualification made on one alloy qualifies the procedure also for the other alloys of the same Group with equal or lower specified tensile strength after welding.

(c) The qualification made on Group B alloy qualifies the procedure also for Group A alloys.

(3) **Thickness**

(a) The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in **Table 2.2.6.**

Table 2.2.6. Range of qualification for parent material thickness

Thickness of the test piece t (mm)	Range of approval
t ≤ 3	0.5t ~ 2t
3 < t ≤ 20	3 ~ 2t
t > 20	≥ 0.8t

(b) In case of butt-joints between dissimilar thickness, t is the thickness of the thinner material. In case of fillet joints between dissimilar thickness, t is the thickness of the thicker material.

(c) In addition to the requirements of **Table 2.2.6**, the range of qualification of the throat thickness a is given in **Table 2.2.7.**

Table 2.2.7. Range of qualifications for the throat thickness of fillet welds

Throat thickness of the test piece, a(mm)	Range of qualifications
a < 10	0.75a ~ 1.5a
a ≥ 10	≥ 7.5

(d) Where a fillet weld is qualified by means of a butt weld test, the throat thickness range qualified should be based on the thickness of the deposited weld metal.
(e) Where the majority of production work is fillet welding, an additional fillet weld test may be required.

(4) **Welding position**
Provided that comparable welding parameters are used for the included welding positions a test in any one position qualifies for welding in all positions except for vertical downwards (PG) position where in any case separate welding procedure test is required.

(5) **Type of joint**
The range of approval for the types of joint in relation to the type of joint used in the procedure qualification test is as follows:
(a) butt-joint welded from one side with backing qualifies also for welding from both sides with gouging;
(b) butt-joint welded from one side without backing qualifies also for welding from one side with backing, from both sides with gouging and from both sides without gouging;
(c) butt-joint welded from both sides with gouging only qualifies that condition,
(d) butt-joint welded from both sides without gouging qualifies also for welding from both sides with gouging and from one side with backing.

(6) **Welding process**
(a) The approval is valid only for the welding process used in the welding procedure test.
(b) It is not permitted to change a multi run deposit into a single run (or single run on each side) or vice versa for a given process.
(c) In the case of a multi-process procedure, the approval is only valid for applying the processes in the order used during the procedure qualification tests.
(d) For multi-process procedures each welding process may be approved separately or in combination with other processes.

(7) **Welding consumables**
The welding consumable used in the qualification tests qualifies:
(a) Approved welding consumables of the same strength as the consumable used in the procedure qualification tests.
(b) Approved welding consumables of higher strength than the consumable used in the procedure qualification tests.
(c) The qualification given to shielding gas and backing gas is restricted to the gas/gas mixture used in the welding procedure test, see *ISO* 14175 or other recognised standards for gas designations.

(8) **Type of current**
Changes in the type of current (*AC*, *DC*, pulsed) and polarity require a new welding procedure qualification.

(9) **Preheat and interpass temperature**
The lower limit of approval is the preheat temperature applied at the start of the welding procedure test. The upper limit of approval is the interpass temperature reached in the welding procedure test.

(10) **Post-weld heat treatment or ageing**
Addition or deletion of post weld heat treatment or ageing is not permitted except that artificial ageing for 6000 series alloys gives approval for prolonged natural ageing.

SECTION 5 Welders and Welder Performance Qualification Tests

501. General

1. Qualification of tack welder

Qualification tests for tack welder, specified in **501. 2** of the Rules, are to be carried out in accordance with the followings:

(1) Test assembly is to comply with **Fig 2.2.7** of the Guidance. The leg length of tack welds will not be more than 6 mm. The bead length of tack welds may be of about 50 mm

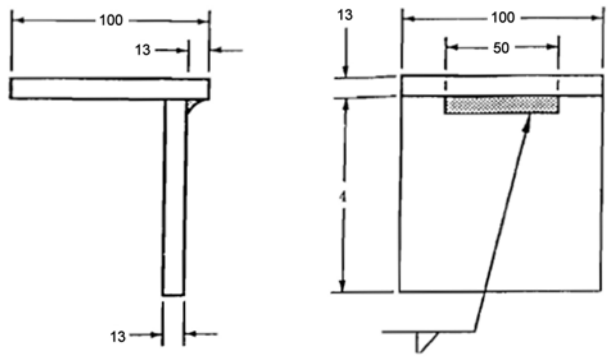


Fig 2.2.7 Type and dimension of test assembly for qualification of tack welder

(2) Visual inspection is to comply with **Pt 2, Ch 2, 503. 3** (2) of the Rules and fracture test is to comply with **Pt 2, Ch 2, 503. 3** (5) of the Rules.

2. Qualification of welding operator

Qualification of welding operator specified in **501. 3** of the Rules are to be carried out as follows:

(1) Test assembly is to comply with **Pt 2, Ch 2, 404. 3** of the Rules. The width of test assembly is not to be less than 300 mm and the length not to be less than 400 mm.
(2) Tests and inspections are to comply with **Pt 2, Ch 2, 503. 3** of the Rules.

3. Qualification of Gas welders

In application to **501. 4** of the Rules, the Qualification of gas welder is to comply with the followings:

(1) Gas welders are to have the qualification in **Table 2.2.12, 2.2.13** and **2.2.14** of the Rules according to the kind of welding material, plate thickness and welding position.
(2) Test assemblies used in the qualification test are to be of without backing, and gas welding rods are to be those for mild steel complying with a *KS D*7005 (Gas welding rods for mild steel) or those considered appropriate by the Society.
(3) To the kind and procedure of the qualification tests, the requirements specified in **Sec 5** of the Rules are to be applied. For roller bend test, the radii of the plunger of the jig and support roller are to be 10 mm, and the roller spans to be 53 mm.
(4) The qualifications for gas welders is to represent "symbol *G*".

4. qualification test for 9 % Ni steel

In application to **501. 4** of the Rules, the Qualification test for 9 % *Ni* steel is to comply with the followings:

(1) *Qualification*

(a) Welders are to have the qualification given in **Table 2.2.12, 2.2.13** and **2.2.14** of the Rules according to the actual welding procedure, and the thickness of welding materials and welding position. However, the requirements equivalent to mild steel apply to welder having the qualification for all positions.

(b) Any applications who intends to be qualified for each Grade and each Kind of 9 % *Ni* steel are to have performance qualification of the corresponding Kind and Grade of mild steel.

(c) The kinds of welding procedure are shield metal arc welding (hereinafter referred to "SMAW") and semi-automatic welding. The welders are to be pass the performance qualification test required according to the each applicable procedure.

(d) Notwithstanding the requirements given in (c), welder having the qualification for SMAW who intended to be qualified for semi-automatic welding may make the performance qualification test for semi-automatic welding of the corresponding and lower qualification with the his SMAW qualification by the Society's approval.

(2) *Kinds and procedures*

The welding procedure, welding position and test procedure for welders are to be in accordance with **Table 2.2.12** and **Table 2.2.13** of the Rules, respectively. In the test procedure for plates, longitudinal face bend test may be substituted for face bend test and root bend test, and longitudinal face bend test for side bend test. In the test procedure for pipes, radiographic inspection may be substituted for bend test.

(3) *Test assemblies and welding consumables*

(a) The test assemblies for plates are to be of *RL* 9*N*53 or *RL* 9*N*60 specified in **Ch 1** of the Rules or those considered equivalent by the society.

(b) The test assemblies for pipes are to be of *RLP* 9 specified in **Ch 1** of the Rules or those considered equivalent by the Society.

(c) Welding consumables used in the test are to be those for 9 % *Ni* steel recognized by the Society.

(4) *Test assemblies for plates*

The shape and size of the test assemblies of plates are to be in accordance with **Fig 2.2.8-1** of the Guidance.

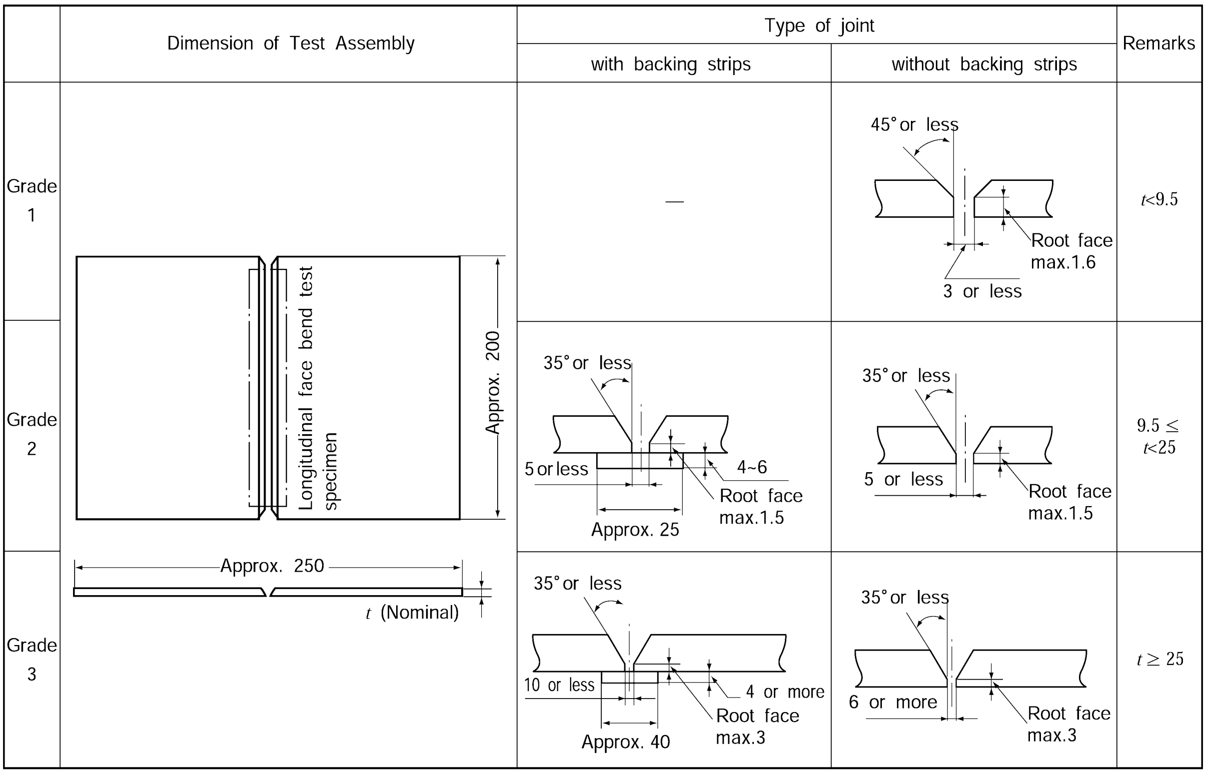


Fig 2.2.8-1 Dimensions and Types of Plate Test Assembly of the Qualification Test for 9% Ni Steel (Units : mm)

(5) *Test assemblies for pipes*

The shape and size of the test assemblies for pipe welding are to comply with **Fig 2.2.8-2** of the Guidance.

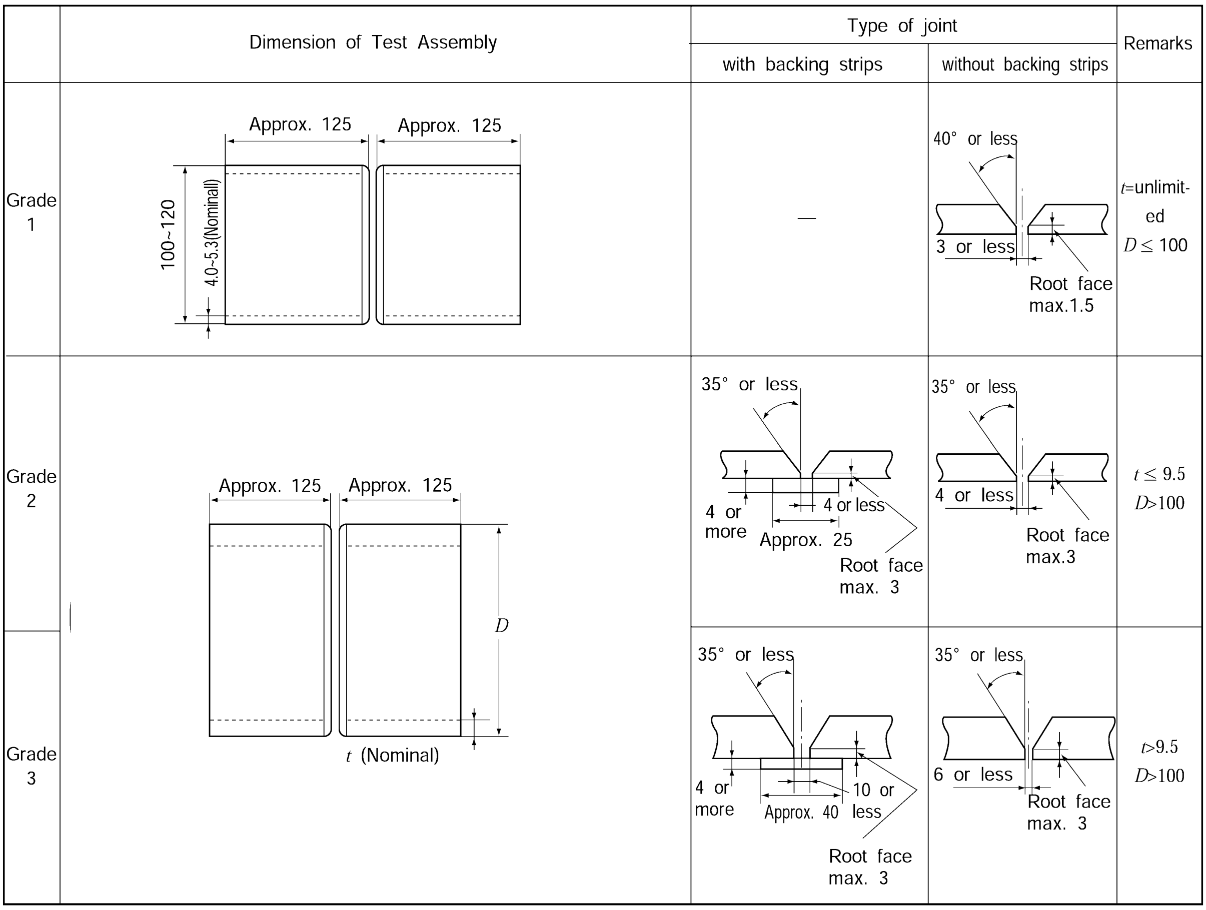


Fig 2.2.8-2 Dimensions and Types of Pipe Test Assembly of the Qualification Test for 9% Ni Steel (Units : mm)

(6) *Longitudinal bend test*

The shape and size of the longitudinal bend test specimen are to be of *RB* 1 in **Table 2.2.2** of the Rules. The test specimen is to be face bent jig shown in **Fig 2.2.1** or **2.2.2** of the Rules, and no cracks of 3 mm or more in length in any direction or no remarkable defect are to exist on the bent outer surface.

(7) *Radiographic test*

Radiographic test is to be carried out on all welding lines of the pipe test assemblies where no significant defects are to exist.

5. Application of equivalent standards

In application to **501. 5** of the Rules, it may be considered as equivalent for that the requirements of the standard internationally recognized(*AWS*, *ASME* etc) or considered as equivalent for those by the Society instead of the requirements for welder performance qualification of this section are applied.

503. Testing procedure

1. Test assembly

In application to **503. 2** (3) of the Rules, the test position, dimensions of test assembly and edge preparation for welding in 2G position are to comply with **Fig 2.2.9** of the Guidance.

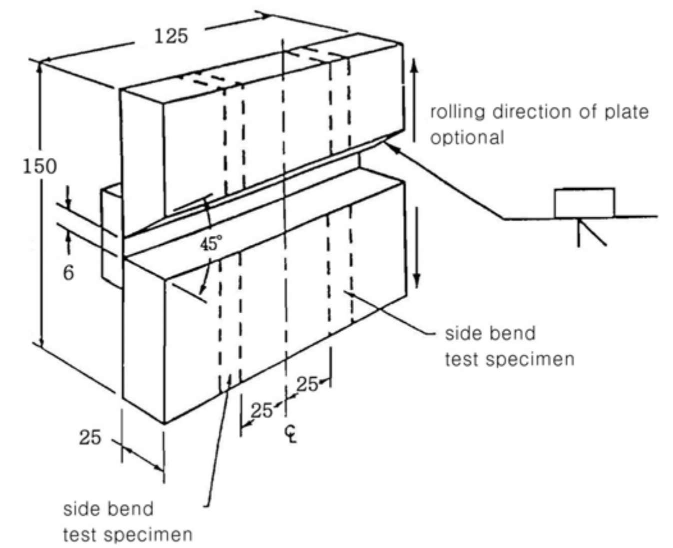


Fig 2.2.9 Dimensions of test assembly and edge preparation in 2G position

2. Radiographic testing

In application to **503. 3** (4) of the Rules, the radiographic testing procedures and acceptance criteria are to be in accordance with the followings :

(1) Where deemed the excess of the amount of heat input by visual inspection after welding, bend tests other than radiographic testing may be required additionally.

(2) The acceptance criteria for radiographic examination is to comply with the requirements specified in **3** (3) of **Annex 2-7**.

3. General requirements for qualification validity

(1) In application to **503. 6** (3) of the Rules, the suspension of welder qualification is to be in accordance with the followings.

(A) When welder quits his job from the company where he had employed and certified.

(B) Where there is some specific reason to question a qualified welder's ability.

(2) The effectiveness of qualification of welder who has switched his job may be considered as remaining, provided that the followings are satisfied

(A) It is to be proved that the welders have kept performance qualification at previous company.

(B) It is to be proved that welding condition is similar to those of previous company, and the welders carried out qualified work with acceptance welding performance.

(C) When welders have not used a particular process and equipment for a period excessing six months.

SECTION 6 Welding Consumables

602. Electrodes for manual arc welding for normal strength steels, higher strength steels and steels for low temperature service. General provision for tests

1. General provisions for tests

Hot cracking test specified in **602. 3** (1) of the Rules is to be done as follows :

(1) Test assemblies are to be T-joint shape as shown in **Fig 2.2.9** of the Guidance. The bottom of the vertical plate is to grind straight, and adhere closely on the surface of horizontal plate. All surface rough(凹凸) on the plate is to be removed before welding. The tack welds in preparation for the fillet welds is to make at the both ends of the plate. Three transverse stiffeners are to reinforce the horizontal plate to prevent welding deformation.

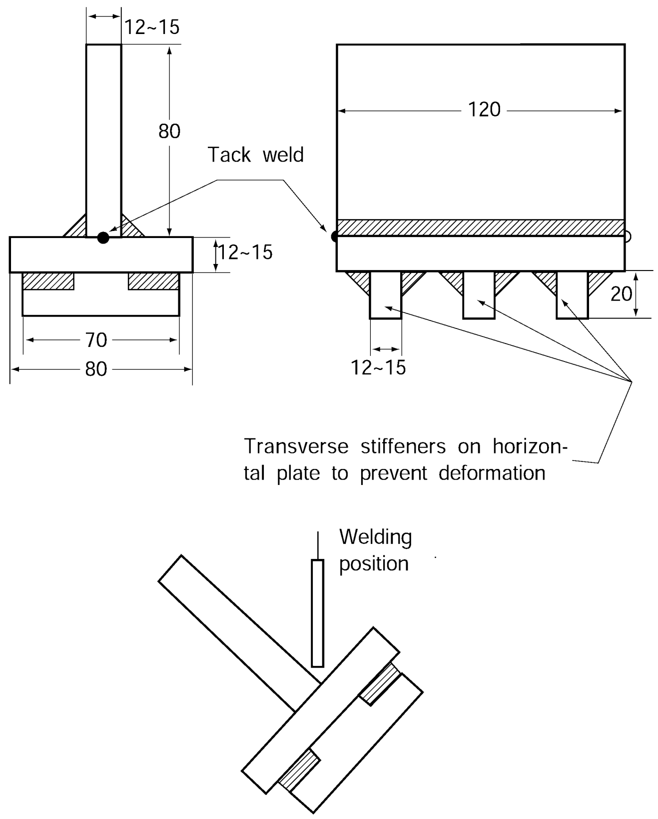


Fig 2.2.9 Hot Cracking Test Assemblies (Units : mm)

(2) The number of test assembly is to be prepared for every each diameter (4 mm, 5 mm or 6 mm) of electrodes.
(3) The fillet welding is to be carried out in the downhand position in one pass on each side and the welding current used is to be the maximum of the range recommended by the manufacturer for the size of electrode used.
(4) The second fillet weld is to be started immediately after the completion of the first fillet weld from the end of the test specimen at which the first fillet weld was finished. Both fillet welds are to be executed at a constant speed and without weaving.
(5) Length of fused electrode in hot cracking test are to be as shown **Table 2.2.9** of the Guidance according to the diameter of electrodes.
(6) After welding, the slag is to be removed from the fillet welds and after complete cooling, they are to be examined for cracks by a magnifying glass or by using penetrant fluids.

(7) The first fillet weld is then to be removed by machining or gouging and the second weld broken by closing the two plates together, subjecting the root of the weld to tension (See **Fig 2.2.10** of the Guidance). The weld is then to be examined for evidence of hot cracking.

Table 2.2.9 Length of Fused Electrode in Hot Cracking Test (Units : mm)

Diameter of electrode	Length of fused electrode	
	1st fillet	2nd fillet
4	Approx. 200	Approx. 150
5	Approx. 150	Approx. 100
6	Approx. 100	Approx. 75

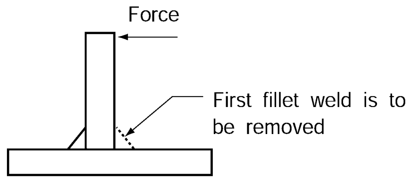


Fig 2.2.10 Hot Cracking Test

(8) There is to be no cracking in the fillet welds either superficial or internal except crater crack. ⚓

Annex 2-1 Guidance for seamless forged steel drums

1. Seamless forged steel drums

1.1 Application

(1) This requirements apply to seamless forged steel drums intended for boiler construction (hereinafter referred to as "forged drums").
(2) Items differing from those specified in this Guidance are to comply with the requirements in **Pt 2, Ch 1, Sec. 1** and **2** of the Rules.

1.2 Kind

The forged drums are classified into grades as given in **Table 1.**

Table 1 Kind

Grades
RSFB 410
RSFB 520

1.3 Mechanical properties

The forged drums are to comply with the following requirements.

(1) **Tensile test**
The forged drums are to conform to the requirements given by **Table 2** in the tensile test.

Table 2 Tensile Test

Grade	Yield strength (N/mm^2]	Tensile strength (N/mm^2]	Elongation (%) (L = 5D)	Reduction of area (%)
RSFB 410	205 min.	410 min.	24 min.	38 min.
RSFB 520	255 min.	520 min.	22 min.	40 min.

(2) **Bend test**
The test specimen is to stand being bent cold through l80 degrees without cracking outside to the inside radius given in **Table 3.**

Table 3 Bend Inside Radius

Grades	*RSFB* 410	*RSFB* 520
Bend inside radius	Tensile strength not more than 490 N/mm^2 : 6 mm	Tensile strength not more than 560 N/mm^2 : 9.5 mm
	Tensile strength over 490 N/mm^2 : 9.5 mm	Tensile strength over 560N/mm^2 : 16 mm

1.4 Selection of test specimens

(1) One set specimens each for tensile test and bend test are to be taken from each end of the forged drum, perpendicular to the centreline of the forged drum as well as opposite side each other with the centreline.
(2) Only in the case where ends of the forged drums are closed by reforging after machining, the test coupon may be cut from the forged drum before the reforging and heat treated simultaneously with the forged drum. In such a case, the forged drum is to be heat treated again after reforging. The latter heat treatment is to be annealing at a temperature above the critical temperature but not above the temperature of the first annealing when the former heat treatment is annealing, and to be same treatment as the former when the former heat treatment is normalizing and tempering. ⚓

Annex 2-2 Guidance for non-destructive examination of marine steel castings

1. Application

(1) The requirements in this Guidance is intended to give general guidance on the extent, methods and recommended quality levels applicable to the non-destructive examinations (NDE), of marine steel castings(hereinafter referred to as "castings") specified in **Pt 2, Ch 1, 501. 8** and **10** of the Rules, except in those cases where alternative criteria have been otherwise approved or specified.

(2) Although no detailed Guidance are given for machinery components, the requirements in this Guidance may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.

2. Personnel Requirements

(1) Personnel carrying out NDE are generally to be qualified and certified to Level II of a recognised certification scheme such as *KS B ISO* 9712, *SNT-TC-1A*, *EN* 473, *ASNT Central Certification Program* (*ACCP*) or equivalent.

(2) Personnel responsible for the NDE activity including approval of procedures should be qualified and certified to Level III.

(3) Personnel qualifications are to be verified by certification.

3. Casting Condition

(1) Non-destructive examinations applied for acceptance purposes should be made after the final heat treatment of the casting. Where intermediate inspections have been performed the manufacturer shall furnish the documentation of the results upon request of the Surveyor.

(2) Castings are to be examined in the final delivery condition free from any material such as scale, dirt, grease or paint that might affect the efficacy of the inspection. A thin coating of contrast paint is permissible when using magnetic particle techniques.

(3) Unless otherwise specified in the order, magnetic particle test shall be carried out within 0.3 mm of the final machined surface condition for *AC* techniques or within 0.8 mm for *DC* techniques.

(4) Ultrasonic testing is to be carried out after the castings have been ground, machined or shot blasted to a suitable condition. The surfaces of castings to be examined should be such that adequate coupling can be established between the probe and the casting and that excessive wear of the probe is avoided.

4. Extent of Examinations

(1) **Castings to be examined**

Castings to be examined by NDE methods are identified in **Fig 1** to **Fig 3** of this Guidance. Criteria for the examination of other castings not identified in **Fig 1** to **Fig 3** of this Guidance will be subject to agreement.

(2) **Zones to be examined**

(A) Zones to be examined in nominated castings are identified in **Fig 1** to **Fig 3** of this Guidance. Examinations are to be made in accordance with an inspection plan approved by the Society. The plan should specify the extent of the examination, the examination procedure, the quality level or, if necessary, level for different locations of the castings.

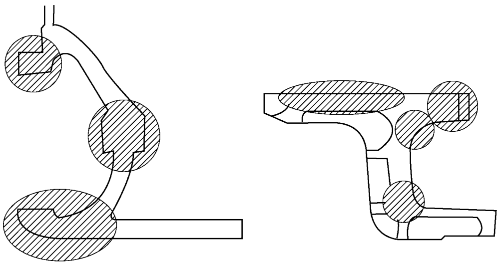
(B) In addition to the areas identified in **Fig 1** and **Fig 2** of this Guidance, surface inspections shall be carried out in the following locations:

(a) at all accessible fillets and changes of section,
(b) in way of fabrication weld preparation, for a band width of 30mm,
(c) in way of chaplets,
(d) in way of weld repairs,
(e) at positions where surplus metal has been removed by flame cutting, scarifying or arc-air gouging.

(C) Ultrasonic testing shall be carried out in the zones indicated in **Fig 1** and **Fig 3** of this Guidance and also at the following locations:

(a) in way of all accessible fillets and at pronounced changes of section,
(b) in way of fabrication weld preparations for a distance of 50 mm from the edge,
(c) in way of weld repairs where the original defect was detected by ultrasonic testing.
(d) in way of riser positions,

(e) in way of machined areas particularly those subject to further machining such as bolt hole positions.

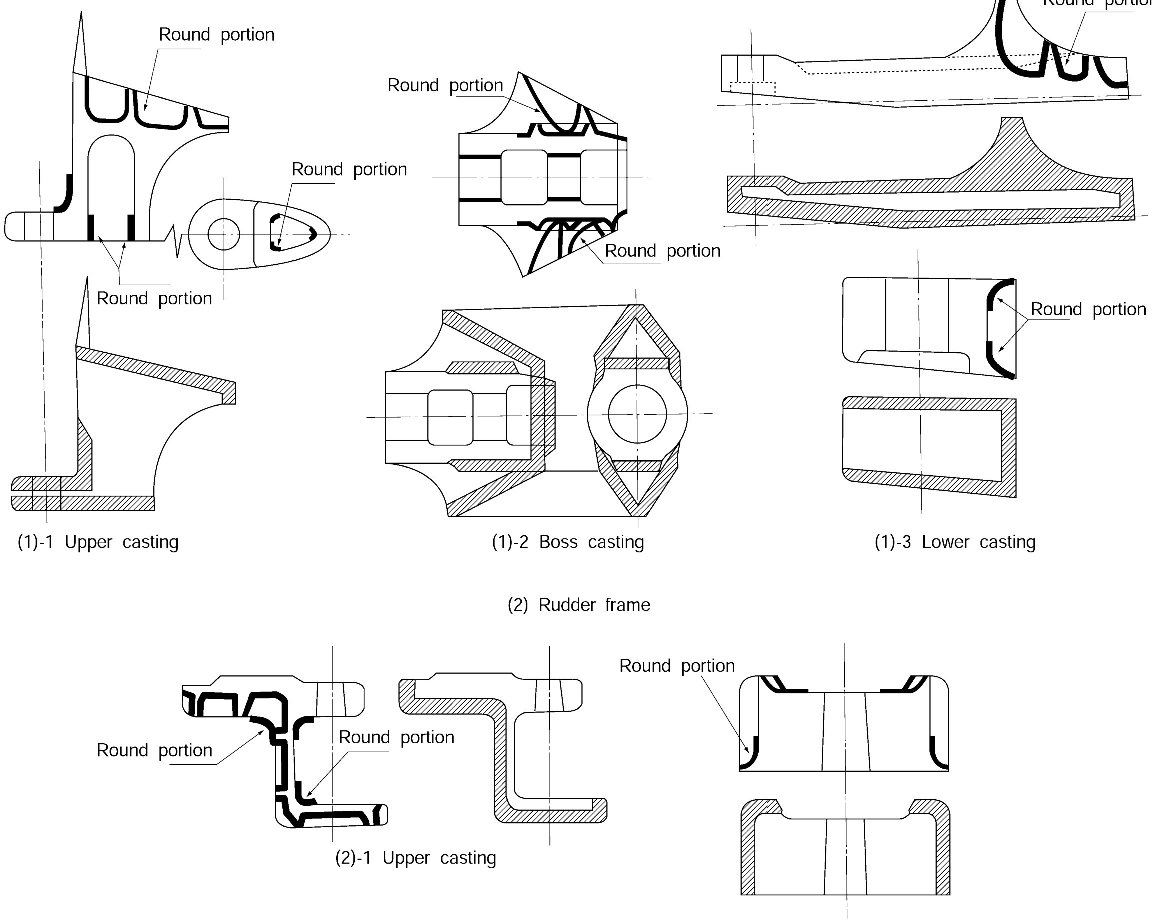


(a) Stern frame (b) Rudder frame

(Cross hatched area shows the outline drawings)

Fig 1 Detection Area for Non-destructive Test

(1) Stern frame



(Notes)
1. The entire edge preparation shown with the hatched area and the 100 mm width from the areas outside are to be subjected to the tests.
2. The portions shown in thick lines are also to be subjected to the test.
3. The portions of feeding heads and gates of the castings are to be subjected to the test.

Fig 2 Example of Application of Magnetic Particle Tests

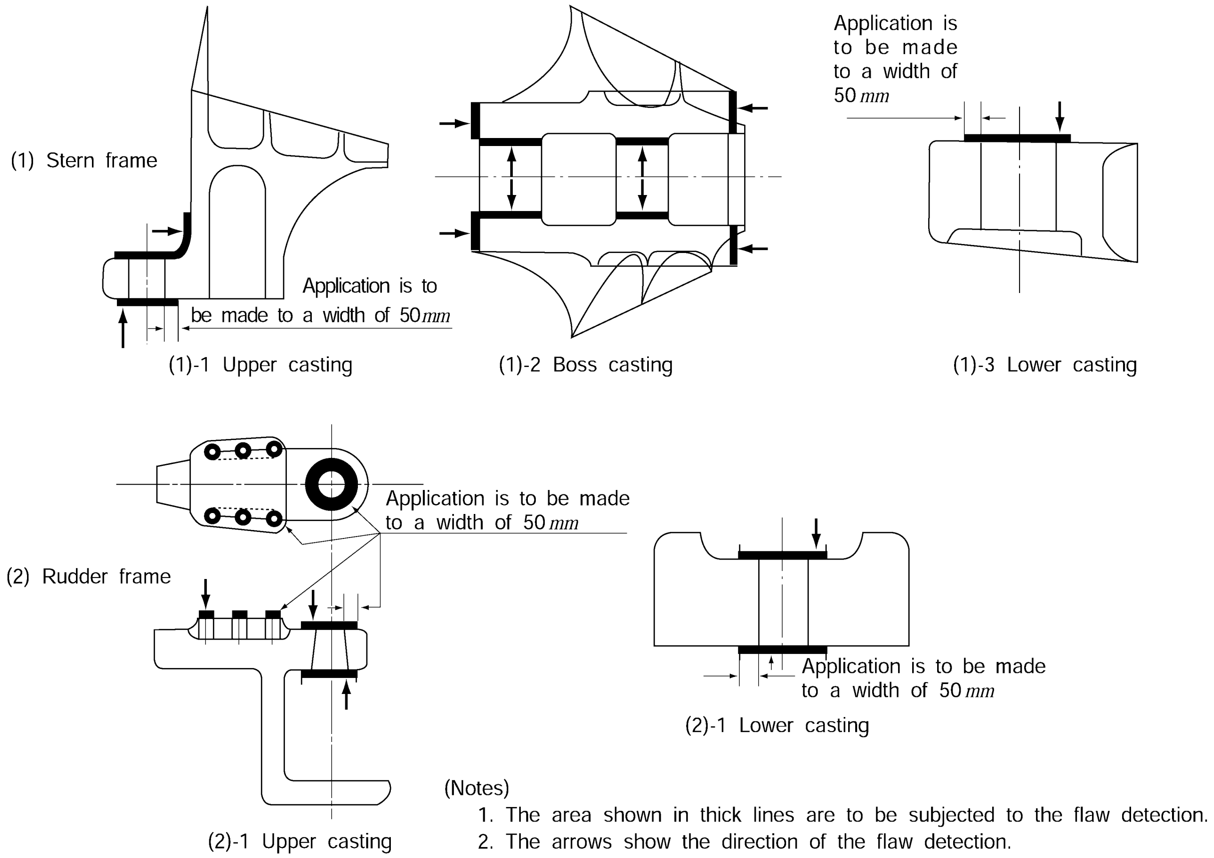


Fig 3 Examples of Application of Ultrasonic Tests

5. Examination Procedures

(1) **Visual Inspection**

Steel castings nominated for NDE shall be subjected to a 100% visual examination of all accessible surfaces by the Surveyor. Lighting conditions at the inspected surfaces shall be in accordance with a nationally or internationally recognised standard. Unless otherwise agreed, the visual and surface crack detection inspections are to be carried out in the presence of the Surveyor.

(2) **Surface Crack Detection**

(a) Magnetic particle inspection will be carried out in preference to liquid penetrant testing except in the following cases;
  (i) austenitic stainless steels,
  (ii) interpretation of open visual or magnetic particle indications,
  (iii) at the instruction of the Surveyor.

(b) The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing other than those specified in this Guidance are to comply with recognised national or international standards.

(c) Magnetic particle testing is to be carried out along two directions so that magnetic field can be directed at an right angle each other by means of the wet prod methods or the yoke method. In making magnetization by the prod method, the distance between prods is to be 200～300 mm. The magnetizing current is to be DC 800～1200 A for the prod method. For the yoke method, lifting power is to be 4.5 kg for AC, 18 kg over for DC.

(d) For magnetic particle testing attention is to be paid to the contact between the casting and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage in its surface. Prods shall not be permitted on finished machined items. Note that the use of solid copper at the prod tips must be avoided due to the risk of copper penetration.

(e) When indications have been detected as a result of the surface inspection, acceptance or rejection is to be decided in accordance with **Art 6.**

(3) **Ultrasonic testing**

(a) Volumetric inspection in accordance with these guidance is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique. The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognised national or international standards. Radiographic testing may be carried out on the basis of prior agreement with the Society.

(b) Only those areas shown in the agreed inspection plan need to be tested. The plan should include those locations nominated in **4.** (2), (c) together with the scanning zones identified for the relevant casting in **Fig 1** to **Fig 3.**

(c) Ultrasonic scans are to be made using a normal probe of 1~4 MHz (usually 2 MHz) frequency. Whenever possible scanning is to be performed from both surfaces of the casting and from surfaces perpendicular to each other.

(d) The back-wall echo obtained on parallel sections should be used to monitor variations in probe coupling and material attenuation. Any reduction in the amplitude of the back-wall echo without evidence of intervening defects should be corrected. Attenuation in excess of 30dB could be indicative of an unsatisfactory annealing heat treatment.

(e) Machined surfaces, especially those in the vicinity of riser locations and in the bores of stern boss castings, should also be subject to a near surface (25 mm) scan using a twin crystal 0o probe. Additional scans on machined surfaces are of particular importance in cases where bolt holes are to be drilled or where surplus material such as 'padding' has been removed by machining thus moving the scanning surface closer to possible areas of shrinkage. Also, it is advisable to examine the machined bores of castings using circumferential scans with 70° probes in order that axial radial planar flaws such as hot tears can be detected. Fillet radii should be examined using 45°, 60°, or 70° probes scanning from the surfaces/direction likely to give the best reflection.

(f) In the examinations of those zones nominated for ultrasonic examination the reference sensitivity is to be established against a 6mm diameter disk reflector. Sensitivity can be calibrated either against 6mm diameter flat bottomed hole(s) in a reference block (or series of blocks) corresponding to the thickness of the casting provided that a transfer correction is made, or, as a preferred alternative, by using the *DGS* (distance-gain-size) method. The DGS diagrams issued by a probe manufacturer identify the difference in dB between the amplitude of a back wall echo and that expected from a 6mm diameter disk reflector. By adding this difference to the sensitivity level initially set by adjusting a back wall echo to a reference height eg 80 %, the amended reference level will be representative of a 6mm diameter disk reflector. Similar calculations can be used for evaluation purposes to establish the difference in dB between a back wall reflector and disk reflectors of other diameters such as 12 or 15 mm.

(g) Having made any necessary corrections for differences in attenuation or surface condition between the reference block and the casting any indications received from the nominated zones in the casting that exceed the 6mm reference level should be marked for evaluation against the criteria given in **6.** (3) below. Evaluation should include additional scans with angle probes in order that the full extent of the discontinuity can be plotted.

6. Acceptance Criteria

(1) **Visual Testing**

(a) All castings shall be free of cracks, crack-like indications, hot tears, cold shuts or other injurious indications. Thickness of the remains of sprues or risers is to be within the casting dimensional tolerance.

(b) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor.

(2) **Surface Crack Detection**

(A) The following definitions relevant to indications apply:

(a) Linear indication : an indication in which the length is at least three times the width.

(b) Non-linear indication : an indication of circular or elliptical shape with a length less than three times the width.

(c) Aligned indication : three or more indications in a line, separated by 2 mm or less edge-to-edge.

(d) Open indication : an indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
(e) Non-open indication : an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
(f) Relevant indication : an indication that is caused by a condition or type of discontinuity that requires evaluation. Only the indications which have any dimension greater than 1.5 mm shall be considered relevant.

(B) For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area shall be taken in the most unfavourable location relative to the indications being evaluated.

(C) The following quality levels recommended for magnetic particle testing (MT) and/or liquid penetrant testing (PT) are;

Level MT1/PT1 - fabrication weld preparation and weld repairs.
Level MT2/PT2 - other locations nominated for surface crack detection in **Fig 1** and **Fig 2**

The allowable numbers and sizes of indications in the reference band length and/or area are given in **Table 1.** The required quality level should be shown on the manufacturer's inspection plan. Cracks and hot tears are not acceptable.

Table 1 Allowable number and size of indications in a reference band length/area

Quality Level	Max. number of indications	Type of indication	Max. number for each type	Max. dimension of single indication, (mm)(2)
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4(1) 4(1) 4(1)	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-linear Linear Aligned	10 6 8	7 5 5

Notes:
(1) 30 mm min. between relevant indications.
(2) In weld repairs, the maximum dimension is 2 mm.

(3) **Ultrasonic testing**

(A) Acceptance criteria for ultrasonic testing are identified in **Table 2** as UT1 and UT2. As stated in **4** (2), (a), the quality levels applicable to the zones to be examined are to be identified on an inspection plan. The following quality levels are nominated for the castings identified in **Fig 1** and **Fig 3.**

(B) Level UT1 is applicable to:
(a) fabrication weld preparations for a distance of 50 mm,
(b) 50 mm depth from the final machined surface including bolt holes and fillet radii to a depth of 50 mm and within distance of 50 mm from the radius end,
(c) castings subject to cyclic bending stresses e.g. rudder horn, rudder castings and rudder stocks - the outer one third of thickness in the zones nominated for volumetric examination by **Fig 1** and **Fig 3.**
(d) discontinuities within the examined zones interpreted to be cracks or hot tears.

(C) Level UT2 is applicable to:
(a) other locations nominated for ultrasonic testing in **Fig 1** and **Fig 3** or on the inspection plan.
(b) positions outside locations nominated for level UT1 examination where feeders and gates have been removed
(c) castings subject to cyclic bending stresses - at the central one third of thickness in the zones of nominated for volumetric inspection by **Fig 1** and **Fig 3.**

(D) Ultrasonic acceptance criteria for other casting areas not nominated in **Fig 1** and **Fig 3** will be subject to special consideration based on the anticipated stress levels and the type, size and position of the discontinuity.

Table 2 Ultrasonic Acceptance Criteria for steel castings

Quality Level	Allowable disc shape according to $DGS^{(1)}$ (mm)	Max. number of indications to be registered$^{(2)}$	Allowable length of linear indications (mm)$^{(3)}$
UT1	> 6	0	0
UT2	12-15 > 15	5 0	50 0

Notes:
(1) DGS: distance-gain size.
(2) grouped in an area measuring 300 x 300 mm
(3) measured on the scanning surface

7. Reporting

(1) All reports of non-destructive examinations should include the following items;
(a) Date of testing.
(b) Names and qualification level of inspection personnel.
(c) Type of casting.
(d) Product number for identification.
(e) Grade of steel.
(f) Heat treatment.
(g) Stage of testing.
(h) Locations for testing.
(i) Surface condition.
(j) Test standards used.
(k) Results.
(l) Statement of acceptance / non-acceptance.
(m) Locations of reportable indications.
(n) Details of weld repairs including sketches.
(2) In addition to the items listed in **7** (1), reports of surface crack detection inspections are to include at least the following items:
(a) for liquid penetrant testing; the consumables used,
(b) for magnetic particle testing: method of magnetising, test media and magnetic field strength.
(3) In addition to the items listed in **7** (1), reports of ultrasonic inspection should include at least the following items:
(a) flaw detector, probes, calibration blocks and couplant used.

8. Rectification of Defects

(1) **General**
(a) Defects and unacceptable indications must be repaired as indicated below.
(b) In either case where, after removing defects, the steel castings are used as they are or repair welding are carried out approval of the surveyor is to be obtained. In case where the depth of the recess after removing the defects is not larger than 15 mm (or 10 % of the thickness of the steel castings, whichever is smaller) and the length is not more than 100 mm, the steel castings may be used without repair welding.
(2) **Rectification of Defects**
Defective parts of material are to be completely removed either by grinding, or by chipping and grinding, or by arc air-gouging and grinding and to be repaired by either of the following methods. Thermal methods of metal removal should only be allowed before the final heat treatment.

(A) **In case of no repair welding being carried out**

The portions required no repair welding after removing defects, are to be finished with a grinder etc. in accordance with the following:

(a) All grooves shall have a bottom radius of approximately three times the groove depth.

(b) Grooves and their vicinity are to be finished smoothly avoiding abrupt changes in configuration.

(c) The portions where defects have been removed are to be verified that they are free from harmful defects by liquid penetrant test or magnetic particle test after finishing of the surface configuration.

(B) The portions required repair welding are to be suitably shaped and verified that they are free from harmful defects by nondestructive tests specified in (2) (A) (c) above and also repaired in accordance with the requirements in **3.** of this Appendix. Weld repairs should be suitably classified as follows.;

(a) *Major repairs*

(i) where the depth is greater than 25 % of the wall thickness or 25 mm whichever is less,

(ii) where the total weld area on a casting exceeds 2 % of the casting surface noting that where a distance between two welds is less than their average width, they are to be considered as one weld.

(iii) Major repairs require the approval of the Society before the repair is carried out. The repair should be carried out before final furnace heat treatment.

(b) *Minor repairs*

(i) where the total weld area (length x width) exceeds 500 mm^2

(ii) Minor repairs do not usually require the approval of the Society but should be recorded on a weld repair sketch as a part of the manufacturing procedure documents. These repairs should be carried out before final furnace heat treatment.

(c) *Cosmetic repairs*

(i) all other welds.

(ii) Cosmetic repairs do not require the approval of the Society but should be recorded on a weld repair sketch. These repairs may be carried out after final furnace heat treatment but are subject to a local stress relief heat treatment.

(3) **Procedure of repair welding**

The procedure of repair welding is to be as follows.

(A) **Welders**

Welders intended to engage in repair work by welding are to pass the qualification tests of the Society.

(B) **Welding consumables**

The welding consumables are to be either low hydrogen type approved by the Society or those deemed equivalent.

(C) **Preheating**

(a) In cases where the carbon equivalent of the steel castings exceeds 0.44 %, the portions of repair welding and their vicinity are to be preheated to a temperature higher than 200°C. In this case, the carbon equivalent is to be calculated by the following formula.

$$C_{eq}(\%) = C + \frac{Mn}{6} + \frac{Si}{24} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14}$$

(b) Even in case where carbon equivalent is 0.44 % or less, preheating may be required taking into account the shape and size of the steel castings.

(D) **Position of welding**

The positions of welding are to be as given in the following **Table 3** in general.

Table 3 Position of Welding

Kind \ Position welding	Flat	Vertical	Horizontal	Overhead
Manual welding	○	○	○	○
Semi-automatic welding	○	—	○	—

(E) **Post weld heat treatment**

(a) Post weld heat treatment may be exempted in the following cases, provided that the carbon equivalent does not exceed 0.44 %.

(i) In case where the depth of chipping after the removal of defects is not more than 25 mm (or 20 % of the thickness, whichever is smaller) and the length is not more than 200 mm.

(ii) In cases where the depth of chipping after the removal of defects is not more than 15 mm and also the area is not more than 250,000 mm^2

(b) Post weld heat treatment is to be carried out in furnaces. The holding temperature is to be 550℃ ~ 650℃ and the period is to be not less than one hour per every 25 mm of welding depth. In case where annealing in furnace is impossible depending on the final condition of the steel castings to be finished, etc. or where the welding depth is not more than 50 mm as well as the length is not more than 300 mm, partial post weld heat treatment may be accepted as an alternative. By the partial post weld heat treatment, the welded portions and their vicinity within 100 mm therefrom are to be heated to a temperature not lower than 600℃ and kept at the temperature in a period not less than 10 minutes per every 25 mm of the welding depth, and then to be cooled gradually.

(F) **Finishing after repair welding**

The portions repaired by welding are to be finished by grinding, etc. so that inspection can be available.

(G) **Inspection after repair welding**

Parts which are repaired should be examined by the same method as at initial inspection as well as by additional methods as required by the Surveyor. ⚓

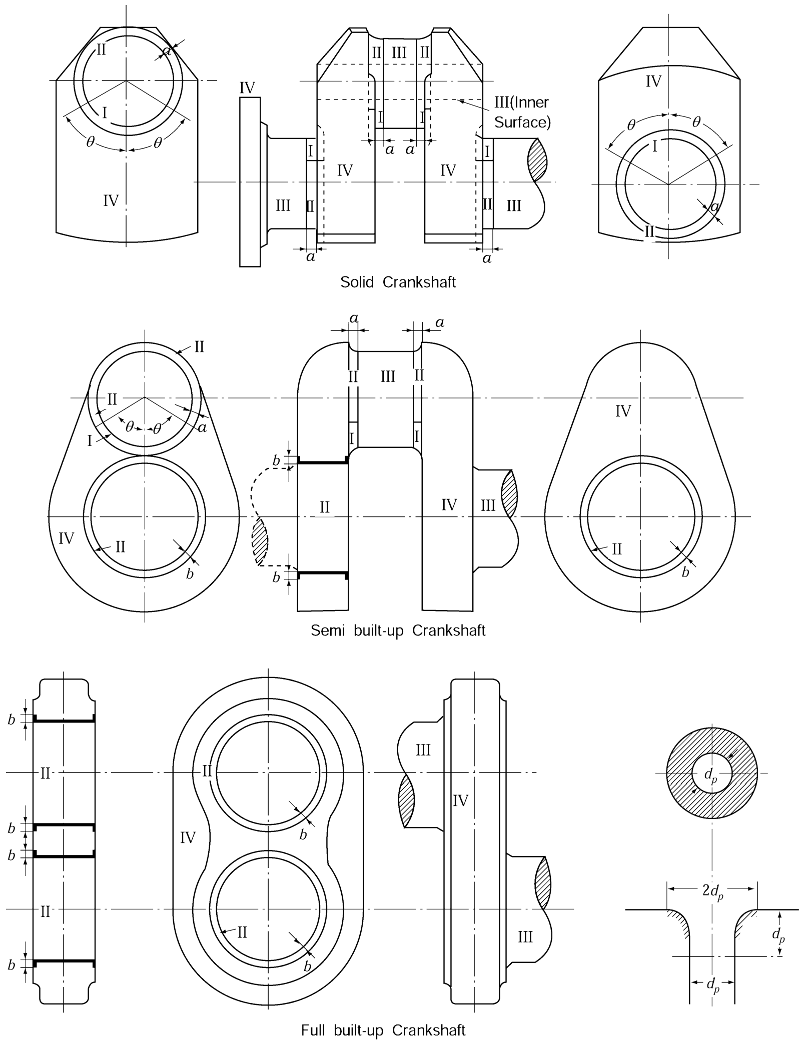
Annex 2-3 Guidance for surface inspection of cast steel crankshafts

1. Application

(1) This Guidance provides for the surface inspection of the cast steel crankshaft to be carried out on completion of machining (for shrunk parts, before shrinkage).
(2) The surface inspection is to be carried out by the methods specified in **3.** Where defects were found as a result of the inspection, the Surveyor is to decide pass or rejection of the crankshaft by the standards for allowable limit of defects prescribed in **6.**
(3) The inspection during the intermediate stage under construction is to be carried out actively by the manufacturer. The inspection methods are prescribed in **4.**
(4) NDE personnel requirements and inspection plans are to comply with the requirements specified in **Annex 2-2, 2** and **4** (2) (a) of this Guidance.

2. Divisions for inspection surface

The inspected surface of the crankshaft is divided into the following I to IV zones as shown in **Fig 1.** The inspection methods and standards are specified depending on the zones respectively.



(Notes)
1. Where the crankpin or journal has oil holes, the circumferential surface of the oil holes should be divided into division II (See the figure).
2. d ; Diameter of crankshaft, θ = 60°, a = 0.1d, b = 0.05d (but not less than 25 mm)

Fig 1 Divisions for Inspection Surface

3. Methods of inspection

(1) The surface is to be inspected as under in accordance with Divisions for inspection surface prescribed in **2.** But where CC defects (refer to **Table 1**) have been detected as a result of the inspection, the Surveyor may demand ultrasonic inspection additionally.

Kinds	Inspections
Zone I and II	Magnetic particle inspection or dye penetrant inspection
Zone III and IV	Visual inspection

(Notes)

1. Regarding the parts used as forged or cast condition, it is to be subjected to magnetic particle inspection notwithstanding the above requirement.
2. Regarding the Zone III of the crankshaft to which quenching and tempering heat treatments are applied, or the same zone of the crankshaft to which surface hardening treatment is applied, it is to be subjected to either magnetic particle inspection or dye penetrant inspection notwithstanding the above requirement.

(2) The methods of magnetic particle inspection, dye penetrant inspection and visual inspection are to be as deemed appropriate by the Society.

4. Inspection during intermediate stage

(1) The manufacturer is recommended to carry out actively ultrasonic inspection for the crankshaft at the appropriate stage during the manufacturing process and prove that the crankshaft has no harmful defects internally.
(2) The manufacturer should carry out actively the surface inspection at each stage under production. As the results when harmful defects of the material were found, the manufacturer is to inform the Surveyor of the facts and obey his instruction. Regarding cast steel crankshafts, when accepted by the Surveyor, defects can be remedied by welding according to the **Annex 2-4.**
(3) Regarding the crankshaft which surface hardening treatment is taken, the manufacturer is actively to inspect the surface. The records of surface inspection are to be submitted to the Surveyor when he requires.

5. Standards for surface inspection

(1) When defects have been detected as a result of the surface inspection prescribed in **3**, pass or rejection is to be decided by the following **6**, considering the results of the inspection of **4.** But even those which have failed to comply with these limits may be taken as passed, if in consideration with the position, size, direction and nature of the defects as well as the shape and dimension of such crankshafts, and the Surveyor accepted justifiable. Conversely, even those which have complied with these limits would be disqualified if they should contain such numerous defects as to make them unsuitable as crankshaft from the nature, distribution and direction of the defects.
(2) The treatment of defects for surface inspection is to be as the followings:
  (A) The lengths of the defects in the Standards are the actual lengths appeared by visual inspection.
  (B) The defects can be removed after acceptance of the Surveyor.
  (C) Removal of defects is to be carried out by grinding.
  (D) Where two defects spaced less than 5 mm apart, these are to be removed regarding as one defect.
  (E) The grooves caused by removing are to be smoothly rounded off by as large radius as possible toward the shaft surface.
  (F) The size of grooves caused by removing means the size before rounding off
  (G) Regarding cast steel crankshafts, when accepted by the Surveyor, defects can be remedied by welding according to the **Annex 2-4.**
  (H) When defects were removed, it is to be confirmed that the defects have been completely removed by magnetic particle inspection or dye penetrant inspection.

(I) Regarding the crankshaft which defects are left and removed, the manufacturer is to make detailed inspection records and submit the same to the Surveyor. In these inspection records, the position, size, direction and nature of the defects on the inspected surface and the position and size of grooves caused by removing the defects is to be recorded.

6. Standards for allowable limit of defects for surface inspection

(1) *Application*

(a) The standards are to be applied to the semi builtup cast steel and full built up crankshafts.

(b) Defects specified in this Guidance are Grade CC shown in (B).

(2) *Classification of material defects*

The surface defects are classified as the following **Table 1**, but Grade CA and CB defects are excluded from consideration by this Guidances.

Table 1 Classification of Material Defects

Classification	Names of defects
Grade CA defects	Microscopic non-metal inclusion
Grade CB defects	Pin hole and inclusion which do not exceed 0.2 mm in length
Grade CC defects	· Exceed 0.2 mm in length, Pin-hole, blowhole, sand-inclusion, slag inclusion · Shrinkage cavity, · Hot tear, cold crack

(3) *Standards*

For Standards, **Table 2** is to be applied.

Table 2 Standards

Divisions	Standards
I	All defects which are detected are to be removed. The depth of grooves caused by such removing is to be less than $0.01d$. In this case, the fillet parts are to be so finished that the original shape is retained. For parallel and plane parts, the grooves are to be so rounded off that the bottom radius of the grooves is not less than three times the depth of the groove.
II	All defects which are detected are to be removed, except the following defects: (i) Defects not exceeding 1 mm which are not crowded. (ii) Defects not exceeding 3 mm with sufficient spacing between each two. The depth of grooves caused by such removing is to be less than $0.01\ d$, and the grooves are to be so rounded off that the bottom radius of the grooves is not less than three times the depth of the groove, and in no case it shall be less than twice the depth.
III	All defects which are detected are to be removed, except the following defects: (i) Defects not exceeding 3 mm which are not crowded. (ii) Defects not exceeding 5 mm with sufficient spacing between each two. The depth of grooves caused by such removing is to be less than $0.01\ d$, and the grooves are to be so rounded off that the bottom radius of the grooves is not less than twice the depth of the groove.
IV	All defects which are detected are to be removed, except those not exceeding 8 mm. The depth of grooves caused by such removing is to be such that it does not affect the strength of the zone, and for the depth, it is necessary to receive the Surveyor's approval.

Annex 2-4 Guidance for repairs by welding for cast steel crank throws

1. Applications

(1) Where defects are discovered in the crank throws of cast steel crankshafts under manufacture (including full built-up crank webs: hereafter called, the crank throws), repairs by welding may be carried out in accordance with the following standards. However where the depth of the depression from which all defects have been removed is less than 0.05t (t is the web s thickness), it is recommended that no repairs by welding be carried out. In this case the finishing of the base part of the depression shall be such that the rounding there is over twice the depth of the depression, and the angle between it and surface is sufficiently rounded up.

(2) When the manufacturer desires to carry out repairs by welding, he shall apply in advance to the Surveyor for approval. In the case the Surveyor has found that such repairs by welding are not suitable or has perceived that there are too many places to be welded in such repairs, he will not approve the application, advising scrapping of the crank throw in question.

(3) When the manufacturer desires to carry out repairs by welding, he shall arrange in advance for the crank throw to be subjected to the preliminary tests stipulated in **7** below.

2. The scope and conditions permitting repairs

(1) The base part of the pin and web : Repairs by welding are not to be carried out the crosshatch zones marked on **Fig 1.**

(2) The depth of the depression from which all defects have been removed is to be less than 0.1 t.

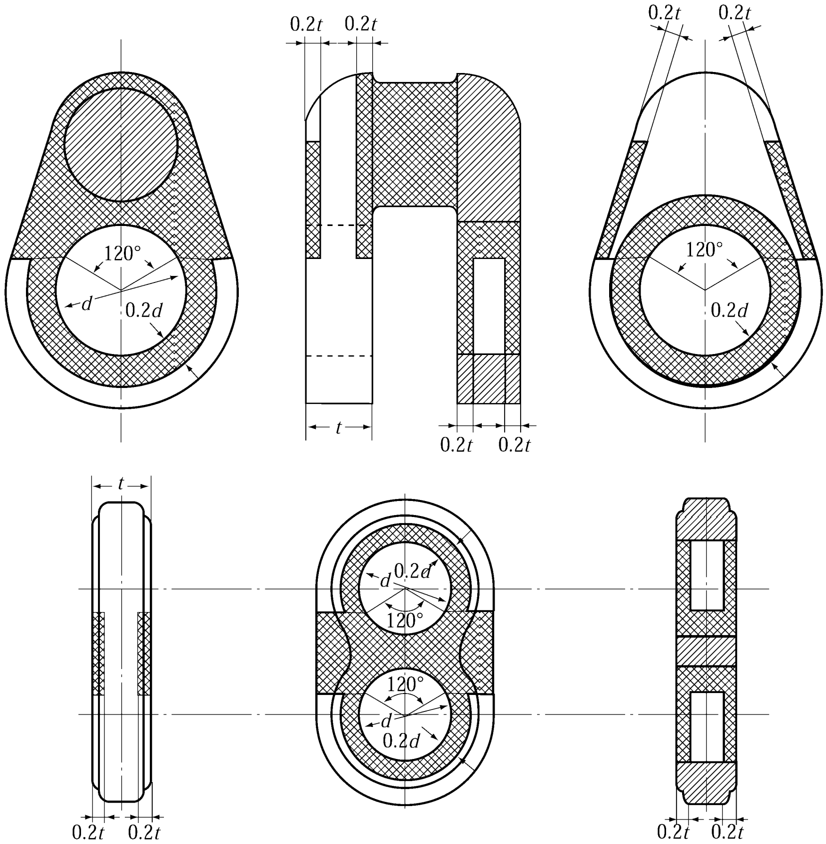


Fig 1 Zones where Repairs of Welding should not be carried out (Cross hatching zone)

3. Timing for repairs

Repairs by welding are to be carried out before the crank throws being given a formal heat treatment. However when approved by the Surveyor the weld repairing of comparatively minor defects may be carried out after the formal heat treatment.

4. Methods of repairs

Repairs by welding are to be carried out in conformity with the requirements of the following items:

(1) **Welder**
The welder engaging in repairs shall be the one who has passed the qualification tests of the Society and who has further had the experience in the preliminary tests stipulated in **7** below.

(2) **Removal of defects**
After defects have been removed by grinding or gouging, the depression is to be made shapely so as to fit for welding; while it is to be confirmed that the defects have been completely removed by means of the magnetic particle inspection or dye penetrant inspection.

(3) **Preheating**
The part undergoing the weld repairing and its neighbourhood are to be preheated to temperatures exceeding 200℃.

(4) **Welding method**
Welding is to be the downhand electric arc welding.

(5) **Electrode**
The low hydrogen electrode approved by the Society is to be used.

(6) **Post heating**
On completion of welding the crank throws are to be heat-treated as specified, but those heat-treated formally previous to repairs by welding with the approval of the Surveyor may require the annealing process only used 600 - 650℃ for stress relief.

(7) **Finish after repairs**
The repaired part shall be finished smoothly by grinding.

5. Inspection after repairs

It is to be confirmed by means of the magnetic particle inspection that the welded part and its neighbourhood are free from harmful defects.

6. Records

The manufacturer is to make a documentation of the records including sketches of the positions and dimensions of the welded repairs, methods of repairs, details the heat treatment and inspection results for submission to the Surveyor.

7. Preliminary test

The manufacturer shall arrange for the following preliminary tests to be given before repairs by welding; provided however except the cases where change has been made in the material used, welding conditions or welders or where the Society has recognized the necessity specifically, these tests need not be repeated on every occasion.

(1) **Mold cavity weld test**

(A) *Test piece*
Material of same quality with the crank throw.

(B) *Shape of test piece and main point of repairs by welding*
The dimensions of test piece are shown in **Fig 2** Make the cavities as shown there, and then carry out padding welding.

(a) Sizes cavities
Proper sizes within the scope permitting free use of the operating electrode.

(b) Distribution of cavities
Distribution of cavities and distance of each cavity of the edge of test piece shall be such that these simulate the actual situation in the crank throw to be welded.

(c) Welding process
Same as in the actual welding.

(d) Electrode
The welding rod same as in the actual welding shall be used.

(e) Preheating and post heating
Similar heat treatments to those applied for the crank throw.

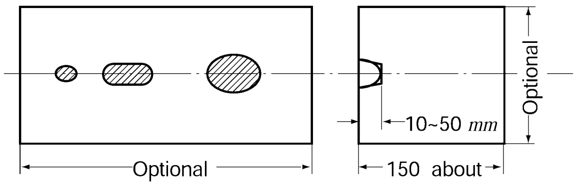


Fig 2 Dimensions and Shape of Test Coupon (Units : mm)

(C) *Tests*

(a) Macro-structure test

After heat treatment cut down the test piece at the place where the welded part is included, confirming that there is no penetration in the root part of weld nor is any crack.

(b) Hardness test

Check and confirm that there are no changes in the hardness of the weld metal, base metal and the boundary part between them.

(c) Micro-structure

Check and confirm that there are no changes in the structure of the weld metal, base metal and boundary part between them.

(2) **Butt weld test**

(A) *Test coupon*

Material of same quality with the crank throw.

(B) *Shape of test coupon and main point of repairs by welding*

Dimensions and shape of test coupon are shown in **Fig 3.** The welding conditions and heat treatment are same as in (I) above.

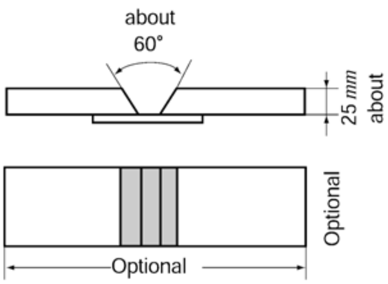


Fig 3 Dimensions and Shape of Test Coupon

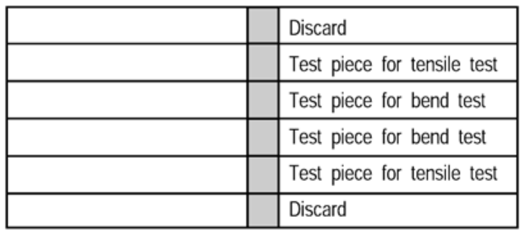


Fig 4 Test Assembly

(C) *Test*

Each two test pieces are to be prepared for tension test and bending test respectively as shown in **Fig 4** from the test coupon described in **Fig 3.**

(a) Tensile test

Tensile test is to be carried out with the welded metal at the center part of the gauge length. The value obtained is not to be less than the specified minimum value of the base metal. (Test piece dimension = 14 mm $\phi \times$ 70 mm)

(b) Bending test

Place the welded metal on the center part of test piece, bending to 180° with the inside radius of 25 mm, and confirm that no defects have appeared in the welded part and heat affecting part.

(Test piece dimension = 25 mm × 19 mm × any given length) ⚓

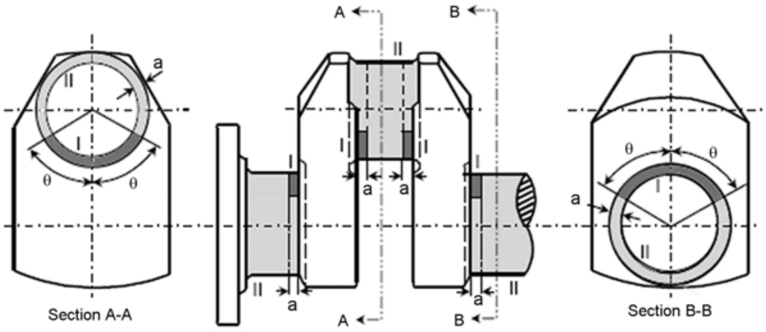
Annex 2-5 Guidance for non-destructive examination of hull and machinery steel forgings

1. Application

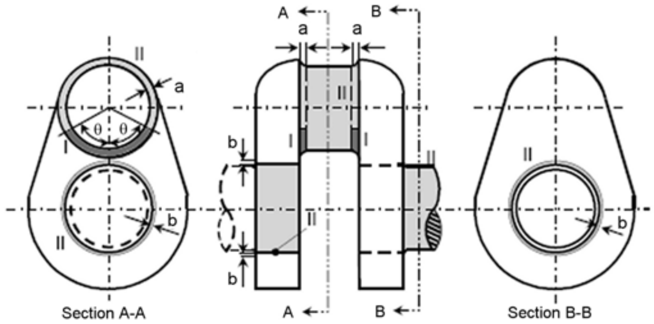
(1) The requirements in this Guidance is intended to give general guidance on the extent, methods and recommended quality levels applicable to the non-destructive examinations (NDE) of steel forgings(hereinafter referred to as "forgings") specified in **Ch 1, 601. 8** and **10** of the Rules.
(2) For steel forgings(e.g. components for couplings, gears, boilers and pressure vessels) other than those specified in this Guidance, the requirements in this Guidance may apply correspondingly considering their materials, kinds, shapes and stress conditions being subjected.
(3) Forgings should be examined in the final delivery condition. Where intermediate inspections have been performed the manufacturer shall furnish a documentation of the results upon the request of the Surveyor.
(4) Where a forging is supplied in semi finished condition, the manufacturer shall take into consideration the quality level of final finished machined components.
(5) NDE personnel requirements and inspection plans are to comply with the requirements specified in **Annex 2-2, 2** and **4** (2), (a) of this Guidance.

2. Surface Inspections

(1) **General**
(a) Surface inspections in this Guidance are to be carried out by visual examination and magnetic particle testing or liquid penetrant testing.
(b) The testing procedures, apparatus and conditions of magnetic particle testing and liquid penetrant testing are to comply with the recognized national or international standards.
(c) Personnel engaged in visual examination is to have sufficient knowledge and experience. Personnel engaged in magnetic particle testing or liquid penetrant testing is to be qualified in accordance with the Society's Rules. The qualification is to be verified by certificates.
(2) **Products**
(A) The steel forgings specified in **Pt 2, Ch 1, 601.** shall be subjected to a 100 % visual examination by the Surveyor. For mass produced forgings the extent of examination is to be as deemed appropriate by the Society.
(B) Surface inspections by magnetic particle and/or liquid penetrant methods generally apply to the following steel forgings:
(a) crankshafts with minimum crankpin diameter not less than 100 mm;
(b) propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm;
(c) connecting rods, piston rods and crosshead with minimum diameter not less than 75 mm or equivalent cross section,
(d) bolts with minimum diameter not less than 50 mm, which are subjected to dynamic stresses such as cylinder cover bolts, tie rods, crankpin bolts, main bearing bolts, propeller blade fastening bolts.
(3) **Zones for Surface Inspections**
Magnetic particle or where permitted liquid penetrant testing, shall be carried out in the zones I and II as indicated in **Figs 1** to **4.**
(4) **Surface Condition**
The surfaces of forgings to be examined are to be free from scale, dirt, grease or paint.

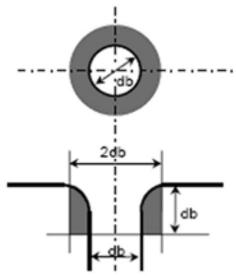


(a) Solid crankshaft



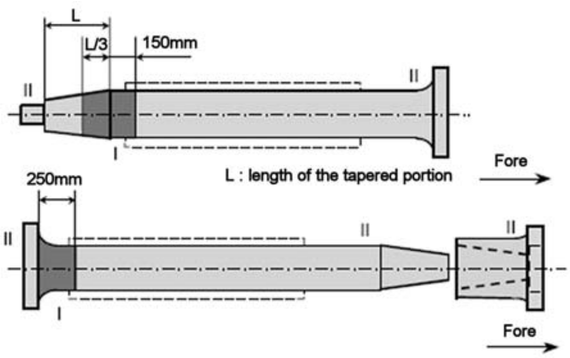
(a) Semi built−up crankshaft

Notes)
1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I. (See the figure in the right.)
2. In the above figures, "θ", "a" and "b" mean:
   θ = 60°
   a = 1.5 r
   b = 0.05 d (circumferential surfaces of shrinkage fit)
   where,
   r : fillet radius
   d : journal diameter
3. Identification of the Zones (Similar in Figs. 1 thru 4):
   : Zone I
   : Zone II



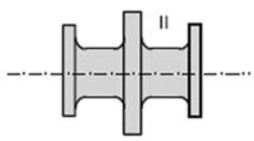
db : oil hole bore diameter

Fig 1 Zones for magnetic particle / liquid penetrant testing on crankshafts



(a) Propeller shaft

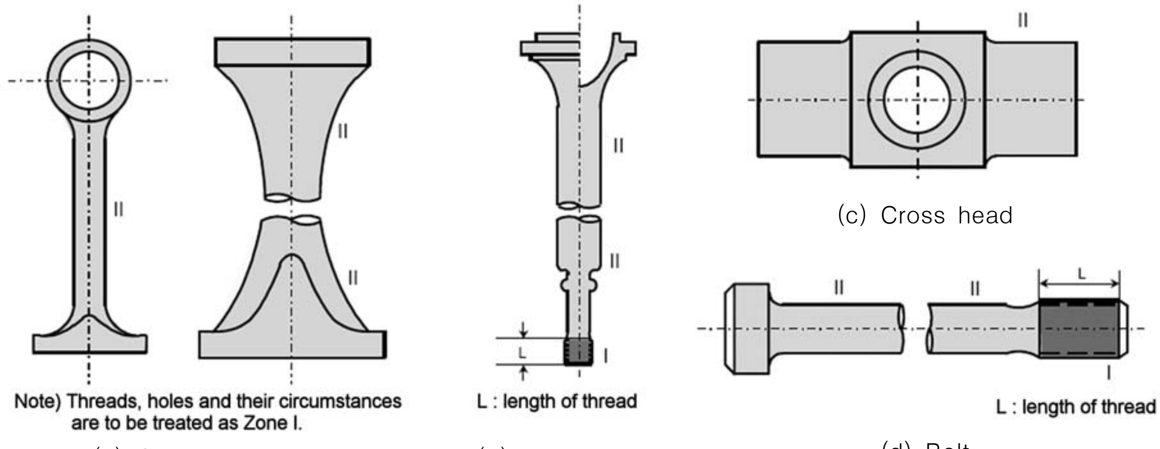
(b) Intermediate shaft



(c) Thrust shaft

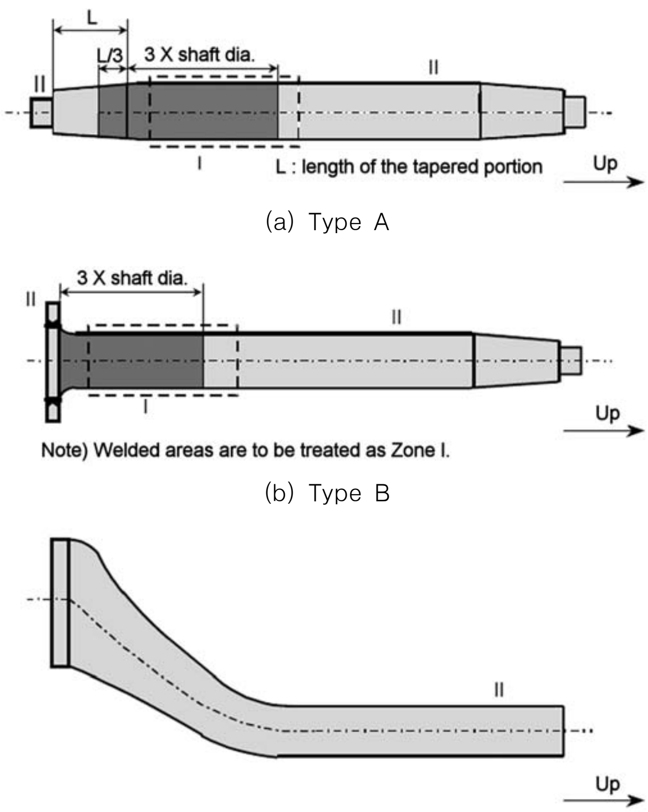
Note) For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig 2 Zones for magnetic particle / liquid penetrant testing on shafts



(a) Connecting rod (b) Piston rod (c) Cross head (d) Bolt

Fig 3 Zones for magnetic particle / liquid penetrant testing on machinery components



(a) Type A

(b) Type B

(c) Type C

Fig 4 Zones for magnetic particle / liquid penetrant testing on rudder stocks

(5) **Surface Inspection**

(a) Where indicated by **Figs 1** to **4**, magnetic particle inspection will be carried out with the following exceptions, when liquid penetrant testing will be permitted :
- austenitic stainless steels;
- interpretation of open visual or magnetic particle indications,
- at the instruction of the Surveyor.

(b) Unless otherwise specified in the order, the magnetic particle test shall be performed on a forging in the final machined surface condition and final thermally treated condition or within 0.3 mm of the final machined surface condition for *AC* techniques (0.8 mm for *DC* techniques).

(c) Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor. The surface inspection is to be carried out before the shrink fitting, where applicable.

(d) For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods shall not be permitted on finished machined items.

(e) When indications were detected as a result of the surface inspection, acceptance or rejection is to be decided in accordance with clause (6)

(6) **Acceptance Criteria and Rectification of Defects**

(A) *Acceptance Criteria Visual Inspection*

(a) All forgings shall be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, liquid penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

(b) The bores of hollow propeller shafts are to be visually examined for imperfections uncovered by the machining operation. Machining marks are to be ground to a smooth profile.

(B) *Acceptance Criteria Magnetic Particle Testing and Liquid Penetrant Testing*

(a) The following definitions relevant to indications apply:

(i) Linear indication : an indication in which the length is at least three times the width;

(ii) Nonlinear indication : an indication of circular or elliptical shape with a length less than three times the width;

(iii) Aligned indication : three or more indications in a line, separated by 2 mm or less edge-to-edge;

(iv) Open indication : an indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant;

(v) Non-open indication : an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant,

(vi) Relevant indication : an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1.5 mm shall be considered relevant.

(b) For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2. The area shall be taken in the most unfavorable location relative to the indication being evaluated.

(c) The allowable number and size of indications in the reference area is given in **Table 1** for crankshaft forgings and in **Table 2** for other forgings, respectively. Cracks are not acceptable. Irrespective of the results of non-destructive examination, the Surveyor may reject the forging if the total number of indications is excessive.

(C) *Rectification of Defects*

(a) Defects and unacceptable indications must be rectified as indicated below and detailed in (i) thru (v)

(i) Defective parts of material may be removed by grinding, or by chipping and grinding. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to the adjacent surface.

(ii) To depress is to flatten or relieve the edges of a non-open indication with a fine pointed abrasive stone with the restriction that the depth beneath the original surface shall be 0.08 mm minimum to 0.25 mm maximum and that the depressions be blended into the bearing surface. A depressed area is not considered a groove and is made only to prevent galling of bearings.

(iii) Non-open indications evaluated as segregation need not be rectified.

(iv) Complete removal of the defect is to be proved by magnetic particle testing or penetrant testing, as appropriate.

(v) Repair welding is not permitted for crankshafts. Repair welding of other forgings is subjected to prior approval of the individual Class Society.

(b) *Zone I in crankshaft forgings*
Neither indications nor repair are permitted in this zone.
(c) *Zone II in crankshaft forgings*
(i) Indications must be removed by grinding to a depth no greater than 1.5 mm.
(ii) Indications detected in the journal bearing surfaces must be removed by grinding to a depth no greater than 3.0 mm. The total ground area shall be less than 1 % of the total bearing surface area concerned.
(iii) Non-open indications, except those evaluated as segregation, shall be depressed but need not be removed.

Table 1 - Crankshaft forgings ; Allowable number and size of indications in a reference area of 225 cm²

Inspection Zone	Max. number of indications	Type of indication	Max. number for each type	Max. dimension (mm)
I (critical fillet area)	0	Linear Nonlinear Aligned	0 0 0	- - -
II (important fillet area)	3	Linear Nonlinear Aligned	0 3 0	- 3.0 -
III (journal surfaces)	3	Linear Nonlinear Aligned	0 3 0	- 5.0 -

Table 2 - Steel forgings excluding crankshaft forgings ; Allowable number and size of indications in a reference area of 225 cm²

Inspection Zone	Max. number of indications	Type of indication	Max. number for each type	Max. dimension (mm)
I	3	Linear Nonlinear Aligned	0(1) 3 0(1)	- 3.0 -
II	10	Linear Nonlinear Aligned	3(1) 7 3(1)	3.0 5.0 3.0

Note:
(1) Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts, cylinder cover bolts.

(d) *Zone I in other forgings*
Indications must be removed by grinding to a depth no greater than 1.5 mm. However, grinding is not permitted in way of finished machined threads.
(e) *Zone II in other forgings*
Indications must be removed by grinding to a depth no greater than 2 % of the diameter or 4.0 mm, whichever is smaller.
(f) *Zones other than I and II in all forgings*
Defects detected by visual inspection must be removed by grinding to a depth no greater than 5 % of the diameter or 10mm, whichever is smaller. The total ground area shall be less than 2 % of the forging surface area.

(7) **Record**

Test results of surface inspections are to be recorded at least with the following items:

(a) Date of testing;
(b) Names and qualification level of inspection personnel;
(c) Kind of testing method;
- for liquid penetrant testing : test media combination
- for magnetic particle testing : method of magnetizing, test media and magnetic field strength

(d) Kind of product;
(e) Product number for identification;
(f) Grade of steel;
(g) Heat treatment;
(h) Stage of testing;
(i) Position (zone) of testing;
(j) Surface condition;
(k) Test standards used;
(l) Testing condition;
(m) Results;
(n) Statement of acceptance/non acceptance,
(o) Details of weld repair including sketch;

3. Ultrasonic testing

(1) **General**

(a) Volumetric inspection in this Guidance is to be carried out by ultrasonic testing using the contact method with straight beam and/or angle beam technique.

(b) The testing procedures, apparatus and conditions of ultrasonic testing are to comply with the recognized national or international standards. Generally the *DGS*(distance-gain size) procedure is to be applied using straight beam probes and/or angle beam probes with 2 to 4 MHz and inspection should be carried out using a twin crystal 0° probe for near surface scans (25 mm) plus an 0o probe for the remaining volume. Fillet radii should be examined using 45°, 60° or 70° probes.

(c) Personnel engaged in ultrasonic testing is to be qualified in accordance with the Society’s Rules. The qualification is to be verified by certificates.

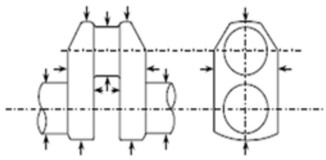
(2) **Products**

(A) Volumetric inspections by ultrasonic testing generally apply to the following steel forgings :

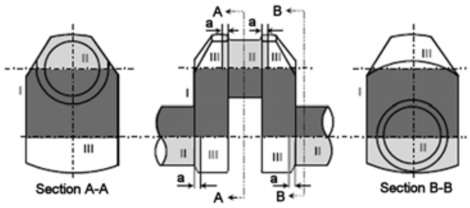
(a) crankshaft with minimum crankpin diameter not less than 150 mm;
(b) propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm,
(c) connecting rods, piston rods and crosshead with minimum diameter not less than 200 mm or equivalent cross section.

(3) **Zones for ultrasonic testing**

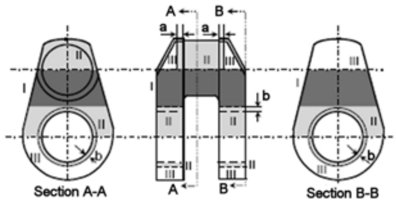
(A) Ultrasonic testing shall be carried out in the zones I to III as indicated in **Figs 5** to **8**. Areas may be upgraded to a higher zone at the discretion of the Surveyors.



Scanning direction



(a) Solid crankshaft

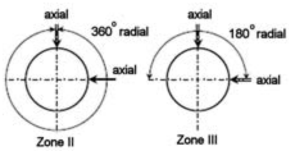


(b) Semi built-up crankshaft

Note)
1. In the above figures, "a" and "b" mean:
   a = 0.1d or 25mm, whichever greater
   b = 0.05d or 25mm, whichever greater (circumstances of shrinkage fit)
   where,
   d : pin or journal diameter
2. Core areas of crank pins and/or journals within a radius of 0.25d between the webs may generally be coordinated to Zone II.
3. Identification of the Zones (Similar in Figs. 5 thru 8.):

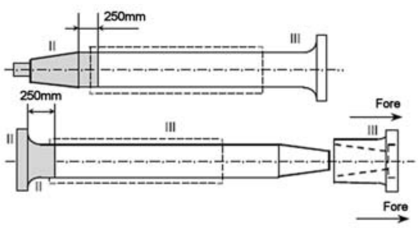
: Zone I
: Zone II
: Zone III

Fig 5 Zones for ultrasonic testing on crankshafts

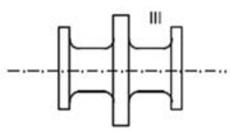


Scanning direction

(b) Intermediate shaft



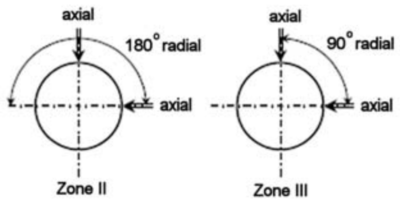
(a) Propeller shaft



(c) Thrust shaft

Notes)
1. For hollow shafts, 360° radial scanning applies to Zone III.
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II.

Fig 6 Zones for ultrasonic testing on shafts



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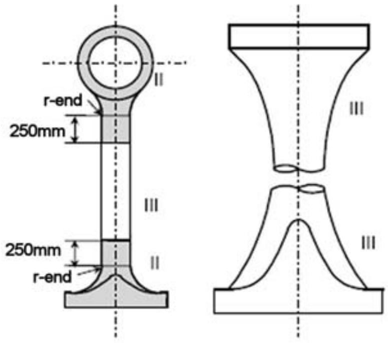
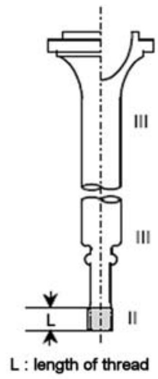
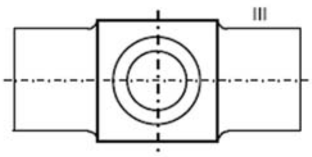


(a) Connecting rod

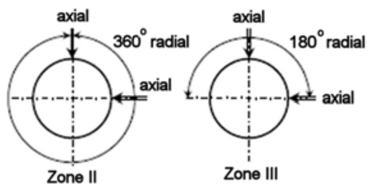


(b) Piston rod

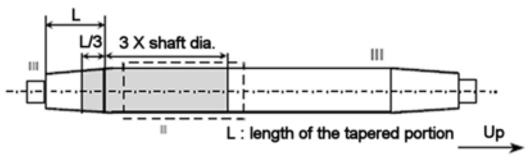


(c) Cross head

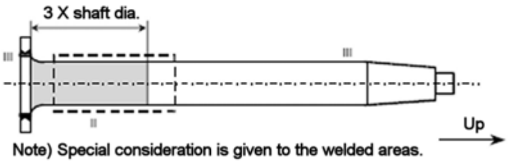
Fig 7 Zones for ultrasonic testing on machinery components



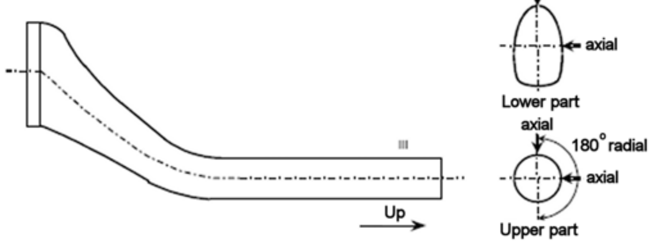
Scanning direction for Type A and Type B



(a) Type A



(b) Type B



(c) Type C Scanning direction Type C

Fig 8 Zones for ultrasonic testing on rudder stocks

(4) **Surface Condition**

(a) The surfaces of forgings to be examined are to be such that adequate coupling can be established between the probe and the forging and that excessive wear of the probe can be avoided. The surfaces are to be free from scale, dirt, grease or paint.

(b) The ultrasonic testing is to be carried out after the steel forgings have been machined to a condition suitable for this type of testing and after the final heat treatment , but prior to the drilling of the oil bores and prior to surface hardening. Black forgings shall be inspected after removal of the oxide scale by either flame descaling or shot blasting methods.

(5) **Acceptance Criteria**

(a) Acceptance criteria of volumetric inspection by ultrasonic testing are shown in **Table 3** and **4.**

Table 3 - Acceptance Criteria for Crankshafts

Type of Forging	Zone	Allowable disc shape according to *DGS*(1)	Allowable length of indication(2)	Allowable distance between two indications(3)
Crank shaft	I	d ≤ 0.5 mm	-	-
	II	d ≤ 2.0 mm	≤ 10 mm	≥ 20 mm
	III	d ≤ 4.0 mm	≤ 15 mm	≥ 20 mm

Notes :
(1) *DGS* : Distance Gain Size evaluation system
(2) The transference distance of the probe in the range where the echo height exceeds 50% of DGS line is taken as the length of indication.
(3) In case of accumulations of two or more isolated indications which are subjected to registration the minimum distance between two neighboring indications must be at least the length of the bigger indication. This applies as well to the distance in axial direction as to the distance in depth. Isolated indications with less distances are to be determined as one single indication.

Table 4 - Acceptance Criteria for Shafts and Machinery Components

Type of Forging	Zone	Allowable disc shape according to *DGS*(1)(2)	Allowable length of indication(3)	Allowable distance between two indications(4)
Propeller shaft, intermediate shaft Thrust shaft, Rudder stock	II	outer: d≤2 mm inner: d≤4 mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
	III	outer: d≤3 mm inner: d≤6 mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
Connecting rod, Piston rod, Crosshead	II	d≤2.0 mm	≤ 10 mm	≥ 20 mm
	III	d≤4.0 mm	≤ 10 mm	≥ 20 mm

Notes :
(1) *DGS* : Distance Gain Size evaluation system
(2) Outer part means the part beyond one third of the shaft radius from the center, the inner part means the remaining core area.
(3) The transference distance of the probe in the range where the echo height exceeds 50% of *DGS* line is taken as the length of indication.
(4) In case of accumulations of two or more isolated indications which are subjected to registration the minimum distance between two neighboring indications must be at least the length of the bigger indication.

(6) **Record**

Test results of volumetric inspection are to be recorded at least with the following items:

(a) Date of testing;
(b) Names and qualification level of inspection personnel;
(c) Kind of testing method;
(d) Kind of product;
(e) Product number for identification;
(f) Grade of steel;
(g) Heat treatment;
(h) Stage of testing;
(i) Position (zone) of testing;
(j) Surface condition;
(k) Test standards used;
(l) Testing condition;
(m) Results,
(n) Statement of acceptance/non acceptance; ⚓

Annex 2-6 Guidance for liquid penetrant inspection and repair of defects of copper alloy propeller castings

1. Applications

This requirement applies to the liquid penetrant inspection and repair of defects of propeller castings. Repair method for propeller differing from those specified in this Guidance are to comply with the discretion of the Society.

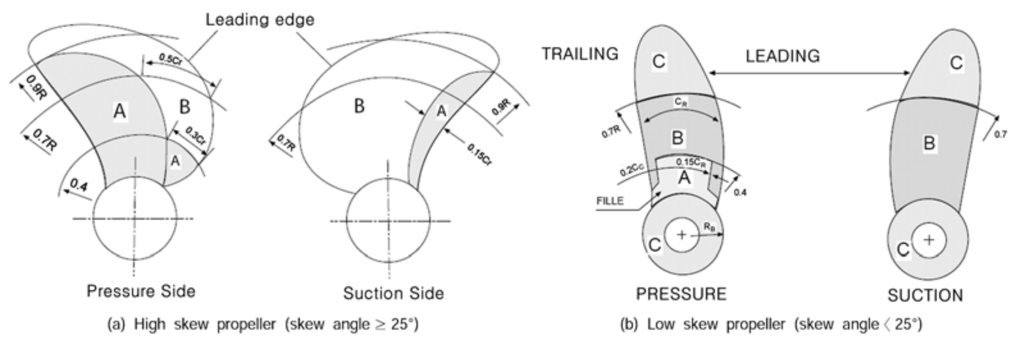
2. The liquid penetrant inspection

(1) **Area of test (Severity zones)**

(a) In order to relate the degree of inspection to the criticality of defects in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into the three zones designated A, B and C as shown in **Fig 1** and **Fig 2**

(b) The severity zones "A" are to be subjected to a dye penetrant inspection in the presence of the Surveyor. In zones "B" and "C" the dye penetrant inspection is to be performed by the manufacturer and may be witnessed by the Surveyor upon his request.

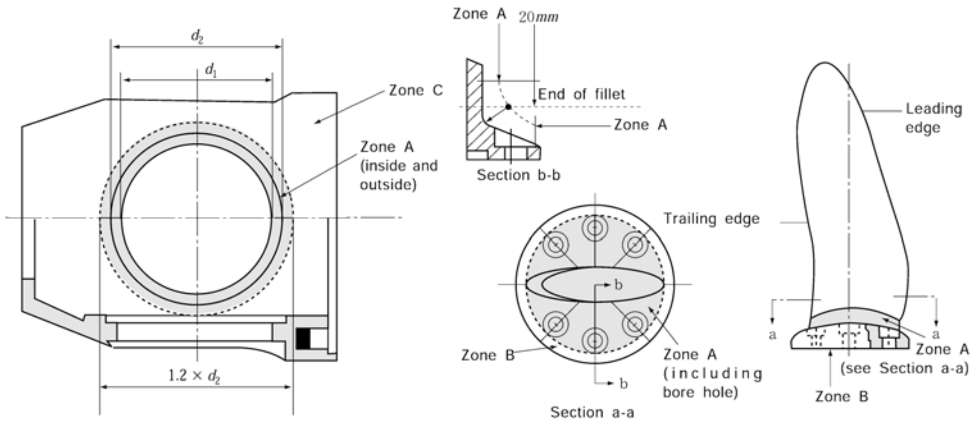
(c) If repairs have been made either by grinding or by welding the repaired areas are additionally to be subjected to the dye penetrant inspection independent of their location and/or severity zone.



*The definition of skew angle comply with the requirements in the **Pt 5, Ch 3, 303.** of the Guidances

(Notes)
1. R : The radius of the propeller, l : The cord length at any radius
2. The boss area of an integrally cast propeller is regarded as Zone C.
3. Where stress distribution on propeller blade surface is estimated in detail, the non-destructive inspection zones different from those shown in this figure may be applied subject to this Society's approval.

Fig 1 Zones for Non-destructive Inspection of Propeller Castings



(a) Zones for non-destructive Inspection for controllable pitch propeller boss
(b) The zones for non-destructive inspection of the root area of the controllable pitch or build up propeller blades

Fig 2 Zones for Non-destructive Inspection on the Root Area of the Controllable Pitch or Build up Propeller Blades and Controllable Pitch Propeller Boss

(2) **Methods of testing**

(a) The methods of testing are to conform to the standard of *KS B* 0816 or equivalent.

(b) In the dye penetrant inspection an indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

(c) Where indications of defects appear, the type of defects and the size of the indications are to be recorded in detail. These records are to be presented to the Surveyor. For reference, the true size of the defects are also to be confirmed.

(3) **Types of defects**

The defects detected by the liquid penetrant test are divided into following types of (A) to (D).

(A) Cracks : the defects regarded as a crack.

(B) Circular defects : the defects other than crack, in which the length is less than 3 times the width.

(C) Linear defects : the defects other than crack, in which the length is equal to or greater than 3 times the width.

(D) Aligned defects : Aligned defects consisting of two or more linear or circular defects which are almost aligned and the spacings between them do not exceed 2 mm. The length of an aligned defect is to be equal to the sum of the lengths of a1l individual defects and all spacings between them.

(4) **Acceptance criteria**

(A) Where cracks or other defects which do not meet the acceptance criteria given in **Table 1** are detected by the penetrant test, the defects are to be repaired in accordance with the requirements in **3.**

Table 1 Acceptance Criteria

Are of test	Type of Defect (excluding crack)	Acceptance Criteria		
		Max. total number of all defects(1)	defects of same type	
			Max. number of each type(II)	Max. size for each indication(III) (mm)
Zone A	Circular	7	5	4
	Linear		2	3
	Aligned		2	3
Zone B	Circular	14	10	6
	Linear		4	6
	Aligned		4	6
Zone C	Circular	20	14	8
	Linear		6	6
	Aligned		6	6

(Notes)
(1) The defects are to be repaired when they do not meet one or more criteria of (I) through (III) in this table.
(2) The counting of the number of defects is to be conducted at the most unfavourable location relative to the indication being evaluated. The area of a reference zone is to be 100 cm^2
(3) Singular circular indications less than 2 mm for zone A and less than 3 mm for other zones may be disregarded.
(4) Where only circular defects were detected, all defects(I) are to be repaired for the judgement.

(B) Areas which are prepared for welding are independent of their location always to be assessed according to zone A. The same applies to the welded areas after being finished machined and/or grinded.

(C) Indications exceeding the acceptance standard of **Table 1**, cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blow holes and other discontinuities which may impair the safe service of the propeller are defined as defects and must be repaired in accordance with the requirements specified in **3** below.

3. Repair of defects

(1) **Repair procedures**

(A) In general, the repairs are to be carried out by mechanical means, e. g. by grinding, chipping or milling. After milling or chipping, grinding is to be applied for such defects.

(B) The contour of the ground depression is as smooth as possible in order to avoid stress concentrations or to minimize cavitation corrosion.

(2) **Repair of defects in zone A**

(a) In zone A of **Fig 1** and **Fig 2**, repair welding will generally not be allowed unless specially approved by the Society.

(b) Grinding may be carried out to an extent which maintains the blade thickness of the approved drawing.

(c) The possible repair of defects which are deeper than those referred to above is to be considered by the Society.

(3) **Repair of defects in zone B**

(a) In zone B of **Fig 1** and **Fig 2**, defects that are not deeper than dB = (t/40) mm (t = min. local thickness in mm according to the Rules) or 2 mm (whichever is greatest) below min. local thickness according to the Rules should be removed by grinding.

(b) Those defects that are deeper than allowable for removal by grinding may be repaired by welding.

(c) Where the propellers in zone B in accordance with the requirements specified in previous (b) are repaired by welding, the limits of the repair welding are to be as shown in **Table 2.**

Table 2 Limits of Repair Welding (2)(3)

	Pressure side	Suction side
Each area of repair welding(1)	75 cm^2 or 0.006 S whichever is larger	150 cm^2 or 0.01 S whichever is larger
Total area of repair welding	200 cm^2 or 0.02 S whichever is larger	
Depth of welding(cm)	0.1 t basically	0.15t basically

Notes:
(1) Welding of areas less than 5 cm^2 is to be avoided.

(2) $S = \frac{\pi D^2 \cdot B}{4n} (cm^2)$
D = Diameter of the propeller (cm)
n = Number of propeller blade
B = Developed area ratio

(3) t is the thickness of the blade at the portion of repair welding.(cm)

(4) **Repair of defects in zone C**

In zone C of **Fig 1** and **Fig 2**, repair welds are generally permitted.

4. Repair Welding

Repair welding which permitted in accordance with the requirements in **3** (3) and (4) above is to comply with the following;

(1) **General**

(a) Companies wishing to carry out welding work on propellers must have at their disposal the necessary workshops, lifting gear, welding equipment, preheating and, where necessary, annealing facilities, testing devices.

(b) All welding work is to be carried out preferably in the shop free from draughts and influence of the weather.

(2) **Welder**

The welders are to have qualifications deemed appropriate by the Society.

(3) **Edge preparation**

(a) Defects to be repaired by welding are to be ground to sound material according to the requirements as given under para **3** (1). To ensure complete removal of the defects the ground areas are to be examined by dye penetrant methods in the presence of the Surveyor.

(b) The edge preparation for repair welding after removing the defects is to be as shown in **Fig 3** and **4.**

(4) **Propeller drawing out**

For heating the boss to draw out the propeller, propeller is to be heated slowly and below 150℃. In this case, the heating method which the heat is concentrated is not be used. A heat source such as electric heater and steams recommended.

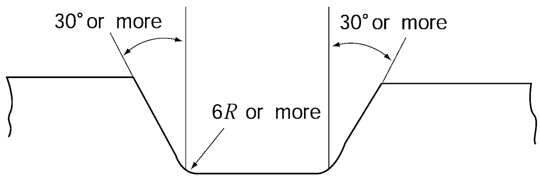


Fig 3 Edge Preparation after Removing Defects

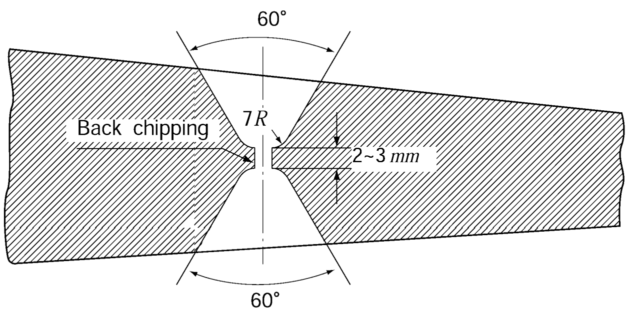


Fig 4 Edge Preparation for Repair Welding of Blade Edge

(5) **Welding repair procedure**

(a) Arc welding with coated electrodes and gas-shielded metal arc process ($GMAW$) are generally to be applied. Argon-shielded tungsten welding ($GTAW$) should be used with care due to the higher specific heat input of this process.

(b) For material thickness less than 30 mm, gas welding may give a satisfactory weldment for CU 1 and CU 2 materials.

(c) Recommended filler metals, pre-heating and stress relieving temperatures are listed in **Table 3.** However, the welding consumables are to be approved by the approval tests for welding procedure specified in (5).

(d) All propeller alloys are generally to be welded in down-hand (flat) position. Where this cannot be done, gas-shielded metal arc welding should be carried out.

(e) The section to be welded is to be clean and dry. Flux-coated electrodes are to be dried before welding according to the maker's instructions.

(f) Adequate pre-heating is to be carried out with care to avoid local overheating, c.f. **Table 3.**

(g) Slag, undercuts and other defects are to be removed before depositing the next run.

(h) To minimize distortion and the risk of cracking, interpass temperatures are to be kept low. This is especially the case with CU 3 alloys.

Table 3 Recommended filler metals and heat treatments

Alloy type	Filler metal	Preheat temperature (℃)	Interpass temperature (℃)	Stress relief temperature (℃)
CU 1	*Al*-bronze[(1)] *Mn*-bronze	150 min	300 max	350～500
CU 2	*Al*-bronze *Ni*-*Mn*-bronze	150 min	300 max	350～550
CU 3	*Al*-bronze *Ni*-*Al*-bronze[(2)] *Mn*-*Al*-bronze	50 min	250 max	450～550
CU 4	*Mn*-*Al*-bronze	100 min	300 max	450～600

Notes:
(1) *Ni*-*Al*-bronze and *Mn*-*Al*-bronze are acceptable.
(2) Stress relieving not required, if filler metal *Ni*-*Al*-bronze is used.

(i) With the exception of alloy *CU* 3 (*Ni*-*Al*-bronze) all weld repairs are to be stress relief heat treated, in order to avoid stress corrosion cracking. However, stress relief heat treatment of alloy *CU* 3 propeller castings may be required after major repairs in zone B (and specially approved welding in Zone A) or if a welding consumable susceptible to stress corrosion cracking is used. In such cases the propeller is to be either stress relief heat treated in the temperature 450 to 500°C or annealed in the temperature range 650-800°C, depending on the extent of repair, c. f. **Table 3.**

(j) The soaking times for stress relief heat treatment of copper alloy propellers should be in accordance with **Table 4.** The heating and cooling is to be carried out slowly under controlled conditions. The cooling rate after any stress relieving heat treatment shall not exceed 50°C/h until the temperature of 200°C is reached.

Table 4 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief Temp.	Alloy grade *CU*1 and *CU*2		Alloy grade *CU*3 and *CU*4	
	Hours per 25 mm thickness	Max. recommended total time hours	Hours per 25 mm thickness	Max. recommended total time hours
350	5	15	-	-
400	1	5	-	-
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	-	-	1/4	1

(6) **Welding procedure qualification test**

The manufacturer of propellers intending to carry out repair welding in zone B and zone C is to pass the welding procedure qualification test as shown below. The qualification test is also to be in accordance with the requirements specified in **Pt 2, Ch 2, Sec 4** of the Rules, in addition to the following requirements:

(a) *Tests for butt welding*

(i) Test assembly

The test assembly as specified in **Fig 5** is to be prepared by means of butt welding. The edge preparation is, in principle, to be either the V shape or an appropriate shape and the bevel angle is to be not less than 60°.

(ii) Welding procedure
The welding procedures are to comply with the requirements in (5) above.

(iii) Visual inspection
The welded surface is to be regular and uniform and free from harmful defects such as cracks and undercuts.

(iv) Tensile test
Tensile tests are to be carried out using the two test specimens taken in accordance with **Fig 5**, and the values obtained are to be less than those given in **Table 5.** The form of the test specimens are to comply with **Fig 6.**

Table 5 Tensile Test Requirements for Approval Test

Material	Tensile Strength (N/mm^2)
CU 1	370 min.
CU 2	410 min.
CU 3	500 min.
CU 4	550 min.

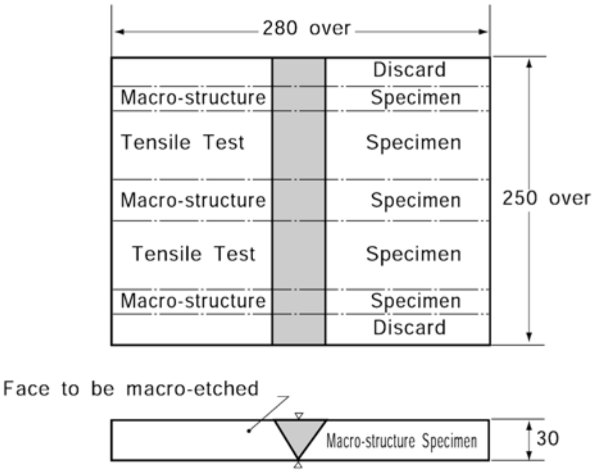


Fig 5 Test Assembly (Unit: mm)

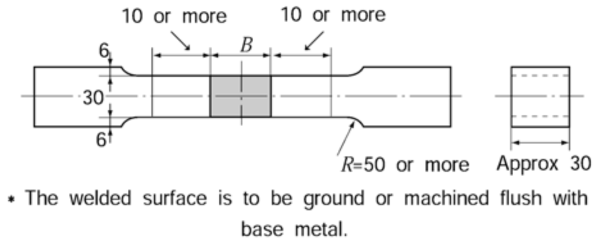


Fig 6 Size of Tensile Test Specimen (Unit : mm)

(v) Non-destructive inspection
Welded joint is to be tested for the whole length by liquid penetrant test, and is to show that there are no crack and other injurious defects.

(vi) Macro-structure inspection
Macro etched test specimen is to be prepared as shown in **Fig 5.** Pores greater than 3 mm and cracks not permitted.

(b) *Test of mold cavity welding*

(i) Test piece and dimension of test piece
Test piece is to be of the material of same quality as the actual propeller. The dimensions of test piece are shown in **Fig 7.** The cavities are made as shown in the figure and then welding same as condition in the actual welding is carried out.

(ii) Sizes of cavities
Proper sizes permitting free operation of electrode.

(iii) Distribution of cavities
Distribution of cavities and distance of each cavity from the edge of test piece is to be such that these simulate the actual condition in the propeller to be welded.

(iv) Welding process
To be same as in the actual welding.

(v) Macro structure test
Macro structure test is to confirm that no defects such as crack exist in the cross sections of weld parts.

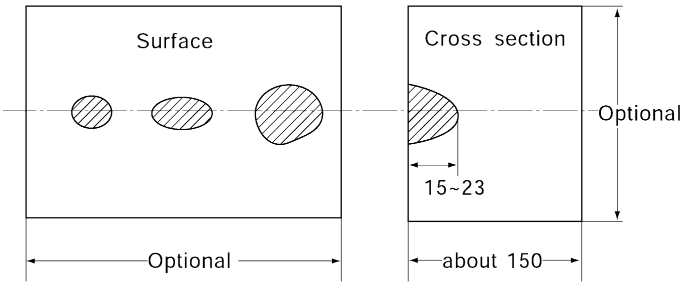


Fig 7 Test of mold cavity welding (Unit : mm)

(vi) Hardness test
Hardness test is to confirm that there is no unacceptable fluctuation in hardness between the deposit metal, base metal and heat-affected zones.

(vii)Non-destructive inspection
Welded joint is to be tested by liquid penetrant inspection or ultrasonic inspection and is to free from any crack and other harmful defects.

(c) *Additional tests*
Where deemed necessary, additional tests may be requested by the Society.

5. Straightening

(1) **Hot straightening**

(a) Straightening of a bent propeller blade or pitch modification is to be carried out after heating the bent region and approximately 500 mm wide zones on either side of it to the suggested temperature range given in **Table 6.** The heating is to be slow and uniform and the concentrated flames such as oxy-acetylene and oxy-propane is not used.

(b) Sufficient time is to be allowed for the temperature to become fairly uniform through the full thickness of the blade section. The temperature must be maintained within the range given in **Table 6** through the straightening operation.

Table 6 Temperature Range for hot Straightening

Material	*CU* 1	*CU* 2	*CU* 3	*CU* 4
Temperature of hot straightening (℃)	500～800	500～800	700～900	700～850

(c) A thermocouple instrument or temperature indicating crayons are to be used for measuring the temperature.

(d) The area heated is to be enclosed with asbestos or similar material to reduce the cooling speed after straightening.

(2) **Cold straightening**
Cold straightening is to be used for minor repairs of tips and edge only. Cold straightening on *CU* 1, *CU* 2 and *CU* 4 are to be followed by a stress relieving heat treatment(See **Table 3** and **Table 4**)

(3) **Application of load**
For hot straightening, static loading and dynamic loading are to be used, but for cold straightening, static loading is to be used only. ⚓

Annex 2-7 Guidance for non-destructive testing of ship hull steel welds

1. General

(1) **Application**

(A) This Guidance applies to the Non-destructive inspection for all hull welds of ships whose, in general, length exceeds 30 m to confirm the quality of the hull welds.

(B) In ships of less than 30m in length, the range of the inspection, the members to be inspected and the number of checkpoints are to be determined by the Surveyor based on consultation with the manufacturer.

(C) The quality levels given in this Guidance refer to production quality and not to fitness for-purpose of the welds examined.

(D) The non-destructive testing is normally to be performed by the Shipbuilder or its subcontractors in accordance with this Guidance. Surveyor may require to witness some testing.

(E) It should be the Shipbuilder's responsibility to assure that testing specifications and procedures are adhered to during the construction and the report is made available to the Society on the findings made by the NDT.

(F) This Guidance is intented to apply to welds of irons and nonferrous metals. Other marine structures may be applied subject to the approval by the Society. However, in case of ultrasonic inspection, the transducer design and calibration block material used are appropriate to the material under inspection.

(2) **Means of Non-destructive Inspection**

(A) Applicable methods for testing of the different types of weld joints are given in **Table 1.**

Table 1 Applicable methods for testing of weld joints

Weld Joint	Parent material thickness(mm)	Applicable testing methods
Butt welds with full penetration	t≤10	VT, PT, MT, RT
	t>10	VT, PT, MT, UT, RT
Tee joints, corner joints and cruciform joints with full penetration	t≤10	VT, PT, MT
	t>10	VT, PT, MT, UT
Tee joints, corner joints and cruciform joints without full penetration and fillet welds	All	VT, PT, MT, UT(1)
Note: (1) UT can be used to monitor the extent of penetration in tee, corner and cruciform joints.		

(B) All welds should be subject to visual testing by personnel designated by the Shipyard.

(C) Non-destructive inspection for detection of surface imperfections of weld joints of hull construction is, in principle, to be magnetic particle testing specified in **2** (2) However liquid penetrant testing can be applied under consideration of this Society.

(D) Non-destructive inspection for detection of internal imperfections is, in principle, to be radiographic testing specified in **3.**

(E) For welded joints of hull construction in thickness of 6mm and above, a part or all of radiographic inspection may be replaced by the Ultrasonic Inspection based on the requirements given in **4**, in case that the shipyard submitting ultrasonic testing specifications containing information on the items mentioned below

(a) Approval of inspection manual

Prior to carrying out the inspection, the shipyard has to submit the inspection manual containing the items mentioned below, and have the manual approved by the Society.

(i) Type of ultrasonic detector and kind of probe (nominal frequency and material, dimension, type and nominal angle of refraction of transducer), and the applicable range of the testing (thickness, welding process, etc.)

(ii) Calibration block and reference block for calibration

(iii)Kind of ultrasonic test process (Angle beam technique is to be of standard one), and extent of the measurements and method for sensitivity adjustment for the process

(iv)Judgement criteria for ultrasonic test (The criteria for angle beam technique test is to be in accordance with **Table 11**. For the other kind of ultrasonic test process, judgement criteria are to be described in detail.)
(v) Record of the results of ultrasonic test
(vi)List of operators and judges

(b) The capability of shipyard
The capability of shipyard about the reliability of the test methods is to judged by the items mentioned below.
(i) Qualification of engineers
(ii) Quality control conditions
(iii)Reliability
(iv)Keeping the Standards and their application ability
(v) Documents for type, extent and repair of defects

(c) Confirmation by radiographic inspection
(i) When the initial ultrasonic inspection is carried out according to this Guidance, ultrasonic testing for 1/10 of welds to be subject, based on the instructions of the Surveyor, to radiographic testing of at least three ships to confirm that the results match those of (a) (iv) and is approved by the Society for the consistence. However the confirmation by radiographic inspection can be waived for the shipyard which has the records to carry out confirmation inspection more than 3 ships.
(ii) Non-destructive inspection such as radiographic inspection may be required at random in important locations such as those specified (ii) at the discretion of the Surveyor.

(d) Alternative means to the radiographic inspection
(i) In case where shipyard intend to apply the new advanced NDT technologies such as Phased array UT (PAUT) or Time of Flight Diffraction (TOFD) in lieu of radiographic inspection, the shipyard has to submit the inspection manual as specified above (a) and have the manual approved by the Society.
(ii) Additional test and/or data for comparison of alternative means with radiographic inspection may be required when deemed necessary by the Society.

(F) Although radiographic inspection was replaced by the ultrasonic inspection according to (E), 20 % of total numbers of checkpoints are to be examined by the radiographic or alternative means approved by the Society.

(G) The additional non-destructive inspection required for workmanship control of welded joints of hull is to be in accordance with the requirements specified in **3** (2), (C).

(3) **Testing apparatus**
The testing apparatus of radiographic and ultrasonic Inspection are to be calibrated and/or corrected in accordance with the recognised national or international standards.

(4) **Personnel requirements**
(a) Personnel carrying out non-destructive inspection are generally to be qualified and certified to Level II or above in *KS B ISO* 9712, *SNT-TC-1A*, *EN* 473, *ASNT Central Certification Program* (ACCP) or equivalent. However, the personnel qualified to Level I can engage in the testing under supervision of those qualified for Level II 2 or above.
(b) Personnel responsible for the radiographic and/or ultrasonic Inspection activity including approval of procedures should be qualified and certified to Level III.
(c) Periodic re-evaluations of test personnel are to be conducted in accordance with *KS B ISO* 9712 or equivalent to verify that such capability is maintained.

(5) **NDE plan**
(a) The Shipbuilder should submit a plan for approval by the Society, specifying the areas to be examined and the extent of testing with reference to the NDT procedures to be used according to the ship design, ship type and welding processes used. Particular attention should be paid to highly stressed areas.
(b) The plan should only be released to the personnel in charge of the NDT and its supervision.
(c) The identification system should identify the exact locations of the lengths of weld examined.
(d) Welded connections of large cast or forged components (stern frame, stern boss, rudder parts, shaft brackets...) should be tested over their full length using MT or PT and at agreed locations using RT or UT.

(e) All start/stop points in welds made using automatic (mechanised) welding processes should be examined using RT or UT except for internal members where the extent of testing should be agreed.

(6) **Timing of NDT**

(a) NDT should be conducted after welds have cooled to ambient temperature and after post weld heat treatment where applicable.

(b) For steels with specified minimum yield stress of 420 N/mm^2 and above, NDT should not be carried out before 48 hours after completion of welding. Where post weld heat treatment (PWHT) is carried out the requirement for testing after 48 hours may be relaxed.

(7) **Performance and responsibility**

(A) The non-destructive testing is normally to be performed by the Shipbuilder or its subcontractors in accordance with inspection manual and NDE plan approved by the Society. The Surveyor may require to witness some testing.

(B) It should be the Shipbuilder's responsibility to assure that testing specifications and procedures are adhered to during the construction and the report is made available to the Society on the findings made by the NDT.

(8) **Surface inspections**

(a) Surface inspections shall be carried out as bellows;

(b) The surface of welds to be radiographed are to be sufficiently free from irregularities that may mask or interfere with interpretation

(c) The test surface (within I skip distance from welds edge) to be ultrasonic tested are free from spatter, floating scales, painting film, remarkable rust which prevent transmission of ultrasonic wave and the likes. They are removed if existed.

2. NDT for detection of surface imperfections

(1) **Visual testing**

(a) The welds examined should be clean and free from paint.

(b) Acceptance criteria are given in **Table 2.**

Table 2 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Acceptance criteria for visual testing
Crack	not accepted
Lack of fusion	not accepted
Incomplete root penetration in butt joints welded from one side	not accepted
Surface pore	Single pore diameter d ≤ 0.25t(1) for butt welds (d ≤0.25a(1) for fillet welds) with maximum diameter 3mm; 2.5d as minimum distance to adjacent pore.
Undercut in butt welds	depth ≤ 0.5mm whatever is the length depth ≤ 0.8mm with a maximum continuous(2) length of 90mm
Undercut in fillet welds	depth ≤ 0.8mm whatever is the length

Note:
(1) “t” is the plate thickness of the thinnest plate and “a” is the throat of the fillet weld.
(2) Adjacent undercuts separated by a distance shorter than the shortest undercut should be regarded as a single continuous undercut.

(2) **Magnetic particle testing**

(a) Methods of inspection not specified in this Guidance are to comply with the *KS B ISO* 9934-1 or other recognized standard subject to the approval by the Society.

(b) The Shipbuilder should submit a procedure for approval by the Surveyor, specifying the surface preparation, magnetizing equipment, calibration methods, detection media and application, viewing conditions and post demagnetization.

(c) The surface to be examined should be free from scale, weld spatter, oil, grease, dirt or paint and should be clean and dry.

(d) When using current flow equipment with prods, care shall be taken to avoid local damage to the material. Copper prod tips must not be used. The prod tips should be lead, steel, aluminium or aluminium-copper braid.
(e) To ensure detection of discontinuities of any orientation, the welds are magnetized in two directions approximately perpendicular to each other with a maximum deviation of 30°. Adequate overlapping shall ensure testing of the whole zone.
(f) Continuous wet particle method should be used as far as practicable.
(g) magnetic particle testing should cover a minimum weld length of 500 mm.
(h) Acceptance criteria are given in **Table 2**. Only the indications which have any dimension greater than 2 mm should require evaluation.

(3) **Liquid penetrant testing**
(a) Methods of inspection not specified in this Guidance are to comply with the *KS B ISO* 3452 or other recognized standard subject to the approval by the Society.
(b) The Shipbuilder should submit a procedure for approval by the Surveyor, specifying the calibration equipment, surface preparation, cleaning and drying prior to testing, temperature range, type of penetrant, cleaner and developer used, penetrant application and removal, penetration time, developer application and development time and lighting conditions during testing.
(c) The surface to be examined should be clean and free from scale, oil, grease, dirt or paint and should include the weld bead and base metal for at least 10 mm on each side of the weld, or the width of the heat affected zone, whichever is greater.
(d) The temperature of parts examined should be typically between 5°C and 50°C, outside this temperature range special low/high temperature penetrant and reference comparator blocks should be used.
(e) The penetration time should not be less than 10 minutes and in accordance with the manufacturer’s specification. The development time should not be less than 10 minutes and in accordance with the manufacturer’s specification, normally between 10-30 minutes.
(f) magnetic particle testing should cover a minimum weld length of 500 mm.
(g) Acceptance criteria are given in **Table 2.** Only the indications which have any dimension greater than 2 mm should require evaluation.

(4) **Survey records**
(A) In addition to generic items, reports of magnetic particle testing should include the following specific items and their records are to be filed to compare the inspection locations with their results.
(a) type of magnetization
(b) magnetic field strength
(c) detection media
(d) viewing conditions
(e) demagnetization, if required
(B) In addition to generic items, reports of liquid penetrant testing should include the following specific items and their records are to be filed to compare the inspection locations with their results.
(a) type of penetrant, cleaner and developer used
(b) penetration time and development time

3. Radiographic Inspection

(1) **Methods of radiography**
(A) Methods of inspection not specified in this Guidance are to comply with the *KS B* 0845(Methods of radiographic examination for welded joints in steel) or other recognized standard subject to the approval by the Society.
(B) Test range of radiographic inspection is to be not less than 250 mm or overall length of the welds inspected, whichever is smaller.
(C) Processed films should display hull no., frame no., weld boundary indicators, Port/Starboard, location (or film serial number) and date as radiographic image.
(D) **Film density**
Film density through the area of interest shall be within 1.8 to 4.0 except for the defect images.
(E) **Penetrameter**
(a) The penetrameter is to be a wire type image quality indicator specified in the *KS A*

4054 (Radiographic image quality indicators for non-destructive testing - Principles and identification)

(b) The penetrameters including wire having minimum perceptible diameter are to be placed across a weld and near the both edge (end) of the weld, facing the radiation source. However, if the length under examination is less than three times the width of penetrameter, only one penetrameter may be laid on the center of the weld length.

(c) Minimum perceptible wire diameter of penetrameter on the radiographic films are to be less than the value specified in **Table 3.**

(d) When using IQI's of wire type, the image of a wire is considered visible on the film if a continuous length of at least 10 mm is clearly visible in a section of uniform optical density.

Table 3 Minimum perceptible wire diameter of penetrameter (Unit : mm)

Thickness of base metal	Minimum perceptible wire diameter of penetrameter (mm)	Thickness of base metal	Minimum perceptible wire diameter of penetrameter (mm)
$t \leq 4.0$	0.10	$32.0 < t \leq 40.0$	0.63
$4.0 < t \leq 6.3$	0.16	$40.0 < t \leq 63.0$	0.80
$6.3 < t \leq 10.0$	0.20	$63.0 < t \leq 80.0$	1.00
$10.0 < t \leq 12.5$	0.25	$80.0 < t \leq 125$	1.25
$12.5 < t \leq 16.0$	0.32	$125 < t \leq 200$	1.60
$16.0 < t \leq 20.0$	0.40	$200 < t \leq 320$	2.00
$20.0 < t \leq 32.0$	0.50	$320 < t$	2.50

(2) **Extent of survey**

(A) *Survey of welded joints of the shell and deck plating in ships*

(a) The number of checkpoints

The minimum number of radiographic check points for the welded joints of the shell and deck plating in ships is to be governed by the following equation or the same as the length of the ship(m), (round off), whichever is the greater.

$$N = \frac{L(B+D)}{46.5}$$

where,

N = minimum number of checkpoints

L = length specified in **Pt 3, Ch 1, 102.** of the Rules (m)

B = breadth specified in **Pt 3, Ch 1, 104.** of the Rules (m)

D = depth specified in **Pt 3, Ch 1, 106.** of the Rules (m)

(b) Survey location and distribution of checkpoints

(i) Survey location and distribution of checkpoints are to comply with the requirements in **Table 4.** These inspection spots are not to adjoin each other.

(ii) In the distribution of checkpoints, the selection of inspection locations is to be considered the followings and carried out by the field Surveyor.

① Welds in high stressed areas

② Welds which are inaccessible or very difficult to inspection in service

③ Intersections of field erected welds

(iii) If the welds to be inspected can not be inspected because of the structure, other possible welds in the vicinity of that weld are to be subjected to radiographic inspection.

Table 4 Survey location and distribution of checkpoints for the welded joints of the shell and deck plating in ships

Survey location	distribution of checkpoints	
	Butt welds within 0.6 L midship	Butt welds outside 0.6 L midship
(1) Strength deck(excluding the area within hatch side lines) (2) Sheer strake, (3) Side shell plating, (4) bilge strake (5) Bottom shell plating, (including flat plate keel.) (6) Hatch side coaming(including the top plate)(1)	$N^{(2)}$	$\frac{1}{10}N$
Note (1) Butt joints of the hatch side coaming exceeding 0.15L in length. (2) one-third of the number of checkpoints is to be the intersections of weld lines.		

(B) *Survey of welded joints of internal structural members of ships*
   (a) Survey location and distribution of checkpoints are to comply with **Table 5.** These inspection spots are not to adjoin each other.
   (b) Distribution of checkpoints is to be as specified in (2), (A), (b), (ii)

Table 5 Survey location and distribution of checkpoints for the welded joints of internal structural members of ships

Survey location	distribution of checkpoints(1)(2)	
	within 0.6L midship	outside 0.6L midship
	Butt welds	
(1) Web and face plates of longitudinal members on the strength deck (deck longitudinal, girders under deck and above deck).(longitudinal on the deck within the side lines of a cargo hatch opening are excluded.)	$\frac{1}{8}L$	$\frac{1}{40}L$
(2) Uppermost steel plate of longitudinal bulkheads.	$\frac{1}{8}L$	
(3) Lowermost plate of the longitudinal bulkhead.	$\frac{1}{16}L$	
(4) Web and face plates of longitudinal members (longitudinal frames, centerline girder plate, etc.) on sheer strake, shell plating, turn of bilge strake and keel plate.	$\frac{1}{16}L$	
(5) Web and face plates of transverse and horizontal girders.	$\frac{1}{16}L$	
Note (1) Number of inspections is to round up decimal places per joints of each members subject to inspections. (2) Distribution of number of inspections may change in consideration of the type of ship, structural arrang ement, welding process, arrangement of joints, etc.		

(C) *Workmanship control of welded joints of hull*
   (a) In addition to preceding (A) and (B), non-destructive testing may be required additionally for parts of start, interrupted and end points of automatic welded joints, welded joints of hatch corner, connections of stern frame or rudder horn made of casting steel to rolled steels for hull, welded joints of insert plate for working holes and welded joints in the vicinity of parts where stress is concentrated.
   (b) In addition to (a) above, non-destructive testing may be required additionally for the

areas where welding workmanship is suspect, the areas where new welding methods have been adopted, the areas where defects are liable to occur easily, the welds which are inaccessible or very difficult to inspect in service and other appropriate areas deemed necessary by the Surveyor to encourage good welding work.

(c) The locations of and the number of joints to be inspected additionally according to (a) and (b) above are to be appropriately decided by the Surveyor according to the actual status of workmanship of the shipyard.

(D) *Addition/Reduction in the number of checkpoints*

(a) If it is deemed necessary in considering the results of visual inspection for welds of the members, the Surveyor may require, additional non-destructive inspections for welds other than those subject to non-destructive inspection, or alteration of non-destructive inspection procedure.

(b) If the survey results (before repair) of a previously constructed ship show that the number of welds that need to be repaired exceeds 20 % of the total number of locations, then the number of checkpoints is to be a minimum of twice the number required.

(c) If automatic welding has been carried out at joints to be surveyed and the results of the survey verify that the quality of the welding procedure is consistent satisfactory quality, the number of checkpoints may appropriately be reduced.

(d) If a weld that needs to be repaired is found from automatically welded joints whose number has been reduced in accordance with (c), additional radiographs amounting to the number of checkpoints as prescribed in (c), are to be taken immediately. The number of checkpoints is not to be reduced until an appropriate period has elapsed and the quality is verified to be stable and satisfactory.

(e) For ships whose length 120 m or under, the survey locations and the number of checkpoints can be reduced.

(3) **Acceptable Criteria of Radiographic Inspections**

In radiographic testing, the Surveyor is to decide whether or not the results are acceptable when the test records specified in **3.** (5) The judgement may be required to the engineers of the shipbuilder (personnel with qualifications) but the results of its judgement frequently are to be verified. Where deemed necessary by the society, all radiographic films related with the ship are to be submitted.

(A) *Classification of Defects*

(a) Classification of defects is to be as given in **Table 6.**

Table 6 Classification of defects

Types of defects	Kind of defects
Type 1	Porosity(blow hole) and similar defects
Type 2	Elongated slag inclusion, pipe, incomplete penetration, incomplete fusion, and similar defects
Type 3	Crack and similar defects

(b) Where it is difficult to classify the defects into type 1 or type 2, classify respective defects into type 1 or type 2, and then decide whether or not the results are acceptable.

(c) In case of butt welded joints between plates with different thickness, thickness of the thinner plate is taken.

(B) *Defect of Type 1*

(a) Size of defect of type 1 is to be represented by score and maximum length of the defect. The test field vision specified in **Table 8** is to be selected from radiographic so that the defects of maximum size exists and the sum of size of defects is maximum. Where the flaw falls on the boundary of the test field of vision, the part outside the test field of vision shall be included for measurement.

(b) The score of defect in the case of single defect of type 1 shall be determined by using the value in **Table 7** according to the dimension of the major diameter of the defect. The score of defect for two or more defect of type 1 shall be the grand total of the score for each defect in the test field of vision.

Table 7 Score of defect Units : mm

Major diameter of flaw (mm)	Up to and incl. 1.0	Over 1.0, up to and incl. 2.0	Over 2.0, up to and incl. 3.0	Over 3.0, up to and incl. 4.0	Over 4.0, up to and incl. 6.0	Over 6.0, up to and incl. 8.0	Over 8.0
Score	1	2	3	6	10	15	25

(c) The defects of type 1 are to be judged unacceptable, if the size of the defects exceeds the value of acceptable criteria specified in **Table 8.**

Table 8 Acceptance criteria for type 1 defect

	Thickness of base metal t(mm)	t ≤ 10	10 < t ≤25	25 < t ≤50	50 < t ≤ 100
	Test field of vision	10 mm × 10 mm		10 mm × 20 mm	
Acceptance criteria	Maximum size of single defect (mm)	4	5	t/5	10
	Total score of defect	6	12	24	30
Note (1) Where the thickness of base metal is not more than 25 mm, the defects of not more than 0.5 mm may be ignored. Where the thickness of base metal is more than 25 mm, the defects of n ot more than 0.7 mm may be ignored.					

(C) *Defect of Type 2*

(a) Size of defect of type 2 is to be represented by length of the defect. Where defects are present in a row and the distance between the mutual defects does not exceed the length of larger defect, the sizes of all defects including the spaces between the mutual defects is to be considered as the length of the defect.

(b) The defects of type 2 are to be judged unacceptable, if the length of a defect exceeds the value of acceptable criteria specified in **Table 9.**

(c) Incomplete root penetration is not accepted in butt joint welded from one side

Table 9 Acceptance criteria for type 2 defect

	Thickness of base metal t (mm)	t ≤ 12	12 < t ≤ 50	50 < t
Acceptance criteria	Sum of size of defect (mm)	6 or under	t/2 or under	24 or under

(D) *Defect of Type 3*

Any defect of type 3 is to be judged unacceptable.

(E) *In Case of Coexistence of Defects of Type 1 and Type 2*

Where two or more types of defects are coexistent, the defects are to be judged unacceptable, provided the size of defects of each type are more than half of the size specified in **Table 8** and **Table 9** respectively.

(4) **Repair and Treatment after the Repair**

(A) Unacceptable indications should be eliminated and repaired where necessary. The repair welds should be examined on their full length using magnetic particle and ultrasonic or radiographic testing method.

(B) When unacceptable indications are found, additional areas of the same weld length should be examined unless the indication is judged isolated without any doubt. In case of automatic welded joints, additional NDT should be extended to all areas of the same weld length. Same weld length mean the locations where, for manual and semi-automatic welding, identical person, identical postures and identical time and, for automatic welding, identical welding method, and identical time.

(C) The extent of testing can be extended at the surveyor's discretion when repeated non-acceptable discontinuities are found.

(D) The Shipbuilder should take appropriate actions to monitor and improve the quality of welds to the required level. The repair rate at which corrective action is to be instigated should be identified in the builder''s QA system.

(5) **Survey records**

(A) The survey results are to be recorded to the survey records such as followings and their records are to be filed to compare the inspection locations with their results.

(a) Radiation source, type and focal spot size
(b) Geometry of radiographic setup
(c) Film type
(d) Intensifying screens
(e) Film coverage
(f) Image quality indicators
(g) Film identification marking
(h) Exposure conditions
(i) Film processing
(j) Film density
(k) Film viewing conditions
(l) The result of judgement for acceptance
(m) Name of personnel performed the radiographic inspection
(n) Name of personnel performed the radiographic review

(B) The Society may require to duplicate some radiographs in order that some processed films are handed over to the Society together with testing reports. Alternative method to duplicate the processed film can be agreed with the Society.

4. Ultrasonic Inspection

(1) **Methods of ultrasonic inspection**

(A) *General*

(a) The inspection methods other than those specified in this Guidance are to comply with *KS B* 0896 (Method for ultrasonic examination for welds of ferritic steel) except in those cases where alternative criteria have been otherwise approved or specified.

(b) In general, the scanning of weld is performed by using angle beam technique. However, normal beam technique is appled to the place where the application of angle beam technique is difficult or the place specially specified as that where the other technique are more suitable than angle beam technique for detecting a discontinuity.

(c) The stage of the test is the time when the final heat treatment is completed, in the case where heat treatment or the like after completion of weld has been specified in the document.

(d) The test of parent materials of the part through which ultrasonic waves pass when angle beam technique is performed, are previously tested normal technique to detect a discontinuity such as lamination etc.

(e) The probes may be affixed to suitable wedges designed to induce beam waves in the material under test at the selected angles.

(f) The couplant, in general, is to be used the glycerine-water solution of 75 % or more. The kinds and temperature of the couplant used for test are to be equivalent to those used for calibration of ultrasonic test instrument.

(g) The weld reinforcement is adequately finished in case where its form affects the results of the test.

(B) *Checking the overall performance characteristics of ultrasonic equipment*

(a) The vertical linearity is to be checked in accordance with the 4.1 of the *KS B* 0534 (Method for Assessing the Overall Performance Characteristics of Ultrasonic pulse echo instrument) and the result is to be within ±3% of full scale.

(b) The linearity of the time base is to be measured in accordance with the 4.2 of the *KS B* 0534 and the result is to be within ±1% of full scale.

(c) A margin of gain control is to be measured in accordance with the 4.3 of the *KS B* 0534 and the result is to be not less than 40dB.

(d) Periodical checks of ultrasonic test instrument are to be performed not less once every year. However, The check of the test instrument immediately is to be performed in the case that the repair relating to the performance characteristics of the ultrasonic test instrument was performed within this period.

(C) *Probes*

(a) In general, the scanning of weld is performed by using probes of angle beam technique. In case where normal probe is used, the standard is to comply with the *KS B* 0896.

(b) The frequency to be used for angle beam technique is in accordance with **Table 10.** However, the frequency lower than the value specified in **Table 10** may be used for the test of test object with remarkable ultrasonic attenuation and the frequency higher than the value specified in **Table 10** may be used for improving the resolution.

Table 10 Nominal Frequency to be used for Angle Beam Technique

Plate thickness of parent materials (mm)	Nominal frequency (MHz)
75 or less	5 or 2
over 75	2

(c) The refraction angle of probe to be used is to comply with **Table 11** according to the thickness of parent materials. Where deemed appropriate by the Society, the different refraction angle of probe may be used.

Table 11 Nominal Refraction Angle of Probe used

Plate thickness of parent materials (mm)	Nominal refraction angle
40 or less	70°
Over 40 to 60 incl.	70° or 60°
Over 60	70° and 45° or 60° and 45°

(D) *Adjustment of ultrasonic test instrument*

(a) Measurement of probe index
The probe index is measured by using A1 calibration block or A3 calibration block specified in *KS B* 0831. The probe index is measured in precision of ±1% and to be indicated on the both sides of probe.

(b) Measurement of refraction angle
Refraction angle is measured in unit of 0.5° by using A1 calibration block or A3 calibration block

(c) Adjustment of time base range and correction of the starting point
The adjustment of time base range is performed in precision of ±1% by using A1 calibration block or A3 calibration block and the starting point is corrected.

(d) The equipment (instrument and probes) should be verified by the use of appropriate standard calibration blocks at suitable time intervals.

(E) *Making of curve for dividing echo height*

(a) Curve for dividing echo height
The height for evaluation of the depth is made for four regions specified in **Fig 2.** The positions of probe for making the curves for dividing echo height using the distance amplitude characteristic curve are to comply with **Fig 1.**

(b) Determination of H line, M line and L line
The curve for dividing echo height by working sensitivity of (d) is selected to take it as H line, and the curve for dividing echo height lower than H line by 6 dB is taken as M line and the curve lower than H line by 12 dB is taken as L line. H line is of over 40 %.

(c) Regions
The regions divided by H, M and L line are designated as given in **Table 12** and the examples of regional division are indicated as given in **Fig 2.**

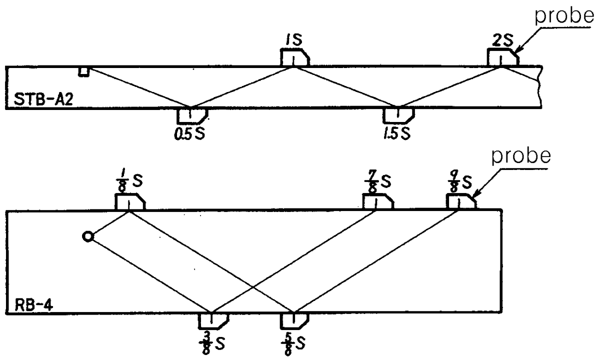


Fig 1 Position of Probe for making the Curves for Dividing Echo Height

An example in which the third dividing line from the lowest is taken as H line in the case where the time base range is 125*mm* and path length used for evaluation is 85*mm*.

Probe used : 5Z10 x 10A70

An example in which the third dividing line is taken as H line in the case where the time base range is 125*mm* and path length used for evaluation is 75*mm* to 115mm.

Probe used : 5Z10 x 10A70

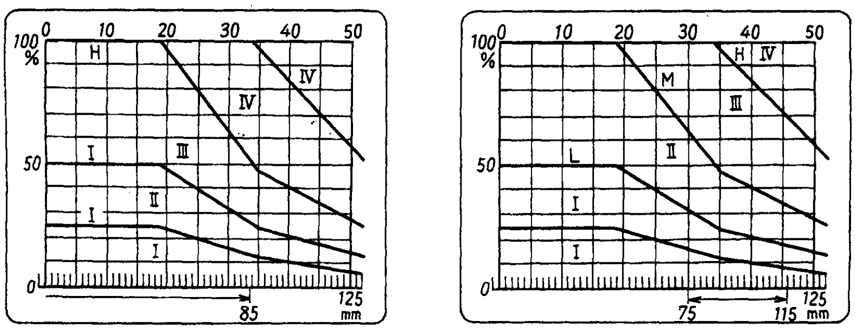


Fig 2 Examples for Drawing Curves for Dividing Echo Height

Table 12 Designation of Regional Division of Echo Height

Range of echo height	Region of echo height
L line or less	I
Over L to M line incl.	II
Over M to H line incl.	III
Over H line	IV

(F) *Working sensitivity*

(a) Using the A2 calibration block
In the case of using nominal refraction angle of 60° or 70°, the gain of instrument is adjusted so that the echo height of the standard hole of ϕ 4 x 4 mm agrees with H line. In the case of using nominal refraction angle of 45°, the gain of instrument is increased by 6 dB after it is adjusted so that the echo height of the standard hole of ϕ 4 x 4 mm agrees with H line. In both case, where deemed appropriate by Society, sensitivity compensation calculated according to Annex of *KS B* 0896 to be added.

(b) Using the RB-4 reference block
The gain of instrument is adjusted so that the echo height of the standard hole agrees with H line.

(c) Where deemed appropriate by the Society, other blocks considered as equivalent for block specified in (a) and (b) may be used.

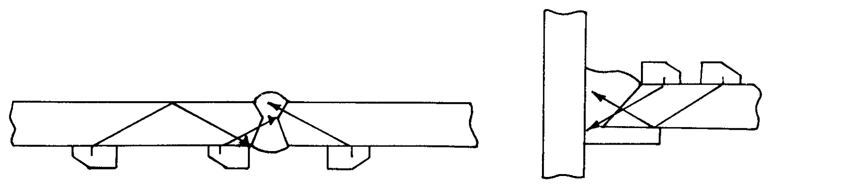
(d) The range and sensitivity should be set prior to each testing and checked at regular intervals as per the procedure and whenever needed.

(G) *Position and direction of scanning*

(a) In general, the scanning of weld is performed by using angle beam technique and scanning method is comply with the **Table 13** and **Fig 3** depending on the type of joints and plate thickness. However, for welds in which the surfaces have been ground, the probe is placed on the weld surface and moved along the weld axis with the sound beam directed parallel to the weld.

Table 13 Position and direction of scanning

Type of Joints	Plate thickness (mm)	Position and direction of scanning	Scanning methods
butt joints	t ≤ 100	both side of single face	Directed and 1 skip reflected.
	t > 100	both side of both face	Directed
T joints, corner joints	t ≤ 60	single side of single face	Directed and 1 skip reflected.
	t > 60	single side of both face	Directed



(a) Scanning of butt joint (b) Scanning of T and corner joint

Fig 3 Position and Direction of Scanning

(b) The scanning technique should be determined to allow the testing of the entire volume of the weld bead and base metal for at least 10 mm on each side of the weld, or the width of the heat affected zone, whichever is greater.

(H) *Ultrasonic discontinuity length and presentation of location of discontinuity*

(a) Ultrasonic discontinuity length

(i) The position indicating the maximum echo height is taken as center of scanning, the transference distance of the probe in the range where the echo height exceeds L line is measured by scanning its circumference is taken as the ultrasonic discontinuity length. The measurement is performed by unit of 1 mm.

(ii) In the case where the plate thickness of part where the probe is contacted is not less than 75 mm, nominal frequency is 2 MHz and the probe with transducer size of 20 x 20 mm is used, the transference distance of the probe in the range where the echo height exceeds one half of the height of the maximum echo is taken as the ultrasonic discontinuity length.

(b) Presentation of location of discontinuity

The discontinuity location in the transverse section [depth(*d*) and distance(*k*) from weld centerline] is presented by the probe location(*Xp*) where the maximum echo can obtain. The discontinuity location in the plane is presented by both ends((*Xs* and *Xe*) of ultrasonic discontinuity length(*l*)

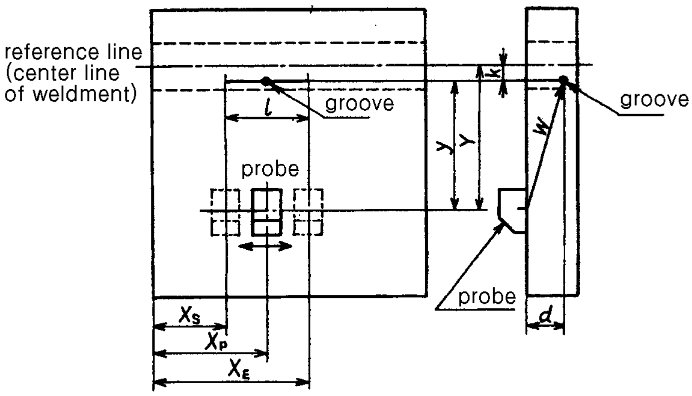


Fig 4 Presentation of location of discontinuity

(2) **Extent of survey**

(A) *Survey of welded joints of the shell and deck plating in ships*

(a) The survey location and distribution of checkpoints are to comply with the requirements given in (A) of **3.**, (2).

(b) The length of checkpoint is entire length of the joint or 750 mm, whichever is smaller.

(B) *Survey of welded joints of internal structural members of ships*

(a) The Survey location and distribution of checkpoints are to comply with the requirements given in (B) of **3.**, (2).

(b) The length of checkpoint is entire length of the joint or 300 mm, whichever is smaller.

(C) *Workmanship control of welded joints of hull*

(a) The survey location and distribution of checkpoints for Workmanship control of welded joints of hull are to comply with the requirements given in (C) of **3** (2).

(b) The length of checkpoint is to comply with the requirements given in (B) above).

(D) *Addition/Reduction in the number of checkpoints*

Addition/reduction in the number of checkpoints is to comply with the requirements given in (D) of **3** (2).

(3) **Acceptance Criteria of ultrasonic inspections**

(A) Defects detected by ultrasonic inspection are to be judged in accordance with **Table 14**

Table 14 Acceptance criteria for defects detected by ultrasonic inspection

	Thickness of base metal t (mm)	t ≤ 50	50 < t	t ≤ 50	50 < t
	Region of maximum echo heights	II and III		IV	
Acceptance Criteria	length of defect (mm)	t or less	50 or less	t/2 or less	25 or less

Note:
1. (1) The symbol t is plate thickness (mm) of the parents materials of the groove side. However, in the case of butt joint weld with different plate thickness of the parents materials, the thinner plate thickness is adopted.
2. In applying this table, in the case where the distance between discontinuities is smaller or equal to the length of the discontinuity with longer ultrasonic discontinuity length that the depth considered to be same, these discontinuities are regarded as same discontinuity group and treated as a continuous discontinuity including such distance. In the case where the distance between discontinuities is longer than the larger one out of the both ultrasonic discontinuity lengths, these discontinuities are regarded as independent from each other. The examination results of straddle scanning, parallel scanning by slanted probe and longitudinal scanning on the weld line are classified in accordance with the agreement between the parties concerned.

(B) Where kind of defect is considered as cracks from welding process, location of defects, etc., the defects are to be judged unacceptable.

(4) **Repair and Treatment after the Repair**
Repair and treatment after the repair is to comply with the requirements given in **3** (4).

(5) **Records**

(A) *Making the records*
The records after test are to be made.

(B) *Items of Records*
The records are to be included the followings.

(a) Name of the work and manufacturer
(b) Number and name of ship
(c) Name and qualification of personnel engaged in the test
(d) Date of the test
(e) Calibration and reference blocks used
(f) Performance of test instrument (identity, probe type, size, frequency, angle etc)
(g) Unusual condition of weld bead
(h) Method of welding and form of groove
(i) Materials and dimension
(j) Location and length of the welds inspected
(k) Length and location of discontinuity
(l) Classification
(m) Kind of couplant
(n) Working sensitivity
(o) Other items(designated items, subject of discussion, witness, sampling method etc.)

(c) *Evaluation of records*
The ultrasonic test reports is to be made under condition of rigid quality control and is to be to the satisfaction of the Surveyor.

5. Improvement of qualification

Where the faulty welds are more than 10 % of the number of inspection specified in **Table 4** or **5**, the results of investigation on the substantial cause and the measures to improve the quality are to be submitted to the Surveyor.

Annex 2-8 Reinforced plastic materials

1. General

(1) **Application**

(A) This Guidance applies to the base materials such as thermosetting resins, fiber reinforcements and core materials (hereinafter refer to FRP materials) used in the construction or repair of FRP ships, composite vessels and other marine structures which are to be certified or are intended for classification.

(B) FRP materials or hybrid materials other than those prescribed in this Guidance may be used where specially approved in connection with the design. In such cases, the detailed data relating to the manufacturing process and mechanical properties, etc. of the materials are to be submitted for approval.

(2) **Approval**

(A) FRP materials such as thermosetting resins, fiber reinforcements, core materials, etc. are to be type approved in accordance with this Guidance and the Guidance specially specified by the Society in advance

(B) The manufacturing process of of FRP ships, composite vessels or other marine structures which are to be certified or are intended for classification is to be approved in accordance with the Guidance specially specified by the Society in advance

(C) In order that a FRP materials can be approved, the manufacturer is required to demonstrate to the satisfaction of the Society that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

(3) **Manufacturing control**

(A) It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications.

(B) Where control imperfection inducing possible inferior quality of FRP materials occurs, the manufacturer is to identify the cause and establish a countermeasure to prevent its recurrence. Also, the complete investigation report is to be submitted to the Surveyor.

(C) For further use, each FRP material affected by previous (B) is to be tested to the Surveyor's satisfaction. The frequency of testing for subsequent products offered may be increased to gain confidence in the quality at the discretion of the Society.

(D) The manufacturer is to provide the material producer with such information as is essential to ensure that the FRP materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

(E) Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

(4) **Testing and inspection**

(A) The FRP materials are to be tested and inspected in accordance with this Guidance and the Guidance specially specified by the Society in advance in the presence of the Society‘s Surveyor except otherwise specially provided, and are to comply with the requirements in this Guidance.

(B) Where the FRP materials are manufactured by the approval of quality assurance scheme specially specified by the Society, a part or all of test and inspection in the presence of the Society's Surveyor may be omitted.

(5) **Execution of testing and inspection**

(A) The manufacturers shall afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify that the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by this Guidance, and for verifying the accuracy of the testing equipment.

(B) In the case of special order, the manufacturer is to show the order specifications, special requirements, etc. of the FRP materials to the Surveyor prior to the material test.

(C) Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and this Guidance and are

to be to the satisfaction of the Surveyors.
(D) All tests and inspections are to be carried out at the place of manufacture before dispatch. The test specimens and procedures are to be in accordance with **2.** thru **4.** of this Guidance. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.
(E) All FRP material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.
(F) During production, check test samples are to be provided as requested by the Surveyor. Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.
(G) Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

(6) **Retest procedure**
(A) Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.
(B) Where an individual test result in a group (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

(7) **Quality**
(A) FRP materials are to be free from surface or internal defects which would be prejudicial to their proper application in service.
(B) In the event of any material proving unsatisfactory during subsequent working or fabrication, such material may be rejected, notwithstanding any previous satisfactory testing and/or certification where the Surveyor considers necessary.

(8) **Identification and marking of materials**
(A) The manufacturer of approved FRP materials is to identify each batch with an unique number or code.
(B) The manufacturer of FRP products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

(9) **Certification**
The manufacturer is to provide the purchaser with test reports or certificates of conformity for each batch of FRP material supplied indicating the relevant values are to comply with this Guidance.

2. Thermosetting resins

(1) The data listed in **Table 1** is to be provided by the manufacturer for each type of thermosetting resin.
(2) The following tests are to be carried out on each type of thermosetting resin:
(A) Tensile strength (stress at maximum load) and stress at break.
(B) Tensile strain at maximum load.
(C) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(D) Temperature of deflection under load.
(E) Barcol hardness.
(F) Determination of water absorption.
(G) Volume shrinkage after cure.
(H) Specific gravity of cast resin.
(3) In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.
(4) The test methods for thermosetting resin are to be in accordance with the Guidance specially specified by the Society.

Table 1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester(3)	Epoxide	Phenolic
Specific gravity of liquid resin	O	O	O
Viscosity	O	O	O
Gel time	O	O	X
Appearance	O	O	O
Mineral content(1)	O	O	X(2)
Volatile content	O	X	X
Acid value	O	X	X
Epoxide content	X	O	X
Free phenol	X	X	O
Free formaldehyde	X	X	O

Notes :
(1) This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
(2) If the resin is pre-filled, the mineral content is required.
(3) Vinylesters are to be treated as equivalent to polyesters.

(5) Minimum property values of gel coat resins are to comply with the values specified in **Table 2.**

Table 2 Minimum property values of gel coat resins

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2.5 %
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	35
Determination of water absorption.	60 ℃
Water absorption	60 mg(max.)
Specific gravity of cast resin	As measured

(6) Minimum property values of cast thermosetting resins are to comply with the values specified in **Table 3.**

Table 3 Minimum property values of cast thermosetting resins

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2.0 %
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	70 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	35
Determination of water absorption.	60 ℃
Water absorption	70 mg(max.)
Specific gravity of cast resin	As measured

3. Fiber reinforcements

(1) The following data is to be provided, where applicable, for each type of fiber reinforcement:
   (A) Reinforcement type.
   (B) Fibre type for each direction.
   (C) Fibre tex value.
   (D) Fibre finish and/or treatment.
   (E) Yarn count in each direction.
   (F) Width of manufactured reinforcement.
   (G) Weight per unit area of manufactured reinforcement.
   (H) Weight per linear metre of manufactured reinforcement.
   (I) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
   (J) Constructional stitching −details of yarn, specific gravity, type, frequency and direction.
   (K) Weave type.
   (L) Binder type and content.
   (M) Density of the fibre material.
(2) The following tests are to be made on each fiber reinforcement:
   (A) Tensile strength (stress at maximum load).
   (B) Tensile strain at break.
   (C) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
   (D) Compressive strength (stress at maximum load).
   (E) Compressive modulus.
   (F) Flexural strength (stress at maximum load).
   (G) Modulus of elasticity in flexure.
   (H) Apparent interlaminar shear.
   (I) Fibre content.
   (J) Determination of water absorption.
(3) The test methods for Fiber reinforcements are to be in accordance with the Guidance specially specified by the Society
(4) Minimum property values of laminates are to comply with the values specified in **Table 4.**

Table 4 Minimum property values of laminates

Material type	Property	Min. value
Chopped strand mat	Tensile strength (stress at maximum load)(N/mm^2) Modulus of elasticity in tension(kN/mm^2)	200Gc+25 15Gc+20
Bi-directional reinforcement	Tensile strength (stress at maximum load)(N/mm^2) Modulus of elasticity in tension(kN/mm^2)	400Gc-10 30Gc-0.5
Uni-directional reinforcement	Tensile strength (stress at maximum load)(N/mm^2) Modulus of elasticity in tension(kN/mm^2)	100Gc-1400Gc+510 130Gc-114Gc+39
All	Flexural strength (stress at maximum load)(N/mm^2) Modulus of elasticity in flexure(kN/mm^2) Compressive strength (stress at maximum load)(N/mm^2) Compressive modulus(kN/mm^2) Interlaminar shear strength(N/mm^2) Water absorption(mg) Glass content(% by weight)	520Gc+106.8 33.4Gc+2.2 150Gc+72 40Gc-6 22-13.5Gc(min. 15) 70(max.) As measured
Notes: (1) After water immersion, the values shall be a minimum of 75 % of the above. (2) Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction. (3) Gc : glass fraction by weight.		

4. Core materials

(1) The following data is to be provided for each type of core material:
- (A) Type of material.
- (B) Density.
- (C) Description (block, scrim mounted, grooved).
- (D) Thickness and tolerance.
- (E) Sheet/block dimensions.
- (F) Surface treatment.
- (G) Full application procedure for use of the product.

(2) For each type of test sample the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:
- (A) Skin and core thickness, and core type and density.
- (B) Resin/catalyst/accelerator ratio.
- (C) Skin construction, including types and weight of reinforcements, resin(s), etc.
- (D) Details of production method and curing conditions (temperature and times).
- (E) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.
- (F) Actual span between base supports for each type of test sample.

(3) Specific requirements for end-grain balsa
- (A) The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenization, sterilization and kiln drying to an average moisture content of no more than 12 per cent.
- (B) The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain. The density of the virgin material is also to be tested.
  - (a) Compressive strength (stress at maximum load).
  - (b) Compressive modulus of elasticity.
  - (c) Tensile strength (stress at maximum load).
- (C) Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.
- (D) The test methods for end-grain balsa are to be in accordance with the Guidance specially specified by the Society
- (E) Minimum property values of end-grain balsa are to comply with the values specified in **Table 5.**

Table 5. Minimum property values of end-grain balsa

Apparent density (kg/mm^3)	Strength (stress at maximum load)(N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear			
	Direction of stress					Direction of stress		
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5.0	0.35	9.00	0.44	1.10	2300	35.2	105
144	10.6	0.57	14.6	0.70	1.64	3900	67.8	129
176	12.8	0.68	20.5	0.80	2.00	5300	89.6	145

(4) Specific requirements for rigid foams (PVC, Polyurethane and other types)
- (A) The foam is to be of the closed cell type and compatible with the proposed resin system (e.g. polyester, epoxide, etc.).
- (B) Foams are to be of uniform cell structure.
- (C) Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

(D) The following test data is to be submitted for each type of foam:
  (a) Density.
  (b) Tensile strength (stress at maximum load).
  (c) Tensile modulus of elasticity.
  (d) Compressive strength (stress at maximum load).
  (e) Compressive modulus of elasticity.

(E) Additionally the compressive properties (see (D) (d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70 °C, whichever is the greater.

(F) The test methods for rigid foams are to be in accordance with the Guidance specially specified by the Society

(G) Minimum characteristics and mechanical properties of rigid expanded foams are to comply with the values specified in **Table 6.**

Table 6 Minimum characteristics and mechanical properties of rigid expanded foams at 20 °C

Material	Apparent density (kg/mm^3)	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0.85	0.60	0.50	17.20	8.50
Polyvinylchloride	60					

(H) Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0.5 N/mm^2 is to be achieved. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 2 MATERIALS AND WELDING

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Rules for the Classification of Steel Ships

Part 3 Hull Structures

Rules

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Guidance Relating to the Rules for the Classification of Steel ships

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Guidance

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Rules for the Classification of Steel Ships

Part 3

Hull Structures

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KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 3 "HULL STRUCTURES"

1. Unless expressly specified otherwise, the requirements in the Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date : 1 July 2011

CHAPTER 1 GENERAL

Section 2 General

- 209. 2 (2) (E) and (F) have been amended.
- Table 3.1.1 has been amended.

Section 8 General

- 803. has been amended.

CHAPTER 2 STEMS AND STERN FRAMES

Section 2 Stern Frames

- 207. 1 (3) has been amended.

CHAPTER 5 DECKS

Section 3 Deck Plating

- 307. has been new added.

CHAPTER 6 SINGLE BOTTOMS

Section 1 General

- 101. has been amended.

CHAPTER 14 WATERTIGHT BULKHEADS

Section 2 Arrangement of Watertight Bulkheads

- 201. 1 has been amended.

Section 4 Watertight Doors

- 401. 2 and 402. 2 have been amended.
- 404. 3 has been deleted.

CHAPTER 16 SUPERSTRUCTURES

Section 1 General

- 101. 1 has been amended.

CONTENTS

CHAPTER 1 GENERAL

Section 1 Definitions

101. Application

The definitions of symbols and terms used in the Rules, except otherwise specified, are to be in accordance with this Section.

102. Length

The length of ship (L) is the distance in *metres* on the load line defined in **110.,** from the fore side of stem to the after side of rudder post in case of a ship with rudder post, or to the axis of rudder stock in case of a ship without rudder post or stern post. L is not to be less than 96 % and need not be greater than 97 % of the extreme length on the load line.

103. Length for freeboard

The length of ship for freeboard (L_f) is 96 % of the length in *metres* measured from the fore side of stem to the aft side of aft end shell plate on the waterline at 85 % of the least moulded depth measured from the top of keel, or the length in *metres* measured from the fore side of stem to the axis of rudder stock on that waterlines, whichever is the greater. However, where the stem contour is concave above the waterline at 85 % of the least moulded depth, the forward terminal of this length is to be taken at the vertical projection to this waterline of the aftermost point of the stem contour. The waterline on which this length is measured is taken to be parallel to the load line defined in **110.**

104. Breadth

The breadth of ship (B) is the horizontal distance in *metres* from the outside of frame to the outside of frame measured at the broadest part of the hull.

105. Breadth for freeboard

The breadth of ship for freeboard (B_f) is the maximum horizontal distance in *metres* from the outside of frame to the outside of frame measured at the middle of L_f.

106. Depth(the least moulded depth)

The depth of ship (D) is the vertical distance in *metres* at the middle of L measured from the top of keel to the top of the freeboard deck beam at side. Where watertight bulkheads extend to a deck above the freeboard deck and are to be registered as effective to that deck, D is the vertical distance to that bulkhead deck.

107. Depth for strength computation

The depth of ship for strength computation (D_s) is the vertical distance in *metres* from the top of keel to the top of beam at side of the superstructure deck at the middle of L, for the part where the superstructure deck is strength deck, or the freeboard deck for other parts. Where the deck does not cover midship, the depth is to be measured at the imaginary deck line which is extended to the middle of L along the strength deck line.

108. Midship

The midship means the part covering $0.4L$ amidships.

109. Fore and aft end part

The fore and aft end part means the part covering $0.1L$ from the fore and aft end of the ship.

110. Load line

The load line is the waterline corresponding to the designed summer load draught in case of a ship which is required to be marked with load lines and the waterline corresponding to the designed maximum draught in case of a ship which is not required to be marked with load lines.

111. Load draught

The load draught (d) is the vertical distance in *metres* from the top of keel to the load line measured at the middle of L_f in case of a ship which is required to be marked with load lines and at the middle of L in case of a ship which is not required to be marked with load lines.

112. Full load displacement

The full load displacement ($\triangle$) is the displacement (including shell plating and appendages, etc.) in *tons* at the summer load line.

113. Block coefficient

The block coefficient (C_b) is the coefficient obtained by dividing the moulded volume corresponding to $\triangle$ by $L \times B \times d$.

114. Freeboard deck

1. The freeboard deck is normally the uppermost continuous deck. However, in cases where openings without permanent closing means exist on the exposed part of the uppermost continuous deck or where openings without permanent watertight closing means exist on the side of the ship below that deck, the freeboard deck is the continuous deck below that deck.

2. In a ship having a discontinuous freeboard deck, the lowest line of the exposed deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck.

3. Where the designed load draught is less than the draught determined assuming the existing deck below the freeboard deck as the freeboard deck in accordance with the provision in **Pt 1, Ch 1, 1202.** the existing lower deck is taken as the freeboard deck in the application of the Rules. In this case, the lower deck is to be continuous at least between the machinery space and peak bulkheads and continuous athwartships. Where a lower deck in stepped, the lowest line of the deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck.

115. Bulkhead deck

The bulkhead deck is the highest deck to which the watertight transverse bulkheads except both peak bulkheads extend and are made effective.

116. Strength deck

The strength deck at a part of ship's length is the uppermost deck at that part to which the shell plates extend. However, in way of superstructures, except sunken superstructures, not exceeding $0.15L$ in length, the strength deck is the deck just below the superstructure deck. The deck just below the superstructure deck may be taken as the strength deck even in way of the superstructure exceeding $0.15L$ in length at the option of the designer.

117. Raised deck

The raised deck is the sunken superstructure deck below which no deck, is provided.

118. Superstructure

The superstructure is a decked structure on the freeboard deck, extending from side to side of the ship or having its side walls at the position not farther than $0.04B_f$ from the side of ship. Raised quarter deck is to be considered as a superstructure.

119. Enclosed superstructure

An enclosed superstructure is a superstructure complying with the following conditions:
(1) Enclosed by bulkheads of efficient construction.
(2) Access openings in these bulkheads are fitted with doors complying with the requirements of **Ch 16, 301.** or equivalent.
(3) All other openings in sides or ends of the superstructure are fitted with efficient weathertight means of closing.
(4) Access means, which are available at all times when bulkhead openings are closed, are provided for the crew to reach machinery and other working spaces within a bridge or poop.

120. Speed of ship

The speed of ship (V) is the designed speed in knots obtainable with clean bottom at calm sea and at the designed summer load line with the engine running at maximum continuous rating.

121. Light weight

The Light Weight (LW) is the displacement in tons excluding cargoes, fuel oil, lubricating oil, ballast and fresh water in tanks, stored goods, crew and their properties.

122. Deadweight tonnage

The deadweight (DW) is the difference in tons between full load displacement and light weight.

123. Fore end and Aft end

The fore end is the start point of forward side, where measuring the length of ship L in **102.,** and after end is the end point of afterward side of L.

124. Section modulus ratio

The section modulus ratios (f_D and f_B) are as following formulae. However, f_B is not to be less than 0.85 or $0.0015L+0.5$, whichever is the lesser.

$$f_D = \frac{Z_{DM\,req}}{Z_{D\,act}}, \quad f_B = \frac{Z_{BM\,req}}{Z_{B\,act}}$$

where:

$Z_{DM\,req}$ and $Z_{BM\,req}$ = required section moduli at the deck and bottom of transverse sections of the hull determined according to the requirements in **Ch 3, 201**. respectively when mild steel material symbol A, B, D and E specified in **Pt 2, Ch 1, 301. Par 3** is used (cm^3).

$Z_{D\,act}$ and $Z_{B\,act}$ = actual section moduli at the deck and bottom of transverse sections of the hull respectively (cm^3).

125. Net thickness

Net thickness is the thickness that does not include corrosion addition and voluntary addition.

Section 2 General

201. Application

1. The requirements in this Part unless otherwise specified elsewhere, are framed for hull structural arrangement and scantlings of ships not less than 90 m in length, of normal form and proportion, and intended for unrestricted service.

2. Hull construction, equipment and scantlings of ships to be classed for restricted service may be appropriately modified according to the condition of service.

3. In the application of relevant provisions in the Rules to ships which are not required to be marked with load lines, L_f is to be read as L and B_f as B.

202. Exception in application

In ships of which length is specially long or in ships to which requirements in the Rules for some special reasons, are not directly applicable, hull construction, equipment, arrangement and scantlings are to be in accordance with the discretion of the Society, notwithstanding the provisions in **201.**

203. Ships of unusual form or proportion, or intended for carriage of special cargoes

In ships of unusual form or proportion, or intended for carriage of special cargoes, the requirements concerning hull construction, equipment, arrangement and scantlings will be decided individually basing upon the general principle of the Rules instead of the requirements in the Rules.

204. Passenger ships

Hull construction, equipment, arrangement and scantlings of passenger ships are to be specially considered with respect to the design features in addition to the requirements in **201.** to **203.**

205. Equivalency

Alternative hull construction, equipment, arrangement and scantlings will be accepted by the Society, provided that the Society is satisfied that such construction, equipment, arrangement and scantlings are equivalent to those required in the Rules.

206. Direct strength calculation

1. Where approved by the Society, scantlings of structural members may be determined basing upon direct strength calculation. Where the calculated scantlings based on direct strength calculation exceed the scantlings required in this Part, the former is to be adopted.

2. Where the direct strength calculation specified in the preceding **Par 1** is carried out, the data necessary for the calculation are to be submitted to the Society.

207. Stability of ship

The requirements in the Rules are framed for ships having appropriate stability in all conceivable conditions. The Society emphasizes that the special attention be paid to the stability by the builders in design and construction stage and by the masters while in service.

208. Carriage of oil

1. The requirements for construction and arrangement for carriage of fuel oils specified in **Pts 3, 4** and **7** are to be applied to the case intended to carry fuel oils having a flash point 60°C or above at a closed cup test.

2. The construction and arrangement for carriage of fuel oils having a flash point below 60°C at a closed cup test, are to be in accordance with the requirements provided in **Pts 3, 4** and **7** or the special requirements are to be applied.

3. The construction and arrangement of deep oil tanks intended to carry cargo oils are to be correspondingly in accordance with the requirements in **Pt 7, Ch 1** or **Pt 7, Ch 10.**

209. Structural testing, leak testing and hose testing

In the Classification Survey during construction, structural testing, leak testing and hose testing are to be carried out in accordance with the following:

1. General

(1) Application
The following requirements determine the testing conditions for :
- gravity tanks, excluding independent tanks of less than 5 m^3 capacity.
- watertight or weathertight structures.
(A) The purpose of these tests is to check the tightness and/or the strength of structural elements at time of ships construction and on the occasion of major repairs.
(B) Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work would not impair the strength and tightness of the structure.
(C) For the general testing requirements, see items **Par 3** and **4.**

(2) Definitions
(A) Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.
(B) Protective coating is a final coating protecting the structure from corrosion.
(C) Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible(for example when it is difficult, in practice, to apply the required head at the top of the tank), hydropneumatic testing may be carried out instead. When a hydropneumatic testing is performed, the conditions should simulate, as far as practicable, the actual loading of the tank.
(D) Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank with water up to its top and applying an additional air pressure. The value of the additional air pressure is to be at least as defined in **2** (2).
(E) Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.
(F) Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and to other components which contribute to the watertight or weathertight integrity of the hull.

2. Testing methods

(1) Structural testing
(A) Structural testing may be carried out after application of the shop primer. Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:
(a) all the welds are completed and carefully inspected visually to the satisfaction of the Suyrveyor prior to the application of the protective coating.
(b) leak testing is carried out prior to the application of the protective coating.
(B) Regardless the previous (A), the protective coating may be applied prior to the structural testing of the following (a), (b) and (c), provided that the tightness of them are confirmed with the next (E) and (F) of (2).
(a) all erection welds, both manual and automatic
(b) all manual fillet weld connections on tank boundaries
(c) manual penetration welds

(2) Leak testing
(A) Where leak testing is carried out, in accordance with **Table 3.1.1,** an air pressure of 0.15 x 10^5 Pa (0.15 kg/cm^2) is to be applied during the test. Prior to inspection, it is recommened that the air pressure in the tank is raised to 0.20 x 10^5 Pa (0.2 kg/cm^2) and kept at this level for about 1 hour to reach a stabilized state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.
(B) The test may be conducted after the pressure has reached a stabilized state at 0.20 x 10^5 Pa

($0.2\ kg/cm^2$), without lowering the pressure, provided they are satisfied of the safety of the personnel involved in the test.

(C) Welds are to be coated with an efficient indicating liquid.

(D) A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure. The U-tube should have a cross section larger than that of the pipe supplying air. In addition, the test pressure is also to be verified by means of one master pressure gauge. The Society may accept alternative means which are considered to be equivalently reliable.

(E) Leak testing is to be carried out, prior to the application of a protective coating on following welds:

(a) all fillet weld connections on tank boundaries and penetrations welds

(b) erection welds on tank boundaries excepting welds made by automatic processes and FCAW (Flux Cored Arc Welding) semi-automatic full penetration butt welds, provided that careful visual inspections show continuous uniform weld profile shape, free from repairs, and the results of selected NDE testing show no significant defects.

(F) Selected locations of automatic and FCAW semi-automatic erection welds and pre-erection manual or automatic welds may be required to be similarly tested at the discretion of the Surveyor taking account of the quality control procedures operating in the shipyard. For other welds, leak testing may be carried out, after the protective coating has been applied, provided that these welds were carefully inspected visually to the satisfaction of the Surveyor.

(G) Any other recognized method may be accepted to the satisfaction of the Surveyor.

(3) Hose testing

When hose testing is required to verify the tightness of the structures, as defined in **Table 3.1.1,** the minimum pressure in the hose, at least equal to 2×10^5 Pa ($2.0\ kg/cm^2$), is to be applied at a maximum distance of 1.5 m. The nozzle diameter is not to be less than 12 mm.

(4) Hydropneumatic testing

When hydropneumatic testing is performed, the same safety precautions as for leak testing(see previous (2)) are to be adopted.

(5) Other testing methods

Other testing methods may be accepted, at the discretion of the Society, based upon equivalency considerations.

3. General testing requirements

General requirements for testing are given in **Table 3.1.1.**

4. Additional requirements for special type vessels/tanks

In addition to the requirements of **Table 3.1.1,** particular requirements for testing of certain spaces within the cargo area of liquefied gas carriers, edible liquid carriers and chemical carriers, are given in **Table 3.1.2.** These requirements intend generally to verify the adequacy of the structural design of the tank, based on the loading conditions which prevailed when determining the tank structure scantlings.

Table 3.1.1 General testing requirements

Item number	Structure to be tested	Type of testing	Test pressure	Remarks
1	Double bottom tanks	Structural testing (1)	The greater of the following : - head of water up to the top of overflow - head of water up to the margin line	Tank boundaries tested from at least one side
2	Double side tanks	Structural testing (1)	The greater of the following : - head of water up to the top of overflow - 2.4 m head of water above highest point of tank	Tank boundaries tested from at least one side
3	Tank bulkheads, deep tanks	Structural testing (1)	The greater of the following : (2) - head of water up to the top of overflow - 2.4 m head of water above highest point of tank - setting pressure of safety relief valves, where relevant	Tank boundaries tested from at least one side
	Fuel oil bunkers	Structural testing		
4	Ballast holds in bulk carriers	Structural testing (1)	The greater of the following : - head of water up to the top of overflow - 0.9 m head of water above top of hatch	–
5	Fore peak and after peak used as tank	Structural testing	The greater of the following : - head of water up to the top of overflow - 2.4 m head of water above highest point of tank	Test of the after peak carried out after the stern tube has been fitted
	Fore peak not used as tank	Refer to **SOLAS Ch.II-1 Reg.14**	–	–
	After peak not used as tank	Leak testing	–	–
6	Cofferdams	Structural testing (3)	The greater of the following : - head of water up to the top of overflow - 2.4 m head of water above highest point of tank	–
7	Watertight bulkheads	Refer to **SOLAS Ch.II-1 Reg.14** (4)	–	–
8	Watertight doors below freeboard or bulkhead deck	Refer to **SOLAS Ch.II-1 Reg.16**	–	–
9	Double plate rudders	Leak Testing	–	–
10	Shaft tunnel clear of deep tanks	Hose testing	–	–
11	Shell doors	Hose testing	–	–

Table 3.1.1 General testing requirements (continued)

Item number	Structure to be tested	Type of testing	Test pressure	Remarks
12	Watertight hatchcovers of tanks in bulk carriers	Hose testing	–	–
	Watertight hatchcovers of tanks in combination carriers	Structural testing (1)	The greater of the following : - 2.4 m head of water above the top of hatch cover - setting pressure of safety relief valves, where relevant	At least every 2nd hatch cover is to be tested
13	Weathertight hatchcovers and closing appliances	Hose testing	–	–
14	Chain locker(if aft of collision bulkhead)	Structural testing	Head of water up to the top	–
15	Independent tanks	Structural testing	Head of water up to the top of overflow, but not less than 0.9 m	–
16	Ballast ducts	Structural testing	Ballast pump maximum pressure	–

Notes :

1. (1) Leak or hydropneumatic testing may be accepted under the conditions specified in **Par 2** (2), provided that at least one tank for each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent vessels of a series of identical new buildings. However, the following spaces are to be structurally tested.
   (a) cargo space boundaries in tankers and combination carriers
   (b) tanks for segregated cargoes or pollutants
   If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.
   (2) Where applicable, the highest point of tank is to be measured to the deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tank is to be taken at the top of the hatch.
   (3) Leak testing may be accepted under the conditions specified in **Par 2** (2) except that structural testing or hydropneumatic testing may be required at the Society discretion.
   (4) When hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc.) already installed, it may be replaced, at the Society discretion, by a careful visual inspection of all the crossings and welded joints; where necessary, dye penetration test or ultrasonic leak test may be required.
2. Tests on hull piping will be as specified in **Pt 5, Ch 6.**

Table 3.1.2 Additional testing requirements for spaces within the cargo area of certain types of ships

Item number	Types of ships	Structure to be tested	Testing requirements	Structural test pressure	Remarks
1	Liquefied gas carriers	Integral tanks	Refer to **Pt 7, Ch 5, 410. 6**	–	–
		Hull structure supporting membrane or semi-membrane tanks	Refer to **Pt 7, Ch 5, 410. 7**	–	–
		Independent tanks type A	Refer to **Pt 7, Ch 5, 410. 10,** (1)	–	–
		Independent tanks type B	Refer to **Pt 7, Ch 5, 410. 10,** (2)	–	–
		Independent tanks type C	Refer to **Pt 7, Ch 5, 410. 10,** (3)	–	–
2	Edible liquid carriers	Independent tanks	Structural testing	Head of water up to the top of overflow without being less than 0.9 m	–
3	Chemical tankers	Integral or independent tanks	Structural testing of cargo tanks boundaries from at least one side	The greater of the following : - 2.4 m head of water above highest point of tank - setting pressure of safety relief valves, where relevant	–

Section 3 Approval of Plans and Documents

301. Plans and documents for approval

When it is intended to build a ship for Classification, the following plans and documents are to be submitted for the approval of the Society before the work is commenced.

(1) Midship section
(2) Construction profile
(3) Shell expansion
(4) Watertight and oiltight bulkheads
(5) Deck plans
(6) Stem, sternframe and rudder
(7) Single bottoms and double bottoms
(8) Superstructure end bulkheads
(9) Fore and aft bodies
(10) Pillars and deck girders
(11) Shaft tunnels
(12) Foundations and the relevant structure plan of boilers, main engines, thrust and plummer blocks, generators, and other heavy weight auxilary machinery.
(13) Machinery casings
(14) Deckhouses
(15) Masts, derrick posts and derrick booms and the relevant structure plans
(16) Final stability data
(17) Loading manual
(18) Other plans and documents deemed necessary by the Society

302. Plans and documents for reference

1. When it is intended to build a ship for Classification, the following plans and documents for reference are to be submitted in addition to the plans and documents for approval in **301.**

(1) General arrangement
(2) Specification
(3) Calculation sheets for midship section modulus
(4) Where special cargoes are to be loaded, the plans showing their distribution and loading arrangements.
(5) Calculation sheets for masts, derrick booms, boat davits, and similar structures requiring strength.
(6) Preliminary stability data.
(7) Other plans and documents deemed necessary by the Society.

2. Lines, hydrostatic curves, capacity plans, records of sea trials and various tests are to be submitted before the delivery of the ship.

303. Plans and documents for assignment of load lines

Where load lines are to be assigned the following plans and documents are to be submitted. But submission of plans and documents already submitted for the Classification Survey during construction may be dispensed with.

(1) General arrangement
(2) Midship section
(3) Construction profile
(4) Superstructures and superstructure end bulkheads
(5) Lines
(6) Hydrostatic curves
(7) If the timber load lines are to be assigned, the plans showing the height of timber deck cargo and the arrangements of lashing and fixing
(8) Other plans and documents deemed necessary by the Society.

Section 4 Materials

401. Standard of materials

The materials used for hull construction and equipment are to be those complying with the requirements in **Pt 2, Ch 1,** unless otherwise specified.

402. Materials outside the Rules

Where materials other than those specified in the Rules are used, the use of such materials and corresponding, scantlings are to be specially approved by the Society.

403. High tensile steels

1. Where high tensile steels are to be used for hull construction, the drawings showing the scope and locations of the used place together with the type and scantlings are to be submitted for the approval of the Society.

2. Where high tensile steels are used for hull construction, material factor K (hereinafter refer to as K in this Part and **Pt 7**) according to steels being used is as specified in **Table 3.1.3.**

Table 3.1.3 Material factor K

Steel grades	K
A, B, D and E	1.0
AH 32, DH 32 and EH 32	0.78
AH 36, DH 36 and EH 36	0.72
AH 40, DH 40 and EH 40	0.68

404. Ships of restricted service area

Materials for hull construction and equipment for ships intended for Classification with the condition of restricted service areas are to be in accordance with the discretion of the Society.

405. Application of steels

1. The steels used for hull structures are to be of the grades provided in **Pt 2, Ch 1** in accordance with the requirements given in **Tables 3.1.4** to **3.1.9.** In applying these requirements, B, D or E may be substituted for A; D or E for B; E for D; DH 32 or EH 32 for AH 32; EH 32 for DH 32; DH 36 or EH 36 for AH 36; and EH 36 for DH 36, DH 40 or EH 40 for AH 40; and EH 40 for DH 40, respectively.

2. For strength members not mentioned in **Table 3.1.4,** grade A, AH 32, AH 36 and AH 40 may generally be used. As for rounded gunwale, the single strake is to have breadth to the satisfaction of the Society.

The steel grade is to correspond to the as-built plate thickness when this is greater than the rule requirement.

3. Plating materials for sternframes, rudder horns, rudders and shaft brackets are not to be of lower grades than corresponding to class II. However, for rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudder (D and E in **Fig 4.1.1** of **Pt 4, Ch 1**) or at upper part of space rudder (C in **Fig 4.1.1** of **Pt 4, Ch 1**)) class III is to be applied.

4. The steels with the thickness above 50 mm up to 100 mm used for stern frame may be of the grades E, EH32, EH36 or EH40.

5. The grades of steel to be used in the hull construction are to be clearly indicated on the hull structural plans.

Table 3.1.4 Material Classes

Structural member category	Material class/grade
○ Secondary: A1. Longitudinal bulkhead strakes, other than that belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	- Class I within 0.4L amidships - Grade A/AH outside 0.4L amidships
○ Primary: B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	- Class II within 0.4L amidships - Grade A/AH outside 0.4L amidships
○ Special: C1. Sheer strake at strength deck (1) C2. Stringer plate in strength deck (1) C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships (1)	- Class III within 0.4L amidships - Class II outside 0.4L amidships - Class I outside 0.6L amidships
C4. Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	- Class III within 0.4L amidships - Class II outside 0.4L amidships - Class I outside 0.6L amidships - Min. Class III within cargo region
C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers combination carriers and other ships with similar hatch opening configurations	- Class III within 0.6L amidships - Class II within rest of cargo region
C6. Bilge strake in ships with double bottom over the full breadth and length less than 150 m (1)	- Class II within 0.6L amidships - Class I outside 0.6L amidships
C7. Bilge strake in other ships (1)	- Class III within 0.4L amidships - Class II outside 0.4L amidships - Class I outside 0.6L amidships
C8. Longitudinal hatch coamings of length greater than 0.15L C9. End brackets and deck house transition of longitudinal cargo hatch coamings	- Class III within 0.4L amidships - Class II outside 0.4L amidships - Class I outside 0.6L amidships - Not to be less than Grade D/DH

(Note)
(1) Single strakes required to be of class Ⅲ within 0.4L amidships are to have breadths not less than $800+5L$ (mm), need not be greater than 1800 mm, unless limited by the geometry of the ship's design.
(2) The symbols in the table mean the grades of steel as follows :
AH : AH 32, AH 36 and AH 40
DH : DH 32, DH 36 and DH 40
EH : EH 32, EH 36 and EH 40

Table 3.1.5 Minimum material grades for ships with length exceeding 150m and single strength deck

Structural member category	Material grade
Longitudinal strength members of strength deck plating	Grade B/AH within 0.4L amidships
Continuous longitudinal strength members above strength deck	Grade B/AH within 0.4L amidships
Single side strakes for ships without inner continuous longitudinal bulkheads between bottom and the strength deck	Grade B/AH within cargo region

Table 3.1.6 Minimum Material Grades for ships with length exceeding 250 m

Structural member category	Material grade
Shear strake at strength deck (1)	Grade E/EH within 0.4L amidships
Stringer plate in strength deck (1)	Grade E/EH within 0.4L amidships
Bilge strake (1)	Grade D/DH within 0.4L amidships
(Note) (1) Single strakes required to be of Grade E/EH and within 0.4L amidships are to have breadths not less than 800+5L (mm), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.	

Table 3.1.7 Minimum Material Grades for single-side skin bulk carriers subjected to SOLAS regulation XII/6.5.3

Structural member category	Material grade
Lower bracket of ordinary side frame (1), (2)	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125 l above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate (1)	Grade D/DH
(Note) (1) The term "lower bracket" means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125 l above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. (2) The span of the side frame, l, is defined as the distance between the supporting structures.	

Table 3.1.8 Minimum material grades for ships with ice strengthening

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	Grade B/AH

Table 3.1.9 Steel grades

Thickness(mm) \ Class	I		II		III	
	MS	HT	MS	HT	MS	HT
$t \le 15$	A	AH	A	AH	A	AH
$15 < t \le 20$	A	AH	A	AH	B	AH
$20 < t \le 25$	A	AH	B	AH	D	DH
$25 < t \le 30$	A	AH	D	DH	D	DH
$30 < t \le 35$	B	AH	D	DH	E	EH
$35 < t \le 40$	B	AH	D	DH	E	EH
$45 < t \le 50$	D	DH	E	EH	E	EH

Note:
The symbols in the table mean the grades of steel as follows:

AH : AH 32, AH 36 and AH 40
DH : DH 32, DH 36 and DH 40
EH : EH 32, EH 36 and EH 40

MS : Mild steels
HT : High tensile steels

406. Special requirements for application of steels

For vessels intended to operate for longer period in areas with low temperatures or to carry refrigerated cargoes, and for the cases where deemed necessary, the Society may require the grade of higher toughness, regardless of the requirements in **405.**

Section 5 Weldings

501. General

1. Arrangements

Special attention is to be paid to the arrangements of hull structural members so that welding may be carried out without much difficulty.

2. Structural details

(1) Structural discontinuities and the abrupt changes of cross sections are to be avoided as far as practicable, and welded joints are to be properly shifted from places where the stresses are highly concentrated.
(2) Corners of all openings are to be well rounded.
(3) Where rigid structural members with small sectional area, such as brackets, are welded on relatively thin plate, at least the toes of members are to be welded just on other rigid members.
(4) Upper ends of sheer strakes for midship part are to be finished smoothly, and bulwark or equipment is not to be directly welded to the sheer strakes.

3. Tee joints

The kinds and sizes of fillet welds are to be in accordance with **Table 3.1.10** and their application to the hull construction parts is to be as required by **Table 3.1.11.**

4. Slot weld

(1) The slot weld is to have adequate shape to permit a thoroughly fused bead to be applied all around the bottom edge of the opening.
(2) The fillet sizes of slot welds are to be F1 and the spacing of slots is to be as determined by the Society.

Section 6 Scantlings

601. General

1. The midship scantlings and scantlings specified in the Rules are to be applied for the parts which specified in **108.** and **109.**

2. The reduction from the midship scantlings to the end scantlings is to be applied for the parts within $0.1L$ from the fore and aft ends.

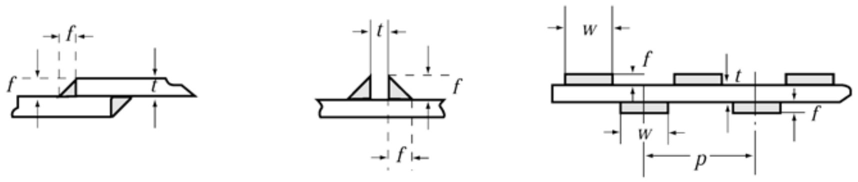
602. Section modulus

Unless otherwise specially specified, the section moduli of members required by the Rules are those including the steel plates with the effective breadth of $0.1\,l$ on either plate side of the members. However, the breadth of $0.1\,l$ is not to exceed one-half of the spacing of member, l is the length specified in the relevant Chapter.

603. Built-up sections

Where flat bars, bulb plates, inverted angles or flanged plates are welded to form beams, frames or stiffeners for which section moduli are specified, they are to be of suitable depth and thickness in proportion to the section modulus.

Table 3.1.10 Kinds and sizes of fillet weld (Unit : mm)

Kind of fillet weld / Thickness of members	Lap joint Tee joint Measurement of weld length and pitch 					
	continuous fillet weld		Intermittent fillet weld			
	size of fillet f		Size of fillet f	Length of fillet w	Pitch p	
	F1	F2			F3	F4
Up to 5	3	3	3	60	150	250
6	4	3	4	75	200	350
7	5	4	5			
8						
9	6		6			
10						
11						
12	7	5	7			
13						
14						
15	8	6	8			
16						
17						
18	9	7	9			
19						
20						
21						
22	10	7	10			
23						
24						
25						
from 26 to 40	11	8	11			

NOTE:
1. The size of fillet "f" for tee joints is in general to be determined according to the thickness of webs in case of connections of beams, frames, stiffeners and girders to deck plating, inner bottom plates, bulkhead plates, shell plating or face plates, and the thickness of the thinner plate in case of connections of other members.
2. Lap joints are to have the fillet size of F1 determined according to the thickness of thinner plate
3. The throat thickness of fillet is to be $0.7f$
4. In general F2 is to be minimum fillet size.
5. Intermittent fillet welds are to be staggered and w at the ends is to be welded on both sides.
6. The minus tolerance of fillet size is to be 10 % of the nominal size.

Table 3.1.11 Application of fillet weld

Line No.	Item			Application		Kind of weld
1	Rudders	Rudder frames		Rudder plates		F3
2				Vertical frames forming main pieces		F1
3				Rudder frames (except above)		F2
4	Single bottoms	Floors plates		Shell plates	In strengthened bottom forward, aft peaks and deep tanks	F2
5					Elsewhere	F4
6				Face plates of floor plates	In strengthened bottom forward and main engine rooms	F2
7					Elsewhere	F4
8				Through plates and rider plates of centre keelsons		F1
9		Centre keelson	Girders	Flat plate keels	In strengthened bottom forward	F2
10					Elsewhere	F3
11				Rider plates		F3
12				Floor plates		F2
13		Side keelson	Girders	Shell plates	In strengthened bottom forward	F2
14					Elsewhere	F4
15				Rider plates	In main engine rooms	F2
16					Elsewhere	F4
17				Floor plates		F3
18	Double bottoms with transverse framing	Solid floors		Shell plates	In strengthened bottom forward	F2
19					Elsewhere	F4
20				Inner bottom plates	Bed plates of main engine and thrust bearings	F2
21					In strengthened bottom forward and engine rooms (except above)	F2
22					Elsewhere	F4
23				Girders under inner bottom below main engine seatings		F1
24				Centre girders	In strengthened bottom forward and main engine rooms (except above)	F2
25					Elsewhere	F3
26				Margin plates		F2
27		Oiltight and watertight floors		Boundaries		F1
28		Stiffeners on floor plates		Oiltight and watertight floors		F3
29				Elsewhere		F4
30		Open floors	Frames	Shell plates		F4
31			Reverse frames	Inner bottom plates		F4
32			Brackets	Centre girders		F3
33				Margin plates		F2
34			Vertical struts	Side girders		F4
35		Centre girders		Flat plate keels	Where oiltight or watertight	F1
36					Elsewhere	F3
37				Inner bottom plates	Where oiltight or watertight	F1
38					Lower portion of girders for main engine seatings or thrust bearings	F2
39					Elsewhere	F3
40		Side girders(intercostal plates)		Shell plates	In strengthened bottom forward	F2
41					Elsewhere	F4
42				Inner bottom plates	In engine rooms	F2
43					Elsewhere	F4
44				Solid floors	In strengthened bottom forward and main engine rooms	F2
45					Elsewhere	F4
46		Main engine girders		Inner bottom plates		F2
47				Shell plates		F2
48		Margin plates		Shell or gusset plates		F1

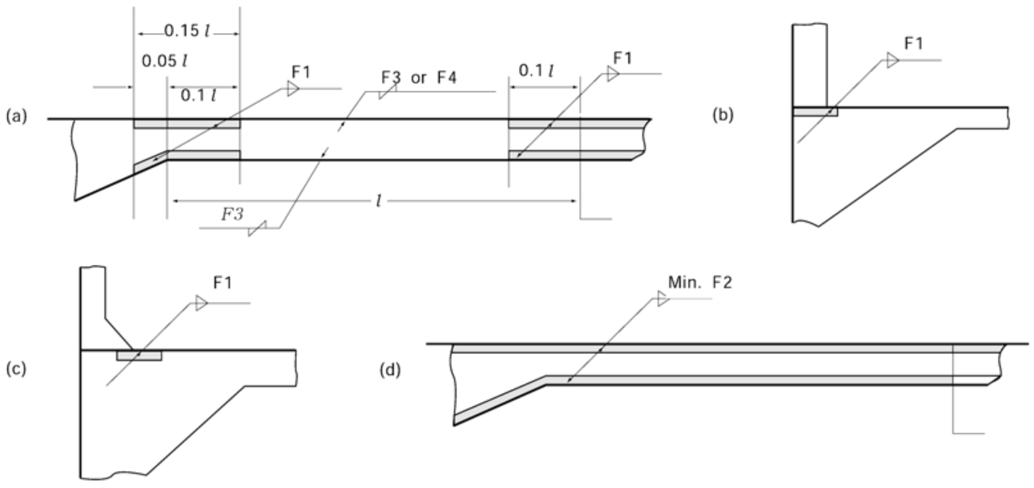
Table 3.1.11 Application of fillet weld (continued)

Line No.	Item		Application		Kind of weld
49		Hold frame brackets	Margin plates		F1
50			Gusset plates		F2
51		Shell stiffeners	Connections to shell plates are as required for longitudinal frames		
52		Half height girders	Connections to shell plates and solid floors are as required for side girders		
53	Double bottoms with longitudinal framing	Longitudinal frames	Shell plates in strengthened bottom forward		F2
54			Shell plates(except above) or inner bottom plates		F4
55		Solid floors	Shell plates and inner bottom plates	For two frame spaces at the end of floors	F2
56				Elsewhere	F3
57			Centre girders		F2
58		Brackets on centre girders	Centre girders, shell plates and inner bottom plates		F3
59		Brackets on margin plates in double bottoms	Margin plates		F2
60			Shell plates and inner bottom plates		F3
61		Stiffeners on side girders	Side girders		F4
62	Frames	Shell plates	In aft peak tanks, for $0.125L$ from fore end, and in deep tanks		F3
63			Elsewhere		F4
64	Built-up frames	Webs	Shell plates or face plates	$0.125L$ from fore end, and in deep tanks	F2
65				Elsewhere	F3
66	Decks	Stringer plates	Shell plates	In strength decks	F1
67				Elsewhere	F2
68		Beams	Decks	In tanks	F3
69				Elsewhere	F4
70	Built-up beams	Webs	Decks or face plates	In tanks	F2
71				Elsewhere	F3
72	Pillars	Pillars	Heels and heads		F1
73			Connections of built-up pillar members		F3
74	Hatchways	Coamings	Decks(except below)		F2
75			Hatchway corners on strength decks		F1
76		Portable beams	Connections of members		F3
77	Bulkheads	Stiffeners	Bulkhead plates	Above the lower ends of brackets connecting stiffeners to deck girders	F1
78				In deep tank bulkheads	F3
79				Elsewhere	F4
80		Bulkhead plates	Boundaries	In oiltight and watertight bulkheads	F1
81				Elsewhere	F3
82	Seatings	Girders or brackets	Bed plates	In seatings for main engines, thrust bearings, boiler bearers and main dynamo engines	F1
83			Inner bottom plates or shell	In seatings for main engine or thrust bearings	F2
84			Girder plates	In seatings for main engine or thrust bearings	F1

Table 3.1.11 Application of fillet weld (continued)

85	Web beams, web frames, side stringers, deck girders and girders on bulkheads	Web plates or girder plates	Shell, decks or bulkhead	In tanks, web frames for 0.125L from fore end and side stringers		F2
86				Elsewhere		F3
87			End connections of web or girder plates to shell, decks, inner bottom plates or bulkheads			F1
88			Webs or face plates of webs	In tanks, web frames for 0.125L from fore end and side stringers		F2
89				Elsewhere	Where face area exceeds 65 cm^2	F2
90					Where face area does not exceed 65 cm^2	F3
91		Tripping brackets on webs or girder plates	Boundaries			F2
92		Serrations of webs or girder plates	Webs of frames, beams or stiffeners			F2
93	Brackets at ends of members		Connections of members to brackets(except otherwise specified)			F1

NOTES:
1. Where longitudinal strength members are mutually, connected by fillet weld, the fillet sizes are to be in accordance with **Table 3.1.10** and this **Table,** except that the total throat areas of fillet joints are not to be less than the minimum sectional area of the members.
2. Where the ends of frames, beams and stiffeners are directly fillet welded to decks, shell, inner bottom plates or bulkhead plates, the fillet sizes are not to be less than 0.7 times the web thickness of members.
3 Where beams, frames, stiffeners and girders are intermittently welded to decks, shell, inner bottom plates and bulkhead plates, the fillet welds are to be partly continuous as shown in **Fig (a).** Where members are fitted at the opposite side of brackets as shown in **Fig (b)** or **(c),** the fillet welds are to be continuous for proper length at the ends of members or at the toe of brackets of members. The fillet weld may be as shown in **Fig (d),** where the whole lengths of the joints are light continuously welded with the fillet size not less effective than F2
4. Where the rider plates or inner bottom plates consist of bed plates of main engine seating or important seatings, the kind of fillet is to in accordance with the requirements for the seatings.
5. As to the connections not specified in double bottoms with longitudinal framing, the requirements for transverse framing are to be applied.



604. Scantlings of end brackets

1. Secondary members, such as longitudinals, beams, frames and stiffeners forming part of the hull structure, are generally to be connected at their ends by the brackets of thickness not to be less than that obtained from the following formula, Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

$$t_b = C_1 \sqrt{Z} + 4.5 \quad \text{(mm)}$$

where:

Z = section modulus in cm^3 specified in the following (a) to (c):

(a) Bracket connecting stiffener to primary member, section modulus of the stiffener.

(b) Bracket at the head of main transverse frame where frame terminated, section modulus of frame

(c) Elsewhere the lesser section modulus of the members being connected by the bracket.

C_1 = factor depending on the flange of bracket is as following:

C_1 = 0.27 : without flange

C_1 = 0.23 : with flange

2. Where a flange is fitted, its breadth is not to be less than that obtained from following formula. Where the length of longer arm exceeds 800 mm, the free edge of brackets are to be stiffened by flanges or other means, except where tripping brackets or the like are provided.

$$w_f = \frac{Z}{33} + 45 \quad \text{(mm)}$$

where:

Z = as specified in **Par 1.**

3. The length of bracket arm measured from shown in **Fig 3.1.1** is not to be less than that obtained from the following formula. The lengths of bracket arms of tank side and hopper side are to be 20 percent greater than that required above.

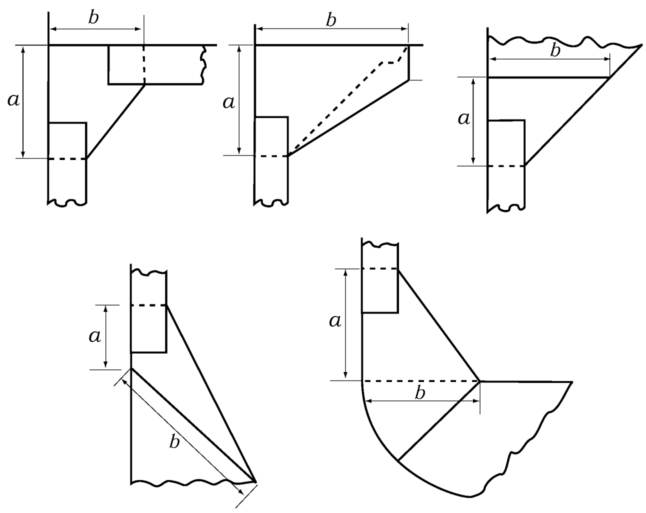


Fig 3.1.1 Measurement of a and b for arms

$a+b \geq 2.0l$

a and $b > 0.8l$

where:

l = as given by the following formula, but in no case is to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

$$l = 180\sqrt{\frac{Z}{14+\sqrt{Z}}} - 90$$

Z = as specified in **Par 1.**

605. Modification of l

Where brackets of not less thickness than that of the girder plates were provided, the value of l specified in **Chs 9, 11, 12, 14** and **15** may be modified in accordance with the following:

(1) Where the face area of the bracket is not less than one-half that of the girder and the face plates or flange on the girder is carried to the bulkhead, deck, tank top, etc., the length l may be measured to a point 0.15 m inside the toe of bracket.(See **Fig 3.1.2**(a))

(2) Where the face sectional area of the bracket is less than one-half that of the girder and the face plate or flange on the girder is carried to the bulkhead, deck, tank top, etc., l may be measured to a point where the sum of sectional area of the bracket outside the line of girder and its free flanges equal to the sectional area of free flanges of girder, or to a point 0.15 m inside the toe of bracket, whichever is the greater.(See **Fig 3.1.2**(b))

(3) Where brackets are provided and the face plate or flange on the girder are extended along the brackets to the bulkhead, deck, tank top, etc., the face plate or flange of bracket may be curved, but l is to be measured to the toe of bracket.

(4) Brackets are not to be considered effective beyond the point where the arm on the girder is 1.5 *times* the length of arm on the bulkhead, deck, tank top, etc.

(5) In no case is the allowance in l at either end to exceed one-quarter of the overall length of the girder.

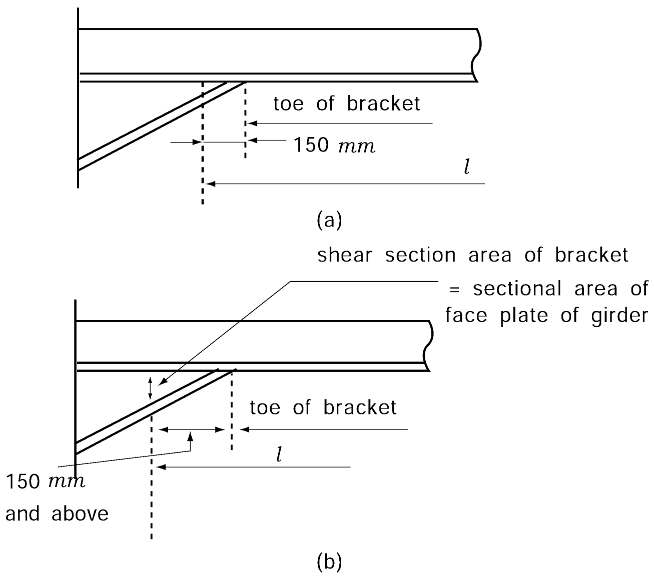


Fig 3.1.2 Modification of l

Section 7 Workmanship

701. General

1. The workmanship is to be of the best quality.

2. During the construction, the builder is to supervise and inspect in detail every job performed in shed or yard and prepare the necessary records.

702. Caulking

Caulking edges are to be finished by edge planing, gas cutting, chipping or other appropriate methods.

703. Penetrating parts

Where frames or beams pass through watertight deck or bulkhead, the deck or bulkhead is to be constructed watertight without the use of wooden materials or cement.

704. Welding

The welding is to be applied in **Pt 2, Ch 2.**

705. Heating

1. In the hot work of steel, the steel is not to be overheated and it is to be hammered or bent in the proper heated condition.

2. Steel which is burnt is not to be used.

Section 8 Corrosion Control

801. Reduction of scantlings due to corrosion control

1. Where an approved measure of corrosion control is applied to deep tanks, double bottom tanks, peak tanks or fuel oil tanks, the required scantlings of structural members in the tanks may be reduced at the discretion of the Society.

2. Where it is intended to apply a system of corrosion control to tanks the plans showing the description and scope of such control, the required scantlings in the Rules and the scantlings intended to be reduced are to be submitted to the Society for approval.

802. Notation for corrosion control

Where an approved measure of corrosion control is applied to a ship, the notation "CoC" will be added and entered in the Record.

803. Corrosion protection coating

1. For ships not intended to receive a corrosion control notation specified in **801.** and **802.,** all sea water ballast spaces having boundaries formed by the hull envelope are to have an effective corrosion protection coating in accordance with the manufacturer's requirements.

2. Corrosion protection coating for dedicated sea water ballast tanks in all types of Ships and double-side skin space of bulk carriers are to be in accordance with the requirements as specially prepared by the Society. ⚓

CHAPTER 2 STEMS AND STERN FRAMES

Section 1 Stems

101. Plate stems

1. The thickness of steel plate stems at the load waterline is not to be less than that obtained from the following formula. Above and below the load waterline, the thickness may be gradually tapered toward the stem head and the keel. And at the upper end of stem it may be equal to the thickness of the side shell plating (at the fore end part) of the ship, and at the lower end of stem, it is to be equal to the thickness of plate keel.

$$t = 1.5\sqrt{L' - 50} + 2.0 \quad \text{(mm)}$$

where:

L' = length of ship (m), where, however, L exceeds 230 m, L' is to be taken as 230 m

2. Horizontal ribs are to be provided on the stem plates at an interval preferably not exceeding 1 m and where the radius of curvature at the fore end of stem is large, proper reinforcement is to be made by providing with a centre line stiffener or by other means.

Section 2 Stern Frames

201. Application

The requirements in this Section apply only to stern frames without rudder post.

202. General

1. Stern frames may be cast, forged, or fabricated of plates and are to be of the shape suitable for the stream line of the stern part of the hull.

2. Cast or plate stern frames are to be fitted with transverse ribs of suitable spacing and where the curvature is large a centre line stiffener is to be fitted.

3. Care is to be taken to avoid any sudden change in thickness or sectional area along the frame.

203. Propeller post

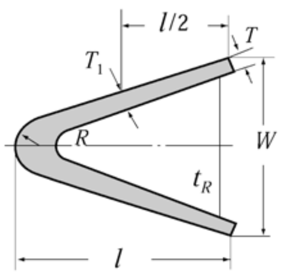
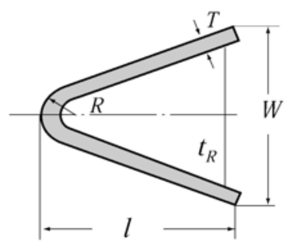
1. The scantlings of propeller post are not to be less than those obtained from the formulae given in **Table 3.2.1.**

2. The propeller post may be built up of plates welded to a suitable bar steel of circular or rectangular cross section at the after end.

3. The scantlings of propeller post below the propeller boss are to be gradually increased to suit the strength of the shoe piece.

4. In ships with relatively high speed for their length, and in ships exclusively engaged in towing purposes, the scantlings of various parts of propeller posts are to be suitably increased.

Table 3.2.1 Standards of propeller posts

Cast steel	Steel plate
$W = 30\sqrt{L}$ (mm) $l = 40\sqrt{L}$ (mm) $T = \dfrac{3\sqrt{L}}{\sqrt{K^{(1)}}}$ (mm) $T_1 = \dfrac{3.7\sqrt{L}}{\sqrt{K^{(1)}}}$ (mm) $t_R = 0.6\,T$ (mm) $R_{min} = 40$ (mm)	$W = 37\sqrt{L}$ (mm) $l = 53\sqrt{L}$ (mm) $T = \dfrac{2.4\sqrt{L}}{\sqrt{K^{(2)}}}$ (mm) $t_R = 0.55\,T$ (mm) $R_{min} = 40$ (mm)
	

Note :
(1) Material factor K for the Propeller post of cast steel is to be as **Pt 4, Ch 1, Table 4.1.1.**
(2) Material factor K for the Propeller post of steel plate is to be as **Pt 4, Ch 1, Table 4.1.2.**

204. Propeller boss

The thickness of propeller boss is not to be less than that obtained from the following formula:

$$t = 0.23\,d_p + 30 \quad \text{(mm)}$$

where:

d_p : diameter (mm) of propeller shaft specified in **Pt 5, Ch 3, 204.**

205. Shoe piece

1. The scantlings of each cross section of the shoe piece are to be determined by the following formula (1) to (4) considering the bending moment and shear force acting on shoe piece when the rudder force specified in **Pt 4, Ch 1, 201.** is applied to the rudder.

(1) The section modulus Z_z around Z-axis(axis of depthwise) is not to be less than that obtained from the following formula:

$$Z_z = \frac{MK_{sp}}{80} \quad (\text{cm}^3)$$

where:

M = bending moment at the section considered, which is obtained from the following formula.(N-m):

$$M = Bx \quad \text{(N-m)}$$

$$M_{max} = B\,l \quad \text{(N-m)}$$

B = supporting force in the pintle bearing as given in **Pt 4, Ch 1, 401**.(N).

x = distance from mid-point of the length of pintle bearing to section considered (m).(See **Fig 3.2.1**).

l = distance from mid-point of the length of pintle bearing to fixed point of the shoe piece (m).(See **Fig 3.2.1**).

K_{sp} = material factor for the shoe piece as given in **Pt 4, Ch 1, 102.**

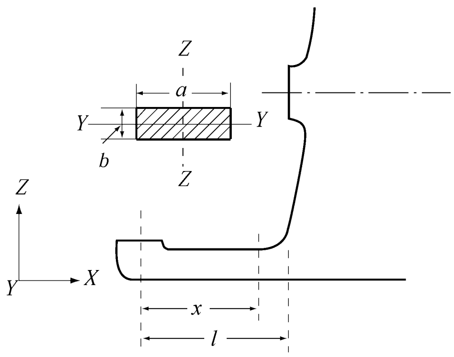


Fig 3.2.1 Shoe piece

(2) The section modulus Z_y around Y-axis(axis of breadthwise) is not to be less than that obtained from the following formula:

$$Z_y = 0.5\,Z_z \quad \text{(cm}^3\text{)}$$

where:

Z_z = as specified in (1)

(3) The total section area A_s in Y-axis is not to be less than that obtained from the following formula:

$$A_s = \frac{BK_{sp}}{48} \quad \text{(mm}^2\text{)}$$

where:

B and K_{sp} = as specified in (1).

(4) At no section within the length of shoe piece, the equivalent stress σ_e is to be exceed 115/K_{sp}(N/mm^2). The equivalent stress σ_e is to be determined by the following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2} \quad \text{(N/mm}^2\text{)}$$

where:

σ_b = bending stress acting on shoe piece is to be determined by the following formula (N/mm^2):

$$\sigma_b = \frac{M}{Z_z(x)} \quad (\text{N/mm}^2)$$

τ = shear stress acting on shoe piece is to be determined by the following formula (N/mm^2):

$$\tau = \frac{B}{A_s(x)} \quad (\text{N/mm}^2)$$

$Z_z(x)$ = actual section modulus of shoe piece around Z-axis at the section considered.(cm^3)

$A_s(x)$ = actual section area of shoe piece in Y-axis at the section considered.(mm^2)

M and B = as specified in (1).

2. The thickness of steel plates forming the main part of shoe piece of steel plate stern frame is not to be less than that of steel plates forming the main part of propeller post. Ribs are to be arranged in the shoe piece below the propeller post, under brackets and at other suitable positions.

206. Heel piece

Heel piece of stern frame is to be of length at least 3 *times* the frame space at that part and is to be strongly connected to the keel.

207. Rudder horn

1. The scantlings of each cross section of the rudder horn are to be determined by the formulae in (1) to (3) considering the bending moment, shear force and torsional moment acting on rudder horn when the rudder force as given in **Pt 4, Ch 1, 201**. is applied to the rudder.

(1) Section modulus Z_x around X-axis(axis of lengthwise) is not to be less than that obtained from the following formula:

$$Z_x = \frac{MK_{rh}}{67} \quad (\text{cm}^3)$$

where:

M = bending moment at the section considered, which is obtained from the following formula (N-m) (See **Fig 3.2.2**):

$$M = Bz \quad (\text{N-m})$$

$$M_{\max} = Bd \quad (\text{N-m})$$

B = supporting force in the pintle bearing (N) as given in **Pt 4, Ch 1, 401.**

z = distance (m) from mid-point of length of the pintle bearing to the section considered (see **Fig 3.2.2**).

d = distance (m) from mid-point of length of pintle bearing to the supporting point of rudder horn (See **Fig 3.2.2**).

K_{rh} = material factor for rudder horn as given in **Pt 4, Ch 1, 102.**

(2) The total section area A_h in Y-axis is not to be less than that obtained from following formula:

$$A_h = \frac{BK_{rh}}{48} \quad (\text{mm}^2)$$

where:

B and K_{rh} = as specified in (1).

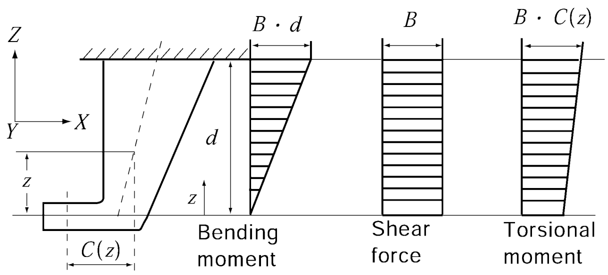


Fig 3.2.2 Rudder horn

(3) At no section within the total height of rudder horn d, the equivalent stress σ_e is to exceed $120/K_{rh}$(N/mm^2). The equivalent stress σ_e is determined by following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3(\tau^2 + \tau_t^2)} \quad (\text{N/mm}^2)$$

where:

σ_b = bending stress acting on rudder horn is determined by the following formula:

$$\sigma_b = \frac{M}{Z_{xa}} \quad (\text{N/mm}^2)$$

τ = shear stress acting on rudder horn is determined by the following formula:

$$\tau = \frac{B}{A_h(z)} \quad (\text{N/mm}^2)$$

τ_t = torsional stress acting on rudder horn is determined by the following formula:

$$\tau_r = \frac{1000\,T_h}{2A_t t_h} \quad (\text{N/mm}^2)$$

T_h = torsional moment at the section considered is determined by the following formula:

$$T_h = BC(z) \quad (\text{N-m})$$

A_t = area in horizontal section enclosed by the rudder horn (mm^2)

t_h = thickness of rudder horn plate (mm)

M, B and K_{rh} = as specified in (1).

$A_h(z)$ = actual section area (mm^2) in Y-axis at the section considered.

Z_{xa} = actual section modulus (cm^3) around X-axis at the section considered.

$C(z)$ = distance (m) from section considered to the centre of rudder stock.

2. At the connection between the rudder horn and the hull structure, special consideration is to given to structural continuity.

208. Attachment to floor plates

The stern frame is to be extended upward at the part of the propeller post and to be connected strongly to the transom floor of thickness not less than that obtained from the following formula:

$$t = 0.035L + 7.5 \quad \text{(mm)}$$

209. Gudgeon

1. The bearing length of pintle, l_p , is to be such that

$$d_p \leq l_p \leq 1.2d_p \quad \text{(mm)}$$

where:

d_p = diameter of pintle (mm)

2. The length of the pintle housing in the gudgeon is not to be less than the pintle diameter d_p.

3. The thickness of the pintle housing is not to be less than 0.25 d_p. For ships specified in **Pt 4, Ch 1, 103.,** however, the thickness of the pintle housing is to be appropriately increased. ⚓

CHAPTER 3 LONGITUDINAL STRENGTH

Section 1 General

101. Application

1. The requirements in this Chapter apply to ships of 90 m in length and above in unrestricted service. For ships having one or more of the following characteristics, special additional considerations will be given by the Society.

(1) Proportion $L/B \leq 5$, $B/D_s \geq 2.5$
(2) Length $L \geq 500$ m
(3) Block coefficient $C_b < 0.6$
(4) Large deck opening
(5) Ships with large flare or high speed ships
(6) Carriage of heated cargoes
(7) Unusual type or design

2. Notwithstanding the requirements in **Par 1,** the requirements specified in **103.** and **104.** are applied to the ships of 65 m and above in L_f.

102. Continuity of strength

Longitudinal members are to be so arranged as to maintain as good continuity of strength as practicable.

103. Loading manual

1. For ships of 65 m in length and above in L_f, in order to enable the ship master to adjust the loading of cargo and ballast to avoid the occurrence of unacceptable stress in the ship's structure, the ship is to be provided with a loading manual approved by the Society. However, a ship may not be provided with a loading manual where deemed unnecessary by the Society.

2. In the loading manual, as required in the preceding paragraph, at least the following items are to be included.

(1) Loading conditions on the basis of which the ship is designed, and the allowable limits of longitudinal still water bending moment and still water shear force.
(2) Results of calculation longitudinal still water bending moment and still water shear force corresponding to the standard loading conditions.
(3) Data and calculation examples to calculate the still water bending moment and the still water shear force for the loading conditions other than standard loading conditions. This requirement, however, may be dispense with to the ships with which the loading instruments specified in **104.** is provided.
(4) Allowable limits of local loads applied to hatch covers, deck, double bottom construction, etc., where deemed necessary by the Society.

104. Longitudinal strength loading instrument

1. In addition to loading manual as specified in **103.** the following ships of 100 m in length and above in L_f are to be provided with loading instrument(Longitudinal strength loading instrument), together with its operating manual, by means of which the still water bending moments, still water shear forces and still water torsional moments, etc. where applicable, in any loading or ballast condition can be easily and quickly ascertained. However, a ship may not be provided with a loading instrument where deemed unnecessary by the Society.

(1) Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads have to be considered.
(2) Ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed. Ships less than 120 m in length, when their design takes into account uneven distribution of cargo or ballast, are deemed unnecessary.

(3) Chemical tankers and gas carriers.

2. The loading instrument specified in **Par 1** is to be approved by the Society and tested at the presence of the surveyor in accordance with the approved test reports after installation on board.

Section 2 Bending Strength

201. Bending strength at amidships

1. The section moduli of the transverse sections of the hull calculated in accordance with the requirements in **203,** at the midship part are not to be less than the values of Z_1 obtained from the formulae given in **Table 3.3.1** at the transverse sections under consideration along the length of hull for all design cargo and ballast loading condition.

2. Notwithstanding the requirements of **Par 1,** the section modulus of the transverse section of hull at $0.4L$ part is not to be less than the value of Z_{min} obtained from formula given in **Table 3.3.1.**

3. Moment of inertia of the transverse section of hull at the middle point of L is not to be less than the value of I_{min} obtained from the formula given in **Table 3.3.1.** and the calculation method for moment of inertia of the actual transverse section is to be correspondingly in accordance with the requirements in **203.**

4. Scantlings of all continuous longitudinal members of hull girder based on the section modulus requirement in **Par 2** and **3** are to be maintained within $0.4L$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the end of the $0.4L$ part, where deemed necessary by the Society.

202. Bending strength at sections other than amidships

1. The bending strength of hull at sections other than $0.4L$ amidships is to be determined according to the requirements of **Ch 5, Sec 2.**

2. Where the Society considers that the application of requirements of the preceding paragraph is inappropriate, the bending strength at sections other than $0.4L$ amidships is to be determined according to **201. 1**. with necessary modifications.

203. Calculation of hull section modulus

As for calculation of the hull section modulus, the following (1) through (6) are to be applied:

(1) All longitudinal members which are considered effective to the longitudinal strength of the ship may be included in the calculation.

(2) Deck openings on the strength deck are to be deducted from the sectional area used in the section modulus calculation. However, small openings not exceeding 2.5 m in length or 1.2 m in breadth need not be deducted, provided that the sum of their breadths in one transverse section is not more than $0.06(B-\Sigma b)$. Where, Σb is the sum of breadths of large openings (m). (See **Fig 3.3.3**)

(3) Notwithstanding the requirement in (2), deck openings on the strength deck need not be deducted, provided that the sum of their breadths in one transverse section is not reducing the section modulus at deck or bottom by more than 3 %.

(4) Deck openings prescribed in (2) and (3) include shadow area which is obtained by drawing two tangential lines with an opening angle of 30 *degrees* having the focus on the longitudinal line of the ship. (See **Fig 3.3.3**)

Table 3.3.1 Section modulus of transverse section of hull, etc.

Item	Requirement
Section modulus	$Z_1 = \frac{\lvert M_s + M_w(+) \rvert}{\sigma} \times 10^3$ (cm^3), $Z_1 = \frac{\lvert M_s + M_w(-) \rvert}{\sigma} \times 10^3$ (cm^3)
Minimum section modulus	$Z_{min} = C_1 L^2 B(C_b + 0.7) K$ (cm^3)
Minimum moment of inertia	$I_{min} = 3 C_1 L^3 B(C_b + 0.7)$ (cm^4)

M_s = longitudinal bending moment in still water (kN-m) at the transverse section under consideration along the length of hull, which is calculated by the method deemed appropriate by the Society. The value of M_s is defined as positive which is obtained assuming that downward loads are taken as positive and are integrated in the forward direction from the aft end of the ship. Sign of positive M_s is shown in **Fig 3.3.1.**

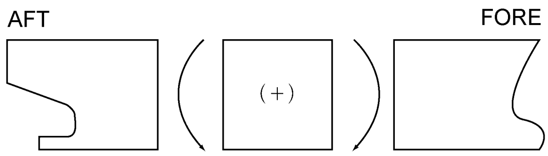


Fig 3.3.1 Sign convention of bending moment

$M_w(+)$ and $M_w(-)$ = wave induced longitudinal bending moments (kN-m) at the transverse section under consideration along the length of hull, which are obtained from the following formulae,

$$M_w(+) = +0.19 C_1 C_2 L^2 B C_b \quad \text{(kN-m)}$$
$$M_w(-) = -0.11 C_1 C_2 L^2 B(C_b + 0.7) \quad \text{(kN-m)}$$

σ = allowable bending stress obtained from the following formula.

$$\sigma = 175/K$$

C_1 = coefficient given by the following table.

L(m)	C_1
$90 \le L \le 300$	$10.75 - \left(\frac{300 - L}{100} \right)^{1.5}$
$300 < L \le 350$	10.75
$350 < L \le 500$	$10.75 - \left(\frac{L - 350}{150} \right)^{1.5}$

C_2 = distribution factor specified along the length of L at positions where the transverse section of the hull is under consideration, as given in **Fig 3.3.2.**

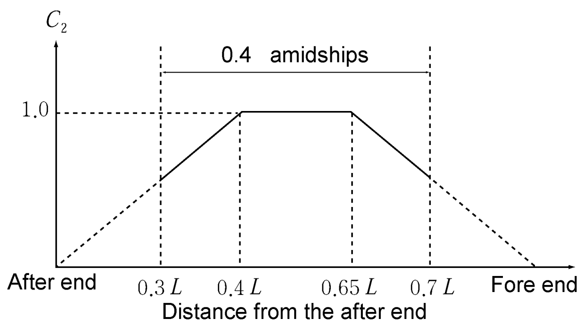
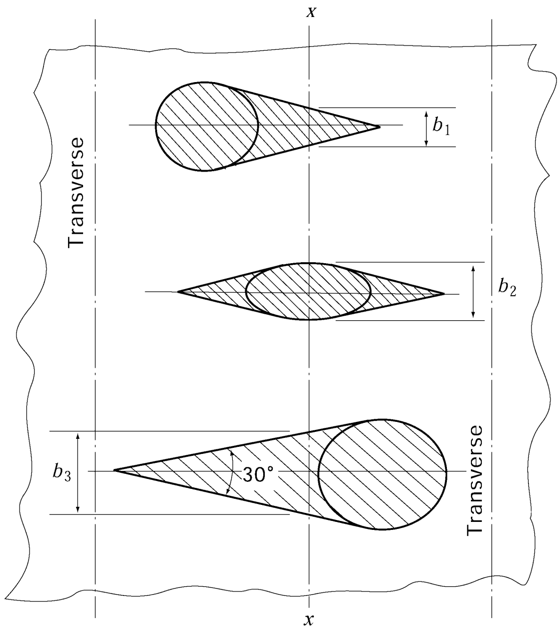


Fig 3.3.2 Value of coefficient C_2

C_b = block coefficient, however, to be taken as 0.6, where it is less than 0.6.



$$\Sigma b_i = b_1 + b_2 + b_3$$

Fig 3.3.3 Deck openings on the strength deck

(5) Continuous trunks and longitudinal hatch coamings are to be included in the longitudinal sectional area provided they are effectively supported by longitudinal bulkheads or deep girders. And the section modulus at the strength deck is to be calculated by dividing the moment of inertia of the athwartship section about its horizontal neutral axis by the following distance (a) or (b), whichever is the greater.

(a) Vertical distance from the neutral axis to the top of the strength deck beam at side.
(b) Distance obtained from the following formula:

$$Y\left(0.9 + 0.2\frac{X}{B}\right)$$

where:

X = horizontal distance from the top of continuous strength member to the centre line of the ship (m).

Y = vertical distance from the neutral axis to the top of continuous strength member (m).

X and Y are to be measured to the point giving the largest value of the above formula.

(6) The section modulus at the bottom is to be calculated by dividing the moment of inertia of the athwartship section about its horizontal neutral axis by the vertical distance from the neutral axis to the top of keel.

Section 3 Shear Strength

301. Thickness of side shell of ships without the effective longitudinal bulkhead

1. Thickness of side shell plating of ships without the effective longitudinal bulkhead is not to be less than the values obtained from the following formulae the transverse section under consideration along the length of hull for all conceivable loading and ballasting conditions.

$$t = \frac{0.5|F_s + F_w(+)|}{\tau} \times \frac{Q}{I} \times 10^2 \quad \text{(mm)}, \qquad t = \frac{0.5|F_s + F_w(-)|}{\tau} \times \frac{Q}{I} \times 10^2 \quad \text{(mm)}$$

I = moment of inertia (cm^4) of the transverse section under consideration about its horizontal neutral axis, where the requirements in **203.** are to be applied to the calculation method.

Q = at the transverse section under consideration, moment of area about the horizontal neutral axis (cm^3) for the longitudinal members above the horizontal line passing through the considered position of side shell plating in case the considered position is above the horizontal axis, or for the longitudinal members under the horizontal line in case the considered position is under the horizontal neutral axis, where the requirements in **203.** are to be applied to the calculation method.

τ = allowable shear stress obtained from the following formula.

$$\tau = 110/K \quad \text{(N/mm}^2\text{)}$$

F_s = shear force in still water (kN) at the transverse section under consideration which is calculated by the method deemed appropriate by the Society. The value of F_s, is defined as positive which is obtained assuming that downward loads are taken as positive and are integrated in the forward direction from the aft end of the ship. Sign of F_s shown in **Fig 3.3.4** is taken as positive.

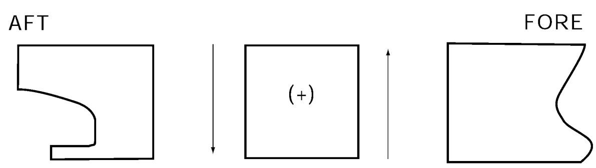


Fig 3.3.4 Sign covention of shear force

$F_w(+)$ and $F_w(-)$ = wave induced shear forces (kN) at the transverse section under consideration along the length of hull, which are obtained from the following formulae.

$$F_w(+) = +0.30 C_1 C_3 L B (C_b + 0.7) \quad \text{(kN)}, \qquad F_w(-) = -0.30 C_1 C_4 L B (C_b + 0.7) \quad \text{(kN)}$$

C_1, C_b = as specified in **Table 3.3.1.**

C_3 and C_4 = distribution factor to be determined at the position of the transverse section under consideration along the length of the ship, where the value is to be as specified in **Fig 3.3.5** and **3.3.6.**

2. In case of ships which have bilge hopper tanks or top side tanks, or ships of which other longitudinal members below the strength deck are considered to share a part of the shear force effectively, the thickness of side shell plate required by **Par 1** may be reduced at the discretion of the Society.

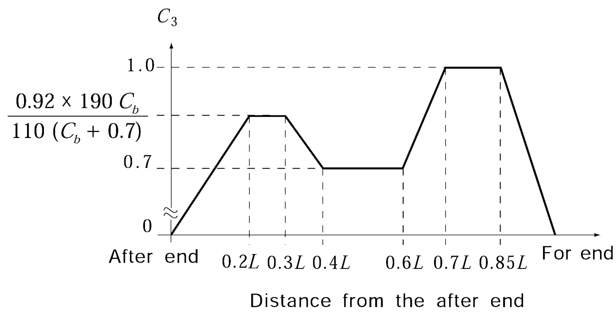


Fig 3.3.5 Value of distribution factor C_3

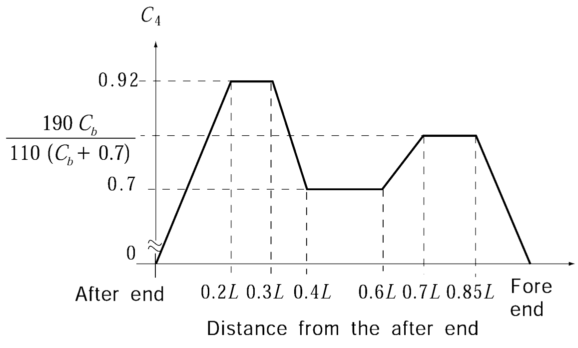


Fig 3.3.6 Value of distribution factor C_4

302. Thickness of side shell and longitudinal bulkhead plating of ships having one to four rows of longitudinal bulkheads

Thickness of side shell and longitudinal bulkhead plating of ships specified **Fig 3.3.7** is not to be less than the value obtained from the following formula at the transverse section under consideration along the length of hull for all conceivable loading and ballasting conditions. Where, however, ships with double side hull construction provided with bilge hoppers in double side hull structure are to be as deemed appropriate by the Society.

$$t = \frac{FQ}{\tau I} \times 10^2 \quad \text{(mm)}$$

where:

τ, I and Q = as specified in **301.**

F = shear force acting on the side shell plating or longitudinal bulkhead plating, the value of which is to be the following $F(+)$ or $F(-)$, whichever is the greater (kN):

$$F(+) = |\alpha(F_s + F_w(+)) + \triangle F| \;, \qquad F(-) = |\alpha(F_s + F_w(-)) + \triangle F|$$

F_s, $F_w(+)$ and $F_w(-)$ = as specified in **301.**

α = sharing factor of shear force shared by the side shell and longitudinal bulkhead, the value of which is to be deemed appropriate by the Society. However, unless otherwise specially specified, α may be obtained from the formulae in **Table 3.3.2.**

ΔF= shear force acting on side shell and longitudinal bulkhead due to local load (kN) the value of which is to be as deemed appropriate by the Society. However, unless otherwise specially specified, ΔF may be obtained from the formulae in **Table 3.3.2.**

Table 3.3.2 Values of α and ΔF

Ship Type	Application	$\alpha(=\alpha_1\times\alpha_2)$		$\Delta F(=n_i(R-\alpha f))$	
		α_1	α_2	R	f
A	Side shell	$0.5-\frac{0.575k_1A_L}{2A_s+A_L}$	1	$4.9W_bbS$	$19.6W_bbS$
	Longitudinal bulkhead	$\frac{0.575k_1A_L}{2A_s+A_L}$	2	$9.8W_bbS$	
B	Side shell	$0.5-\frac{0.55k_1A_L}{A_s+A_L}$	1	$4.9W_bbS$	$19.6(W_aa+W_bb)S$
	Longitudinal bulkhead	$\frac{0.55k_1A_L}{A_s+A_L}$		$9.8(\beta W_aa+0.5W_bb)S$	
C	Side shell	0.5	$1-\frac{1.06k_2A_{DL}}{A_s+A_{DL}}$	$4.9(\beta W_aa+W_cc)S$	$19.6(W_aa+W_cc)S$
	Longitudinal bulkhead		$\frac{1.06k_2A_{DL}}{A_s+A_{DL}}$		
D	Side shell	$0.5-\frac{0.675k_1A_L}{2(A_s+A_{DL})+A_L}$	$1-\frac{1.05k_2A_{DL}}{A_s+A_{DL}}$	$4.9(0.5W_bb+W_cc)S$	$19.6(W_bb+W_cc)S$
	Outer longitudinal bulkhead		$\frac{1.05k_2A_{DL}}{A_s+A_{DL}}$		
	Centre longitudinal bulkhead	$\frac{0.675k_1A_L}{2(A_s+A_{DL})+A_L}$	2	$9.8W_bbS$	
E	Side shell	$0.5-\frac{0.615k_1A_L}{A_s+A_{DL}+A_L}$	$1-\frac{1.04k_2A_{DL}}{A_s+A_{DL}}$	$4.9(0.5W_bb+W_cc)S$	$19.6(W_aa+W_bb+W_cc)S$
	Outer longitudinal bulkhead		$\frac{1.04k_2A_{DL}}{A_s+A_{DL}}$		
	Inner longitudinal bulkhead	$\frac{0.615k_1A_L}{A_s+A_{DL}+A_L}$	1	$9.8(\beta W_aa+0.5W_bb)S$	

NOTE:

k_1 = value is to be as specified in (a) to (c) below for longitudinal bulkheads other than those provided in double side hull.

k_2 = value is to be as specified in (a) to (c) below for longitudinal bulkheads provided in double side hull.

Where, however, values of k_1, and k_2 may be suitably modified for cases where members considered to share part of shear force are provided:

(a) 0, for the part not provided with longitudinal bulkhead

(b) 1.0, for the part provided with longitudinal bulkhead excluding the length of $0.5D_s$ respectively from both ends.

(c) Value obtained by linear interpolation for the intermediate parts between those specified in (a) and (b).

A_s, A_L, and A_{DL} = sectional area of side shell plating amidships, longitudinal bulkhead plating provided other than in double side hull, and longitudinal bulkhead plating in double side hull, respectively at midship part(mm^2).

W_a, W_b, and W_c = value obtained from the following formula, respectively:

$$W_a=h_a+h_d-d'$$
$$W_b=h_b+h_d-d'$$
$$W_c=h_c+h_d-d'$$

d' = draught at the part concerned in the loading condition under consideration(m).

h_a, h_b, h_c, and h_d = water head converted from the pressure of cargo or ballast in the centre tanks, wing tanks, double side hull tanks(excluding double bottom parts) and double bottom tank in the loading conditions under consideration, respectively(m). In this connection, even in case where the double hull forms one single tank, the requirements apply separately to a portion of the double side hull tank and portion of double bottom tank. In case where the double bottom tank is divided within either a, b or c, h_d is to be determined for respective ranges of the tank divided.

Table 3.3.2 Values of α and ΔF (continued)

NOTE:

a , b and c = half breadth of the centre tank, breadth of wing tanks, and breadth of double side hull tanks (m).

S = spacing of floors in double bottom(m).

n_i = number of floors in double bottom from the mid-point of transverse bulkheads to the section under consideration in double bottom. The sign of n_i is negative when counted afterward and positive when counted forward. Where, however, a swash bulkhead with an opening ratio of not less than 20 % is not to be considered as a transverse bulkhead. When a floor is provided at mid-point between transverse bulkheads, n_i in this case, is to be obtained counting the floor as 0.5.

β = as specified by the following table.

Description	β
where effective centre girder is provided	0.7
where no effective centre girder is provided	1.0

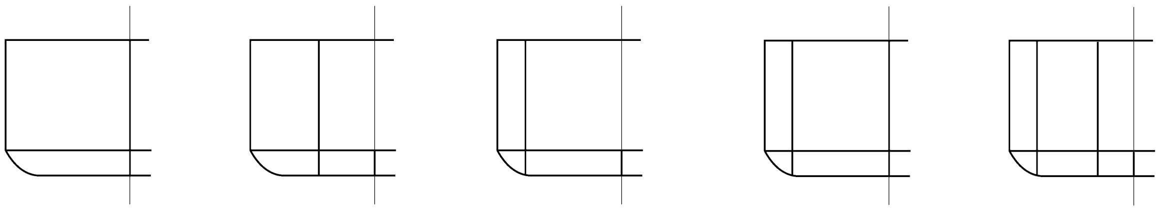


Fig 3.3.7 Types of a ship with longitudinal bulkheads

303. Compensation for opening

Where openings are provided in the shell plating, sufficient consideration is to be paid to the shear strength and suitable compensation is to be made as necessary.

Section 4 Buckling Strength

401. Apllication

The requirements in this section apply to the buckling strength of panels and longitudinal frames subject to hull girder bending stress and shear stress.

402. Working stress

1. Compression stresses

The compression stress σ_{act} (N/mm^2) acting on the members under consideration are given in the following formula, however, minimum value is not to be less than $30/K$:

$$\sigma_{act} = \frac{(M_s + M_w)}{I} y \times 10^5 \quad (\text{N/mm}^2)$$

where:

M_s = as specified in **Table 3.3.1.** For strength deck, value of M_s is taken 0 in case that M_s is always positive.

M_w = wave bending moment as given in **Table 3.3.1.** For the members above the neutral axis of transverse section of hull, value of M_w is taken $M_w(-)$ and for the members under, value of M_w is taken $M_w(+)$.

y = distance(m) from the neutral axis of transverse section of hull to the considered point.

I = as specified in **301. 1**.

2. Shear stresses

The shear stress τ_{act} (N/mm^2) acting on the members under consideration are given in the following formula:

(1) For ships not provided the effective longitudinal bulkheads

$$\tau_{act} = \frac{0.5|F_s + F_w|}{t} \times \frac{Q}{I} \times 10^2 \quad (\text{N/mm}^2)$$

where:

F_s, Q and I = as specified in **301. 1.**

F_w = absolute value of $F_w(+)$ or $F_w(-)$ as given in **301. 1.,** whichever is the greater.

t = actual thickness of the considered plate (mm).

(2) For ships having one to four row longitudinal bulkheads.

$$\tau_{act} = \frac{FQ}{tI} \times 10^2 \quad (\text{N/mm}^2)$$

where:

Q = as specified in **301. 1.**

F = as specified in **302.**

t and I = as specified in (1).

403. Elastic buckling stresses

1. Elastic buckling of plates

(1) Compression

The ideal elastic buckling stress σ_E (N/mm^2) is determined by the following formula:

$$\sigma_E = 0.9kE\left(\frac{t_b}{1000b}\right)^2 \quad (\text{N/mm}^2)$$

where:

k = value is determined by the following formulae depending on direction of working stress:

(a) longitudinal framing panel:

$$k = \frac{8.4}{\varphi + 1.1}$$

(b) transverse framing panel:

$$k = C\left\{1+\left(\frac{b}{a}\right)^2\right\}^2 \frac{2.1}{\varphi+1.1}$$

E = modulus of elasticity of material. For steels, $E = 2.06\times 10^5$ (N/mm^2)

t_b = net thickness of plate (mm), considering standard deductions equal to the values given in **Table 3.3.3.**

b = length of shorter side of panel (m)

a = length of longer side of panel (m)

C = factor depending on kind of stiffeners on longer side of panel is as following:
When plating stiffened by floors or deep girders : C = 1.3
When stiffeners are angles or T-section : C = 1.21
When stiffeners are bulb plates : C = 1.10
When stiffeners are flat bar : C = 1.05

φ = ratio between smallest and largest compression stress σ_{act} when linear variation across panel. $0 \le \varphi \le 1$

(2) Shear
The ideal elastic buckling stress τ_E (N/mm^2) is determined by the following formula:

$$\tau_E = 0.9 k_t E\left(\frac{t_b}{1000b}\right)^2 \quad \text{(N/mm2)}$$

where:

k_t = factor depending on aspect ratio of panel is determined by the following formula:

$$k_t = 5.34 + 4\left(\frac{b}{a}\right)^2$$

E, t_b, b and a = as specified in (1)

Table 3.3.3 Standard deduction

Structure	Standard deduction (mm)	Limit values min-max (mm)
- Compartments carrying dry bulk cargoes - One side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	$0.05t$	$0.5 \sim 1$ mm
- One side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line - Two side exposure to ballast and/or liquid cargo Vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line	$0.10t$	$2 \sim 3$ mm
- Two side exposure to ballast and/or liquid cargo Horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line	$0.15t$	$2 \sim 4$ mm

2. Ideal elastic buckling of longitudinals

The ideal elastic buckling of longitudinals is calculated by the method deemed appropriate by the Society.

404. Critical buckling stresses

1. Compression

The critical buckling stresses σ_c in compression is determined as following:

$$\sigma_c = \sigma_E \qquad \text{for : } \sigma_E \le 0.5\sigma_y$$

$$\sigma_c = \sigma_y\left(1 - \frac{\sigma_y}{4\sigma_E}\right) \qquad \text{for : } \sigma_E > 0.5\sigma_y$$

where:

σ_y = yield stress of material of the member considered, which are given as follows (N/mm^2) :

235 = for mild steels as specified in **Pt 2, Ch 1**

315 = for high tensile steels AH 32, DH 32, EH 32 or FH 32 as specified in **Pt 2, Ch 1**

355 = for high tensile steels AH 36, DH 36, EH 36 or FH 36 as specified in **Pt 2, Ch 1**

390 = for high tensile steels AH 40, DH 40, EH 40 or FH 40 as specified in **Pt 2, Ch 1**

σ_E = ideal elastic buckling stress calculated according to **403., 1** (1) (N/mm^2).

2. Shear

The critical buckling stress τ_c in shear is determined as following:

$$\tau_c = \tau_E \qquad \text{for} \quad \tau_E \le 0.5\tau_y \ ,$$

$$\tau_c = \tau_y\left(1 - \frac{\tau_y}{4\tau_E}\right) \qquad \text{for} \quad \tau_E > 0.5\tau_y$$

where:

τ_y = shear stress of material, in N/mm^2, τ_y is to be determined as $\sigma_y / \sqrt{3}$

τ_E = ideal elastic buckling stress calculated to **401. 1** (2) (N/mm^2).

σ_y = as specified in **Par 1.**

405. Scantling criteria

1. The critical buckling stress σ_c of panel and longitudinal frames in compression calculated according to **404. 1** is to comply with the following formula:

$$\sigma_c \ge \beta\sigma_{act}$$

where:

β = safety factor is as following:

For plate panel and web plating of stiffeners: $\beta = 1.0$

For stiffeners: $\beta = 1.1$

σ_{act} = working stress as given in **402.**

2. The critical buckling stress τ_c of panel and longitudinal frames in shear calculated according to **404. 2** is to comply with the following formula:

$$\tau_c \geq \tau_{act}$$

where:

τ_{act} = working stress as given in **402.** ⚓

CHAPTER 4 PLATE KEELS AND SHELL PLATINGS

Section 1 General

101. Consideration for corrosion

The thickness of shell plating at such parts that the corrosion considered excessive due to the location and/or special service condition of the ship is to be properly increased over that required in this Chapter.

102. Special consideration for contact with the quay, etc.

In cases where the service condition of the ship is considered to be such that there is possibility of indent of shell plating due to contact with the quay, etc., special consideration is to be given to the thickness of shell plating.

103. Consideration for ship with unusually large freeboard

Correction from the requirements in this Chapter will be specially considered where the ship has an unusually large freeboard.

104. Consideration for buckling

With regard to the prevention of buckling of the shell, in addition to complying with the requirements in **Ch 3, Sec 4.** sufficient consideration is to be paid to the prevention of buckling due to compression.

105. Continuity in thickness of the shell plating

Sufficient consideration is to be paid to the continuity in the thickness of shell plating and to the avoidance of remarkable difference between the thickness of the shell plating under consideration and that of the adjacent shell plating.

Section 2 Plate Keels

201. Breadth

The breadth of plate keel over whole length of the ship is not to be less than that obtained from the following formula:

$$b = 2L + 1000 \quad \text{(mm)}$$

202. Thickness

The thickness of plate keel over whole length of the ship is not to be less than the thickness of the bottom shell for the midship part obtained from the requirements in **304.** increased by 2.0 mm. This thickness, however, is not to be less than that of the adjacent bottom shell plating.

Section 3 Shell Plating below Strength Deck

301. Minimum thickness

The thickness of shell plating below the strength deck is not to be less than that obtained from the following formula:

$t = \sqrt{KL}$ (mm)

302. Thickness of side shell plating

The thickness of side shell plating other than the sheer strake of the strength deck of the midship part is to be as required in the following formula, in addition to the requirement specified in **301.**

$$t = C_1 C_2 S \sqrt{d - y + 0.05L' + h_1} + 1.5 \quad \text{(mm)}$$

where:

S = spacing of frames (m).

L' = length of ship (m). Where, however, L exceeds 230 m, L is to be taken as 230 m.

y = vertical distance (m) from the top of keel to the lower edge of plating. Where, however, y is more than d, y is to be taken as d.

h_1 = as given in (a) or (b).

(a) For 0.3L from the fore end : $2.25\ (17 - 20C_b')(1 - x)^2$

(b) For elsewhere except (a) : 0

C_b' = block coefficient. Where, however, C_b exceeds 0.85, C_b' is to be taken as 0.85.

C_1, C_2 and x = coefficient given in **Table 3.4.1.**

303. Sheer strakes for midship part

The thickness of sheer strakes at the strength deck for midship part is not to be less than 0.75 *times* that of the stringer plate of the strength deck. In no case, however, is the thickness to be less than that of the adjacent side shell plating.

304. Thickness of bottom shell plating

The thickness of bottom shell plating for the midship part is not to be less than that obtained from the following formula.

$$t = C_1 C_2 S \sqrt{d + 0.035L' + h_1} + 1.5 \quad \text{(mm)}$$

where:

S = spacing of transverse frames or longitudinals (m).

L', C_1, h_1 = as specified in **302.**

C_2 = coefficient given in **Table 3.4.2.**

Table 3.4.1 Coefficients C_1 and C_2

Framing	C_1	C_2
Transverse	$L \leq 230$ m : 1.0 $L \geq 400$ m : 1.07 For intermediate values of L, C_1 is to be obtained by linear interpolation	$91\sqrt{\dfrac{K}{576-\alpha^2K^2x^2}}$
Longitudinal		$13\sqrt{\dfrac{K}{24-\alpha Kx}}$ But, in no case is it to be less than $3.78\sqrt{K}$

α = either α_1 or α_2 according to value of y. However, value of α is not to be less than β.

$$\alpha_1 = 15.0 f_D\left(\frac{y-y_B}{Y'}\right) \quad y_B \leq y \qquad \alpha_2 = 15.0 f_B\left(\frac{y_B-y}{y_B}\right) \quad y_B > y$$

y_B = vertical distance from the top of keel at midship to the horizontal neutral axis of the athwartship section of hull (m).

y = distance(m) from the top of keel to the lower edge of plating when the platings under consideration are under y_B and to the upper edge of plating when the platings under consideration are above y_B, respectively.

Y' = the greater of the value specified in **Pt 3, Ch 3, 203.,** (5) (a) or (b)

β = coefficient determined according to values of L as specified below:

$\beta = 6/a$ when L is 230 m and under
$\beta = 10.5/a$ when L is 400 m and above

For intermediate values of L, β is to be obtained by liner interpolation.

a = $\sqrt{K}$ when high tensile steels are used for not less than 80 % of side shell plating at the transverse section amidship and 1.0 for other parts.

x = as given by the following formula.

$$x = \frac{X}{0.3L}$$

X = distance from the fore end to the part under consideration for the side shell plating afore the midship, or from the after end to the part under consideration for the side shell plating after the midship (m). Where, however, X is less than $0.1L$, X is to be taken as $0.1L$ and where X exceeds $0.3L$, X is to be taken as $0.3L$.

Table 3.4.2 Coefficient C_2

Framing	C_2
Transverse	$91\sqrt{\dfrac{K}{576-(15.0 f_B Kx)^2}}$
Longitudinal	$13\sqrt{\dfrac{K}{24-(15.0 f_B Kx)}}$ But, in no case is it to be less than $3.78\sqrt{K}$.
x = as specified in **Table 3.4.1**	

305. Bilge plates

1. The thickness of bilge plates is not to be less than that obtained from the following formula. However, it is not to be less than the thickness of the adjacent bottom plating.

$$t=\left\{5.22(d+0.035L')\left(R+\frac{a+b}{2}\right)^{\frac{3}{2}}l\right\}^{\frac{2}{5}}+1.5 \quad \text{(mm)}$$

where:

R = bilge radius (m). (see **Fig 3.4.1**)

a, b = distance from the lower and upper turns of bilge to the longitudinal frames nearest to the turns respectively, taking the distance outward from the bilge part as positive (m). Where, however, $(a+b)$ is negative, $(a+b)$ is to be taken as zero. (see **Fig 3.4.1**)

L' = as specified in **302.**

l = spacing of solid floors, bottom transverses or bilge brackets (m).

2. Where some of longitudinal frames at bilge part in longitudinal framing system is omitted, longitudinal frames are to be provided as near to the turns of bilge as practicable and suitably constructed to maintain the continuity of strength.

3. Where longitudinal frames are provided at bilge part at nearly the same spacing as that of bottom longitudinals, the bilge plates may be in accordance with the requirements in **304.** irrespective of the requirements in **Par 1.**

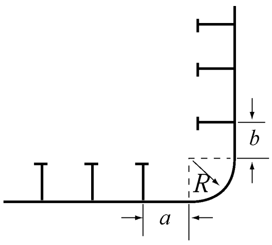


Fig 3.4.1 Measurement of *a* and *b*

Section 4 Special Requirements for Shell Plating

401. Large flared ship

With regard to the shell plating at a location where flare is specially large, sufficient consideration is to be paid to the reinforcement against panting impact, etc. at bow.

402. Shell plating stiffened in a spacing remarkably different from the frame spacing

Where the stiffener spacing measured along the shell plating supported by frames is remarkably different from the frame spacing, the shell plating is to be reinforced in consideration of the stiffener spacing, for example, by suitably increasing in thickness.

403. Aft part of ships with specially high power engines

With regard to the shell plating at the aft part of ships with specially high power engines compared with the ship length, sufficient consideration is to be paid to the reinforcement against vibration.

404. Strengthened bottom forward

1. The thickness of shell plating at the strengthened bottom forward in ships having the bow draught at the ballast condition is not to be less than that obtained from the formula given in **Table 3.4.3.**

Table 3.4.3 Thickness of shell plating at the strengthened bottom forward

Bow draft d_F	Thickness (mm)
$d_F \le 0.025L'$	$t = 0.9CS\sqrt{PK} + 1.5$
$d_F \ge 0.037L'$	$t = 1.34S\sqrt{L'K} + 1.5$

L' = as defined in **302.**
S = spacing of frames, girders or longitudinal shell stiffeners, whichever is the smallest (m).
P = slamming impact pressure specified in **Ch 7, 804.**
C = coefficient given in following formula.

$$C = \left(1.1 - 0.25\frac{S}{l}\right)^2$$

Where, however, $\frac{S}{l}$ is less than 0.4, C is to be taken as 1.0 and where $\frac{S}{l}$ is 1.0, C is to be taken as 0.72.
l = spacing of frames, girders or longitudinal shell stiffeners, whichever is greater (m).

NOTES:
In ships having intermediate value of the bow draught at the ballast condition specified in the above Table, the thickness is to be obtained by linear interpolation.

2. Notwithstanding the requirements in **Par 1,** in ships of which L and C_b are not more than 150 m and 0.7 respectively and $V/\sqrt{L}$ (kt/m) is 1.4 and over, the thickness of shell plating at the strengthened bottom forward is to be increased to a value deemed appropriate by the Society.

405. Spectacle bossings and stern frames

The thickness of shell plating fitted up on spectacle bossings and sternframes is not to be less than that obtained from the following formula. Where, however, the spacing of transverse frames in afterpeak exceeds 610 mm or the length of ship exceeds 200 m, the thickness of shell plating concerned is to be in accordance with the satisfaction of the Society.

$$t = 0.09L + 3.5 \quad \text{(mm)}$$

Section 5 Side Plating in way of Superstructure

501. Superstructure deck not designed as strength deck

Where the superstructure deck is not designed a strength deck, the thickness of superstructure side plating is not to be less than that obtained from the formula given in **Table 3.4.4,** but not less than 5.5 mm. Side plating of superstructures exceeding $0.15L$ in length, except at the end parts, is to be suitably increased in thickness.

Table 3.4.4 Thickness of superstructure side plating

Location	Thickness (mm)
For $0.25L$ from the fore end	$t = 1.15S\sqrt{KL} + 1.0$
Elsewhere	$t = 0.94S\sqrt{KL} + 1.0$
S = spacing of longitudinals or transverse frames (m).	

Section 6 Compensation at ends of Superstructure

601. Strengthening method

Breaks of superstructures are to be strengthened according to the following requirements:

(1) The sheer strakes of the strength deck, clear of the superstructure, are to be extended well into the superstructure and to be increased in thickness by not less than 20 % above the normal thickness of sheer strakes, for a distance well inside and outside the superstructure end.

(2) The side plating of the superstructure is to be tapered into upper deck sheer strakes to avoid abrupt change of the form at the breaks. The thickness of side plating at the superstructure end is to be increased approximately by 20 % above the normal thickness of superstructure side plating.

(3) For the breaks of superstructures located at fore and after end parts, the requirements in (1) and (2) may be suitably modified.

602. Openings in shell

Gangway ports, large freeing ports and other openings in the shell or bulwarks are to be kept well clear of the break. Where holes are necessarily provided in the plating near breaks, they are to be kept as small as possible and to be circular or oval in form.

Section 7 Local Compensation of Shell Plating

701. Openings in shell

All openings in the shell plating are to have well rounded corners and to be compensated as necessary.

702 Thickness of sea chest

In case where a sea chest is provided in the shell plating for sea suction or discharge the thickness of sea chest is not to be less than that obtained from the following formula and to be suitably stiffened so as to provide sufficient rigidity as necessary. The thickness, however, is not to be less than the thickness of shell plating where the sea chest is installed.

$$t = \sqrt{L} + 1.0 \quad \text{(mm)}$$

703. Location of openings

Openings for cargo ports, coaling ports, etc. are to be kept well clear of discontinuous parts in the hull construction, and they are to be locally compensated so as to maintain the longitudinal and transverse strengths of the hull.

704. Hawse pipes and the plating below

The shell plating fitted with hawse pipes and the plating below is to be increased in thickness or to be doubled, and their longitudinal seams are to be protected against damages by anchors or cables. ⚓

CHAPTER 5 DECKS

Section 1 General

101. Steel deck plating

Decks are to be plated from side to side of the ship except deck openings, etc. Decks, however, may be provided with only stringer plates and tie plates, subject to the approval by the Society.

102. Watertightness of decks

Weather decks are to be made watertight.

103. Continuity of steps of decks

Where strength deck or effective decks (the decks below the strength deck which are considered as strength members in the longitudinal strength of hull) change in level, the change is to be accomplished by gradually sloping, or each of structural members which form deck is to be extended, and is to be effectively tied together by diaphragms, girders, brackets, etc. and special care is to be taken for the continuity of strength.

104. Compensation for openings

Hatchways or other openings on strength or effective decks are to have well rounded corners, and compensation is to be suitably provided as necessary.

105. Rounded gunwales

Rounded gunwales, where adopted, are to have a sufficient radius for the thickness of plates.

Section 2 Effective Sectional Area of Strength Deck

201. Definition

The effective sectional area of strength deck is the sectional area, on each side of the ship's centre line, of steel plating, longitudinal beams, longitudinal girders, etc. extending for $0.5L$ amidships.

202. Effective sectional area of strength deck

1. The effective sectional area for the midship part is to be so determined as not to give less modulus of athwartship section of the hull specified in **Ch 3.**

2. Beyond the midship part, the effective sectional area may be gradually reduced, however, at $0.15L$ from each end it is not to be less than 40 % for ships with machinery amidship and 50 % for ships with machinery aft, of the area required for the midship part.

3. Where the section modulus of the hull at $0.15L$ from each end is calculated and approved by the Society, the requirements specified in **Par 2** may not be applied.

203. Strength deck beyond 0.15L from each end

Beyond $0.15L$ from each end, the effective sectional area and the thickness of strength deck may be gradually reduced avoiding abrupt change.

204. Long poop

Notwithstanding the requirements of **202.,** the effective sectional area of strength deck within long poop may be properly modified.

205. Superstructure deck designed as strength deck

Where the superstructure deck is designed as strength deck, the strength deck plating clear of the superstructure is to extend into the superstructure for about $0.05L$ without reducing the effective sectional area, and may be gradually reduced within.

Section 3 Deck Plating

301. Thickness

1. The thickness of deck plating is to be as specified in **Table 3.5.1,** however, within such enclosed spaces as superstructures, deckhouses, etc., the thickness may be reduced by 1 mm.

Table 3.5.1 Thickness of deck plating

<table>
<tr><th>Kind of deck</th><th>Location</th><th>Framing</th><th>Thickness (mm)</th></tr>
<tr><td rowspan="3">Strength deck</td><td rowspan="2">Outside the line of openings for the midship part</td><td>Longitudinal Systems</td><td>$t = 1.47SC\sqrt{Kh} + 1.5$</td></tr>
<tr><td>Transverse Systems</td><td>$t = 1.63SC\sqrt{Kh} + 1.5$</td></tr>
<tr><td>Elsewhere</td><td colspan="2" rowspan="2">$t = 1.25SC\sqrt{Kh} + 1.5$</td></tr>
<tr><td colspan="2">Other deck</td></tr>
<tr><td colspan="4">S = spacing of longitudinal or transverse beams.
C = coefficient obtained from the following formula:
$C = 0.905 + \frac{L'}{2430}$
L' = length of ship (m). Where, however, L is 230 m and under, L' is to be taken as 230 m, and where L is 400 m and above, L' is to be taken as 400 m.
h = deck load as specified in Ch 10, 201. (kN/m^2)</td></tr>
</table>

2. Where strength deck is transversely framed, or decks inside the line of openings are longitudinally framed, sufficient care is to be taken to prevent buckling of the deck plating.

302. Thickness of the top of tanks

The thickness of deck plating forming the top of tanks is not to be less than that required in **Ch 15, 208.** for deep tank bulkhead plating, taking the beam spacing as the stiffener spacing.

303. Thickness of the bulkhead recesses

The thickness of deck plating forming the top of shaft tunnels, thrust recesses or bulkhead recesses is not to be less than that required in **Ch 14, 309.** for watertight bulkhead plating, taking the beam spacing as the stiffener spacing.

304. Under boilers or refrigerated cargoes

1. The thickness of effective deck plating under boilers is to be increased by 3 mm above the normal thickness.

2. The thickness of deck plating under refrigerated cargoes is to be increased by 1 mm above the normal thickness. Where special means for the protection against the corrosion of the deck is provided, the thickness need not be increased.

305. Loaded by wheeled vehicles

The thickness of deck plating loaded by wheeled vehicles is to be determined by considering the concentrated loads from the wheeled vehicles.

306. Deck plating carrying unusual cargoes

The thickness of deck plating subjected to cargo loads which can not be treated as even distributed loads is to be determined taking account of load distribution for particular cargoes.

307. Deck plating for helicopter landing

Where decks for Helicopter taking off and landing are provided, the requirements are to be in accordance with the Guidance relating to the Rules.

Section 4 Wood Decks and Deck Compositions

401. Quality of wood planks

1. Planks of wooden decks are to be of good quality, thoroughly seasoned, free from rot, sap and shakes and reasonably free from bad knots.
2. Teaks and similar woods are treated as hard wood, and cedars and similar woods as soft wood.

402. Scantlings of wood planks

Hard wood planks are not to be less than 50 mm in thickness and soft wood planks not less than 63 mm. They are to be effectively arranged and fastened. For decks used for accommodation or navigation spaces, the thickness may be properly reduced.

403. Deck composition

The deck composition is to be non-destructive to steel, or to be effectively insulated from the steel by a suitable protecting covering. The composition is to be effectively laid on the deck so that the composition may not cause cracks, exfoliation, etc. ⚓

CHAPTER 6 SINGLE BOTTOMS

Section 1 General

101. Application

1. The requirements in this Chapter apply to the single bottoms of ships whose double bottom is omitted partially or wholly in accordance with the requirements in **Ch 7, 101. 2** or **3.**

2. The bottom constructions in way of fore and after peaks are to be in accordance with the requirements in **Ch 13, 201.** and **301.**

Section 2 Centre Keelsons

201. Arrangement and construction

All single bottom ships are to have centre keelsons composed of girder plates and rider plates, and the centre keelsons are to extend as far forward and afterward as practicable.

202. Centre girder plates

1. The thickness of continuous plates or intercostal plates of centre keelsons is not to be less than that obtained from the following formula. Beyond the midship part, the thickness may be gradually reduced and it may be 85 % of the midship value at the ends of the ship.

$t = 0.065L + 4.2$ (mm)

2. The girder plates are to extend to the top of floors.

203. Rider plates

The rider plates are to extend from the collision bulkhead to the aft peak bulkhead and the thickness is not to be less than that required for the continuous centreline plates amidships. The breadth of rider plates is not to be less than that obtained from the following formula or 400 mm whichever is the greater, and where it is more than 400 mm the breadth may be gradually reduced beyond the midship part to the ends where it may be 80 % of the required breadth or 400 mm, whichever is the greater.

$b = 16.6L - 200$ (mm)

204. Centre keelsons in boiler rooms

The thickness of the members forming the centre keelson is to be increased by 1.5 mm in boiler rooms.

Section 3 Side Keelsons

301. Arrangements

1. Side keelsons are to be so arranged that their spacing is not more than 2.15 m between the centre keelson and the lower turn of bilge.

2. At least one row of shell stiffener of proper size is to be provided within $0.4L$ amidships between the centre keelson and the side keelson, between the side keelsons, and between the side keelson and the lower turn of bilge.

3. In the space between the collision bulkhead and the position $0.05L$ after the strengthened bottom forward, the spacing of side keelsons is not to exceed 0.9 m.

302. Construction

Side keelsons are to be composed of intercostal plates and rider plates and are to be extended as far forward and aftward as practicable.

303 Intercostal plates

1. The thickness of intercostal plates of side keelson is not to be less than that given by the following formula for the midship part. Beyond the midship part, the thickness may be gradually reduced to 85 % at the ends of the ship.

$$t = 0.042L + 4.8 \quad \text{(mm)}$$

2. In the machinery room the thickness of intercostal plates is not to be less than that required for the continuous centreline plates in **202.**

304. Rider plates

The thickness of rider plates for side keelson is not to be less than that of the midship intercostal plates and the sectional area of rider plates in the midship part is not to be less than that obtained from the following formula. The sectional area may be gradually reduced to 90 % of the midship value at the ends of the ship.

$$A = 0.454L + 8.8 \quad (\text{cm}^2)$$

305. Side keelsons in boiler rooms

In the boiler rooms, the thickness of intercostal and rider plates is to be 1.5 mm greater than those required in **303.** and **304.** respectively.

Section 4 Floor Plates

401. Arrangements and scantlings

1. Floor plates are to be provided on every frame and the scantlings are not to be less than that obtained from the following formulae, but the thickness needs not exceed 12 mm.

Depth at the centre line: $d_0 = 62.5l$ (mm)

Thickness: $t = 0.01\,d_0 + 3$ (mm)

where:

l = span between the toes of frame brackets measured amidships plus 0.3 mm. Where curved floors are provided, the length l may be suitably modified. (See **Fig 3.6.1**)

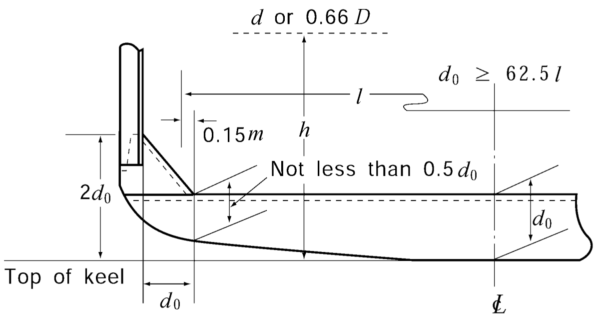


Fig 3.6.1 Shape of floors

2. Beyond $0.5L$ amidships, the thickness of floor plates may be gradually reduced and at the end parts of the ship it may be 0.90 times the value specified in **Par 1.** In the flat part of bottom forward, this reduction is not to be made.

3. Floors under engines and thrust seats are to be of ample depth and to be specially strengthened. Their thickness is not to be less than that of the continuous centre girder plates.

4. The thickness of floors under boilers is to be increased by at least 2 mm above the thickness of midship floors. Where boilers are less than 457 mm clear of the floors, the thickness is to be further increased. This requirement may, however, be modified if the boiler is remote from floor plates or if the boiler is of such a type as well prevent excessive heat to the structures in the vicinity.

402. Depth of floors

1. Upper edges of floor plates at any part are not to be below the level of upper edge at the centre line.

2. In the midship part, the depth of floors measured at a distance d_0 specified in **401. 1** from the inner edge of frames along the upper edge of floors, is not to be less than $0.5d_0$. Where frame brackets are provided, the depth of floors at the inner edge of brackets may be $0.5d_0$. (See **Fig 3.6.1**)

3. In ships having unusually large rise of floor, the depth of floor plates at the centre line is to be suitably increased.

403. Scantlings

1. Where face plates are fitted, the thickness of the face plate is not to be less than that required for the floor plate of that place. The sectional area of the face plates is not to be less than that given by the following formula:

$$A = 42.7\frac{Shl^2}{d_0} - \frac{d_0 t}{600} \quad (\text{cm}^2)$$

where:

l = as defined in **401.1.**

S = frame spacing (m).

h = d or $0.66D$, whichever is the greater (m).

d_0 = depth of floor plates at centre line (mm).

t = thickness of floor plates (mm).

2. Where the upper edge of floor plates is flanged, the breadth of flange is not to be less than that obtained from the following formula:

$$b = \frac{100A}{t} + 1.5t \quad \text{(mm)}$$

where:

A = sectional area of face plates defined in **Par 1.** (cm^2).

t = thickness of floor plates (mm).

3. The sectional areas of face plates are to be doubled for engine and boiler bearer floors. Flanging of floors at these parts is to be avoided.

404. Strengthened bottom forward

In the strengthening of bottom forward the floors are to be increased in their depth or the sectional areas of the face plates are to be doubled.

405. Frame brackets

The scantlings of frame brackets are to be determined in accordance with the requirements of the following. The free edge of the bracket is to be flanged.

(1) The height of the bracket measured from the top of keel is not to be less than twice the required depth of the floor plate at the centreline of the ship. (See **Fig 3.6.1**)

(2) The arm of the bracket measured along the upper edge of the floor plate from the inner edge of frame is not to be less than the depth of the floor plate required at the centreline of the ship. (See **Fig 3.6.1**)

(3) The thickness of frame brackets is not to be less than that of floor plates.

406. Drainage holes

Drainage holes are to be provided on the floor plates on both sides of the centreline and for ships with flat bottom also at the low parts of the turn of bilge.

407. Lightening holes

Lightening holes may be provided in floor plate. Where the holes are provided, appropriate strength compensation is to be made by increasing the floor depth or by some other suitable means.

408. Floor plates forming part of bulkheads

Floor plates forming part of bulkheads are to be in accordance with the requirements in **Chs 14** and **15.** ⚓

CHAPTER 7 DOUBLE BOTTOMS

Section 1 General

101. Application

1. Ships, in principle, are to be provided with double bottoms extending from the collision bulkhead to the after peak bulkhead. The longitudinal system of framing is, in general, to be adopted.

2. Where, for the structural configuration, hull form, purpose etc., it is desired to omit double bottom partially or wholly, the concerned parts to be calculated for flooding with the method as appropriate by the Society.

3. Double bottoms may be omitted in way of tanks of moderate size used exclusively for the carriage of liquids subject to the approval by the Society.

4. The scantlings of double bottom may be determined with the method as appropriate by the Society, in case of special construction such as having inclined side shell or double side shell, where longitudinal bulkheads are provided, or for the parts beyond the midship part.

5. The scantlings of members in double bottom tanks intended to be deep tanks are to be correspondingly in accordance with the requirements in **Ch 15.** However, the thickness of inner bottom plating needs not be increased by 1 mm as given **Ch 15, 208.** for the top plating of deep tanks.

6. The requirements in this Chapter are to be applied, where the apparent specific gravity of cargoes in the loaded hold, γ is 0.9 and under. The requirements in **Pt 7, Ch 3** are to be correspondingly applied, where γ is more than 0.9, or to the holds which are empty in fully loaded condition, or to the ships which are provided with bilge hoppers. However, the specific gravity of cargoes, γ, is to be as obtained from the following formula:

$$\gamma = \frac{W}{V} \quad (\text{t/m}^3)$$

where:

W = mass of cargoes for the hold (t)

V = volume of the hold excluding its hatchway (m^3)

7. Double bottom structure of holds is to be subjected to special consideration, where intended to carry heavy cargoes or where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40 or where cargo loads can not be treated as even distributed loads. Where the value of cargo weight per unit area as given in t/m^2, the value in kN/m^2 should be obtained from the product of the value in t/m^2 and 9.81.

102. Manholes and lightening holes

1. Manholes and lightening holes are to be provided in all non-watertight members to ensure access and ventilation except in way of pillars and where such openings are not permitted by the Rules. The size of holes should not in general exceed 50 % of the double bottom height, unless edge reinforcement is provided, and are to be shown in the plans submitted for approval. The edges of openings are to be made smooth.

2. Care is to be taken for locating the manholes in tank tops to avoid possibility of interconnection of main subdivision compartments through the double bottom so far as practicable.

3. Manhole covers in tank tops are to be of steel, and where no ceiling is provided in the cargo holds, the covers and their fittings are to be effectively protected against damages by cargoes.

103. Drainage

1. The bilge well in suitable size are to be provided for draining water which may gather on the double bottom.

2. The bottoms of bilge wells, except after the tunnel well, are to be situated at a distance of at least 460 mm from the top of keel.

3. The bilge well specified in **Par 2** are not to be formed by shell platings. Where, however, the bilge well are inevitably formed by shell platings due to the hull arrangements subject to the Society, the thickness of the shell platings forming of bilge well is to be increased by 2.5 mm to that of the adjacent shell plating.

104. Drain and air holes

Drain and air holes sufficient for the pumping rates are to be provided in all non-watertight members of the double bottom structure to give efficient passage of drain and air from all parts of the tank to the suction heads and air pipes.

105. Cofferdams

1. The following dedicated tanks are to be separated from adjacent tanks by cofferdams. However, these cofferdams may be omitted provided that the common boundaries of lubricating oil and fuel oil tank have full penetration welds.

(1) Fuel oil
(2) Lubricating oil
(3) Vegetable oil
(4) Fresh water

2. The cofferdams in **Par 1** are to be provided with the air pipes to comply with the requirements in **Pt 5, Ch 6, 201.** and with the manholes of adequate size which are well accessible.

106. Striking plates

Striking plates of adequate thickness or other approved arrangements are to be provided under sounding pipes to prevent from injuring the ship's bottom plating by striking of the sounding rod.

107. Strengthening under boilers

In the boiler room the thickness of structures in the tank under boilers are to be suitably increased. This requirement may, however, be modified if the boiler is remote from the tank top or if the boiler is of such a type as will prevent excessive heat to the structures in the vicinity.

108. Continuity of strength

1. Where the longitudinal system of framing is transformed into the transverse system, or the depth of double bottom changes suddenly, special care is to be taken for the continuity of strength by means of additional intercostal girders or floors.

2. In double bottoms under pillars or the toes of end brackets for bulkhead stiffeners, suitable reinforcement is to be provided by means of additional local side girders or floors.

109. Minimum thickness

No member of the double bottom structure is to be less than 6 mm in thickness.

Section 2 Centre Girders and Side Girders

201. Arrangement and construction

1. Centre girders are to be extended as far forward and afterward as practicable and centre girder plates are to be continuous for $0.5L$ amidships.

2. Where double bottoms are used for carriage of fuel oil or fresh water, the centre girders are to be watertight and may be suitably modified in narrow tanks at the end parts of the ship or where other watertight longitudinal girders are provided at about $0.25B$ from the centre line or where deemed appropriate by the Society.

3. Side girders in $0.5L$ amidships and aft are to be so arranged that the distance from the centre girder to the first side girder, between girders, or from the outermost girder to the margin plate does not exceed approximately 4.6 m and to extend as far afterwards as practicable.

4. In the strengthened bottom forward of ships, side girders and half-height girders are to be provided as required by **802.**

5. Adequate strengthening is to be made under main engines and thrust seatings by means of additional full or half-height girders.

202. Depth of centre girders

The depth of centre girders is not to be less than that obtained from the following formula unless specially approved by the Society.

$$d_0 = 62.5B \quad \text{(mm)}$$

203. Thickness

The thickness of centre girder plates and side girder plates is not to be less than that obtained from the following requirements (1) and (2), whichever is the greater:

(1) The thickness is to be obtained from the following formula depending on the location in the hold:

$$t = C_1 K \frac{SBd}{d_0 - d_1}\left(2.6\frac{x}{l_H} - 0.17\right) \times \left\{1 - 4\left(\frac{y}{B}\right)^2\right\} + 1.5 \quad \text{(mm)}$$

where:

S = distance between the centres of two adjacent spaces from the centre or side girder under consideration to the adjacent longitudinal girders or the line of toes of tank side brackets (m).

d_0 = depth of the centre or side girder under consideration (mm).

d_1 = depth of the opening at the point under consideration (mm).

l_H = length of the hold (m).

x = longitudinal distance between the centre of l_H of each hold and the point under consideration (m). Where, however, x is under 0.2 l_H, x is to be taken as 0.2 l_H, and where x is 0.45 l_H and over, x may be taken as 0.45 l_H.

y = transverse distance from the centre line of ship to the longitudinal girder (m).

C_1 = coefficient given by the following formulae Where, however B/l_H is 1.4 and over, B/l_H is to be taken as 1.4, and where B/l_H is under 0.4, B/l_H is to be taken as 0.4.

$$\text{Longitudinal framing : } C_1 = \frac{\left(3 - \frac{B}{l_H}\right)}{0.103}$$

$$\text{Transverse framing : } C_1 = \frac{\left(3 - \frac{B}{l_H}\right)}{0.09}$$

(2) The thickness is to be obtained from the following formula:

$$t_2 = \frac{C_1' d_0}{1000\sqrt{K}} + 1.5 \quad \text{(mm)}$$

where:

d_0 = depth of the girder at the point under con sideration (mm). Where, however, horizontal stiffeners are provided at the half way of the depth of girder, d_0 is the distance from the horizontal stiffener to the bottom shell plating or inner bottom plating or the distance between the horizontal stiffeners (mm).

C_1' = coefficient obtained from **Table 3.7.1** depending on S_1/d_0. For intermediate values of S_1/d_0, C_1' is to be obtained by linear interpolation.

S_1 = spacing of the brackets or stiffeners provided on the centre girders or the side girders (mm).

Table 3.7.1 Coefficient C_1'

S_1/d_0	C_1'	
	Centre girders	Side girders
0.3 and under	4.4	3.6
0.4	5.4	4.4
0.5	6.3	5.1
0.6	7.1	5.8
0.7	7.7	6.3
0.8	8.2	6.7
0.9	8.6	7.0
1.0	8.9	7.3
1.2	9.3	7.6
1.4	9.6	7.9
1.6 and over	9.7	8.0

204. Brackets

1. Where longitudinal framing system is adopted in the double bottom, transverse brackets are to be provided between the solid floors with a spacing not more than 1.75 m connecting the centre girder plates to the bottom shell plating as well as the adjacent bottom longitudinals. Where, however, the spacing of these brackets exceeds 1.25 m, additional stiffeners are to be provided on the centre girder plates.

2. The thickness of the brackets specified in **Par 1** is not to be less than that obtained from the following formula. However, it need not be greater than that of the solid floors at the same location.

$$t = 0.6\sqrt{L} + 1.5 \quad \text{(mm)}$$

3. The stiffener specified in **Par 1** is to be a flat bar having the same thickness as that of the girder plates and the depth not less than $0.08d_0$, where d_0 is the depth of centre girder in (mm) or equivalent thereto.

205. Thickness of half-height girders

The thickness of half-height girders is not to be less than that obtained from the formula specified in **204. 2.**

206. Vertical stiffeners and struts

1. Vertical stiffeners are to be provided to side girders at every open floor where the double bottom is framed transversely or at a suitable distance where the double bottom is framed longitudinally and vertical struts are to be provided on half-height girders at every open floor.

2. The vertical stiffeners required by the previous **Par 1** are to be a flat bar having the same thickness as that of the girder plates and the depth not less than $0.08d_0$ or the equivalent, where d_0 is the depth of the side girder at the point under consideration (m).

3. The sectional area of vertical struts required by **Par 1** is not to be less than that correspondingly in accordance with the requirements in **404.**

Section 3 Solid Floors

301. Arrangements

1. Solid floors are to be provided at a spacing not exceeding 3.5 m.

2. In addition to complying with the requirements in **Par 1,** solid floors are to be provided at the following locations:

(1) At every frame in the main engine room. Solid floors may, however, be provided at alternate frames outside the engine seatings, if the double bottom is framed longitudinally.
(2) Under thrust seatings and boiler bearers.
(3) Under transverse bulkheads.
(4) At the location specified in **803.** between the collision bulkhead and the after end of the strengthened bottom forward.
(5) Every frame where the height of double bottom changes.

3. Watertight floors are to be so arranged that the subdivision of the double bottom generally corresponds to that of the ship.

302. Thickness

The thickness of solid floors is not to be less than that obtained from the following requirements (1) and (2), whichever is the greater:

(1) The thickness is to be obtained from the following formula depending on the location in the hold:

$$t_1 = C_2 K \frac{SB'd}{d_0 - d_1}\left(\frac{2y}{B''}\right) + 1.5 \quad \text{(mm)}$$

where:

S = spacing of solid floors (m).

B' = distance between the lines of toes of tank side brackets at the top of inner bottom plating at the midship part (m).

B'' = distance between the lines of toes of tank side brackets at the top of inner bottom plating at the position of the solid floor (m).

y = transverse distance from the centre line to the point under consideration (m). Where, however, y is under $B''/4$, y is to be taken as $B''/4$, and where y is $B''/2$ and over, y may be taken as $B''/2$.

d_0 = depth of the solid floor at the point under consideration (mm).

d_1 = depth of the opening at the point under consideration (mm).

C_2 = coefficient obtained from **Table 3.7.2** depending on B/l_H.

l_H = length defined in **203.**

Table 3.7.2 Coefficient C_2

B/l_H		and above		0.4	0.6	0.8	1.0	1.2
		below	0.4	0.6	0.8	1.0	1.2	
C_2	Longitudinal framing		29	27	24	22	19	17
	Transverse framing	Where solid floors are provided at every frame	29	27	24	22	19	17
		Elsewhere	20	19	17	15	13	12

(2) The thickness is to be obtained from the following formula depending on the location in the hold:

$$t_2 = 0.086\sqrt[3]{\frac{H^2 d_0^2}{C_2' K}(t_1 - 1.5)} + 1.5 \quad \text{(mm)}$$

where:

t_1 = thickness obtained from the requirement in Sub-paragraph (1).

d_0 = depth defined in Sub-paragraph (1).

C_2' = coefficient given in **Table 3.7.3** depending on the ratio of the spacing of stiffeners S_1 (mm) to d_0.

H = value obtained from **Table 3.7.4.**

Table 3.7.3 Coefficient C_2'

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7
For intermediate values of S_1/d_0, the value of C_2' is to be determined by linear interpolation										

Table 3.7.4 Value of H

Case	H
(a) Where slots are provided on solid floors without reinforcement	$\sqrt{4.0\frac{d_1}{S_1}} - 1.0$ but, where d_1/S_1 is 0.5 and under, H is to be 1.0.
(b) Where openings are provided on solid floors without reinforcement	$0.5\frac{\phi}{d_0}+1$
(c) Where slots and openings are provided on solid floors without reinforcement	Product of the values given by (a) and (b)
(d) Except where (a), (b) and (c) are applied	1.0
d_1 = depth of slot without reinforcement provided at the upper and lower parts of solid floors, whichever is the greater (mm). ϕ = major diameter of the openings (mm).	

303. Vertical stiffeners

Vertical stiffeners are to be provided on the solid floors at a suitable spacing in case of the double bottom framed transversely, and at every longitudinal in case of the double bottom framed longitudinally. The vertical stiffener is to be a flat bar having the same thickness as that of the floor plate and the depth not less than $0.08d_0$ or the equivalent, where d_0 is the depth of the floor at the point under consideration (mm).

Section 4 Bottom Longitudinals

401. Construction

Longitudinals are to be continuous through floors or to be attached to floors by brackets so as to effectively develop the resistance to tension and bending.

402. Spacing

The standard spacing of longitudinals is obtained from the following formula, but it is recommended not to exceed 1 m.

$$S = 2L + 550 \quad \text{(mm)}$$

403. Section modulus

1. The section modulus of bottom longitudinals is not to be less than that obtained from the following formula:

$$Z_b = \frac{CKSl^2}{24 - 15.0 f_B K}(d + 0.026L') \quad (\text{cm}^3)$$

where:

C = coefficient given in **Table 3.7.5.**

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.

l = spacing of solid floors (m).

S = spacing of longitudinals (m).

Table 3.7.5 Coefficient C

Case		C
In case where no strut specified in **404.** is provided midway between floors		100
In case where a strut specified in **404,** is provided midway between floors	Lower part of deep tanks	62.5
	Elsewhere	50
NOTE: Where, however, the width of vertical stiffeners provided on floors and that of struts are specially large, the coefficient may be properly reduced.		

2. The section modulus of inner bottom longitudinals is not to be less than that obtained from the following formula. However, the section modulus of inner bottom longitudinals is not to be less than 0.75 times that of the bottom longitudinals as specified in **Par 1** at the same location.

$$Z_i = \frac{CKShl^2}{24 - 11.4 f_B K} \quad (\text{cm}^3)$$

where:

C = coefficient obtained from **Table 3.7.6.**

l, S = as specified in **Par 1.**

h = vertical distance from the top of inner bottom plating to the lowest deck at centre line (m). Where, however, the cargo is carried exceeding the lowest deck, h is to be taken from the top of inner bottom plating to the deck just above the top of cargo at centre line.

Table 3.7.6 Coefficient C

Case	C
In case where no strut specified in **404.** is provided midway between floors	90
In case where a strut specified in **404,** is provided midway between floors	54
NOTE: Where, however, the width of vertical stiffeners provided on floors and that of struts are specially large, the coefficient may be properly reduced.	

404. Vertical struts

1. Vertical struts are to be rolled sections other than flat bars or bulb plates and to be well overlapped with the webs of bottom and inner bottom longitudinals.

2. The sectional area of the above-mentioned vertical struts is not to be less than that obtained from the following formula:

$$A = 1.8CKSbh \quad (\text{cm}^2)$$

where:

S = spacing of longitudinals (m).

b = breadth of the area supported by the strut (m).

h = as obtained from the following formula (m). In no case is h to be less than d.

$$h = \frac{d + 0.026L' + h_i}{2}$$

L' = as specified in **403.1.**

h_i = 0.9 times the value of h specified in **403. 2.** (m). However, under deep tanks, h is not to be less than the vertical distance from the upper surface of inner bottom to the midpoint between the top of overflow pipe and the top of inner bottom or 0.7 times the vertical distance from the upper surface of inner bottom to the point of 2.0 m above the top of overflow pipe, whichever is the greater (m).

C = coefficient obtained from the following formula. In no case is the value of coefficient to be less than 1.43.

$$C = \frac{1}{1 - 0.5\frac{l_s}{\sqrt{K}k}}$$

l_s = length of struts (m).

k = minimum radius of gyration of struts obtained from the following formula (cm).

$$k = \sqrt{\frac{I}{A}}$$

I = the least moment of inertia of the struts (cm^4).

A = sectional area of the struts (cm^2).

Section 5 Inner Bottom Plating, Margin Plates and Bottom Shell Plating

501. Thickness of inner bottom plating

1. The thickness of inner bottom plating is not to be less than that obtained from the following formula, whichever is the greater:

$$t_1 = \frac{CKB^2d}{d_0} + 1.5 \quad \text{(mm)}$$

$$t_2 = C'S\sqrt{hK} + 1.5 \quad \text{(mm)}$$

where:

d_0 = height of centre girders (mm).

S = spacing of inner bottom longitudinals for longitudinal framing or frame spacing for transverse framing (m).

h = as specified in **403. 2.**

C = coefficient obtained from **Table 3.7.7.**

C' = coefficient obtained from **Table 3.7.8.**

2. Where cargoes whose specific gravity is especially low are carried, the thickness of inner bottom plating may be suitably modified.

3. The thickness of inner bottom plating under hatchway, where no ceiling is provided, is to be increased by 2 mm above that obtained from the second formula in **Par 1** or that specified in **101. 5,** whichever is the greater, except where the provision in **Par 4** is applied.

4. In ships in which cargoes are handled by grabs or similar mechanical appliances, the thickness of inner bottom plating is to be increased by 2.5 mm above that specified in **Par 1** or in **101. 5,** whichever is the greater, except where ceiling is provided.

5. The thickness of inner bottom plating in main engine room is to be increased by 2 mm above that specified in **Par 1** or in **101. 5,** whichever is the greater.

502. Thickness of margin plates

The thickness of margin plates is to be increased by 1.5 mm above that obtained from the second formula in **501.** However, the thickness of margin plates is not to be less than that of the inner bottom plating at the location.

503. Arrangements of margin plates

1. It is recommended that the margin plates are to be of sufficient height to protect the bottom up to the turn of bilge and for forward $0.2L$ from the stem the margin plates are to extend to the ship' s sides horizontally as far as practicable.

2. Margin plates are to be of adequate breadth and to extend well inside from the line of toes of tank side brackets.

504. Margin brackets

1. Where the double bottom is framed longitudinally, transverse brackets are to be provided at every hold frame extending from the margin plate to the adjacent bottom and inner bottom longitudinals.

2. The thickness of brackets specified in **Par 1** is not to be less than that obtained from the formula in **204. 2** and free edges are to be strengthened by flanging or other suitable method.

505. Bottom shell plating

The thickness of bottom shell plating of cargo holds in way of double bottom is not to be less than that obtained from the formula in **Ch 4, 304.** or from the first formula in **501. 1,** whichever is the greater. However, in application of the latter formula, α is to be as given by the following formula:

$$\alpha = \frac{13.8}{24 - 15.0 f_B K}$$

Table 3.7.7 Coefficient C

$\frac{B}{l_H}$	C
$\frac{B}{l_H} < 0.8$	b_0
$0.8 \le \frac{B}{l_H} < 1.2$	b_0 or αb_1, whichever is the greater
$1.2 \le \frac{B}{l_H}$	αb_1

l_H = as specified in **203.**
α = as given by the following formula.

$$\alpha = \frac{13.8}{24 - 10.6 f_B K}$$

b_0, b_1 = as given by the following table according to the value of B/l_H. However, for transverse framing, b_1 is to be **1.1** times the value given in this Table.

$\frac{B}{l_H}$	b_0	b_1
$\frac{B}{l_H} < 0.4$	4.4	—
$0.4 \le \frac{B}{l_H} < 0.6$	3.9	—
$0.6 \le \frac{B}{l_H} < 0.8$	3.3	—
$0.8 \le \frac{B}{l_H} < 1.0$	2.2	2.2
$1.0 \le \frac{B}{l_H} < 1.2$	1.6	2.1
$1.2 \le \frac{B}{l_H} < 1.4$	—	1.9
$1.4 \le \frac{B}{l_H} < 1.6$	—	1.7
$1.6 \le \frac{B}{l_H}$	—	1.4

Tabie 3.7.8 Coefficient C'

$\frac{l}{S}$	C'
$1.0 \le \frac{l}{S} < 3.5$	$0.43\frac{l}{S} + 2.5$
$3.5 \le \frac{l}{S}$	4.0

l = distance between floors for longitudinal framing or distance between girders for transverse framing (m).

Section 6 Hold Frame Brackets

601. Thickness and scantlings

1. The thickness of brackets connecting hold frames to margin plates is to be increased by 1.5 mm above that obtained from the formula in **204. 2.** The free edges of brackets are to be flanged.

2. Where the shape of ship requires exceptionally long brackets, the thickness of brackets is to be increased or additional stiffness is to be provided by fitting angles longitudinally across the top of flanges, or by other suitable means.

602. Gusset plates

Hold frame brackets and margin plates are to be connected by gusset plates of the same thickness as the margin plates. The gusset plates may be omitted where deemed dispensable in relation to structural arrangements.

Section 7 Open Floors

701. Arrangement

Where the double bottom is framed transversely, open floors composed of brackets fitted at centre girder and margin plate, and main frames and reverse frames are to be provided at every hold frame between solid floors.

702. Main frames

The section modulus of main frames is not to be less than that obtained from the following formula:

$$Z_b = CKShl^2 \quad (\text{cm}^3)$$

where:

l = distance between the brackets attached to the centre girder and the margin plate (m). Where side girders are provided, l is the greatest distance among the distances between the vertical stiffeners on side girders and brackets. (See **Fig 3.7.1**).

S = spacing of frames (m).

h = $d+0.026L$ (m)

L' = as specified in **403. 1.**

C = coefficient given in **Table 3.7.9.**

703. Reversed frames

The section modulus of reverse frames is not to be less than that obtained from the following formula:

$$Z_i = C'KShl^2 \quad (\text{cm}^3)$$

where:

l, S = as specified in **702.**

h = as specified in **403. 2.**

C' = coefficient given in **Table 3.7.10.**

Table 3.7.9 Coefficient C

Case		C
In case where no vertical strut specified in **705.** is provided		6.67
In case where vertical struts specified in **705.** are provided	For holds which are used as deep tanks	4.17
	For holds which become empty in the full load condition	
	Elsewhere	3.33

Table 3.7.10 Coefficient C'

Case	C'
In case where no vertical strut specified in **705.** is provided	6.0
In case where vertical struts specified in **705.**. are provided	3.6

704. Brackets

1. Frames and reverse frames are to be connected to the centre girder and margin plates by brackets of not less than thickness obtained from the formula in **204. 2.**

2. The breadth of brackets specified in **Par 1** is not to be less than $0.05B$ and the brackets are to be well overlapped with frames and reverse frames. The free edges of brackets are to be flanged.

705. Struts

Vertical struts are to be rolled sections other than flat bars or bulb plates and to be well overlapped with the frames and reverse frames. The sectional area of the struts is to be in accordance with the requirements of **404.**

Section 8 Construction of Strengthened Bottom Forward

801. Application

1. In ships having bow draught under $0.037L'$ at the ballast condition, the construction of strengthened bottom forward is to be in accordance with the requirements of this Section, where L' is as defined in **403. 1.**

2. In ships having unusually small draught in the ballast condition and having specially high speed length ratio, special consideration is to be paid to the construction of strengthened bottom forward.

3. In ships having bow draught not less than $0.037L'$ at the ballast condition, the construction of strengthened bottom forward may be as specified in **Sec. 2** to **4.**

802. Definition

1. The strengthened bottom forward is the part of the ship's bottom up to a height of $0.05d_F$(d_F : Bow draught at the ballast condition) from the top of keel at forward from the position specified in **Table 3.7.11.**

Table 3.7.11 Range of strengthened bottom forward

$V/\sqrt{L}\,(=a)$	Position(from Fore Perpendicular)
$a \leq 1.1$	$0.15L$
$1.1 < a \leq 1.25$ $1.25 < a \leq 1.4$	$0.175L$ $0.2L$
$1.4 < a \leq 1.5$ $1.5 < a \leq 1.6$	$0.225L$ $0.25L$
$1.6 < a \leq 1.7$ $1.7 < a$	$0.275L$ $0.3L$

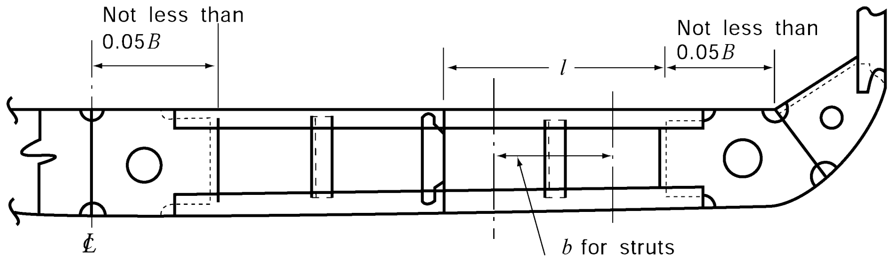


Fig 3.7.1 Open floors

2. Notwithstanding the requirement in **Par 1,** in case of ships of which C_b and especially small, the ships of which the draft in the ballast condition are especially small, and so on, the extent of the strengthened bottom forward is to be extended up to the satisfaction of the Society.

803. Construction

1. Between the collision bulkhead and $0.05L$ abaft the aft end of strengthened bottom forward, side girders are to be provided with a spacing not more than 2.3 m. Where transverse framing system is adopted between the collision bulkhead and $0.025L$ abaft the aft end of strengthened bottom forward, half height girders or longitudinal shell stiffeners are to be provided between the side girders.

2. Between the collision bulkhead and the aft end of strengthened bottom forward, solid floors are to be provided at every frame in transverse framing system, and at alternate frames in longitudinal framing system.

3. The solid floors are to be strengthened by fitting vertical stiffeners in way of half-height girders or longitudinal shell stiffeners except where the shell stiffeners are spaced considerably close and the solid floors are adequately strengthened, the vertical stiffeners may be provided on alternate shell stiffeners.

4. In ships having bow draught more than $0.025L'$ but less than $0.037L'$ at the ballast condition, where the construction and arrangement of strengthened bottom forward are impracticable to comply with each above mentioned requirement, suitable compensation is to be provided for floors and side girders.

804. Scantlings

1. In ships having bow draught not more than $0.025L'$ at the ballast condition, the section modulus of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward is not to be less than that obtained from the following formula:

$$Z = 0.53\,KCPal^2 \quad (\text{cm}^3)$$

where:

l = spacing of solid floors (m).

a = $0.774l$. Where, however, the spacing of longitudinal shell stiffeners or bottom longitudinals in not more than 0.774 l, a is to be taken as the spacing.

C = coefficient obtained from the following formula:

$$C = \frac{L}{1.9L - 45d_F}$$

Where, however, C is 1.0 or over, C is to be taken as 1.0.

P = slamming impact pressure obtained from the following formula:

$$P = 2.48 \times \frac{LC_1C_2C_3C_4}{\beta} \quad \text{(kPa)}$$

C_1 = coefficient given in **Table 3.7.12.** For intermediate values of $V/\sqrt{L}$, C_1 is to be obtained by linear interpolation.

C_2 = coefficient given in **Table 3.7.13.**

C_3 = coefficient given in the following value.

$C_3 = 1.0$, when x is x_1 and above.

$C_3 = 0.5 + \frac{0.5x}{x_1}$, when x is less than x_1.

x = longitudinal distance from F.P. to cross section considered (m)

x_1 = as given in the following value.

x_1 = $0.1L$ (m), when C_b is less than 0.7.

x_1 = $(0.1 - 0.5(C_b - 0.7)L$ (m), where C_b is greater than 0.7 and less than 0.8.

x_1 = $0.05L$(m), when C_b is 0.8 and above.

C_4 = coefficient obtained from the following formula:

$$C_4 = 1.9 - 0.9\left(\frac{d_F}{0.02L}\right)$$

Where, however, C_4 is less than 1.0, C_4 is to be taken as 1.0.

d_F = bow draught at the ballast condition.

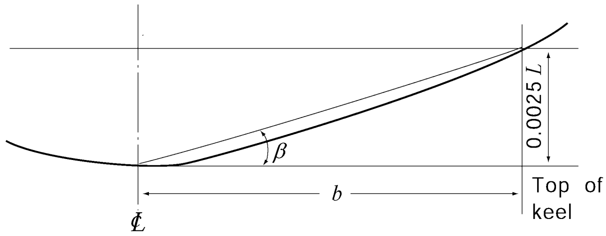
β = slope of the ship's bottom obtained from the following formula, but C_2/β need not be taken as greater than 11.43.

$$\beta = \frac{0.0025L}{b}$$

b = horizontal distance measured at the station 0.2L from the stem, from the center line of ship to the intersection of the horizontal line 0.0025L above the top of keel with the shell plating(m). (See **Fig 3.7.2**)

β = slope of the ship's bottom obtained from the following formula, but C_2/β need not be taken as greater than 11.43.

b = horizontal distance measured at the station $0.2L$ from the stem, from the centre line of ship to the intersection of the horizontal line $0.0025L$ above the top of keel with the shell plating (m). (See **Fig 3.7.2**)



(Hull section at the station $0.2L$ from the stem)

Fig 3.7.2 Measurement of *b*

Table 3.7.12 Value of C_1

$\frac{V}{\sqrt{L}}$	1.0 and under	1.1	1.2	1.3	1.4	1.5 and above
C_1	0.12	0.18	0.23	0.26	0.28	0.29

Table 3.7.13 Value of C_2

$\frac{V}{\sqrt{L}}$	less than 0.9	greater than 0.9 and less than 1.3	1.3 and above
C_2	0.333	$0.667\frac{V}{\sqrt{L}} - 0.267$	$1.5\frac{V}{\sqrt{L}} - 1.35$

2. In ships having bow draught more than $0.0025\,L$ but less than $0.037\,L'$ at the ballast condition, the section modulus of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward is to be obtained by linear interpolation from the values given by the requirements in **Par 1** and **Sec 4.** ⫝

CHAPTER 8 FRAMES

Section 1 General

101. Application

The requirements in this Chapter apply to ships having transverse strength due to bulkheads not less effective than that specified in **Ch 14.** Where the transverse strength due to bulkheads is less effective, additional stiffening is to be made by means of increasing the scantlings of frames, the number of web frames, etc.

102. Frames in way of deep tanks

The strength of frames in way of deep tanks are not to be less than those required for stiffeners on deep tank bulkheads.

103. Frames in way of tank tops

Frames are not to extend through tops of tanks, unless the effective watertight or oiltight arrangements are specially submitted and approved.

104. Increase of scantlings due to holes

Where large holes are cut in the webs of frames or holes are cut in the flanges of frames, the scantlings of the frames are to be appropriately increased.

105. Frames in boiler spaces and in way of bossing

1. In boiler spaces, the scantlings of frames and side stringers are to be appropriately increased.

2. The construction and scantlings of frames in way of bossing are to be to the satisfaction of the Society.

106. Frames and stringers fitted up at extremely small angles

Where the angle between the web of frames and shell plating is extremely small, the scantlings of frames are to be suitably increased above the normal requirements and where necessary, appropriate supports are to be provided to prevent tripping.

107. Lower end construction of frames

Thorough considerations are to be given to stress concentration, etc. at lower end construction of frames.

108. Frames at a location where flare is specially large

The transverse frames, side longitudinals and web frames supporting side longitudinals, which are fitted in the bow flare position considered to endure large wave impact pressure, are to be properly strengthened taking care of the effectiveness of their end connections.

109. Direct strength calculation

Where approved by the Society, the scantlings of frames may be determined basing upon direct strength calculation as specified in **Ch 1, 206.**

Section 2 Frame Spacing

201. Transverse frame spacing

1. The standard spacing of transverse frames is obtained from the following formula:

$S = 2L + 450$ (mm)

2. Transverse frame spacing in peaks or cruiser sterns is not to exceed 610 mm.

3. Transverse frame spacing between 0.2L from the fore end and the collision bulkhead is not to exceed 700 mm or the standard spacing specified in **Par 1,** whichever is the smaller.

4. The requirements in **Par 2** and **3** may be modified, where structural arrangement or scantlings are suitably considered.

202. Longitudinal frame spacing

The standard spacing of longitudinal frames is obtained from the following formula:

$S = 2L + 550$ (mm)

203. Maximum frame spacing

Frame spacing is recommended not to exceed 1 m.

204. Consideration for frame spacing exceeding the standard

Where the spacing of frames is equal to or above the spacing of 250 mm greater than the standard spacing in **201.** and **202.,** the scantlings and structural arrangement of single and double bottoms and of other relevant structures are to be specially considered.

Section 3 Hold Frames

301. Application

1. The transverse hold frame is the frame provided below the lowest deck from the collision bulkhead to the aft peak bulkhead, including the machinery space.

2. The provisions in **302.** to **304.** are applicable to the transverse hold frames of ordinary construction.

3. The transverse hold frames of ships which have hopper side tanks, top side tanks, or which have a special construction such as inner hulls, will be specially considered.

4. Special considerations are to be given to the scantlings of transverse hold frames, where the specific gravity of cargoes γ defined in **Ch 7, 101. 7** in the loaded hold exceeds 0.9.

302. Scantlings of transverse hold frames

1. The section modulus of transverse hold frames is not to be than that obtained from **Table 3.8.1.**

2. Where the depth of double bottom centre girder is less than $B/16$, the scantlings of frames are to be suitably increased.

3. Where long hatchways or multi-row hatchways are provided on the deck at the top of frames, special considerations are to be given to the scantlings of transverse hold frames and their upper end construction of frames.

303. Hold frames supported by web frames and side stringers

1. Where transverse hold frames are supported by web frames and side stringers specified in **Ch 9,** the section modulus of frames is not to be less than that obtained from the following formula:

$$Z = C_0 CKShl^2 \quad (\mathrm{cm}^3)$$

where:

S = spacing of frames (m).

h = as specified in **302. 1.**

l = vertical distance from the top of inner bottom plate at side to the line of the lowest side stringers (m) and it is to be measured at the measuring point for l stipulated in **301. 1.** Where this distance is less than 2 m, l is to be 1 m greater than one half of the distance. (See **Fig 3.8.1** and **3.8.2** (c))

C_0 = coefficient given in **Table 3.8.2.**

C = as obtained from the following formula, but to be taken as 1.0, where C is less than 1.0.

$$C = \left\{ \alpha_1 \left(3 - \frac{l_2}{l} \right) - \alpha_2 \frac{e}{l} \right\} C_4$$

l_2 = vertical distance at side from the lowest side stringer to the one immediately above or to the deck (m). (See **Fig 3.8.2.** (c)).

e = height of the lower bracket measured from the lower end of l, where, however, this height exceeds 0.25 l, e is to be taken as $0.25l$ (m). (See **Fig 3.8.2** (c))

α_1, α_2 = as given in **Table 3.8.3.**

C_4 = as obtained from the following formula, but to be taken as 1.0, where C_4 is less than 1.0, and as 2.2 where C_4 exceeds 2.2.

$$C_4 = 2\frac{H}{H_0} - 1.5$$

H_0 = vertical distance from the top of inner bottom plate at side to the lowest deck (m). (See **Fig 3.8.2** (c))

H = vertical distance from the lower end of H_0 to the freeboard deck at side (m). (See **Fig 3.8.2** (c))

2. The difference between any two adjacent unsupported spans of the frames in the preceding paragraph is not to be more than 25 % nor is it to be more than 50 % between the largest and smallest spans in case of more than two stringers.

3. Where the height of lower brackets of frames is less than 0.05 times l specified in **Par 1,** special considerations are to be given to the scantlings of transverse hold frames and their lower end construction of frames.

Table 3.8.1 Section modulus

Location	Section modulus (cm^3)
(1) Between $0.15L$ from the fore end and the after peak bulkhead	$Z = KC_0 CShl^2$
(2) Between $0.15L$ from the fore end and the collision bulkhead	$Z = 1.3C_0 CShl^2$
(3) For the frames under deck transverse supporting deck longitudinals	$Z = 2.4Kn\left\{0.17 + \frac{1}{9.81}\frac{h_1}{h}\left(\frac{l_1}{l}\right)^2 - 0.1\frac{l}{h}\right\}Shl^2$

S = frame spacing (m).

l = vertical distance from the top of inner bottom plating at side to the top of deck beams above the frames (m). For frames abaft $0.25L$ from the fore end, l is to be measured at midship. For frames between $0.25L$ and $0.15L$ from the fore end, l is to be measured at $0.25L$ from the fore end. For frames provided to the shell with a remarkable flare, l is to be the unsupported length of frames. Where the length of frames is markedly different from that measured at the aforementioned place on account of discontinuity in the lowest deck or change in the height of double bottom, lines extended from the lowest deck or the top of double bottom in parallel with the upper deck or keel respectively are to be taken as the lowest deck or double bottom top and l is to be measured at the corresponding place of measurement. (see **Fig 3.8.1** and **Fig 3.8.2**).

h = vertical distance from the lower end of l at the place of measurement to a point of $d + 0.038L'$ above the top of keel (m). (see **Fig 3.8.2**).

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.

C_0 = coefficient obtained from the following formula, but not to be less than 0.85.

$$C_0 = 1.25 - 2\frac{e}{l}$$

e = height of the tank side bracket measured from the lower end of l (m).

n = ratio of the deck transverse spacing to the frame spacing.

h_1 = deck load stipulated in **Ch 10, Sec 2** for the deck transverse at the top of frame (kN/m^2).

l_1 = total length of the transverse web beam (m). (see **Fig 3.8.2** (a)).

C = coefficient obtained from the following formula:

$$C = C_1 + C_2$$

Framing systems	C_1	C_2
For ordinary framing systems without top side tanks	$2.1 - 1.2\frac{l}{h}$	$0.022 - k\alpha\frac{d}{h}$
For framing systems with top side tanks	$3.4 - 2.4\frac{l}{h}$	$0.27\alpha\frac{d}{h}$ (*1)

(*1) Where B/l exceeds 4.0, the value of C_2 is to be suitably increased.

α = coefficient given in the following table. For intermediate values of B/l_H, α is to be obtained by linear interpolation.

l_H = length of hold (m)

B/l_H	0.5 and under	0.6	0.8	1.0	1.2	1.4 and over
α	2.3	1.8	1.0	0.6	0.34	0.2

k = coefficient given in the following table according to the number of layers of deck:

No. of layers of deck	k	Value of B/l (*2)
For single deck systems	13	2.8
For double deck systems	21	4.2
For triple deck systems	50	5.0

(*2) Where B/l exceeds the value given in the above table according to the deck systems, the value of k is to be suitably increased:

NOTE:
Where the ratio of the depth of frame to the length measured from the deck at the top of frame to the toe of lower bracket is less than 1/24 and 1/22 in case of the frame prescribed in line (1) and of that in line (2) respectively, the scantlings of such frames are to be suitably increased.

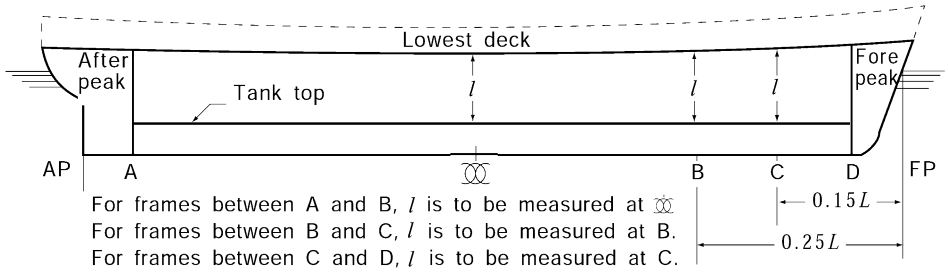


Fig 3.8.1 Measuring points of l for hold frames

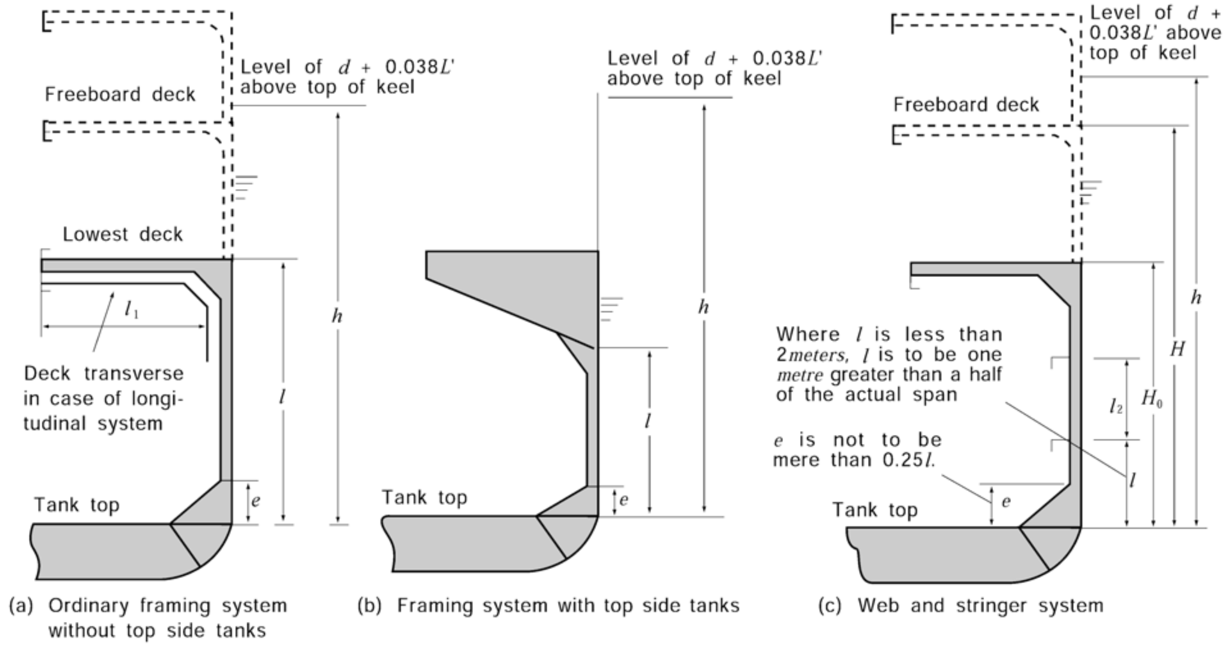


Fig 3.8.2 Measurement of $l, h, H,$ etc.

Table 3.8.2 Coefficient C_0

Location of frames	C_0
Between 0.15L from the fore end and the after peak bulkhead	2.1
Between 0.15L from the fore end and the collision bulkhead	3.2

Table 3.8.3 Values of α_1 and α_2

Nos. of side stringers provided below the lowest deck	α_1	α_2
1	0.75	2.0
2	0.90	1.8
3 and more	1.25	1.3

304. Connection

1. Transverse hold frames are to be overlapped with tank side brackets by at least 1.5 times the depth of frame sections and are to be effectively connected thereto.

2. The upper ends of transverse hold frames are to be effectively connected by brackets with the deck and deck beams, and where the deck at the top of frames is longitudinally framed, the upper end brackets are to be extended and connected to the deck longitudinals adjacent to the frames.

Section 4 Side Longitudinals

401. Section modulus

The section modulus of side longitudinals in the midship part below the freeboard deck is not to be less than that obtained from the following formula, whichever is the greater:

$Z_1 = 100CShl^2$ (cm^3), $Z_2 = 2.9K\sqrt{L}Sl^2$ (cm^3)

where:

S = spacing of longitudinals (m).

l = distance between the web frames or between the transverse bulkhead and the web frame including the length of connection (m).

h = vertical distance from the side longitudinal concerned to a point $d+0.038L'$ above the top of keel (m).

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.

C = coefficient given by the following formula:

$$C = \frac{K}{24-\alpha K}$$

α = either α_1 or α_2 according to value of y. However, value of α is not to be less than β.

$$\alpha_1 = 15.0 f_D\left(\frac{y-y_B}{Y'}\right) \quad \text{for} \quad y \geq y_B, \qquad \alpha_2 = 15.0 f_B\left(\frac{y_B-y}{Y_B}\right) \quad \text{for} \quad y < y_B$$

β = coefficient determined according to value of L as specified below:

$\beta = 6/a$ when L is 230 m and under

$\beta = 10.5/a$ when L is 400 m and above

For intermediate values of L, β is to be obtained by linear interpolation.

Y' = the greater of the value specified in **Pt 3, Ch 3, 203.,** (5) (a) or (b)

a = $\sqrt{K}$, when high tensile steels are used for not less than 80 % of side shell platings at the transverse section amidship and 1.0 for other parts.

2. Beyond the midship part, the section modulus of side longitudinals may be gradually reduced towards the ends of ships, and may be 0.85 times that obtained from the formula in **Par 1** at the ends. However, the section modulus of side longitudinals between 0.15L from the fore end and the collision bulkhead is not to be less than that obtained from the formula in **Par 1.**

3. The depth of flat bars used for longitudinals is not to exceed 15 times the thickness of flat bars.

4. Side longitudinals on sheer strakes in the midship part are to be, as far as possible, of slenderness ratio not greater than 60.

5. The section modulus of bilge longitudinals need not exceed that of bottom longitudinals.

402. Attachment

1. Side longitudinals are to be continuous at transverse bulkheads or to be attached thereto by brackets so as to provide adequate fixity and continuity of longitudinal strength.

2. Webs of longitudinals and web frames are to be attached to each other.

Section 5 Tween Deck Frames

501. General

The scantlings of tween deck frames are based on the standard structural arrangement which the maintenance of general transverse stiffness is kept by means of efficient tween deck bulkheads provided above the hold bulkheads or by web frames extended to the tops of superstructures at proper intervals. Tween deck frames are to be considered in relation to hold frames and care is to be given to the maintenance of continuity of strength in the framing from the bottom to the top of hull.

502. Scantlings of tween deck frames

The section modulus of tween deck frames is not to be less than that obtained from **Table 3.8.4.**

503. Special care to tween deck frames

1. Care is to be taken so that the strength and stiffness of framing at the ends of ship may be increased in proportion to the actual unsupported length of frame as well as the vertical height of tween decks.

2. In ships having specially large freeboard, the scantlings of tween deck frames may be properly reduced.

504. Superstructure frames

1. Superstructure frames are to be provided at every frame located below.

2. Superstructure frames for four frame spaces at the ends of bridges and of detached superstructures within $0.5L$ amidships are to be of the section modulus obtained from the formula in **Table 3.8.4** (2) using 0.74 as the coefficient C.

3. Web frames or partial bulkheads are to be provided above the bulkheads or at other positions such as may be considered necessary to give effective transverse rigidity to the superstructures.

Table 3.8.4 Section modulus

Locations	Section modulus (cm^3)
(1) Tween deck frames below the freeboard deck	$Z = 6KShl^2$
(2) Tween deck frames except those specified in (1)	$Z = CKSlL$
(3) Tween deck frames supporting deck transverse	$Z = 2.4K\left(0.143n\dfrac{h_1}{h} + 1.0\right)Shl^2$

S = frame spacing (m).
l = tween deck height (m).
h = vertical distance from the middle of l to the point $d + 0.038L'$ above top of keel (m). Where, however, h is less than $0.03L$(m), h is to be taken as $0.03L$(m).
L' = length of ship (m). Where, however, L exceeds 230 m , L' is to be taken as 230 m .
h', n = as specified in **Table 3.8.1.**
C = coefficient given in the following table.

Description of tween deck frames	C
Superstructure frames (excluding the (following two lines)	0.44
Superstructure frames for $0.125L$ from aft end	0.57
Superstructure frames for $0.125L$ from fore end and cant frames at stem	0.74

NOTES:
1. The scantlings of tween deck frames below the freeboard deck within $0.15L$ from the fore end and within $0.125L$ from the after end are to be appropriately increased above those given by line (1).
2. The section modulus of tween deck frames supporting web beams is not to be less than that obtained from the above line (1).

505. Frames of cruiser sterns

Cruiser sterns are to have frames of section modulus not less than 86 % of that required for frames under freeboard deck in aft peak in **Ch 13, 302.** ⚓

CHAPTER 9 WEB FRAMES AND SIDE STRINGERS

Section 1 General

101. Application

1. The requirements in **Sec 2** and **3** apply to the structures stiffened by side stringers supporting the transverse ordinary frames specified in **Ch 8, 303.** and web frames supporting side stringers.

2. The requirements in **Sec 4** apply to the structures stiffened by side transverse supporting the longitudinal frames specified in **Ch 7, 401.**

102. Arrangement

1. Web frames and side stringers are to be arranged to provide effective stiffness to the ship side structures.

2. Side stringers are to be in line with bulkhead stringers, if fitted, as far as possible.

103. Minimum strength

The strength of web frames and side stringers in way of deep tanks is not to be less than that required for vertical or horizontal girders on deep tank bulkheads.

104. Web frames and side stringers at a location where flare is specially large

The side stringers supporting transverse frames and web frames supporting these side stringers, which are fitted in the bow flare position considered to endure large wave impact pressure, are to be properly strengthened taking care of the effectiveness of their end connections.

105. Direct strength calculation

Where approved by the Society, the scantlings of structural members may be determined basing upon direct strength calculation as specified in **Ch 1, 206.**

Section 2 Web Frames

201. Scantlings

1. The scantlings of web frames supporting side stringers are not to be less than those obtained from the following formulae:

Depth : $d = 125\, l$ (mm)

Section modulus : $Z = C_1 KSh\, l^2$ (cm^3)

Thickness of web : t_1 or t_2, whichever is the greater.

$$t_1 = \frac{C_2 KShl}{d_0} + 1.5 \quad \text{(mm)}, \qquad t_1 = 0.086 \sqrt[3]{\frac{d_0^2 (t_1 - 1.5)}{kK}} + 1.5 \quad \text{(mm)}$$

where:

S = web frame spacing(m).

l = unsupported length of web frame (m)

h = vertical distance from the lower end of l to a point $d + 0.038L'$ above the top of keel (m).

L' = length of ship (m). Where, however, L exceeds 230 m, L is to be taken as 230 m.

d_0 = depth of web frame (mm). Where the webs are provided with vertical stiffeners, the divided web depth may be used for d_0 in the formula for t_2.

C_1, C_2 = coefficients given in **Table 3.9.1.**

k = coefficient given in **Table 3.9.2** according to the ratio of S_1 (mm) to d_0, where S_1 is the spacing of stiffeners or tripping brackets provided on web plates of web frames. For the intermediate values of S_1/d_0, k is to be obtained by linear interpolation.

Table 3.9.1 Coefficients C_1 and C_2

Location	C_1	C_2
For web frames abaft $0.15L$ from the fore end	3.0	23
For web frames between $0.15L$ from the fore end and the collision bulkhead	3.8	28

Table 3.9.2 Coefficient k

S_1/d_0	k
0.3 and under	60.0
0.4	40.0
0.5	26.8
0.6	20.0
0.7	16.4
0.8	14.4
0.9	13.0
1.0	12.3
1.5	11.1
2.0 and over	10.2

2. Where the web frames are in the close proximity to boilers, the thickness of webs and face bars is to be suitably increased.

202. Stiffeners of webs

1. Stiffeners or tripping brackets are to be provided on deep webs as may be required.

2. Tripping brackets are to be arranged at an interval of about 3 m. Where the breadth of face plates on either side of the web exceeds 180 mm, the tripping brackets are to be arranged to support the face bars.

203. Continuity of transverse strength

Tween deck web frames are to be provided below the bulkhead deck over the hold web frames as may be required, to provide continuity of transverse strength above the main web frames in holds and machinery space.

204. Beams at the top of web frames

Beams at the top of web frames are to be suitably increased in both strength and stiffness.

Section 3 Side Stringers

301. Scantlings

1. The scantlings of side stringers are not to be less than those obtained from the following formulae:

Depth : $d_0 = 125\,l$ (mm) added by one quarter of the depth (mm) of slot for ordinary frames.

Section modulus : $Z = C_1 KShl^2$ (cm^3)

Thickness of web : t_1 or t_2, whichever is the greater

$$t_1 = \frac{C_2 KShl}{d_0} + 1.5 \quad \text{(mm)}, \qquad t_2 = 0.086 \sqrt[3]{\frac{d_0^2(t_1 - 1.5)}{kK}} + 1.5 \quad \text{(mm)}$$

where:

S = distance between the mid-points of the spaces from the side stringer concerned to the adjacent side stringers or to the top of inner bottom plating at side or to the top of deck beams at side (m).

l = web frame spacing (m). Where, however, effective brackets are provided, the span l may be modified as specified in **Ch 1, 605.**

h = vertical distance from the middle of S to a point $d + 0.038L'$ above the top of keel (m). Where, however, h is less than $0.05L$(m), h is to be taken as $0.05L$ (m).

L' = as specified in **201. 1.**

d_0 = depth of side stringer (mm). Where, however, the depth of the web is divided by providing a stiffener in parallel to the face bar, the divided depth may be taken as d_0 in the calculation of t_2.

C_1, C_2 = coefficients given in **Table 3.9.3.**

k = coefficient given in **Table 3.9.2** according to the ratio of S_1(mm) to d_0, where S_1 is the spacing of stiffeners or tripping brackets provided on web plates of side stringers. For the intermediate values of S_1/d_0, k is to be obtained by linear interpolation.

Table 3.9.3 Coefficients C_1 and C_2

Location	C_1	C_2
For web frames abaft $0.15L$ from the fore end	5.1	42
For web frames between $0.15L$ from the fore end and the collision bulkhead	6.4	52

2. In boiler spaces, the thickness of web plates, face bars, etc. of stringer plates is to be suitably increased.

302. Stiffeners on webs

Stiffeners, the length of which is equal to the web depth, are to be provided on the webs of side stringers at alternate frames.

303. Tripping brackets

1. Tripping brackets are to be provided on side stringers at an interval of about 3 m.

2. Where the breadth of face bar on either side of the side stringer exceeds 180 mm, tripping brackets are to be arranged to support the face bars.

304. Connections

1. Connection of side stringers to web frames is to extend for the full depth of web frame.

2. Where stringers are of the same depth as web frames, the face bars of side stringers are to be connected with the face bars of web frames by efficient gussets.

3. Side stringers are to be effectively connected to the transverse bulkheads by brackets of proper size.

Section 4 Side Transverse

401. Arrangements

Side transverses supporting the side longitudinal frames are to be provided at places where solid floors are located.

402. Scantlings

The scantlings of side transverses are not to be less than that obtained from the following formulae:

Depth : $d_0 = 100l$ (mm)or 2.5 times the depth of slot for the longitudinals, whichever is the greater.

Section modulus : $Z = C_1 KShl^2$ (cm^3)

Thickness of web : t_1 or t_2, whichever is the greater.

$$t_1 = \frac{C_2 KShl}{d_0} + 1.5 \quad \text{(mm)}, \qquad t_2 = 0.086\,\frac{\sqrt[3]{d_0^2(t_1 - 1.5)}}{kK} + 1.5 \quad \text{(mm)}$$

where:

S = side transverses spacing (m).

l = unsupported length of side transverse (m).

d_0 = depth of side transverses (mm). In the calculation of t_1, however, the depth of slots for side longitudinals, if any, is to be deducted from the web depth. Where the depth of webs is divided by vertical stiffeners, the divided depth may be taken as d_0 in the calculation of t_2.

h = vertical distance from the lower end of l to a point $d + 0.038L'$ above the top of keel (m), where, however, the distance is less than 1.43 l (m), h is to be taken a 1.43 l (m).

L' = as specified in **201. 1.**

C_1, C_2 = coefficients given in **Table 3.9.4.**

k = coefficient given in **Table 3.9.2** according to the ratio of S_1(mm) to d_0, where S_1 is the spacing of stiffeners or tripping brackets provided on web plates (mm). For the intermediate values of S_1/d_0, k is to be obtained by linear interpolation.

Table 3.9.4 Coefficients C_1 and C_2

Location	For side transverses abaft $0.15L$ from the fore end	For side transverses between $0.15L$ from the fore end and the collision bulkhead
C_1	$6.6\left(1-0.4\frac{l}{h}\right)$	$8.6\left(1-0.4\frac{l}{h}\right)$
C_2	$35\left(1.43-0.43\frac{l}{h}\right)$	$45.5\left(1.43-0.43\frac{l}{h}\right)$

403. Tripping brackets

1. Side transverses are to be provided with tripping brackets at an interval of above 3 m.

2. Where the breadth of face plates of side transverses exceeds 180 mm on either side of the web, the tripping brackets are to support the face plates as well.

404. Attachments

1. A stiffener is to be provided on the web at every longitudinal except for the middle part of the span of where stiffeners may be provided at alternate longitudinals.

2. Webs of longitudinals and side transverses are to be connected each other.

Section 5 Cantilever Beams

501. Scantlings

Cantilever beams are to comply with the following requirements:

(1) The root depth of cantilever beams measured at the toes of end brackets at side is not to be less than one fifth of the horizontal distance from the inboard end of cantilever beam to the toe of end bracket at side.

(2) The depth of cantilever beams may be gradually tapered from the root towards the inboard end where it may be reduced to about a half of the root depth.

(3) The section modulus of cantilever beams at the toe of end brackets is not to be less than that obtained from the following formula: (see **Fig 3.9.1**)

$$Z=7.1KSl_0\left(\frac{1}{2}b_1h_1+b_2h_2\right) \quad (\text{cm}^3)$$

where:

S = cantilever beam spacing (m).

l_0 = horizontal distance from the inboard end of cantilever beams to the toe of end brackets (m).

b_1 = horizontal distance from the inboard end of cantilever beams to the inner edge of beam knees or end brackets of transverse beams at side (m). Where, however, the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, b_1 is to be taken as l_0.

b_2 = one-half of the breadth of hatch opening in the deck supported by the cantilever beams (m).

h_1 = deck load stipulated in **Ch 10, Sec 2** for the deck transverses of the deck supported by the cantilever beams (kN/m^2).

h_2 = load on hatch covers of the deck supported by the cantilever beams which is not to be less than that obtained from the following (a) to (c), depending on the type of the deck (kN/m^2):

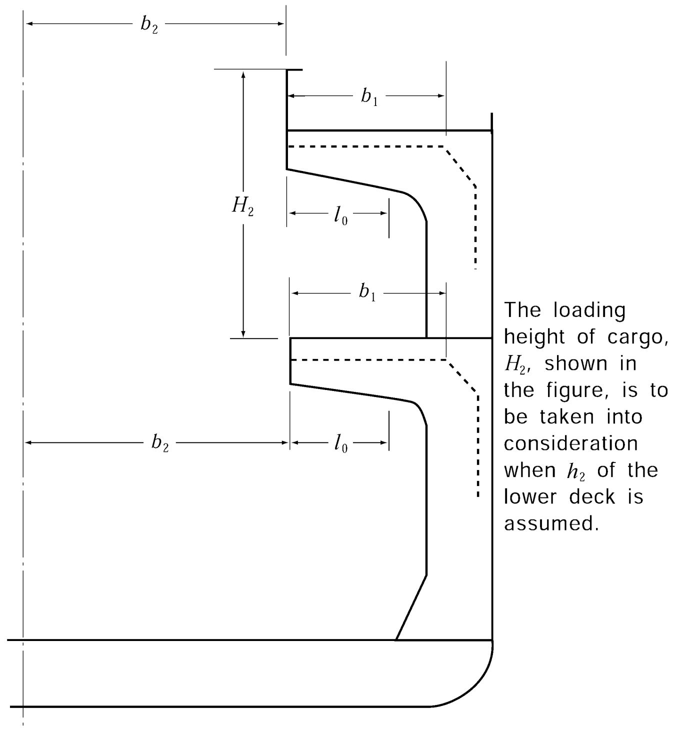


Fig 3.9.1 Measurement of l_0, b_1, b_2, etc

(a) For the weather deck, h_2 is the deck load stipulated in **Ch 10, 201. 2** for the deck transverses or the maximum design cargo weight on hatches per unit area (kN/m^2), whichever is the greater. In **Ch 10, 201. 2** (1), the value of y may be taken as the vertical distance from the load line to the upper edge of hatch coaming. In either case, h_2 is not to be less than 17.5 (kN/m^2) for hatches at Position I and 12.8 (kN/m^2) for those at Position II, specified in **Pt 4, Ch 2,** respectively.

(b) For decks other than the weather deck where ordinary cargoes or stores are intended to be carried, h_2 is the deck load stipulated in **Ch 10, 201.1.**

(c) For decks other than those specified in (a) or (b) above, h_2 is the value equal to h_1.

(4) The sectional area of face bars of cantilever beams may be gradually tapered from the inner edge of end brackets towards the inboard end of cantilever beams, where it may be reduced to 0.60 times that at the inner edge of end brackets.

(5) The web thickness of cantilever beams at any place of it is not to be less than that obtained from the following formula, whichever is the greater:

$$t_1 = 9.5\frac{S\left(\frac{1}{2}b_1h_1 + b_2h_2\right)\sqrt{K}}{d_c} + 1.5 \quad \text{(mm)}, \qquad t_2 = 0.058\sqrt[3]{\frac{d_c^2(t_1 - 1.5)}{K}} + 1.5 \quad \text{(mm)}$$

where:

S, b_1, b_2, h_1, h_2 = as stipulated in (3). Where, however, the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, $b_1/2$ is to be substituted by the horizontal distance in *metres* from the inboard end of cantilever beams to the section under consideration in the formula for t_1.

d_c = depth of the cantilever beam at the section under consideration (mm). In the calculation of t_1, however, the depth of slots for deck longitudinals, if any, is to be deducted from the depth of cantilever beams. Where the webs are provided with horizontal stiffeners, the divided web depth may be used for d_c in the formula for t_2.

(6) Cantilever beams are to be provided with tripping brackets at an interval of about 3 m. Where the breadth of face bars of cantilever beams exceeds 180 mm on either side of the web, the tripping brackets are to support the face bars as well. And a stiffener is to be provided on the web at every deck longitudinal adjacent to the root of cantilever beams and at alternate longitudinals elsewhere.

(7) Web plates adjacent to the inner edge of end brackets are to be specially reinforced.

502. Web frames

Web frames supporting cantilever beams are to comply with the following requirements:

(1) The depth of web frames is not to be less than one eighth the length including the length of connection at both ends.

(2) The section modulus of web frames is not to be less than that obtained from the following formula. Where, however, a tween deck web frame in association with cantilever beam supporting the deck above is provided at the top of web frame, the value of the formula may be reduced to 60 %.

$$Z = 7.1KSl_1\left(\frac{1}{2}b_1h_1 + b_2h_2\right) \quad (\text{cm}^3)$$

where:

S = web frames spacing (m).

l_1 = horizontal distance from the end of supported cantilever beams to the inside of web frames (m).

b_1, b_2, h_1, h_2 = as stipulated in **501.** (3) for the supported cantilever beams, where, however, the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, l_1 is to be substituted for b_1.

(3) The section modulus of tween deck web frames is to be in accordance with the requirements in (2), and additionally, it is not to be less than that obtained from the following formula:

$$Z = 7.1KSl_1\left(\frac{1}{2}b_1h_1 + b_2h_2\right) \quad (\text{cm}^3)$$

where:

S, l_1, b_1, b_2, h_1, h_2 = as stipulated in (2).

C_1 = coefficient obtained from the following formula:

$$C_1 = 0.5\left(\frac{\frac{1}{2}b'_1h'_1 + b'_2h'_2}{\frac{1}{2}b_1h_1 + b_2h_2}\right) + 0.15$$

b'_1, b'_2, h'_1, h'_2 = b_1, b_2, h_1, and h_2 respectively stipulated in (2) in respect of cantilever beams to be provided below the web frames concerned.

(4) The web thickness is not to be less than that obtained from the following formula, whichever is the greater:

$$t_1 = 9.5K\frac{C_2 S\left(\frac{1}{2}b_1 h_1 + b_2 h_2\right)}{d_w} \times \frac{l_1}{l} + 1.5 \quad \text{(mm)}, \qquad t_2 = 0.058\sqrt[3]{\frac{d_w^2(t_1 - 1.5)}{K}} + 1.5 \quad \text{(mm)}$$

where:

S, b_1, b_2, h_1, h_2 l_1 = as stipulated in (2).

d_w = the smallest depth of web frame (mm). In the calculation of t_1, however, the depth of slots for side longitudinals, if any, is to be deducted from the web depth. Where the depth of webs is divided by vertical stiffeners, in the calculation of t_2, the divided depth may be used for d_w.

l = length of web frame including the length of connections at both ends (m).

C_2 = coefficient given in **Table 3.9.5,** where, however, C_1, as specified in (3).

Table 3.9.5 Coefficient C_2

Location		C_2
For hold web frames	Where web frame in association with cantilever beam supporting the deck above is provided at the top of them	0.9
	Elsewhere	1.5
For tween deck web frames		$C_1 + 0.6$

(5) Where web frames supporting cantilever beams also support side longitudinals or side stringers, the scantlings are to comply with the following requirements in addition to those in **Ch 2, Ch 3** and **Ch 4.**

(a) The section modulus is not to be less than that obtained from the formula in (2), multiplied by the following coefficient:

Where tween deck web frame together with cantilever beam is provided above:

$$\alpha = 9.81\left\{\frac{0.05hl^2 + 0.09h_u l_u^2}{1.4\left(\frac{1}{2}b_1 h_1 + b_2 h_2\right)l_1}\right\} + 0.6$$

Elsewhere: $\alpha = 1.0$

where:

l = length of hold web frame including the length of connections at both ends (m).

l_u = length of tween deck web frame provided directly above, including the length of connections at both ends (m).

h = vertical distance from the middle of l to a point $d + 0.038L'$ above the top of keel (m).

h_u = vertical distance from the middle of l_u to a point to which h is to be measured (m). Where, however, the point is below the middle of l_u, h_u is to be taken as zero.

L' = as specified in **201. 1.**

b_1, b_2, h_1, h_2 l_1 = as given by (2).

(b) The web thickness is not to be less than that given by (4), in which the value of t_1 is to be increased by the amount obtained from the following formula:

$$\beta = 25.5 \frac{Shl}{d_w} \quad \text{(mm)}$$

where:

S = web frame spacing (m).

h , l = as stipulated in (a) above.

d_w = as stipulated in (4).

(6) Web frames are to be provided with tripping brackets at an interval of about 3 m. Where the breadth of face bars of web frames exceeds 180 mm on either side of the web, the tripping brackets are to support the face bars as well. And a stiffener is to be provided on the webs at every side longitudinal except for the middle part of the span of web frames where stiffeners may be provided at alternate longitudinals. Webs of longitudinals and web frames are to be connected each other.

(7) Web frames are to be effectively connected with those located beneath or solid floors so as to maintain strength continuity.

503. Connections

Cantilever beams and their supporting web frames are to be effectively connected by brackets to meet the following requirements:

(1) The radius of curvature of the free edges of brackets is not to be less than the depth of cantilever beams at the toe of brackets.

(2) The thickness of brackets is not to be less than that of webs of cantilever beams or web frames, whichever is the greater.

(3) The brackets are to be sufficiently strengthened by stiffeners.

(4) The free edges of brackets are to have face bars of sectional area not less than that of cantilever beams or web frames, whichever is the greater, and the face bars are to be connected with those of cantilever beams and web frames. ⚓

CHAPTER 10 BEAMS

Section 1 General

101. Standard camber

The standard camber of weather decks is $0.02B$ at midship.

102. Connections of ends of beams.

1. Longitudinal beams are to be continuous or to be connected with brackets at their ends in such a manner as to effectively develop the sectional area and to have sufficient strength to bending and tension.
2. Transverse beams are to be connected to frames by brackets.
3. Transverse beams provided at positions where frames are omitted in tween decks or superstructures, are to be connected to the side plating by brackets.
4. Transverse beams on boat decks, promenade decks, etc. may be connected by clips at their ends.

103. Beams on bulkhead recesses and others

The section modulus of beams at deck forming the top of bulkhead recesses, tunnels and tunnel recesses is not to be less than that obtained from the formula in **Ch 14, 309.,** using h measured from the top of beams to the top of bulkhead deck at the centre line of ship. Where, however, h is less than 6.0 m, h is to be taken as 0.8 times the actual height plus 1.2 m.

104. Beams on the top of deep tanks

The section modulus of beams at deck forming the top of deep tanks is to be in accordance with this Chapter, and not to be less than that obtained from the formula in **Ch 15, 203.,** taking the top of deck beams as the lower end of h and beams as stiffeners.

105. Special heavy loads

The deck beams supporting special heavy loads or arranged at the ends of superstructures or deckhouses, in way of masts, winches, windlasses and auxiliary machineries, etc. are to be properly reinforced by increasing the scantlings of beams, or by the additional deck girders or pillars.

106. Long machinery opening

For unusually long machinery opening, suitable strengthening is to be made by means of adequate cross ties provided at each level of deck or equivalent arrangement.

107. Loaded by wheeled vehicles

The section modulus of beams on deck loaded by wheeled vehicles is to be determined by considering the concentrated loads from the wheeled vehicles.

108. Continuity of strength

In parts where longitudinal systems are transformed to transverse systems, special care is to be taken to keep the continuity of strength.

109. Beams on deck carrying unusual cargoes

The section modulus of beams on deck subjected to cargo loads which can not be treated as evenly distributed loads is to be determined taking account of load distribution for particular cargoes.

Section 2 Deck Load

201. Value of h

1. Deck load h (kN/m^2) for decks intended to carry cargoes or stores, etc. on them is to be as specified in the following (1) to (3):

(1) h is to be equivalent to the standards given by 7 times the tween deck height at side of the space (m), or 7 times the height from the deck concerned to the upper edge of hatch coaming of the above deck (m). However, h may be specified as the maximum design cargo weight per unit area of deck (kN/m^2). In this case, the value of h is to be determined by considering the loading height of cargo.

(2) Where timber and other cargoes are intended to be carried on the weather deck, h is cargo weight per unit area of the deck (kN/m^2) or the value stipulated in **Par 2,** whichever is the greater.

(3) Where cargoes are suspended from the deck beams, or deck machinery is installed, h is to be suitably increased.

2. Deck load h (kN/m^2) for the weather deck is to be as specified in the following (1) to (4):

(1) h for the freeboard deck and the superstructure deck and the top of deckhouses on the freeboard deck is not to be less than that obtained from the following formula:

$$h = a(bf - y) \quad (\text{kN/m}^2)$$

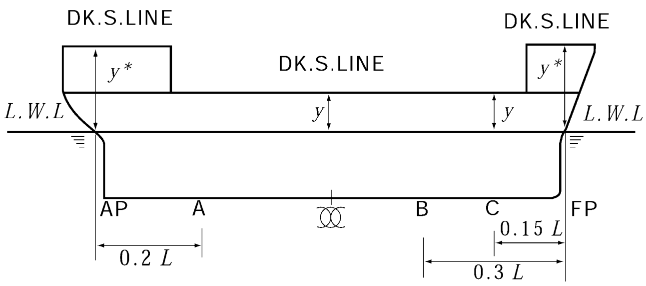
where:

a, b = as given by **Table 3.10.1** according to the position of decks.

C_{b1} = block coefficient, however, where C_b is less than 0.6, C_{b1} is to be taken as 0.6, and where C_b is 0.8 and over, C_{b1} is to be taken as 0.8.

f = as given in **Table 3.10.2.** (see **Fig 3.16. 1**):

y = vertical distance from the load line to weather deck at side (m), and y is to be measured at fore end for deck forward of 0.15L abaft the fore end; at 0.15L abaft the fore end for deck between 0.3L and 0.15L abaft the fore end; at midship for deck between 0.3L abaft the fore end and 0.2L afore the aft end; and at aft end for deck aftward of 0.2L afore the aft end (see **Fig 3.10.1**):



Abaft A — y is to be measured at AP.
Between A and B — y is to be measured at ⊗ .
Between B and C — y is to be measured at C.
Afore C — y is to be measured at FP.
y^* : In case of no superstructure, y is the distance to the upper deck.

Fig 3.10.1 Position of measuring y

Table 3.10.1 Values of a and b

Line	Position of deck	a			
		Beams[(1)], Deck plating	Pillars	Deck girders	b
I	Forward of 0.15L abaft the fore end	14.7	4.90	7.35	$1+\dfrac{0.338}{(C_{b1}+0.2)^2}$
II	Forward of 0.15L and 0.3L abaft the fore end	11.8	3.90	5.90	$1+\dfrac{0.158}{(C_{b1}+0.2)^2}$
III	Between 0.3L abaft the fore end and 0.2L afore the aft end	6.90	2.25	2.25[(2)] 3.45[(3)]	1.0
IV	Afterward of 0.2L afore the aft end	9.80	3.25	4.90	$1+\dfrac{0.123}{(C_{b1}+0.2)^2}$

NOTE:
(1) Where L is 150 m or less, value a may be multiplied by the value of following formula:
$C=0.0055L+0.175$
(2) In case of longitudinal deck girders outside the line of hatchway opening of the strength deck for mid-ship part.
(3) In case of deck girders other than (2).

Table 3.10.2 Coefficient f

Length of ship	f
$L<150$ m	$\dfrac{L}{10}e^{-\frac{L}{300}}+\left(\dfrac{L}{150}\right)^2-1.0$
150 m $\leq L<$300 m	$\dfrac{L}{10}e^{-\frac{L}{300}}$
300 m $\leq L$	11.03

Table 3.10.3 Minimum Values of h

Line	Position of deck	h[(1)]	C	
			Beams[(2)], Deck plating	Pillars, Deck girders
I and II	Forward of 0.3L abaft the fore end	$C\sqrt{L'+50}$	4.20	1.37
III	Between 0.3L abaft the fore end and 0.2L afore the aft end		2.05	1.18
IV	Afterward of 0.2L afore the aft end	$C\sqrt{L}$	2.95	1.47
Second tier superstructure deck above the freeboard deck			1.95	0.69

NOTES:
(1) L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.
(2) Where L is 150 m or less, value C may be multiplied by the value of following formula:.

$0.0055L+0.175$

(2) h for deck in Line II in **Table 3.10.1,** need not exceed that in Line I.
(3) h is not to be less than that obtained from the formulae in **Table 3.10.3,** irrespective of the provisions in (1) and (2).
(4) Value of h is to be in accordance with the discretion of the Society, where the ship has an unusual large freeboard.

3. For an enclosed part of superstructure decks and of top of deckhouses in accommodation or navigation spaces, at the first and second tier above the freeboard deck, h is to be **12.8.**

Section 3 Longitudinal Beams

301. Spacing

1. The standard spacing of the longitudinal beams is obtained from the following formula:

$$S = 2L + 550 \quad \text{(mm)}$$

2. It is recommended that the spacing of the longitudinal beams should not exceed 1 m.

302. Proportion

1. Longitudinal beams are to be supported by deck transverses of appropriate spacing. In midship part of the strength deck, the slenderness ratio of deck longitudinals is not to exceed 60. This requirement may, however, be suitably modified where longitudinal beams are given a sufficient strength to prevent buckling.

2. Flat bars used for longitudinals are not to be of depth-thickness ratio exceeding 15.

303. Section modulus

1. The section modulus of longitudinal beams outside the line of openings of the strength deck for the midship part is not to be less than that obtained from the following formula:

$$Z = 1.14KShl^2 \quad (\text{cm}^3)$$

where:

S = spacing of longitudinal beams (m).

h = deck load specified in **Sec 2** (kN/m^2).

l = horizontal distance between bulkhead and deck transverse or between deck transverses (m).

2. The section modulus of longitudinal beams outside the line of openings of strength deck at $0.1L$ from fore end and aft end is not to be less than that obtained from the following formula:

$$Z = 0.43KShl^2 \quad (\text{cm}^3)$$

where:

S, h, and l = as specified in **Par 1.**

3. The section modulus of longitudinal beams outside the line of openings of strength deck for the parts forward and aftward the midship part may be gradually reduced from the value given in **Par 1,** and may be taken as **Par 2** at $0.1L$ from fore end and aft end.

304. Deck transverses

In single deck ships, the deck transverses are to be provided in line with the solid floors in double bottom, and in two deck ships, the transverses are also to be provided in line with the solid floors in double bottoms as far as practicable.

Section 4 Transverse Beams

401. Arrangements

Transverse beams are to be provided on every frame.

402. Proportion

It is preferable that the length-depth ratio of transverse beams be 30 or less at the strength deck, and 40 or less at effective decks (the decks below the strength deck which are considered as strength members in the longitudinal strength of hull) and superstructure decks as far as practicable.

403. Section modulus

The section modulus of transverse beams is not to be less than that obtained from the following formula:

$$Z = 0.43 K S h l^2 \quad (\text{cm}^3)$$

where:

S = spacing of transverse beams (m).

h = deck load specified in **Sec 2** (kN/m^2).

l = horizontal distance from the inner edge of beam brackets to the longitudinal deck girder, or between the longitudinal deck girders (m). ⚓

CHAPTER 11 DECK GIRDERS

Section 1 General

101. Application

Transverse deck girders supporting longitudinal deck beams and longitudinal deck girders supporting transverse deck beams are to be in accordance with the requirements in this Chapter.

102. Arrangement

In way of the bulkhead recesses and the top of tanks, deck girders are to be arranged at an interval not exceeding 4.6 m as far as practicable.

103. Construction

1. Deck girders are to be composed of face plates provided along the lower edge.

2. Tripping brackets are to be provided at an interval of about 3 m and where the breadth of face plates exceeds 180 mm on either side of the girder, these brackets are to be so arranged as to support the face plates as well.

3. The thickness of face plates forming girders is not to be less than that of web plates and the width of the face plates is not to be less than that obtained from the following formula:

$$b = 2.7\sqrt{d_0 l} \quad \text{(mm)}$$

where:

d_0 = depth of webs (mm).

l = span of girders specified in **201.** (m).

4. The depth of girders is more than 2.5 times that of slots for beams, and is to be kept constant between two adjacent bulkheads for the longitudinal girders.

5. The girders are to have a sufficient rigidity to prevent excessive deflection of decks and excessive additional stresses in deck beams.

104. End connection

1. End connections of deck girders are to be in accordance with the requirements in **Ch 1, 604.**

2. Bulkhead stiffeners or girders at the ends of deck girders are to be suitably strengthened to support deck girders.

3. Longitudinal deck girders are to be continuous or to be effectively connected so as to maintain the continuity at ends.

Section 2 Longitudinal Deck Girders

201. Section modulus

1. The section modulus of longitudinal deck girders outside the lines of hatchway opening of the strength deck for midship part is not to be less than that obtained from the following formula:

$$Z = 1.29Kl(bhl + kW) \quad (\text{cm}^3)$$

where:

l = distance between supporting points (m). Where the deck girder is effectively bracketed to bulkhead, l may be modified as specified in **Ch 1, 605.** (See **Fig 3.11.1**)

b = distance between the centres of two adjacent spans of beams supported by the girders or the frames (m). (See **Fig 3.11.1**)

h = deck load specified in **Ch 10, Sec 2** for the deck supported (kN/m^2).

W = deck load supported by the tween deck pillar as specified in **Ch 12, 201.** (kN).

k = as specified in the following (a) and (b):

(a) Coefficient obtained from the following formula according to the ratio of the horizontal distance from the pillar or bulkhead supporting the deck girder to the tween deck pillar a (m) and l. (See **Fig 3.11.1**)

$$12\frac{a}{l}\left(1-\frac{a}{l}\right)^2$$

(b) Where there is only one tween deck pillar, k is to be obtained basing upon the smaller value of a. Where there are two or more tween deck pillars, a is to be measured from the same end of l for each tween deck pillar, and the sum of kW is to be used for the computation of the formula. In this case, the greater value between the sums of kW obtained basing upon a measured from each end of l is to be used.

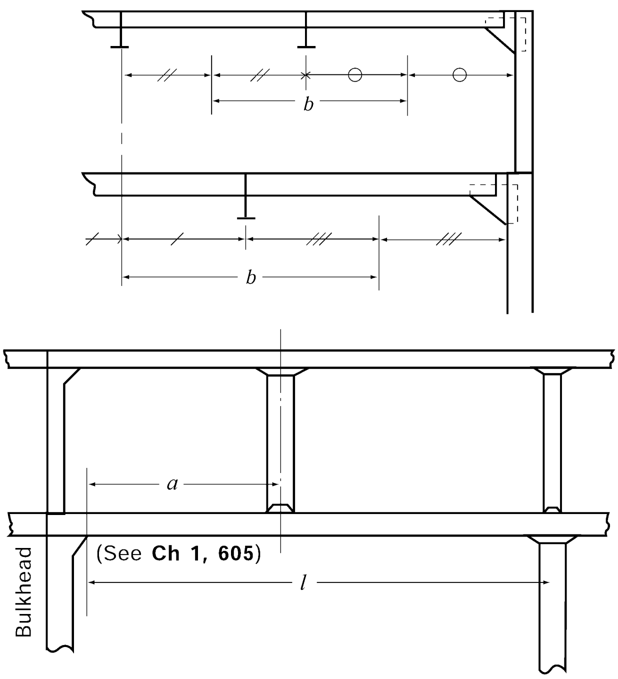


Fig 3.11.1 Measurement of *b*, *l* and *a*

2. The section modulus of longitudinal deck girders outside the lines of hatchway opening of the strength deck for the parts forward and afterward the midship part may be gradually reduced. In no case, however, is the section modulus to be less than that obtained from the following formula:

$$Z = 0.484Kl(bhl + kW) \quad (\text{cm}^3)$$

where:

l, b, h, W, k = as specified in **Par 1.**

3. The section modulus of longitudinal deck girders for the parts other than that stipulated in **Par 1** and **2** is not to be less than obtained from the formula in **Par 2.**

4. Where a deck carrying cargoes which loads can not be treated as evenly distributed loads, deck load supported by a pillar is to be determined taking account of load distribution for particular cargoes. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **1.** to **3.** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillar(W).

202. Moment of inertia

It is advised that the moment of inertia of girders is not to be less than that obtained from the following formula:

$$I = CZl \quad (\text{cm}^4)$$

where:

C = coefficient obtained from the following formulae:

For deck girders arranged outside the line of deck openings of strength deck of midship part of ship -- 1.6

For other deck girders --------------------------- 4.2

Z = required section modulus of girders specified in **201.** (cm^3).

l = as specified in **201. 1.**

203. Thickness of web plates

1. The thickness of web plates of longitudinal deck girders outside the line of openings of strength deck amidship is not to be less than that obtained from the following formula. This thickness, however, is not to be less than that obtained from the formula in **Par 2.:**

$$t = 10 S_1 \sqrt{f_D} + 1.5 \quad (\text{mm})$$

where:

S_1 = spacing of web stiffeners or depth of girders, whichever is the smaller (m).

2. The thickness of web plates of longitudinal deck girders other than those in parts specified in **Par 1** is not to be less than that obtained from the following formula:

$$t = 10 \frac{S_1}{\sqrt{K}} + 1.5 \quad (\text{mm})$$

where:

S_1 = as specified in **Par 1.**

3. The thickness of web plates at both end parts of $0.2\,l$ is not to be less than that specified in **Par 1, 2** or that obtained from the following formula in (1) and (2) according to kinds of steel, whichever is the greatest:

(1) For mild steel

$$t = \frac{4.43 K b h l}{d_0} + 1.5 \quad (\text{mm})$$

where:

d_0 = depth of webs (mm).

b, h and l = as specified in **201. 1.**

(2) For high tensile strength steel, this thickness, however, is not to be less than that obtained from (1).

$$t = 8.13\sqrt[3]{\frac{bhlS_1^2}{d_0}} + 1.5 \quad \text{(mm)}$$

where:

S_1 = as specified in **Par 1.**

d_0, b, h and l = as specified in (1).

Section 3 Transverse Deck Girders

301. Section modulus

1. The section modulus of transverse deck girders is not to be less than that obtained from the following formula:

$$Z = 0.484Kl(bhl + kW) \quad \text{(cm}^3\text{)}$$

where:

l = distance between the centres of pillars or from the centre of pillar to the inner edge of beam bracket (m).

b = distance between the centres of two adjacent girders or bulkhead (m).

h, W, k = in accordance with **201.**

2. Where a deck carrying cargoes which loads can not be treated as evenly distributed loads, deck load supported by a pillar is to be determined taking account of load distribution for particular cargoes. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **1.** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillar(W).

302. Moment of inertia

It is advised that the moment of inertia of girders is not to be less than that obtained from the following formula:

$$I = 4.2Zl \quad \text{(cm}^4\text{)}$$

where:

Z = required section modulus of girders specified in **301.** (cm^3).

l = as specified in **301.**

303 Thickness of web plates

The thickness of web plates is to be in accordance with the requirements in **203.**

Section 4 Deck Girders in Tanks

401. Section modulus

The section modulus of deck girders in tanks is to be in accordance with the requirements in **201.** or **301.,** and is to be in compliance with the requirements in **Ch 15, 204. 1** as well.

402. Moment of inertia

The moment of inertia of girders is to be in accordance with the requirement in **Ch 15, 204. 2.**

403. Thickness of web plates

The thickness of web plates is to be in accordance with the requirements in **203.** or **303.** and is to be in compliance with the requirements in **Ch 15, 204. 3** as well.

Section 5 Hatch Side Girders

501. Deep coamings on decks

Where deep coamings are provided on decks as in the case of hatchway on weather deck, the horizontal coaming stiffener and the coaming up to its stiffener may be included in the calculation of the section modulus, subject to the approval by the Society.

502. Strength continuity

At hatchway corners, the face plates of hatch coamings and longitudinal deck girders or their extension parts and the face plates on both sides of hatch end girders are to be effectively connected so as to maintain the strength continuity.

Section 6 Hatch End Girders

601. Scantling

The scantlings of hatch end girders are to be in accordance with the requirements in **Sec 2** to **5.**
⚓

CHAPTER 12 PILLARS

Section 1 General

101. Pillars in tween decks

Pillars in tween decks are to be arranged directly above those under the deck, or effective means are to be provided for transmitting their loads to the supports below.

102. Pillars in holds

Pillars in holds are to be provided in line with the keelsons or double bottom girders or as close thereto as practicable, and the structure under pillars is to be of ample strength to provide effective distribution of the load.

103. End connection of pillars

The head and heel of pillars are to be secured by thick doubling plates and brackets as necessary. Where the pillars which may be subjected to tensile loads such as under bulkhead recesses, tunnel tops or deep tank tops, the head and heel of pillars are to be efficiently secured to withstand the tensile loads.

104. Reinforcements

Where the pillars are connected to the deck plating, the top of shaft tunnels, or the frames, these structures are to be efficiently strengthened.

Section 2 Scantling of Pillars

201. Sectional area

1. The sectional area of pillars is not to be less than that obtained from the following formula:

$$A = \frac{0.223\,W}{2.72 - \dfrac{l}{k_0\sqrt{K}}} \quad (\mathrm{cm}^2)$$

where:

l = distance from the top of inner bottom, deck or other structures on which the pillars are based to the underside of beam or girder supported by the pillars (m). (See **Fig 3.12.1**)

k_0 = minimum radius of gyration of the section of pillars (m).

W = deck load (kN) supported by the pillar obtained from the following formula:

$$W = k w_0 + S b h \quad (\mathrm{kN})$$

S = distance between the mid-points of two adjacent spans of girders supported by the pillars or the bulkhead stiffeners or bulkhead girders (m). (See **Fig 3.12.1**)

b = mean distance between the mid-points of two adjacent spans of beams supported by the pillars or the frames (m). (See **Fig 3.12.1**)

h = deck load specified in **Ch 10, Sec 2** for the deck supported ($\mathrm{kN/m}^2$).

w_0 = deck load supported by the upper tween deck pillar (t).

k = as obtained from the following formula according to the ratio of the horizontal distance a_i(m) from the pillar to the tween deck pillar above to the distance l_j(m) from the pillar to the pillar or bulkhead. (See **Fig 3.12.1**)

$$k = 2\left(\frac{a_i}{l_j}\right)^3 - 3\left(\frac{a_i}{l_j}\right)^2 + 1$$

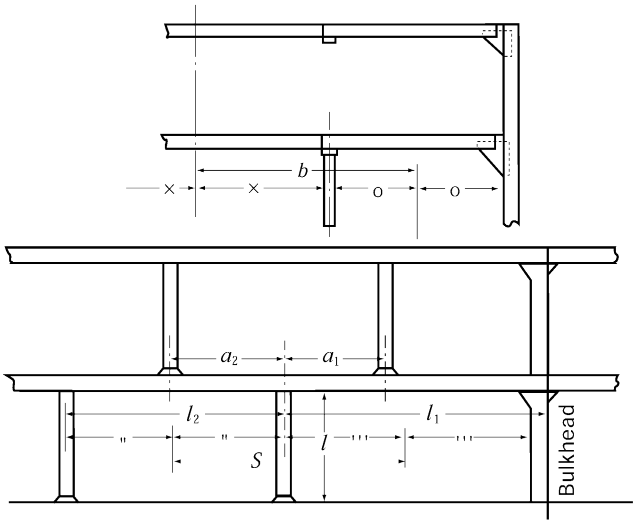


Fig 3.12.1 Measurement of *S*, *b*, *l*, etc.

2. Where there are two and over tween deck pillars provided on the deck girder supported by a line of lower pillars, the lower pillar is to be of the scantlings required by **Par 1,** taking kw_0 for each tween deck pillar provided on two adjacent spans supported by the lower pillars.

3. Where tween deck pillars are shifted from the lower pillars in athwartship direction, the scantlings of lower pillars are to be determined in accordance with the principle in **Par 1** and **2.**

4. Where a deck carrying cargoes which loads can not be treated as evenly distributed loads, deck load supported by pillar is to be determined taking account of load distribution for particular cargoes. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **1.** and **2.** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillar(w_o).

202. Thickness

1. The plate thickness of tubular pillars is not to be less than that obtained from the following formula. This requirement may, however, be suitably modified for the pillars provided in accommodation spaces.

$$t = 0.022d_p + 3.6 \quad \text{(mm)}$$

where:

d_p = outside diameter of the tubular pillar (mm).

2. The thickness of web and flange plates of built-up pillars is to be sufficient for the prevention of local buckling.

203. Outside diameter of round pillars

The outside diameter of solid round pillars and tubular pillars is not to be less than 50 mm.

204. Pillars provided in deep tank

1. Pillars provided in deep tank are not to be tubular pillars.

2. The sectional area of pillars is not to be less than that specified in **201.** or that obtained from the following formula, whichever is the greater.

$$A = 1.09\,Sbh \quad (\text{cm}^2)$$

where:

S and b = as specified in **201.**

h = 0.7 times the vertical distance from the top of deep tank to the point of 2 m above the top of overflow pipe (m).

205. Longitudinal bulkheads and others provided in lieu of pillars

The transverse bulkheads supporting longitudinal deck girders and the longitudinal bulkheads provided in lieu of pillars are to be stiffened in such a manner as to provide supports not less effective than required for pillars.

206. Casings provided in lieu of pillars

The casings provided in lieu of pillars are to be of sufficient scantlings to withstand the deck load and side pressure. ⚓

CHAPTER 13 ARRANGEMENTS TO RESIST PANTING

Section 1 General

101. Application

In way of the spaces from the fore end of ship to a proper place beyond the collision bulkhead and from the aft end of ship to a proper place beyond the aft peak bulkhead, suitable arrangements to resist panting are to be provided according to the ship form at the place.

102. Swash plate

In fore and aft peak tanks to be used as deep tanks, effective swash plates are to be provided at the centre line of ship or the scantlings of structural members are to be suitably increased.

103. Stringers fitted up with extremely small angle

Where the angle between the web of stringers and the shell plating is extremely small, the scantlings of stringers are to be suitably increased above the normal requirements and, where necessary, appropriate supports are to be provided to prevent tripping.

Section 2 Arrangements to Resist Panting forward the Collision Bulkhead

201. Arrangement and construction

1. Deep centre girders, etc. are to be provided forward the collision bulkhead.

2. In fore peaks of transverse framing, floors of sufficient height are to be arranged at the frame spacing stipulated in **Ch 8, 201. 2** and side girders are to be arranged at an interval not exceeding about 2.5 m. Transverse frames are to be supported by the structures specified in **203. 2** at an interval not exceeding 2.5 m.

3. In fore peaks of longitudinal framing, bottom transverses supporting bottom longitudinals and side transverses supporting side longitudinals are to be arranged at an interval not exceeding about 2.5 m. Bottom transverses and side transverses are to be effectively connected each other and deck transverses are to be arranged on the deck in the same section to providing structures.

202. Floors and centre girders

1. The thicknesses of floors and centre girders in fore peaks are not to be less than those obtained from the following formula:

$$t = 0.6\sqrt{L} + 3 \quad \text{(mm)}$$

2. Floors are to extend to such a height as being necessary to give adequate stiffness to the structure and are to be properly stiffened with stiffeners as may be required.

3. The upper edges of the floors and centre girders are to be properly stiffened.

4. The thickness of side girders is to be approximately equal to that of centre girders and side girders are to extend to such a proper height as may be required according to the height of floors.

203. Transverse framing

1. Transverse frames below the freeboard deck.

The section modulus of transverse frames below the freeboard deck is not to be less than that obtained from the following formula.

$Z = 8Shl^2$ (cm^2)

where:

S = frame spacing (m).

l = distance between the supports of transverses (m), but to be taken as 2.15 m where the height is less than 2.15 m.

h = vertical distance from the midpoint of l to a point of 0.12L above the top of keel (m), but to be taken as 0.06L where the height is less than 0.06L.

2. Side construction to resist panting

(1) Where panting beams are provided at alternate frames together with stringer plates connected to the shell plating:

(a) Panting beams are to be angles or channel sections of sectional area not less than that obtained from the following formula, being connected effectively with frames by means of brackets having the thickness not less than that of the frames. And further, the panting beams are to be sufficiently connected vertically and longitudinally at the centre line of ship by means of angles as may be required in consideration of the span.

$A = 0.3L$ (cm^2)

(b) The scantlings of stringer plates are not to be less than those obtained from the following formula, and their inner edges are to be suitably stiffened by flanging or by angle sections.

Breadth: $b = 2.5L + 500$ (mm)

Thickness: $t = 0.02L + 5.5$ (mm)

(c) The frames to which no panting beam is provided are to be connected to the stringer plates by brackets. The length of each arm of brackets is to be at least equal to one half of the breadth of stringer plates required in (b) and the thickness of brackets at least equal to that of the stringer plates. In this case, the stringer plates are to be stiffened by providing flat bars extending from the toe of brackets to the inner edge of stringer plates.

(d) Stringer plates are to be connected by effective brackets to the breast hooks and the horizontal girders of transverse bulkhead.

(2) Where panting beams are provided at every frame together with perforated steel plates completely fitted up thereon from side to side:

(a) The sectional area of panting beams is not to be less than that obtained from the following formula:

$A = 0.1L + 5$ (cm^2)

(b) The thickness of perforated steel plates completely plated on the panting beams is not to be less than that obtained from the following formula:

$t = 0.02L + 4.5$ (mm)

(3) Where transverse frames are supported by side stringers:

(a) The scantlings of side stringers are not to be less than those obtained from the following formula:

Web depth: $d_1 = 200l$ (mm), $2.5L + 500$ (mm) or 2.5 times the depth of slot for the transverse frames, whichever is the greatest.

Section modulus : $Z = 8Shl^2$ (cm^3)

Web thickness : t_1 or t_2, whichever is the greater.

$$t_1 = 42\frac{Shl}{d_0} + 1.5 \quad \text{(mm)}, \qquad t_2 = 0.11\sqrt[3]{\frac{d_0^2(t_1 - 1.5)}{k}} + 1.5 \quad \text{(mm)}$$

where:

S = spacing of side stringers (m).

l = horizontal distance between the supporting points of side stringers (m).

h = vertical distance from the middle of S to a point $0.12L$ above the top of keel (m). Where, however, h is less than $0.06L$(m), h is to be taken as $0.06L$(m).

d_0 = depth of side stringers (mm). ln the calculation of t_1, however, the depth of slot for longitudinals, if any, is to be deducted from the depth of side stringers. Where the depth of side stringers is divided by horizontal stiff-eners, the divided depth may be taken as d_0 in the calculation of t_2.

k = coefficient given in **Table 3.13.1** according to the ratio of S_1 to d_0, where S_1 (mm) is the spacing of stiffeners or tripping brackets provided on web plates of side stringers. For the intermediate values of S_1/d_0, k is to be obtained by linear interpolation.

Table 3.13.1 Coefficient k

S_1/d_0	k
0.3 and under	60.0
0.4	40.0
0.5	26.8
0.6	20.0
0.7	16.4
0.8	14.4
0.9	13.0
1.0	12.3
1.5	11.1
2.0 and over	10.2

(b) Side stringers are to be provided with tripping brackets at an interval of about 3 m. Where the breadth of face bars of side stringers exceeds 180 mm on either side of the web the tripping brackets are to support the face bars as well. And stiffeners are to be provided on the webs at every longitudinal except for the middle part of the span of side stringers where they may be provided at alternate transverse frames.

(c) Where the side stringers are supported by cross ties, the scantlings of cross ties are not to be less than those obtained from the formula given in **Table 3.13.2.**

Table 3.13.2 Scantlings of cross ties

$\frac{l}{k_0}$	Sectional area (cm^2)	Web thickness (mm)
$\frac{l}{k_0} \geq 0.6$	$A = \dfrac{0.77Sbh}{1-0.5\frac{l}{k_0}}$	$t_w = 0.016\, d_w \sqrt{\dfrac{Sbh}{A}}$
$\frac{l}{k_0} < 0.6$	$A = 1.1\, Sbh$	

S = spacing of side stringers (m).
b = breadth of area supported by the cross tie (m)
h = vertical distance from the middle of b to a point $0.12L$ above the top of keel (m). Where, however, h is less than $0.06L$(m), h is to be taken as $0.06L$(m).
l = length of cross tie (m).
k_0 = minimum radius of gyration of cross tie, obtained from the following formula (cm).

$$k_0 = \sqrt{\frac{I}{A}}$$

I = the least moment of inertia of cross tie (cm^4)
A = sectional area of cross tie (cm^2).
d_w = web depth of cross tie (mm). Where, however, stiffeners are fitted up horizontally, the largest divided web depth may be taken as d_w.

(d) Cross ties are to be effectively connected with the side stringers by brackets or by other suitable arrangements and the side stringers are to be provided with tripping brackets in way of the cross ties.
(e) Where the breadth of face bars of cross ties on either side of the web exceeds 150 mm, stiffeners are to be provided on the webs at a suitable interval, to be connected with the face bars and to support the face bars.

204. Longitudinal framing

1. Longitudinal frames below the freeboard deck are to comply with the following requirements:

(1) The section modulus is not to be less than that obtained from the following formula. However, the section modulus obtained from the formula is to be increased by 25 % between $0.15D$ and $0.15D$ from the top of keel and 50 % below $0.05D$ from the top of keel.

$$Z = 8Shl^2 \quad (cm^3)$$

where:

S = longitudinal frame spacing (m).

l = distance between side transverse or between side transverse and transverse bulkhead (m), but where it is less than 2.15 m, l is to be taken as 2.15 m.

h = vertical distance from longitudinal frames to a point $0.1L$ above the top of keel (m), but where it is less than $0.06L$(m), h is to be taken as $0.06L$(m).

(2) Longitudinal frames are to be connected at each end to breast hooks or transverse bulkheads by efficient brackets.

2. The side transverses supporting longitudinal frames are to comply with the following requirements. However, where these are found impractical to apply these requirement are to be to the satisfaction of the Society.

(1) Side transverses on both sides are to be connected providing cross ties at a vertical interval not greater than that obtained from the following formula:

$S = 0.0125L + 2.5$ (m)

(2) The scantlings of transverses are not to be less than those obtained from the following formula:

Web depth : $d_1 = 200l$ (mm), $2.5L + 500$ (mm) or 2.5 times the depth of slots for longitudinals, whichever is the greatest.

Section modulus : $Z = 8Shl^2$ (cm^3)

Web thickness : t_1 or t_2, whichever is the greater.

$$t_1 = 42\frac{Shl}{d_0} + 1.5 \quad \text{(mm)}, \qquad t_2 = 0.11\sqrt[3]{\frac{d_0^2(t_1 - 1.5)}{k}} + 1.5 \quad \text{(mm)}$$

where

l = vertical distance between supporting points of side transverses (m).

S = spacing of side transverses (m).

h = vertical distance from the middle of l to a point $0.12L$ above the top of keel (m). Where, however, h is less than $0.06L$(m), h is to be taken as $0.06L$(m).

d_0 = depth of side transverse (m). In the calculation of t_1, however, the depth of slot for longitudinals, if any, is to be deducted from the depth of transverses. Where the depth of side transverses is divided by vertical stiffeners, the divided depth may be taken as d_0 in the calculation of t_2.

k = coefficient given in **Table 3.13.1** according to the ratio of S_1 to d_0, where S_1 (mm) is the spacing of tripping brackets or stiffeners provided on web plates of side transverses. For the intermediate values of S_1/d_0, k is to be obtained by linear interpolation.

(3) Side transverses are to be connected effectively with the bottom transverses. Where side transverses are connected with bottom transverses, the scantlings of webs and face bars in the lowest span are to be so decided as to provide strength continuity in the transient from side to bottom transverse; the sum of effective sectional area of web and area of face bar in the lower half of the lowest span is not to be less than the required sectional area of web of the bottom transverse.

(4) Side transverses are to be provided with tripping brackets at an interval of about 3 m. Where the breadth of face bars of side transverses exceeds 180 mm on either side of the web, the tripping brackets are to support the face bars as well. And stiffeners are to be provided on the webs at every longitudinal, except that these stiffeners may be provided at alternate longitudinals in the middle part of spans other than the lowest span.

3. Cross ties specified in **Par 2** (1) are to comply with the requirements in items **203. 2** (3) (c), (d) and (e). In this case, side stringers of quotable paragraph are to be replaced with side transverse. Where, however, it is found impracticable to apply these requirements, the constructions are to be at the discretion of the Society.

4. Bottom transverses supporting bottom longitudinals are to be of the construction specified in (1) to (6) or to be of that deemed equivalent thereto by the Society. In case of ships capable of maintaining adequate fore draught in rough seas, however, the section modulus of transverses and the sectional area of webs specified in (1) to (3) may be reduced by 10 % respectively.

(1) The scantlings of bottom transverses are not to be less than that obtained from the following formula, and the bottom transverses are to be supported by struts at the centre line, and further the adjacent bottom transverses are to be connected each other by a centre girder of about the same scantlings as those of the bottom transverses or to be supported by a specially deep centre girder or a longitudinal bulkhead.

Web depth : $d_0 = 5.5L + 450$

Section modulus : $Z = 1.2SLl^2$ (cm^3)

Web thickness : $t_w = 0.6\sqrt{L} + 3$ (mm)

where:

S = spacing of bottom transverses (m).

l = distance between the supporting points of bottom transverses (m).

(2) Where bottom transverses and centre girders are of scantlings exceeding those obtained from the following formula, notwithstanding the requirements in (1), the centre line struts may be arranged at alternate bottom transverses.

(a) Centre girders:

Web depth : $d_0 = 8L + 680$ (mm)

Web thickness : $t_w = 0.65\sqrt{L} + 3.5$ (mm)

Section modulus : Value obtained from the formula in (1). In the formula, however, the average load bearing width (m) of the centre girder is to be taken as S and the distance between the supporting points of the centre girder (m) as l.

(b) Bottom transverses :

Web depth : $d_0 = 5.5L + 450$ (mm)

Web thickness : $t_w = 0.65\sqrt{L} + 3.5$ (mm)

Section modulus :Value obtained from the formula in (1).

(3) Where the scantlings of bottom transverses are greater than those obtained from the following formula, notwithstanding the requirements in (1) the centre line struts or longitudinal bulkheads may be dispensed with. In this case, the scantlings of web plates of centre girders are not to be less than those required in (1) for bottom transverses and free edges of web plates are to be suitably stiffened.

Web depth : $d_0 = 8L + 680$ (mm)

Web thickness : $t_w = 0.7\sqrt{L} + 4$ (mm)

Section modulus : Value obtained from the formula in (1).

(4) Where the web depths of bottom transverses and centre girders are greater than those obtained from (3) their thicknesses may be reduced from the thicknesses prescribed in (3) notwithstanding the requirements in (3). However, in no case is the thickness to be less than that obtained from the following formula:

$t_w = 0.55\sqrt{L} + 2.5$ (mm)

(5) Where the length of bottom transverses measured between their supporting points at each side exceeds 0.045L(m) or the spacing of bottom transverses exceeds 2.5 m, the scantlings of bottom transverses and centre girders prescribed in (1) to (4) are to be suitably increased.

(6) Bottom transverses are to be provided with tripping brackets at an interval of about 3 m. Where the breadth of face bars of bottom transverses exceeds 180 mm on either side of the web, the tripping brackets are to support the face bars as well. And stiffeners are to be provided on the webs at every longitudinal.

5. The struts stipulated in **4** (1) and (2) are not to be less effective than those required by the following (1) to (3) or equivalent thereto.

(1) The scantlings of struts are not to be less than that obtained from the formula given in **Table**

3.13.3.

Table 3.13.3 Scantlings of struts

$\frac{l}{k_0}$	Sectional area (cm^2)	Web thickness (mm)
$\frac{l}{k_0} \geq 0.6$	$A = \frac{0.115 S b L}{1 - 0.5 \frac{l}{k_0}}$	$t_w = 0.0062 d_w \sqrt{\frac{S b L}{A}}$
$\frac{l}{k_0} < 0.6$	$A = 0.164 S b L$	

S = length in longitudinal direction of the area supported by strut (m).
b = breadth of the area supported by strut (m).
l = length of strut (m).
k_0 = minimum radius of gyration of struts, obtained from the following formula (cm).

$$k_0 = \sqrt{\frac{I}{A}}$$

I = the least moment of inertia of strut (cm^4).
A = sectional area of strut (cm^2).
d_w = breadth of web (mm). Where, however, the web is provided with stiffeners along the length of strut, the maximum spacing of such stiffeners is to be taken as d_w.

(2) As a rule, the struts are to extend to the lowest deck, and are to be effectively connected with the cross ties by brackets.
(3) Where the breadth of face bars on either side of the webs exceeds 150 mm, stiffeners are to be provided on the webs and so arranged as to support the face bars at a suitable interval.

6. Side girders are to be provided in line with those abaft collision bulkhead in order to give additional stiffness to the structure of flat bottom.

205. Bulbous bow

Structural arrangements at the fore end part of ship having bulbous bow or other similar unusual form of bow section will be specially considered by the Society.

Section 3 Arrangements to Resist Panting abaft Aft-peak Bulkhead

301. Floors

The scantling and arrangement of floors in aft-peak are to be in accordance with the requirements in **202.** of this Chapter. The floors are to extend well above the stern tubes.

302. Frames

1. The section modulus of transverse frames below the freeboard deck is not to be less than that obtained from the following formula:

$$Z = 8 S h l^2 \quad (\text{cm}^3)$$

where:

S = frame spacing (m).

l = unsupported length of frame (m). Where, however, the length is less than 2.15 m, l is to be taken as 2.15 m.

h = vertical distance from the middle of l to a point $d+0.038L'$ above the top of keel (m). Where, however, the distance is less than $0.04L$(m), h is to be taken as $0.04L$(m).

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.

2. Where the speed of ship exceeds 14 kts, the section modulus of side frames is to be increased over the value required by **Par 1** at the rate of 2 % per knot excess, but the increase need not exceed 12 %.

303. Panting beams and stringers

1. The structure below the lowest deck is to be effectively stiffened by means of panting beams and stringers as required for the fore peak in **203. 2.**

2. Where the distance between supports at any part of the girth of the frame exceeds 2.5 m, the scantlings of frames are to be increased, or side stringers or struts are to be additionally provided to give adequate stiffness to the structure.

304. Cruiser sterns

Cruiser sterns are to be strengthened by means of web frames, side stringers, etc. as may be required.

Section 4 Arrangements to Resist Panting between Both Peaks

401. Abaft collision bulkhead

Between the collision bulkhead and $0.15L$ from the fore end, side stringers are recommended to be provided in line with stringer plates or side stringers in way of the fore peak tanks, in association with web frames provided at a suitable interval. Even in case where no web frame and side stringer are provided, brackets, etc. are to be provided to provide continuity at sections where side stringers or perforated steel plates in the fore peak tanks are located.

402. Forward after peak bulkhead

As for forward of the aft peak bulkhead, side stringers are to be provided or the frames are to be increased in size in a similar manner as prescribed in the preceding Article, where the frames have specially long unsupported spans as compared with the span amidships. ⚓

CHAPTER 14 WATERTIGHT BULKHEADS

Section 1 General

101. Application

In general all ships are to be provided with strength and watertight bulkheads in accordance with the requirements in this Chapter. In ships of special types, arrangements where it is impracticable to be in accordance with the requirements of this Chapter, are to be specially approved by this Society.

102. Symbols

Watertight bulkheads constructed in accordance with the requirements in this Chapter will be recorded in the Register Book as *WT* the symbols being prefixed in each case by the number of such bulkheads.

Section 2 Arrangement of Watertight Bulkheads

201. Collision bulkheads

1. All ships are to have a collision bulkhead, at a position not less than $0.05L_f$ or 10 m, whichever is the lesser, but not more than $0.08\,L_f$ or $0.05\,L_f + 3$ m, whichever is the greater except where the larger distance be accepted by the Society due to special structural reasons from the forward terminal of the length for freeboard. However, where any part of the ship below the waterline at 85 % of the least moulded depth extends forward beyond the forward terminal of the length for freeboard, the above-mentioned distance is to be measured from a point either: (See Fig **3.14.1**)

(a) at the mid-length of such extension; or
(b) at a distance of $0.05L_f$ forward from the above mentioned forward terminal; or
(c) at a distance of 3 m forward from the forward terminal; whichever gives the smallest measurement.

2. For ships having a collision bulkhead with steps or recesses, the measurement of the distance may be observed in accordance with **Fig 3.14.1** (B).

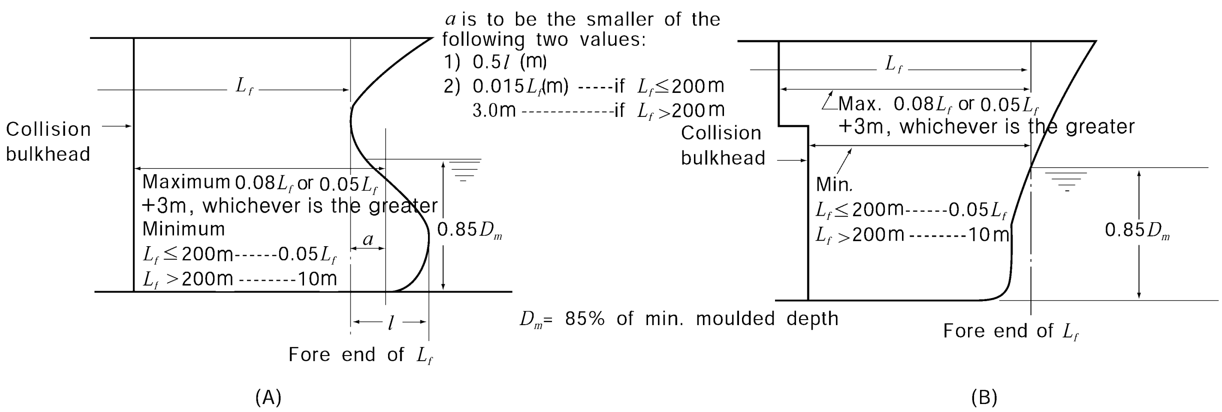


Fig 3.14.1 Measuring positions of collision bulkhead location

3. Arrangement of collision bulkhead in a ship provided with bow door is to be at the discretion of the Society. However, where a sloping ramp forms a part of the collision bulkhead above the freeboard deck, the part of the ramp which is more than 2.3 m above the freeboard deck may extend forward of the limit specified in the above **Par 1.** In this case, the ramp is to be weathertight over its complete length.

202. Aft peak bulkheads

1. All ships are to have an after peak bulkhead situated at a suitable positions.

2. The stern tube is to be enclosed in a watertight compartment by the after peak bulkhead or other suitable arrangements.

203. Machinery bulkheads

1. Watertight bulkhead is to be provided at each end of the machinery space.

2. In ships having the machinery room at aft body, aft end bulkhead of machinery room specified in **Par 1** may be regarded as aft peak bulkhead specified in **202.**

204. Hold bulkheads

1. Cargo ships of ordinary type, are to have hold bulkheads in addition to the bulkheads specified in **201.** to **203.** at a reasonable interval so that the total number of the watertight bulkheads including the bulkheads specified in **201.** to **203.** may not be less than that given by **Table 3.14.1.**

Table 3.14.1 Number of watertight bulkheads

Length of ship (m)	Total number of bulkhead	
	Ships with machinery room at aft body	Elsewhere
$90 \le L < 102$	4	5
$102 \le L < 123$	5	6
$123 \le L < 143$	6	7
$143 \le L < 165$	7	8
$165 \le L < 186$	8	9
$186 \le L$	to be considered individually	

2. The requirements in **Par 1** may be not applied to the arrangements of bulkhead subject to the approval of the Society.

205. Height of watertight bulkheads

The watertight bulkheads required in **201.** to **204.** are the extend to the freeboard deck with the following exceptions:

(1) A watertight bulkhead in way of raised quarter or sunken forecastle deck is to extend up to the said deck.

(2) Where a forecastle having openings without closing appliances led to a space below the freeboard deck is provided, or where a forecastle of $0.25L_f$ or above in length is provided, the collision bulkhead is to extend up to the forecastle deck. However, the extended part above freeboard deck may have steps within the limit of bulkhead position specified in **201.** and may be weathertight.

(3) Aft peak bulkhead may terminate at a deck above the load line, provided that this deck is made watertight to stern or to watertight stern floor of the ship.

206. Construction

1. Where the watertight bulkheads required in **201.** to **204.** are not extended up to the strength deck, deep webs or partial bulkheads situated immediately or nearly above the main watertight bulkheads are to be provided so as to maintain the transverse strength and stiffness of the hull.

2. Where the length of a hold exceeds 30 m, suitable means are to be provided so as to maintain the transverse strength and stiffness of the hull.

207. Chain lockers

1. Chain lockers located abaft the collision bulkhead or in forepeak tanks are to be watertight and to be provided with means for effective drainage by pumps.

2. Chain lockers are to be subdivided by centre line screen walls.

Section 3 Construction of Watertight Bulkheads

301. Thickness

1. The thickness of bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.2S\sqrt{hK} + 1.5 \quad \text{(mm)}$$

where:

S = spacing of stiffeners (m).

h = vertical distance from the lower edge of plate to the bulkhead deck at centre (m). but in no case is it to be less than 3.4 m.

2. Notwithstanding the requirements in **Par 1**. In no case is the thickness of watertight bulkhead platings to be less than that obtained from following formula:

$$t_{min} = 5.9S + 1.5 \quad \text{(mm)}$$

where:

S = as specified in **Par 1.**

302. Increase of thickness

1. The thickness of lowest strake of plating is not to be less than that obtained from the above formula given in **301.** plus 1 mm.

2. The lowest strake of bulkhead plating is to extend at least 610 mm above the top of inner bottom plating in way of double bottom or 915 mm above the top of keel in way of single bottom. Where the double bottom is provided only on one side of the bulkhead, the extension of the lowest strake is to be of the greater value among the two cases above.

3. The bulkhead platings in way of bilge wells are to be at least 2.5 mm thicker than given by **301.**

4. The bulkhead plating is to be doubled or increased in thickness in way of stern tube opening, notwithstanding the requirements in the preceding Article.

303. Stiffeners

The section modulus of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$Z = CKShl^2 \quad (\text{cm}^3)$$

where:

l = span measured between the adjacent supports of stiffeners including the length of connection (mm). Where girders are provided, it is the distance from the heel of end connection to the first girder or the distance between the girders.

S = spacing of stiffeners (m).

h = vertical distance measured from the midpoint of l for vertical stiffeners, and from the midpoint of distance between the adjacent stiffeners for horizontal stiffeners, to the top of bulkhead deck at the centre line of ship (mm). Where the vertical distance is less than 6.0 m, h is to be taken as 0.8 times the vertical distance plus 1.2 m.

C = coefficient given in **Table 3.14.2** according to the type of end connection.

Table 3.14.2 Valua of C

<table>
<tr><td rowspan="6">Vertical Stiffener</td><td rowspan="2">Upper end / Lower end</td><td rowspan="2">Lug-connection or supported by horizontal girders</td><td colspan="2">Connection</td><td rowspan="2">End of stiffener unattached</td></tr>
<tr><td>Type A</td><td>Type B</td></tr>
<tr><td>Lug-connection or supported by horizontal girders</td><td>2.80</td><td>2.80</td><td>3.22</td><td>3.78</td></tr>
<tr><td>Bracketed</td><td>2.24</td><td>2.24</td><td>2.52</td><td>2.80</td></tr>
<tr><td>Only the web of stiffener attached at end</td><td>3.22</td><td>3.22</td><td>3.78</td><td>4.48</td></tr>
<tr><td>End of stiffener unattached</td><td>3.78</td><td>3.78</td><td>4.48</td><td>5.60</td></tr>
<tr><td rowspan="3">Horizontal Stiffener</td><td>One end / The other end</td><td colspan="2">Lug-connection, bracketed or supported by vertical girders</td><td colspan="2">End of stiffener unattached</td></tr>
<tr><td>Lug-connection, bracketed or supported by vertical girders</td><td colspan="2">2.80</td><td colspan="2">3.78</td></tr>
<tr><td>End of stiffener unattached</td><td colspan="2">3.78</td><td colspan="2">5.60</td></tr>
<tr><td colspan="6">NOTES:
1. "Lug-connection" is such a connection as both web and face bar of stiffener are effectively attached to the bulkhead plating, decks or inner bottoms which are strengthened by effective supporting members on the opposite side of plating.
2. "Connection-Type A" of vertical stiffeners is a connection by bracket to the longitudinal members or to the adjacent members, in line with the stiffeners, of the same or larger sections, (See Fig 3.14.2 (a))
3. "Connection-Type B" of vertical stiffeners is a connection by bracket to the transverse members such as beams, or other connections equivalent to the connections mentioned above. (See Fig, 3.14.2 (b))</td></tr>
</table>

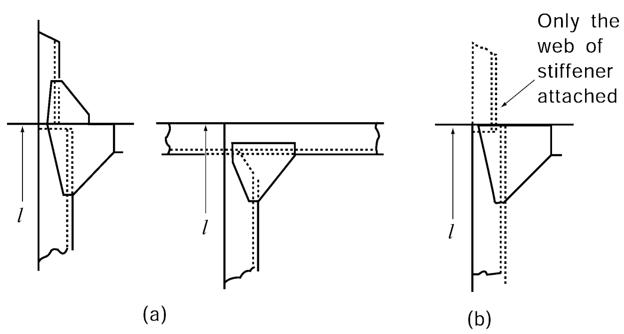


Fig 3.14.2 Types of end connection

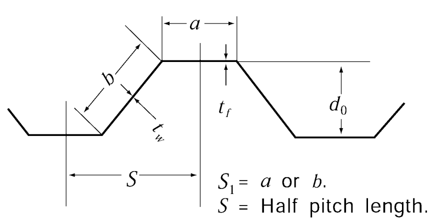


Fig 3.14.3 Measurement of S

304. Corrugated bulkheads

1. The plate thickness of corrugated bulkheads is not to be less than that obtained from the following formula, whichever is the greater:

$$t_1 = 0.0034 C S_1 \sqrt{hK} + 1.5 \quad \text{(mm)}$$
$$t_2 = 0.0059 C S_1 + 1.5 \quad \text{(mm)}$$

where:

h = as specified in **301.**

S_1 = breadth of face part and web part, respectively (mm), indicated as a and b in **Fig 3.14.3.**

C = coefficient given below:

Face part: $C = \dfrac{1.5}{\sqrt{1 + \left(\dfrac{t_w}{t_f}\right)^2}}$

Web part: $C = 1.0$

t_f , t_w = thickness of plates of face part and web part, respectively (mm).

2. The section modulus per half pitch of corrugated bulkheads is not to be less than that obtained from the following formula:

$$Z = 3.6 CKShl^2 \quad (\text{cm}^3)$$

where:

S = half pitch length of the corrugation (m). (See **Fig 3.14.3**)

h = as specified in **303.**

l = length between the supports (m), as indicated in **Fig 3.14.4.**

C = coefficient given in **Table 3.14.3,** according to the type of end connection.

3. Where the end connection of corrugated bulkheads is remarkably effective, the value of C specified in **Par 2** may be adequately reduced.

4. The thickness of plates at end parts for $0.2\,l$ in line with l is not to be less than that obtained from the following formulae respectively:

Web part : $t_1 = 41.7 \dfrac{CKShl}{d_0} + 1.5 \quad \text{(mm)}$

In no case is the web thickness to be less than that obtained from the following formula:

$$t_1 = 0.174 \sqrt[3]{\frac{CShlb^2}{d_0}} + 1.5 \quad \text{(mm)}$$

Face part, except the upper end part of vertically corrugated bulkheads:

$$t_1 = \frac{0.012a}{\sqrt{K}} + 1.5 \quad \text{(mm)}$$

where:

S, h, l, d_0 = as specified in **Par 2.**

a, b = breadth of face part and web part, respectively (mm).

C = coefficient given in **Table 3.14.4.** Where the vertically corrugated bulkheads are constructed with single span, the value of C may be taken as the value for the uppermost span in the Table.

Tale 3.14.3 Values of C

Line	One end of bulkhead / The other end of bulkhead	Supported by rule horizontal or vertical girders	Upper end welded directly to deck	Upper end welded to stool efficiently supported by ship structure
(1)	Supported by rule horizontal or vertical girders or lower end of bulkhead welded directly to decks or inner bottoms	$\dfrac{4}{2+\dfrac{Z_1}{Z_0}+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2.2+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2.6+\dfrac{Z_2}{Z_0}}$
(2)	Lower end of bulkhead welded to stool efficiently supported by ship structure	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2+\dfrac{Z_1}{Z_0}+\dfrac{d_H}{d_0}}$	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2.2+\dfrac{d_H}{d_0}}$	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2.6+\dfrac{d_H}{d_0}}$
		In no case is the value of C less than that obtained from (1).		

Z_0 = minimum section modulus per half pitch of mid part for $0.6l$ of the corrugated bulkhead (cm^3).
Z_1, Z_2 = section modulus per half pitch of end part (cm^3). In case of vertical corrugation, Z_1 is the section modulus of the upper end part and Z_2 is that of lower end part. Where the plate thickness is increased in accordance with **Par 5** the section modulus is to be that for the plate thickness reduced by the increment.
l_H = height of stool measured from the inner bottom (m).
d_H = breadth of stool measured on the inner bottom plating (mm).
d_0 = depth of corrugation (mm).

Tale 3.14.4 Values of C

Position		Upper end	Lower end
Vertically corrugated bulkhead	Uppermost span	0.4	1.6
	Other spans	0.9	1.1
Both ends of horizontally corrugated bulkhead		1.0	

e = 0.5A or 0.5B. whichever is the smaller.

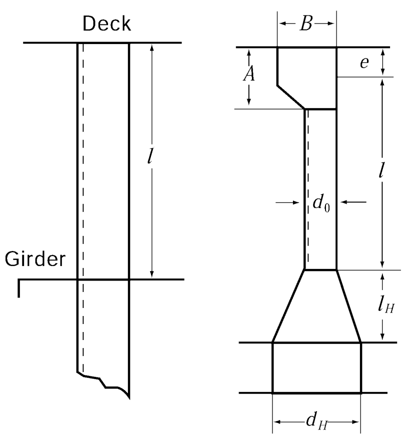


Fig 3.14.4 Measurement of l

5. The thickness of the plates specified in the preceding Paragraphs are to be in accordance with **302.**

6. The actual section modulus per half pitch of corrugated bulkheads is to be calculated by the following formula:

$$Z_a = \frac{a t_f d_0}{2} + \frac{b t_w d_0}{6} \quad (\text{cm}^3)$$

where:

a, b = breadth of face part and web part respectively (m).

t_f, t_w = thickness of plates of face part and web part respectively (mm).

d_0 = depth of corrugation (mm).

305. Collision bulkheads

For collision bulkheads, the plate thickness and section modulus of stiffeners are not to be less than those specified in **301., 303**. and **304.** taking h as 1.25 times the specified height.

306. Girders

1. The section modulus of girders supporting bulkhead stiffeners (hereinafter referred to as girder) is not to be less than that obtained from the following formula:

$$Z = 4.75 K S h l^2 \quad (\text{cm}^3)$$

where

S = breadth of the area supported by the girder (mm).

h = vertical distance measured from the midpoint of l for vertical girders, and from the mid-point of S for horizontal girders, to the top of bulkhead deck at the centre line of ship (m). Where the vertical distance is less than 6.0 m, h is to be taken as 0.8 times the vertical distance plus 1.2 m.

l = span measured between the adjacent supports of girders (m). l may be modified in accordance with **Ch 1, 605.** Where brackets with curved free edge are attached the effective arm length of the brackets is to be taken as b indicated in **Fig 3.14.5.**

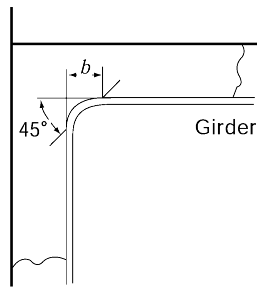


Fig 3.14.5 Measurement of *b*

2. The moment of inertia of girders is not to be less than that obtained from the following formula. In no case is the depth of girders to be less than 2.5 times the depth of slots for stiffeners.

$$I = 10hl^4 \quad (cm^4)$$

where:

h, l = as specified in **Par 1.**

3. The thickness of web plates is not to be less than that obtained from the following formula:

$$t = 0.01S_1 + 1.5 \quad (mm)$$

where:

S_1 = spacing of web stiffeners or depth of girders, whichever is the smaller (mm).

4. The thickness of web plates at both end parts for 0.2 l is not to be less than that obtained from the following formulae, whichever is the greater:

$$t_1 = 41.7\frac{CKShl}{d_0} + 1.5 \quad (mm), \qquad t_2 = 0.174\sqrt{\frac{CShlS_1^2}{d_0}} + 1.5 \quad (mm)$$

where:

S, h, l = as specified in **Par 1.**

d_0 = depth of girders (mm).

S_1 = as specified in **Par 3.**

C = as specified in **304. 4.**

5. Tripping brackets are to be provided at an interval of about 3 m and where the breadth of face plates exceeds 180 mm on either side of the girder, these brackets are to be so arranged as to support the face plates.

6. The actual section modulus and moment of inertia of girders are to be calculated in association with the steel plates specified in **Ch 1, 602.** Where stiffeners are provided within the effective breadth, they may be included in the calculation.

307. Brackets

The scantlings of the effective brackets at the ends of bulkhead stiffener are to be in accordance with the requirement in **Ch 1, 604. 2.**

308. Strengthening of bulkhead plating, deck plating, etc.

Platings of bulkheads, decks, inner bottoms, etc. are to be, if necessary, strengthened at the location of the end brackets of stiffeners and the end of girders.

309. Bulkhead recesses

1. In way of bulkhead recesses, beams are to be provided at every frame and under the upper bulkhead in accordance with the requirements in **Ch 10, 403.** and **Ch 14, 303.** taking the beam spacing as the stiffener spacing. Where the lower end of upper bulkhead is specially strengthened, the beam under the upper bulkhead may be dispensed with.

2. The thickness of deck plating in way of bulkhead recesses is to be at least 1 mm greater than that given by **301.,** regarding the deck plating as bulkhead plating and the beams as stiffeners respectively. In no case is the thickness to be less than that required for deck plating in that location.

3. The thickness of pillars supporting bulkhead recesses are to be determined taking account of the water pressure which might be applied on the upper surface of recesses, and their end connections are to be sufficient to withstand the water pressure which might be applied on the under surface.

310. Construction of bulkheads in way of watertight doors

Where stiffeners are cut or the spacing of stiffeners is increased in order to provide the watertight door in the bulkhead, the opening is to be suitably framed and strengthened as to maintain the full strength of the bulkhead. In this case the door frames are not to be considered as stiffeners.

Section 4 Watertight Doors

401. General

1. Any access openings, doors, manholes or ducts for ventilation, etc. are not to be cut in the collision bulkhead below freeboard deck. The number of openings in collision bulkheads above the freeboard deck is to be kept to a minimum as possible and all such openings are to be provided with weathertight means of closing.

2. Watertight doors(or access hatch cover) are to be provided for all access openings in the watertight bulkheads or openings to ensure the watertight integrity of the inner decks in accordance with the requirements in the following **402.** to **405.**

402. Type of watertight doors

1. Watertight doors are to be of sliding type. Hinged or rolling type may, however, be accepted having regard to the position or the service condition of the door.

2. Notwithstanding the provisions in **1.** above, where watertight door is as small as crew can pass, the watertight door may be of hinged type or rolling type, except where the doors are required to be capable of being closed remotely in accordance with **404. 2.**

3. Notwithstanding the provisions in **1.** above, watertight doors in large cargo hold division may be of a type other than sliding type provided that such doors are permanently closed at sea.

4. Doors which are closed by dropping or by the action of a dropping weight are not permitted.

403. Strength and watertightness

1. Watertight doors are to be of ample strength and watertightness for water pressure to a head up to the bulkhead deck, and door frames are to be effectively secured to the bulkheads. Where deemed necessary by the Society, watertight doors are to be tested by water pressure before they are fitted.

2. Where watertight doors are provided in cargo spaces, such doors are to be protected against damages due to cargoes, etc. by suitable means.

404. Control

1. All watertight doors, except those which are to be permanently closed at sea, are to be capable of being opened and closed by hand locally, from both sides of the doors, with the ship listed of 30 degrees to either side.

2. In addition to the requirements of **1.** above, watertight doors which are used at sea or normally open at sea, are to be capable of being remotely closed by power from the navigation bridge.

3. It is not to be possible to remotely open any watertight door. In addition, watertight doors which are applying to the provisions of **402. 3** are not to be remotely controlled.

405. Indication

1. Watertight doors, except those permanently closed at sea, are to be provided with position indicators showing whether the doors are open or closed at all operating positions.

2. In addition to the requirements of **1.** above for watertight doors which are to be capable of being remotely closed, an indication is to be placed locally showing that the door is in remote control mode.

406. Alarms

Watertight doors which are capable of being remotely closed are to be provided with an audible alarm which will sound at the door position whenever such a door is remotely closed.

407. Source of power

1. The remote controls, indications and alarms required in **404.** to **406.** are to be operable in the event of main power failure.

2. Electrical installations for devices specified in **1.** except water-proof type approved by the Society are to be not provided with under freeboard deck.

3. Cables for devices specified in 1. are to comply with the requirements of **Pt 6, Ch 1 Sec 4.** of the Rules.

408. Notices

1. Watertight doors which are to be normally closed at sea are to have notices fixed to both sides of the doors stating "**To be kept closed at sea**".

2. Watertight doors which are to be permanently closed at sea are to have notices fixed to both sides stating "**Not to be opened at sea**". Such doors which are accessible during the voyage are to be fitted with a device which prevents opening.

409. Sliding doors

1. Sliding watertight doors are to be capable of being operated from an accessible position above the bulkhead deck and are to have an index at the operating positon showing whether the door is open or closed. This remote control of the door may, however, be omitted where the Society is satisfied with such an arrangement having regard to the service condition of the door.

2. Where the above control means is operated by rods, the lead of operating rods is to be as direct as possible and the screw is to work in a nut of gun-metal or other approved material.

3. Sliding doors controlled from remote positions are also to be capable of being operated at the position of the door.

4. The frames of vertically sliding watertight doors are to have no groove at the bottom in which dirt might lodge and prevent the door from closing.

410. Hinged and rolling doors

1. For hinged and rolling watertight doors, the hinge pins and the wheel axle of these doors are to be of gun-metal or other approved materials.

2. Hinged and rolling watertight doors except those are to be permanently closed at sea, are to be of quick acting or single acting type which is capable of being closed and secured from both sides of the doors.

411. Others

For fitting of valves or cocks to a watertight bulkhead, see **Pt 5, Ch 6, 107. 11.** For pipes passing through bulkheads, see **Pt 5, Ch 6, 107. 8** and **10.** For electric cables passing through bulkhead, see Pt **6, Ch 1, 408.1** to **3.** ⚓

CHAPTER 15 DEEP TANKS

Section 1 General

101. Definition

A deep tank is a tank used for carriage of water, fuel oil and other liquids, forming a part of the hull in holds. The deep tanks used for carriage of oil are designated as "deep oil tanks", if necessary.

102. Application

1. The constructions of all deep tanks are to be in accordance with the requirements in this Chapter. Where the bulkhead of deep tank partly serves as a watertight bulkhead, the part of the bulkhead is to be in accordance with the requirement in **Ch 14.**

2. The requirements in **Pt 7, Ch 1** are to be applied to the bulkheads of the deep tanks for carriage of oils having flash a point below 60°C, in addition to those in this Chapter.

103. Divisions in tanks

1. Deep tanks are to be of proper size and to be provided with such longitudinal watertight divisions as necessary to meet the requirements for stability in service conditions as well as while the tanks are being filled or discharged.

2. Tanks for fresh water or fuel oil or those which are not intended to be kept entirely filled in service conditions are to have additional divisions or deep wash plates as necessary to minimize the dynamic forces acting on the structure.

3. Where it is impracticable to comply with the requirements in **Par 2,** the scantlings required in this Chapter are to be properly increased.

4. Longitudinal watertight divisions which will be subjected to pressure from both sides, in tanks which are to be entirely filled or emptied in service conditions, may be of the scantlings required for ordinary watertight bulkheads by **Ch 14.** In such cases, the tanks are to be provided with deep hatches, etc., fitted with inspection plugs in order to ensure that the tanks are kept full in service conditions.

104. Minimum thickness

In wing tanks and hold tanks with the length or breadth which exceeds $0.1L+5.0$ (mm) and in topside tanks and hopper tanks, the thickness of girders, struts and the brackets and bulkhead plates is not to be less than that given by **Table 3.15.1** in accordance with the length of ship.

105. Additional strengthening of bulkheads in large tanks

As for large tank boundaries, the scantlings of bulkhead plates, stiffeners, girders and cross ties are not to be less than that obtained from the relevant formulae in **202.** to **205.** and **207.,** where the value of h is the one specified in each requirement or that given by the following formula, whichever is the greater.

$$H=0.85(h+\Delta h) \quad \text{(m)}$$

where:

h = water head as specified in each requirement

Δh = additional water head given by the following formula:

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10) \quad \text{(m)}$$

l_t = tank length (m). It is not to be less than 10 m.

b_t = tank breadth (m). It is not to be less than 10 m. but may be $\frac{2}{3}B$ in case of ballast hold of bulk carrier with top side tanks.

Table 3.15.1 Minimum thickness

Length of ship (m)	Thickness (mm)
$90 \le L < 105$	8.0
$105 \le L < 120$	8.5
$120 \le L < 135$	9.0
$135 \le L < 150$	9.5
$150 \le L < 165$	10.0
$165 \le L < 180$	10.5
$180 \le L < 195$	11.0
$195 \le L < 225$	11.5
$225 \le L < 275$	12.0
$275 \le L < 325$	12.5
$325 \le L < 375$	13.0
$375 \le L$	13.5

Section 2 Bulkheads of Deep Tanks

201. Application

The construction of bulkheads and decks forming boundaries of deep tanks is to be in accordance with the requirements in **Ch 14,** unless otherwise specified in this Chapter.

202. Bulkhead plates

The thickness of deep tank bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.6S\sqrt{hK} + 2.5 \quad \text{(mm)}$$

where:

S = spacing of stiffeners. (m).

h = distance given below, whichever is the greater:

(1) Vertical distance measured from the lower edge of plate to the midpoint of the distance between the top of tanks and the top of overflow pipes (m).

(2) 0.7 times the vertical distance measured from the lower edge of plate to the point of 2.0 m above the top of overflow pipes (m).

203. Bulkhead stiffeners

The section modulus of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$Z = CKShl^2 \quad (\text{cm}^3)$$

where:

S and l = as specified in **Ch 14, 303.**

h = vertical distance given below, whichever is the greater, the lower end being regarded as the midpoint of l for vertical stiffeners and as the midpoint of distance between the adjacent stiffeners for horizontal stiffeners.

(1) Vertical distance measured from the lower end to the mid-point of the distance between the top of tanks and the top of overflow pipes (m).

(2) 0.7 times the vertical distance measured from the lower end to the point of 2.0 m above the top of overflow pipes (m).

C = coefficient given in **Table 3.15.2** according to the type of end connections.

Table 3.15.2 Value of C

The other end of stiffeners \ One end of stiffeners	Connection Type A	Connection Type B	Supported by rule girders or lug connection	Snip
Connection Type A	4.90	8.05	5.95	9.10
Connection Type B	8.05	5.95	9.10	8.05
Supported by rule girders or lug connection	5.95	9.10	7.00	10.50
Snip	9.10	8.05	10.50	10.50

NOTES:
1. "Connection Type A" is a connection by bracket to the double bottoms or to the adjacent members, such as longitudinals or stiffeners in line, of the same or larger sections, or a connection by bracket to the equivalent members mentioned above. (see **Fig, 3.14.2** (a))
2. "Connection Type B" is a connection by bracket to the transverse members such as beams or equivalent thereto. (see **Fig, 3.14.2** (b))

204. Girders supporting bulkhead stiffeners

1. The section modulus of girders supporting bulkhead stiffeners (hereinafter referred to as "girder") is not to be less than that obtained from the following formula:

$$Z = 7.13KShl^2 \quad (\text{cm}^3)$$

where:

S = breadth of the area supported by the girders (m).

h = vertical distance measured from the midpoint of S for horizontal girders, and from the mid-point of l for vertical girders, to the top h specified in **203.** (m).

l = span specified in **Ch 14, 306** (m).

2. The moment of inertia of girders is not to be less than that obtained from the following formula.

The depth of girders is not to be less than 2.5 times the depth of slots for stiffeners.

$$I = 30Khl^4 \quad (\text{cm}^4)$$

where:

h, l = as specified in preceding Paragraph.

3. The thickness of plates of web part is not to be less than that obtained from the following formulae, whichever is the greater:

$$t_1 = 41.7\frac{CKShl}{d_1} + 2.5 \quad (\text{mm}), \qquad t_2 = 0.174\sqrt{\frac{CShlS_1^2}{d_1}} + 2.5 \quad (\text{mm}), \qquad t_3 = 0.01S_1 + 2.5 \quad (\text{mm})$$

where:

S, h and l = as specified in **Par 1.**

S_1 = spacing of web stiffeners or the depth of girders, whichever is the greater (mm).

d_1 = depth of the girder at the location considered, reduced by the depth of slots for stiffeners (mm)

C = coefficient obtained from the following formulae. It is not to be less than 0.5.

For horizontal girders : $C = \left|1 - 2\frac{x}{l}\right|$

For vertical girders : $C = \left|1 + \frac{1}{5} \times \frac{1}{h} - \left(2 + \frac{l}{h}\right)\frac{x}{l} + \frac{l}{h}\left(\frac{x}{l}\right)^2\right|$

x = distance measured from the end of l for horizontal girders, and from the lower end l for vertical girders, to the location considered (m)

4. The actual section modulus and moment of inertia of girders are to be calculated in accordance with the provisions in **Ch 14, 306. 6.**

205. Cross ties

1. Where efficient cross ties are provided across deep tanks connecting girders on each side of the tanks, the span l of girders specified in **204.** may be measured between the end of girder and the centre line of cross tie or between the centre lines of adjacent cross ties.

2. The sectional area of cross ties is not to be less than that obtained from the following formula:

$$A = 1.3Sb_sh \quad (\text{cm}^2)$$

where :

S, h = as specified in **204.**

b_s = breadth of the area supported by the cross ties (m).

3. The end of cross ties are to be bracketed to girders.

206. Brackets

The scantlings of effective brackets on both end of stiffeners are to be in accordance with the requirements in **Ch 14, 307.**

207. Corrugated bulkheads

1. The thickness of plates of corrugated bulkheads is not to be less than that obtained from the following formula:

$$t = 0.0036 C S_1 \sqrt{hK} + 2.5 \quad \text{(mm)}$$

where:

S_1, t_f and t_w = as specified in **Ch 14, 304. 1.**

h = as specified in **202.**

C = coefficient given below:

For face part : $C = \dfrac{1.4}{\sqrt{1 + \left(\dfrac{t_w}{t_f}\right)^2}}$

For web par t: $C = 1.0$

2. The section modulus per half pitch of corrugated bulkheads is not to be less than that obtained from the following formula:

$$Z = 7 CKShl^2 \quad \text{(cm}^3\text{)}$$

where:

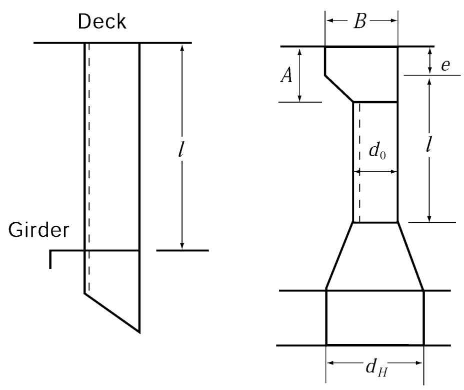
S = as specified in **Ch 14, 304. 2.**

l = length between the supports (m), as indicated in **Fig 3.15.1.**

h = as specified in **203.**

C = coefficient given in **Table 3.15.3,** according to the type of end connection.

As for bulkheads with lower stools of which the width in longitudinal direction at the lower end, d_H is less than 2.5 times of web depth of the bulkhead, d_0 (See **Fig 3.15.1**), the measurement of l and the values of C are to be at the discretion of the Society.



$$e = A - \frac{d_0}{2B} \cdot A$$

Fig 3.15.1 Measurement of *l*

Table 3.15.3 Values of C

Column	Upper end / Lower end	Supported by Girders	Welded directly to deck	Welded to stool efficiently supported by ship structure
(1)	Supported by girders or welded directly to deck or inner bottoms	1.00	1.50	1.35
(2)	Welded to stool efficiently supported by ship structure	1.50	1.20	1.00

3. The thickness of plates at end parts for $0.2l$ in line with l is not to be less than that obtained from the following formulae :

Thickness of web part : $t = 41.7\dfrac{CKShl}{d_0} + 2.5$ (mm)

It is not to be less than that obtained from the following formula :

$$t_{\min} = 0.174\sqrt[3]{\frac{CKShl}{d_0}} + 2.5 \quad \text{(mm)}$$

Thickness of the face part except the upper end part of vertically corrugated bulkheads:

$$t_f = \frac{0.012a}{\sqrt{K}} + 2.5 \quad \text{(mm)}$$

where:

h = as specified in **203.**

C, l = as specified in **Par 2.**

S, d_0, a and b = as specified in **Ch 14, 304. 4.**

208. Top and bottom construction

The scantlings of the members forming the top or the bottom of deep tanks are to be in accordance with the requirements in this Chapter, regarding the members as the members forming the deep tank bulkheads at the location. They are not to be less than that required for the deck plating or the bottom plating at the location. For top plating of deep tanks the thickness of plates is to be at least 1 mm greater than the thickness specified in **202.**

209. Scantling of members not in contact with sea water

The thickness of plates of bulkheads and girders which are not in contact with sea water in service conditions may be reduced from the requirements in **202., 204.** and **207.** by the values given below:

For the plates of which only side is in contact with sea water .... 0.5 mm

For the plates of which neither side is in contact with sea water .... 1.0 mm

However, bulkhead plate in way of the location such as bilge wells are to be regarded as the plates in contact with sea water.

Section 3 Fittings of Deep Tanks

301. Limbers and air holes

Limbers and air holes are to be cut suitably in the structural members to ensure that air or water does not remain stagnated in any part of the tank.

302. Drainage

Efficient arrangement is to be made for draining bilge water on the top of deep tanks.

303. Inspection plug

The inspection plugs provided on deep tank tops as required in **103. 4** are to be located in readily accessible positions.

304. Cofferdam

1. The following dedicated tanks are to be separated from adjacent tanks by cofferdams. However, these cofferdams may be omitted provided that the common boundaries of lubricating oil and fuel oil tank have full penetration welds.

(1) Fuel oil
(2) Lubricating oil
(3) Vegetable oil
(4) Fresh water

2. The cofferdams in **Par. 1** are to be provided with the air pipes to comply with the requirements in **Pt 5, Ch 6, 201** and with the manholes of adequate size which are well accessible.

3. Crew spaces and passenger spaces are not to be directly adjacent to the tanks for carriage of fuel oil. Such compartments are to be separated from the fuel oil tanks by cofferdams which are well ventilated and is not less than 600 mm in width for easy access. Where the top of fuel oil tanks has no opening and is coated with incombustible coverings of 38 mm and over in thickness, the cofferdam between such compartments and the top of fuel oil tanks may be omitted. ⚓

CHAPTER 16 SUPERSTRUCTURES

Section 1 General

101. General

1. All ships are to have forecastles, or increased sheer so that the vertical distance at FP measured from the summer load water line to the top of exposed deck at side is not to be less than that obtained from the following formula. However, for ships to which timber freeboard are assigned, the summer freeboard(and not the timber summer freeboard) is to be assumed when applying this requirement.

$$H = (6075(L/100) - 1875(L/100)^2 + 200(L/100)^3) \times (2.08 + 0.609\,C_b - 1.603\,C_{wf} - 0.0129(L/d_1))$$

d_1 : Draft at 85 % of the least moulded depth

C_{wf} : Waterplane area coefficient forward of $L/2$, $C_{wf} = A_{wf}/(L/2) \times B)$

A_{wf} : Waterplane area forward of $L/2$ at draft d_1 (m^2)

2. The length of forecastles is to be extended to a point not less than 0.07L abaft the forward perpendicular. Where an increase of sheer is adopted in lieu of forecastle, the sheer is to continue to a point not less than 0.15L abaft the forward perpendicular.

102. Application

1. The construction and scantlings of superstructures are to be in accordance with the relevant Chapters in addition to this Chapter.

2. The requirements in this Chapter are prescribed for the superstructures up to the third tier above the freeboard deck. As for the superstructures above the third tier, the construction and scantlings thereof are to be as deemed appropriate by the Society.

3. As for the superstructures in ships with specially large freeboard, the construction of end bulkheads may be suitably modified subject to the approval by the Society.

Section 2 Superstructure End Bulkheads

201. Head of water

1. The head of water for the calculation of the scantlings of superstructure end bulkheads is not to be less than that obtained from the following formula:

$$h = a(bf - y) \quad \text{(m)}$$

where:

a = as given in **Table 3.16.1.**

b = as given in **Table 3.16.2.**

f = as given by **Fig 3.16.1.**

y = vertical distance from the summer waterline to the mid-point of span of stiffener in case where the scantlings of stiffeners are determined, and to the mid-point of plate in case where the thickness of bulkhead plating is determined (m).

Table 3.16.1 Values of a

Bulkhead	Superstructure	a
Exposed front bulkhead	First tier	$\frac{L'}{120}+2.0$
	Second tier	$\frac{L'}{120}+1.0$
	Third tier	$\frac{L'}{150}+0.5$
Protected end bulkheads of the all tiers		
Aft bulkhead	Afterward of the midship	$\frac{L'}{1000}-0.8\frac{x}{L}+0.7$
	Forward of the midship	$\frac{L'}{1000}-0.4\frac{x}{L}+0.5$

L' = length of ship (m). Where, however, L exceeds 300 m, L' is to be taken as 300 m.
x = distance from the bulkhead to the after perpendicular (m).

Table 3.16.2 Values of b

$\frac{x}{L}$	b
$\frac{x}{L}<0.45$	$\left(\frac{0.45-\frac{x}{L}}{C_{b1}+0.2}\right)^2+1.0$
$\frac{x}{L}\geq 0.45$	$1.5\left(\frac{\frac{x}{L}-0.45}{C_{b1}+0.2}\right)^2+1.0$

x = distance from the bulkhead to the after perpendicular (m).
C_{b1} = block coefficient. Where, however, C_b is less than 0.6, C_{b1} is to be taken as 0.6, and where C_b is 0.8 or over, C_{b1} is to be taken as 0.8. And in calculating b for aft bulkhead located forward of the midship, C_{b1}, is to be taken as 0.8.

2. The head of water is not to be less than that obtained from the formulae in **Table 3.16.3,** irrespective of the provisions in **Par 1.**

Table 3.16.3 Head of water, h (m)

Length of ship	Exposed front bulkhead of the first tier superstructure	Others
$L\leq 250$ m	$\frac{L}{100}+2.5$	$\frac{L}{200}+1.25$
$L>250$ m	5.0	2.5

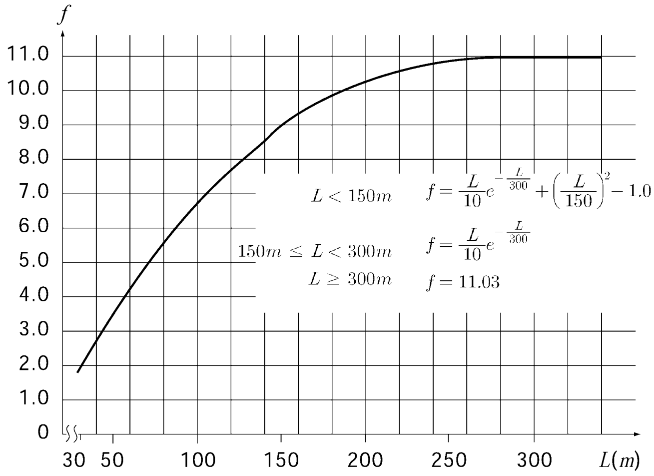


Fig 3.16.1 Value of f

202. Thickness

1. The thickness of superstructure end bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3S\sqrt{hK} \quad \text{(mm)}$$

where:

h = head of water specified in **201.** (m).

S = spacing of stiffeners. (m)

2. The thickness of bulkhead plating is not to be less than that obtained from the following formula, irrespective of the provisions in **Par 1.**

Bulkhead plating of the first tier superstructure : $t = \dfrac{L'}{100} + 4.0$ (mm)

Plating of other bulkheads : $t = \dfrac{L'}{100} + 3.0$ (mm)

where:

L' = as specified in **Table 3.16.1.**

203. Stiffeners

1. The section modulus of stiffeners on superstructure end bulkheads is not to be less than that obtained from the following formula:

$$Z = 3.5KShl^2 \quad (\text{cm}^3)$$

where:

S, h = as specified in **202.**

l = tween deck height (m). Where, however, l is less than 2 m, l is to be taken as 2 m.

2. Both ends of stiffeners on the exposed bulkheads of superstructures are to be connected to the deck by welding except where otherwise approved by the Society.

204. End bulkheads of raised decks

1. The fore ends of the raised decks are to be provided with intact bulkheads.

2. The thickness of plating and the scantlings of stiffeners of the bulkhead specified in **Par 1** are not to be less than those required in **202.** and **203.** taking this bulkhead as that of the first-tier superstructure.

Section 3 Access Openings in Superstructure End Bulkheads

301. Closures for access openings

1. The doors to be provided on the access openings in the end bulkheads of enclosed superstructures are to be in accordance with the requirements in (1) through (5).

(1) The doors are to be made of steel or other equivalent materials and to be permanently and rigidly fitted up to the bulkheads;
(2) The doors are to be rigidly constructed, to be of equivalent strength to that of intact bulkhead and to be weathertight when closed;
(3) The means for securing weathertightness are to consist of gaskets and clamping devices or other equivalent devices and to be permanently fitted up to the bulkhead or the door itself;
(4) The doors are to be operated from the both sides of the bulkheads;
(5) Hinged doors are, as a rule, to open outward.

2. The height of sills of access openings specified in **Par 1** is not to be less than 380 mm above the upper surface of the deck except where higher sills may be required when deemed necessary by the Society. ⚓

CHAPTER 17 DECKHOUSES

Section 1 General

101. Application

1. The construction and scantlings of deckhouses are to be in accordance with the relevant Chapters in addition to this Chapter.

2. The requirements in this Chapter are prescribed for the deckhouses up to the third tier above the freeboard deck. As for the deckhouses above the third tier, the construction and scantlings thereof are to be as deemed appropriate by the Society.

3. As for the deckhouses in ships with specially large freeboard the construction of bulkhead may be suitably modified subject to the approval by the Society.

Section 2 Construction

201. Head of water

1. The head of water for the calculation of the scantlings of boundary walls of deckhouses is not to be less than that obtained from the following formula:

$$h = ac(bf - y) \quad \text{(m)}$$

where:

a = as given by **Table 3.17.1.**

b = as given by **Table 3.17.2.**

Table 3.17.1 Values of a

<table>
<tr><th>Walls</th><th>Location</th><th>a</th></tr>
<tr><td rowspan="3">Exposed front wall</td><td>First tier</td><td>$\frac{L'}{120}+2.0$</td></tr>
<tr><td>Second tier</td><td>$\frac{L'}{120}+1.0$</td></tr>
<tr><td>Third tier</td><td rowspan="2">$\frac{L'}{150}+0.5$</td></tr>
<tr><td colspan="2">Side walls and protected front walls of the all tiers</td></tr>
<tr><td rowspan="2">Aft walls</td><td>Afterward of the midship</td><td>$\frac{L'}{1000}-0.8\frac{x}{L}+0.7$</td></tr>
<tr><td>Forward of the midship</td><td>$\frac{L'}{1000}-0.4\frac{x}{L}+0.5$</td></tr>
<tr><td colspan="3">L' and x = as specified in Table 3.16.1</td></tr>
</table>

Table 3.17.2 Values of b

<table>
<tr><th>$\frac{x}{L}$</th><th>b</th></tr>
<tr><td>$\frac{x}{L} < 0.45$</td><td>$\left(\frac{0.45-\frac{x}{L}}{C_{b1}+0.2}\right)^2 + 1.0$</td></tr>
<tr><td>$\frac{x}{L} \geq 0.45$</td><td>$1.5\left(\frac{\frac{x}{L}-0.45}{C_{b1}+0.2}\right)^2 + 1.0$</td></tr>
<tr><td colspan="2">x = distance from the end wall to the after perpendicular, however, in case of side wall, distance from the mid-point of side wall to the after perpendicular (m). Where, however, the length of side wall exceeds $0.15L$, the side wall is to be nearly equally subdivided as not to exceed $0.15L$ and the distance from the mid-point of the subdivision to the after perpendicular to be taken.
C_{b1} = block coefficient. Where, however, C_b is 0.6 and under, C_{b1} is to be taken as 0.6 and where C_b is 0.8 and over, C_{b1} is to be taken as 0.8. And, in calculating b for the aft wall located forward of the midship, C_{b1} is to be taken as 0.8.</td></tr>
</table>

f = as given in **Fig 3.16.1.**

c = as given by the following formula, where, however, b'/B' is less than 0.25, b'/B' is to be taken as 0.25.

$$c = 0.7\frac{b'}{B'} + 0.3$$

b' = breadth of deckhouse at the position under consideration (m).

B' = breadth of ship on the exposed deck at the position under consideration (m).

y = vertical distance from the summer waterline to the mid-point of span of stiffener in case where the scantlings of stiffeners are determined, and to the mid-point of plate in case where the thickness of boundary wall plating is determined (m).

2. The head of water is not to be less than that obtained from the requirements in **Ch 16, Table 3.16.3,** irrespective of the provisions in **Par 1.**

202. Scantlings

1. The thickness of boundary wall plating and the scantlings of stiffeners are not to be less than those required in **Ch 16, 202.** and **203.** taking the head of water specified in **201.** as h.

2. Both ends of stiffeners on exposed boundary walls of deckhouses are to be connected to the deck by welding except where otherwise approved by the Society.

203. Closing means

Access openings of deckhouses protecting companionways giving access to the spaces under the freeboard deck or the spaces in the enclosed superstructures are to be provided with the closing means at least complying with the requirements in **Ch 16, 301.** Where, however, stairways are enclosed with boundary walls fitted with closing means complying with the requirements in **Ch 16, 301.** the external doors need not be weathertight.

204. Reinforcement of construction under deckhouses

1. Where transverse bulkheads are provided under deckhouses, special consideration is to be paid not to have discontinuity in the construction of deckhouses just above the transverse bulkheads as far as practicable.

2. On the side walls and end walls of large deckhouses, partial bulkheads or special stiffeners are to be arranged at intervals not exceeding about 9 m just above the bulkheads, web frames or under deck girders underneath.

3. In the vicinity of both ends of long deckhouses, special consideration is to be paid to the construction connecting boundary walls of deckhouses to the decks. The side walls are to be suitably constructed so as to maintain strength continuity and to avoid stress concentration.

4. The connections between deckhouses supporting crane post and deck structure are to be of appropriate construction such that beams or longitudinal members are arranged beneath surrounding wall of deckhouses, etc. to avoid stress concentration.

205. Loaded with heavy equipment articles

Deckhouses under the spaces loaded with specially heavy equipment articles such as lifeboats, deck machineries and so on are to be suitably strengthened.

206. Deckhouses on the upper tiers of deck

As for deckhouses on the upper tiers of deck, suitable measures are to be taken to prevent vibration in such a manner as to arrange the side walls and pillars of respective tiers of deckhouses in a same plane as far as practicable. ⚓

CHAPTER 18 MACHINERY SPACES AND ENGINE CASINGS

Section 1 General

101. Application

The construction of machinery space in addition to this Chapter is to be in accordance with the requirements in relevant Chapters.

102. Compensation

Machinery space is to be sufficiently strengthened by means of web frames, strong beams and pillars or other suitable arrangements.

103. Construction

Machineries, shafting, etc. are to be efficiently supported and the adjacent structures are to be adequately stiffened.

104. Twin screw ships and others of high power

In twin screw ships and others of high power, the structure and attachments of the seatings are to be specially strengthened in relation to the proportion of the height of engines to their length or width, weight, power, type, etc.

105. Means of escape

1. In each engine room and boiler room, at least two means of escape are to be provided. These means are to be formed by steel ladders as widely separated as possible leading to doors in the casing similarly separated and from which an access is provided to the lifeboat embarkation deck.

2. Where a watertight door is available as a means of escape from each engine room or boiler room to other spaces from which an access is provided to the embarkation deck, one of the means specified in the preceding Paragraph may be dispensed with.

3. In case of ships of less than 2000 tons gross, where it is difficult to separate ladders or doors from each other, the requirement in **Par 1** may be suitably modified.

Section 2 Main Engine Foundation

201. Single bottoms

In ships with single bottoms, the main engine are to be seated upon thick seat plates laid on heavy foundation girders efficiently bracketed and stiffened and having sufficient strength in proportion to the power and size of engines. Transverse rigidity of the seat plates is to be provided by means of tripping brackets fitted at the position of each floor.

202. Double bottoms

In ships with double bottoms, the main engines are to be seated directly upon thick inner bottom plating or thick seat plates on top of heavy foundation girders so arranged as to effectively distribute the weight. Transverse rigidity of the seat plates is to be provided by means of tripping brackets fitted at the position of each floor.

Section 3 Construction of Boiler Rooms

301. Boiler foundations

1. Boilers are to be supported by deep saddle type floors or by transverse or longitudinal girders so arranged as to effectively distribute the weight.

2. Where boilers are supported by transverse saddles or girders, the floors in way of same are to be specially stiffened.

302. Boiler location

1. Boilers are to be so placed as to ensure accessibility and proper ventilation.

2. Boilers are to be at least 457 mm clear of tank tops, etc. The thickness of adjacent members is to be increased as may be required where the clear space is unavoidable less. The available clearance is to be indicated on the plans submitted for approval.

3. Hold bulkheads and decks are to be kept well clear of the boilers and uptakes, or provided with suitable insulating arrangements.

4. Side sparrings are to be provided on the bulkheads adjacent to the boilers, keeping suitable clearance on **502.** their hold sides.

Section 4 Thrust Blocks and Foundations

401. Thrust blocks and foundations

1. Thrust blocks are to be bolted to efficient foundations extending well beyond the thrust blocks and so arranged as to effectively distribute the loads into the adjacent structures.

2. Additional intercostal girders are to be provided in way of the foundations as necessary.

402. Plummer blocks and auxiliary machinery seats

Plummer blocks and auxiliary machinery seats are to be of ample strength and stiffness in proportion to the weight supported and to the height of foundations.

Section 5 Engine Casings

501. Plates

1. The thickness of casing plates on exposed decks or within not enclosed superstructures is not to be less than that obtained from the requirements in **Ch 17, 201.** and **202**. with such modifications that 1.0 is substituted for c.

2. The thickness of casing plates below the freeboard deck or within enclosed superstructures is not to be less than 6.5 mm in cargo spaces and not to be less than 4.5 mm in accommodation spaces. Where the spacing of stiffeners exceeds 760 mm, the thickness is to be increased at the rate of 0.5 mm per 100 mm excess in spacing.

502. Stiffeners

1. The section modulus of stiffeners of the casings on exposed decks or within not enclosed superstructures is not to be less than that obtained from the requirements in **Ch 17, 201.** and **202.** with such modifications that 1.0 is substituted for c. The ends of stiffeners are to be attached to decks.

2. The stiffeners of casings below the freeboard deck or within enclosed superstructures are to be provided at the position of every deck beam in cargo spaces and their section modulus is not to be less than that obtained from the following formula:

$$Z = 1.2Sl^3 \quad (\mathrm{cm}^3)$$

where:

l = tween deck height (m).

S = spacing of stiffeners (m).

503. Casing top

The thickness of top plating of exposed casings is not less than that obtained from the following formulae:

Position I $t = 6.3S + 1.5$ (mm)

Position II $t = 6.0S + 1.5$ (mm)

where:

S = spacing of stiffeners (m). ⚓

CHAPTER 19 TUNNELS AND TUNNEL RECESSES

Section 1 General

101. Arrangement

1. In ships with machinery amidships, the shafting is to be enclosed by watertight tunnels of sufficient dimensions.

2. Watertight doors are to be provided at the fore end of the tunnel. The closing and construction of the watertight doors are to be as required in **Ch 14.**

3. In tunnels which are provided with watertight doors in accordance with the requirement in the preceding paragraph, escape trunks are to be provided at a suitable location and they are to be led to the bulkhead deck or above.

102. Flat side plating

The thickness of plating on flat sides of tunnel is not to be less than that obtained from the following formula:

$$t = 2.9S\sqrt{h} + 1.5 \quad \text{(mm)}$$

where:

S = spacing of stiffener (m).

h = vertical distance at the mid-length of each hold from the lower edge of the side wall plating to the bulkhead deck at the centre line of ship (m).

103. Flat top plating

1. The thickness of flat plating on the top of tunnels or tunnel recesses is not to be less than that obtained from the formula given in **102.** h being taken as the height from the top plates to the bulkhead deck at the centre line of ship.

2. Where the top of the tunnel or tunnel recess forms part of deck, the thickness is to be increased by at least one mm above that obtained from the requirements in **Par 1,** but in no case is it to be less than that required for the deck plating at the same position.

104. Curved top or side plating

The thickness of curved top or side plating is to be determined by the requirements in **102.** in association with stiffener spacing reduced by 150 mm from the actual spacing.

105. Top plating under hatchways

Top plating of tunnel under hatchways is to be increased by at least 2 mm or to be protected by wood sheathing not less than 50 mm in thickness.

106. Wood sheathings

The wood sheathing prescribed in **105.** is to be so secured as to keep watertightness of tunnel where it might be damaged by cargo.

107. Stiffeners

1. Stiffeners are to be provided not more than 915 mm apart on the top and side plating of tunnels.

2. The section modulus of stiffeners is not to be less than that obtained from the following formula.

$$Z = 4Shl^2 \quad (\text{cm}^3)$$

where:

l = distance from the heel of the lower edge of side wall to the top of flat side (m).

S = spacing of stiffeners (m).

h = vertical distance at mid-length of each hold from the mid-point of l to the bulkhead deck (m).

3. Where the ratio of the radius of the rounded tunnel top to the distance between the bottom and top of the tunnel is comparatively large, the section modulus of the stiffeners is to be adequately increased over that specified in the preceding Paragraph.

4. The lower ends of stiffeners over 150 mm in depth are to be connected to the inner bottom plating, etc. by lug connection.

108. Construction under masts, stanchions, etc.

Where masts, stanchions, etc. are based upon tunnels or tunnel recesses, local strengthening is to be provided in proportion to the weight carried.

109. Construction under top of tunnels or tunnel recesses

Beams, pillars and girders under the top of tunnels or tunnel recesses are to be of the scantlings as required for similar members of bulkhead recesses.

110. Ventilators and escape trunks

Escape trunks and ventilators provided on tunnels or tunnel recesses are to be made watertight up to the bulkhead deck and are to be strong enough to withstand the pressure to which they may be subjected.

111. Tunnels in water or oil tanks

Tunnels in water or oil tanks are to be of equivalent construction and strength to those required for deep tank bulkheads.

112. Watertight tunnels

Where watertight tunnels similar to the shaft tunnels are provided, they are to be of similar construction to the shaft tunnels.

113. Tunnels of curved form

Where the tunnels of curved form pass through deep tanks, the thickness of the plating in way of the tanks is not to be less than that obtained from the following formula.

$$t = 0.134 d_t h + 8.1 \quad (\text{mm})$$

where:

d_t = diameter of tunnel (m).

h = vertical distance measured from the bottom of tunnel to the mid-point between the top of tanks and the top of overflow pipes, or 0.7 times the vertical distance measured from the bottom of tunnel to the point of 2.0 m above the top of overflow pipes, whichever is the greater (m)⫝

CHAPTER 20 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 General

101. Application

1. The construction and equipment of ship intended to be registered and classed as the ship strengthened for navigation in ice are to be in accordance with the requirements in this Chapter in addition to those in other Chapters of this Part.

2. Where an ice class notation is desired, the main propelling machinery, etc. are to be in accordance with the requirements in this Chapter in addition to those in **Part 5**.

3. The requirements in this chapter are framed for the ice strengthening of ships which are intended to navigate in the Northern Baltic complying with the **Finnish-Swedish Ice Class Rules 2008** or in the Canadian Arctic complying with the **Arctic Shipping Pollution Prevention Regulations.** However, where the ships are intended to navigate in other sea areas, this Chapter may be applied.

4. The low temperature of the ship's ambience is to be considered for designing structures, equipment and arrangements essential for the safety and operation of the ship, e.g. the functioning of hydraulic systems, hazard of freezing of water piping and tanks, starting of emergency diesels, etc.

5. In ships of unusual proportions, hull form or propulsion arrangements, the Society may make special requirements in addition.

102. Documentation

1. Forward region, midship region, aft region, ice belt, UIWL and LIWL defined in **202.** are to be indicated in the Shell Expansion.

2. The engine output defined in **202.,** the displacement defined in **203. 3** and the dimensions necessary for the engine output calculation required in **204.** are to be described in the General Arrangement.

Section 2 Ice Strengthening

201. Classification of Ice Strengthening

1. Strengthening for navigation in ice is classified into the following 5 classes dependent on the degree of reinforcement and engine output of the ship.

(1) IA Super : ships with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers
(2) IA : ships with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary
(3) IB : ships with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary
(4) IC : ships with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary
(5) ID : ships that have a steel hull and that are structurally fit for navigation in the open sea and that, are capable of navigating in very light ice conditions with their own propulsion machinery

2. It is the responsibility of the Owner to determine which class in **Par 1** is most suitable for this requirement.

202. Definitions

The definitions of terms which appear in this Chapter are to be specified as the following, unless otherwise specified elsewhere.

1. The forward, midship, and aft regions in way of hull part are defined for ships of ice classes IA Super, IA, IB and IC and the forward region is defined for ships of ice class ID as follows:

(1) Forward region: From the stem to a line parallel to and $0.04L$ aft of the forward borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes IA Super and IA the overlap over the borderline need not exceed 6 m, and for ice classes IB, IC and ID this overlap need not exceed 5 m.

(2) Midship region: From the aft boundary of the Forward region to a line parallel to and $0.04\,L$ aft of the aft borderline of the part of the hull where the waterlines run parallel to the centreline. For ice classes IA Super and IA the overlap over the borderline need not exceed 6 m, and for ice classes IB and IC this overlap need not exceed 5 m.

(3) Aft region: From the aft boundary of the Midship region to the stern.

2. The ice belt is the part of the shell plating which has to be reinforced. (see **Fig 3.20.1**)

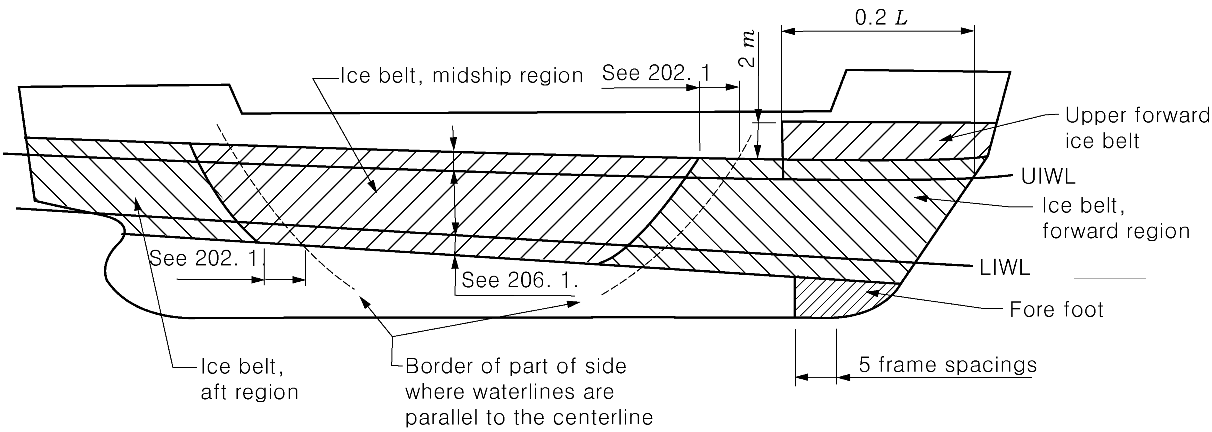


Fig 3.20.1 Ice Belt at each region

3. The upper ice waterline (UIWL) shall be the highest waterline at which the ship is intended to operate in ice. The line may be a broken line. The lower ice waterline (LIWL) shall be the lowest waterline at which the ship is intended to operate in ice. The maximum and minimum ice class draughts at fore and aft perpendiculars shall be determined in accordance with the upper and lower ice waterlines.

4. Restrictions on draughts when operating in ice shall be documented and kept on board readily available to the master. The maximum and minimum ice class draughts fore, amidships and aft shall be indicated in the classification certificate. For ships built on or after 1 July 2007, if the summer load line in fresh water is located at a higher level than the UIWL, the ship's sides are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships. Ships built before 1 July 2007 shall be provided with such a marking, if the UIWL is below the summer load line, not later than the first scheduled dry docking after 1 July 2007.

5. The draught and trim, limited by UIWL, must not be exceeded when the ship is navigating in ice. The salinity of sea water along the intended route shall be taken into account when loading the ship.

203. Security of Minimum Draught

1. Any ballast tank, situated above the LIWL and needed to load down the ship to this water line is to be equipped with proper devices to prevent the water from freezing.

2. The propeller is to be fully submerged, if possible, entirely below the ice.

3. The minimum forward draught is not to be less than that obtained from the following formula, which need not exceed $4h_0$.

$$d_f = (2.0 + 0.00025\Delta)h_0 \quad \text{(m)}$$

Δ = the displacement (ton) of ship on the maximum ice-class draught according to **202. 3**

h_0 = level ice thickness given in **Table 3.20.1**

Table 3.20.1 Level ice thickness h_0

Ice Class	h_0 (m)
IA Super	1.0
IA	0.8
IB	0.6
IC	0.4
ID	0.4

Section 3 Engine Output

301. Definition of engine output

The engine output P is the maximum output the propulsion machinery can continuously deliver to the propeller(s). If the output of the machinery is restricted by technical means or by any regulations applicable to the ship, P shall be taken as the restricted output.

302. Required engine output for ice classes IA Super, IA, IB, IC and ID

The engine output shall not be less than that determined by the formula below and in no case less than 1000 kW for ice class IA, IB, IC and ID, and not less than 2800 kW for IA Super.

1. Definitions

The dimensions of the ship and some other parameters are defined below:

L = length of the ship between the perpendiculars (m)

L_{BOW} = length of the bow (m)

L_{PAR} = length of the parallel midship body (m)

B = maximum breadth of the ship (m)

T = actual ice class draughts of the ship according to **302. 2** (m)

A_{wf} = area of the waterline of the bow (m^2)

α = the angle of the waterline at B/4 (deg)

ϕ_1 = degree the rake of the stem at the centerline (deg)

ϕ_2 = degree the rake of the bow at B/4 (deg)

D_p = diameter of the propeller (m)

H_M = thickness of the brash ice in mid channel (m)

H_F = thickness of the brash ice layer displaced by the bow (m)

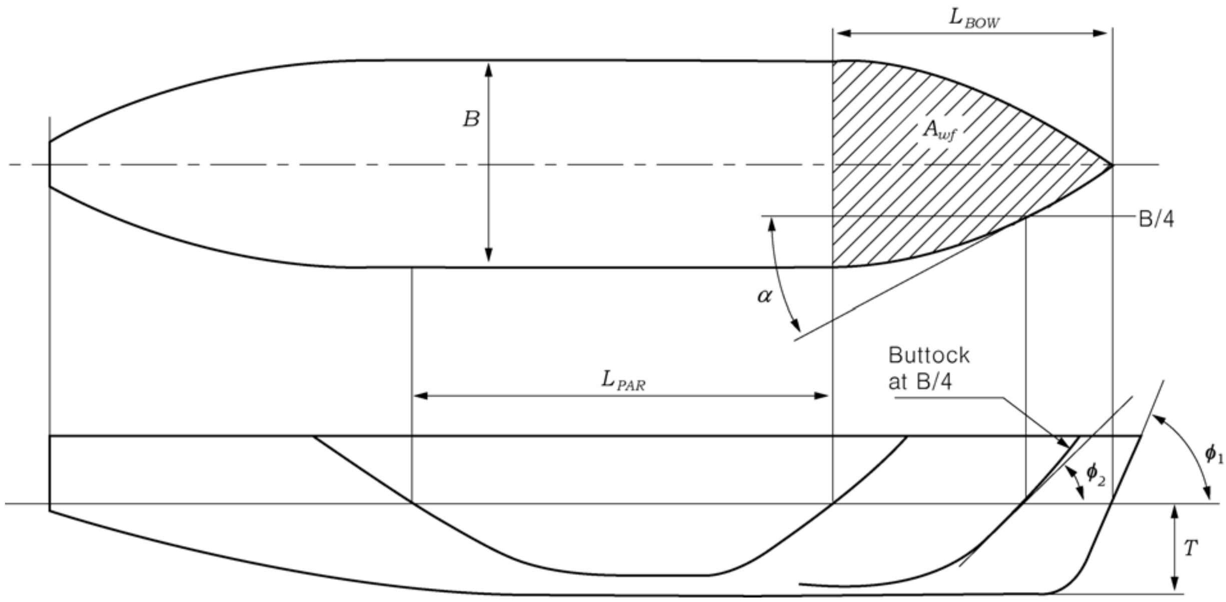


Fig 3.20.2 Determination of the geometric quantities of the hull. If the ship has a bulbous bow, then ϕ_1 = 90°.

2. New ships

To be entitled to ice class IA Super, IA, IB, IC or ID a ship the keel of which is laid or which is at a similar stage of construction on or after 1 September 2003 is to comply with the following requirements regarding its engine output. The engine output requirement is to be calculated for two draughts. Draughts to be used are the maximum draught amidship referred to as UIWL and the minimum draught referred to as LIWL, as defined in **202.** In the calculations the ship's parameters which depend on the draught are to be determined at the appropriate draught, but L and B are to be determined only at the UIWL. The engine output is not to be less than the greater of these two outputs.

$$P = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P} \text{ [kW]},$$

where K_e : as given in **Table 3.20.2**

Table 3.20.2 Values of constant K_e

Number of Propeller	CP or electric or hydraulic propulsion machinery	FP propeller
1 propeller	2.03	2.26
2 propellers	1.44	1.60
3 propellers	1.18	1.31

These K_e values apply for conventional propulsion systems. Other methods may be used for determining the required power for advanced propulsion systems (see **302. 4**).

RCH is the resistance in Newton of the ship in a channel with brash ice and a consolidated surface layer:

$$R_{CH} = C_1 + C_2 + C_3 C_\mu (H_F + H_M)^2 (B + C_\psi H_F) + C_4 L_{PAR} H_F^2 + C_5 \left(\frac{LT}{B^2}\right)^3 \frac{A_{wf}}{L}$$

where

$C_\mu = 0.15\cos\phi_2 + \sin\psi \sin\alpha$, C_μ is to be taken equal or larger than 0.45.

$C_\psi = 0.047\psi - 2.115$, and C_ψ = 0 if $\psi \leq 45$.

$H_F = 0.26 + (H_M B)^{0.5}$

H_M = 1.0 for ice class IA and IA Super
= 0.8 for ice class IB
= 0.6 for ice class IC
= 0.5 for ice class ID

C1 and C2 = coefficients obtained by taking into account a consolidated upper layer of the brash ice

For ships of ice classes IA, IB, IC and ID : $C_1 = 0$, $C_2 = 0$

For ships of ice classes IA Super

$$C_1 = f_1 B L_{PAR} / (2T/B + 1) + (1 + 0.021\phi_1)(f_2 B + f_3 L_{BOW} + f_4 B L_{BOW})$$
$$C_2 = (1 + 0.063\phi_1)(g_1 + g_2 B) + g_3 (1 + 1.2T/B) B^2 / \sqrt{L}$$

For a ship with a bulbous bow, ϕ_1 is to be taken as 90°.

$f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4$ and C_5 = values given in **Table 3.20.3**

Table 3.20.3 $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4$ and C_5

f_1(N/m^2)	23	g_1(N)	1530	C_3(kg/(m^{2}s^2))	845
f_2(N/m)	45.8	g_2(N/m)	170	C_4(kg/(m^{2}s^2))	42
f_3(N/m)	14.7	g_3(N/m$^{1.5}$)	400	C_5(kg/s^2)	825
f_4(N/m^2)	29				

ψ = $\arctan(\tan\phi_2/\sin\alpha)$

$\left(\frac{LT}{B^2}\right)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

Further information on the validity of the above formulas can be found in Annex I together with sample data for the verification of powering calculations. If the ship's parameter values are beyond the ranges defined in **Table 1-1 of Annex I**, other methods for determining R_{CH} shall be used as defined in **302. 5.**

3. Existing ships of ice class IB or IC

To be entitled to retain ice class IB or IC a ship, the keel of which has been laid or which has been at a similar stage of construction before 1 September 2003, is to comply with the following requirements regarding its engine output. The engine output is not to be less than that determined by the formula below and in no case less than 740 kW.

$$P = f_1 \cdot f_2 \cdot f_3(f_4\Delta + P_0) \text{ [kW]}$$

where

f_1 = 1.0 for a fixed pitch propeller

= 0.9 for a controllable pitch propeller

f_2 = $\phi_1/200 + 0.675$ but not more than 1.1,

where,

ϕ_1 is the rake of the stem at the centerline [degrees] (see **Fig 3.20.2**)

The product $f_1 \times f_2$ shall not be taken as less than 0.85.

$f_2 = 1.1$ for a bulbous bow

$f_3 = 1.2B/\Delta^{1/3}$ but not less than 1.0

f_4 and P_0 shall be taken as follows:

Table 3.20.4 Value f_4 or P_0

Ice Class	IB	IC	IB	IC
Displacement	D<30000		D≥30000	
f_4	0.22	0.18	0.13	0.11
P_0	370	0	3070	2100

Δ is displacement [t] of the ship on the maximum ice class draught according to **202. 1.** It need not be taken as greater than 80,000 t.

4. Existing ships of ice class IA Super or IA

To be entitled to retain ice class IA Super or IA a ship, the keel of which has been laid or which has been at a similar stage of construction before 1 September 2003, shall comply with the requirements in **302. 2** above at the following dates:

- 1 January 2005 or
- 1 January in the year when 20 years has elapsed since the year the ship was delivered, whichever occurs the latest.

When, for an existing ship, values for some of the hull form parameters required for the calculation method in section **302. 2** are difficult to obtain, the following alternative formulae can be used:

$$R_{CH} = C_1 + C_2 + C_3(H_F + H_M)^2(B + 0.658H_F) + C_4LH_F^2 + C_5\left(\frac{LT}{B^2}\right)^3\frac{B}{4}$$

Where,

For ships of ice classes IA, $C_1 = 0$, $C_2 = 0$

For ships of ice classes IA Super without a bulbous bow, C_1 and C_2 is to be calculated as follows;

$$C_1 = f_1 \frac{BL}{(2T/B+1)} + 1.84(f_2 B + f_3 L + f_4 BL)$$

$$C_2 = 3.52(g_1 + g_2 B) + g_3\left(1 + 1.2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}$$

For ships of ice classes IA Super with a bulbous bow, C_1 and C_2 is to be calculated as follows;

$$C_1 = f_1 \frac{BL}{(2T/B+1)} + 2.89(f_2 B + f_3 L + f_4 BL)$$

$$C_2 = 6.67(g_1 + g_2 B) + g_3\left(1 + 1.2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}$$

$f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4$ and C_5 = values given in **Table 3.20.5**

Table 3.20.5 Values of $f_1, f_2, f_3, f_4, g_1, g_2, g_3, C_3, C_4$ and C_5

f_1(N/m^2)	10.3	g_1(N)	1530	C_3(kg/(m^{2}s^2))	460
f_2(N/m)	45.8	g_2(N/m)	172	C_4(kg/(m^{2}s^2))	18.7
f_3(N/m)	2.94	g_3(N/m$^{1.5}$)	400	C_5(kg/s^2)	825
f_4(N/m^2)	5.8				

$\left(\frac{LT}{B^2}\right)^3$ is not to be taken as less than 5 and not to be taken as more than 20.

5. Other methods of determining Ke or R_{CH}

For an individual ship, in lieu of the K_e or R_{CH} values defined in **302. 2** and **302. 3**, the use of K_e or R_{CH} values based on more exact calculations or values based on model tests may be approved. Such an approval will be given on the understanding that it can be revoked if experience of the ship's performance in practice motivates this.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

IA Super H_M = 1.0 m and a 0.1 m thick consolidated layer of ice
IA = 1.0 m
IB = 0.8 m
IC = 0.6 m
ID = 0.5 m

Section 4 Hull Structural Design

401. Design ice pressures

1. Design ice pressure P_d is not to be less than that obtained from the following formula:

$$P_d = C_d C_1 C_a P_0 \quad \text{(MPa)}$$

$$C_d = \frac{ak+b}{1000}$$

$$k = \frac{\sqrt{\Delta P}}{1000}$$

Δ = displacement (ton) of the ship specified in **203. 3.**
P = engine output (kW).
a and b = as given in **Table 3.20.6** according to the region under consideration and the value of k

Table 3.20.6 Value of a and b

	Forward region		Midship region and Aft region	
	$k \le 12$	$k > 12$	$k \le 12$	$k > 12$
a	30	6	8	12
b	230	518	214	286

C_1 = a factor which takes account of the probability that the design ice pressure occurs in a certain region of the hull for the ice class in question, as given in **Table 3.20.7** according to the ice class and the region.
P_0 = the nominal ice pressure; the value 5.6 MPa is to be used.
C_a = a factor which takes account of the probability that the full length of the area under consideration will be under pressure at the same time, as given by the following formula. Where, however, C_a is less than 0.6, C_a is to be taken as 0.6 and where C_a exceeds 1.0, C_a is to be taken as 1.0.

$$C_a = \frac{47-5l_a}{44}$$

l_a = to be taken as specified in **Table 3.20.8** according to the structural member under consideration.

Table 3.20.7 Coefficient C_1

Ice class	Forward region	Midship	Aft region
IA Super	1.00	1.00	0.75
IA	1.00	0.85	0.65
IB	1.00	0.70	0.45
IC	1.00	0.50	0.25
ID	1.00	-	-

Table 3.20.8 Value of l_a

Structure	Type of framing	l_a (m)
Shell	Transverse	Frame Spacing
	Longitudinal	2 frame Spacing
Frames	Transverse	Frame Spacing
	Longitudinal	span of frame
ice stringer	-	span of stringer
web frame	-	2-spacing of web frames

2. h is the height of the area under the ice pressure P_d specified in **Par 1** and is to be as given in **Table 3.20.9** according to the ice class.

402. Shell plating

1. The vertical extension of ice belt is to be as given in **Table 3.20.10** according to the ice class and is to comply with the following requirements.

Table 3.20.9 Value of h

Ice Class	h (m)
IA Super	0.35
IA	0.30
IB	0.25
IC	0.22
ID	0.22

Table 3.20.10 Vertical extension of the Ice belt b

Ice Class	Above UIWL	Below LIWL
IA Super	0.6 m	0.75 m
IA	0.5 m	0.6 m
IB	0.4 m	0.5 m
IC	0.4 m	0.5 m
ID	0.4 m	0.5 m

(1) Fore foot
For ice class IA Super the shell plating below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line is to have at least the thickness required in the ice belt in the midship region.
(2) Upper forward ice belt
For ice classes IA Super and IA on ships with an open water service speed equal to or exceeding 18 kt, the shell plate from the upper limit of the ice belt to 2 m above it and from the stem to a position at least 0.2 L abaft the forward perpendicular, is to have at least the thickness required in the ice belt in the midship region. A similar strengthening of the bow region is to apply to a ship with lower service speed, when it is, e.g. on the basis of the model tests, evident that the ship will have a high bow wave.
(3) Side scuttles are not to be situated in the ice belt.
(4) If the weather deck in any part of the ship is situated below the upper limit of the ice belt, the bulwark and the construction of the freeing ports are to be given at least the same strength as is required for the shell in the ice belt.

2. The thickness of shell plating in the ice belt is not to be less than that obtained from the following formula:

For the transverse framing : $t = 667S\sqrt{\dfrac{f_1 P_{PL}}{\sigma_y}} + 2.0$ (mm)

For the longitudinal framing : $t = 667S\sqrt{\dfrac{P_{PL}}{f_2 \sigma_y}} + 2.0$ (mm)

S : frame spacing (m)

P_{PL}: 0.75 P_d (MPa)

P_d : as specified in **401. 1**

f_1 : as given in the following formula. Where, however, f_1 is greater than 1.0, f_1 is to be taken as 1.0

$$f_1 = 1.3 - \frac{4.2}{(h/S + 1.8)^2}$$

f_2 : as given by the following formula depending on the value of h/S

Where $h/S < 1.0$: $f_2 = 0.6 + \frac{0.4}{h/S}$

Where $1.0 \le h/S < 1.8$: $f_2 = 1.4 - 0.4(h/S)$

h : as specified in **Table 3.20.9.**

σ_y : yield stress of the material of the member considered, which are given as follows (N/mm^2)

235 : for mild steels as specified in **Pt 2, Ch 1**

315 : for high tensile steels AH 32, DH 32, EH 32 or FH 32 as specified in **Pt 2, Ch 1**

355 : for high tensile steels AH 36, DH 36, EH 36 or FH 36 as specified in **Pt 2, Ch 1**

390 : for high tensile steels AH 40, DH 40, EH 40 or FH 40 as specified in **Pt 2, Ch 1**

403. Frames

1. Vertical extension of ice strengthening

(1) The vertical extension of ice strengthening of the framing is to be at least as given in **Table 3.20.11** according to the respective ice classes and regions. Where an upper forward ice belt is required in **402. 1** (2) the ice strengthening part of the framing is to be extended at least to the top of this ice belt. Where the ice strengthening would go beyond a deck or a tanktop by no more than 250 mm, it can be terminated at that deck or tanktop.

(2) Within the ice strengthening area all frames are to be effectively attached to all the supporting structures. A longitudinal frame is to be attached all the supporting web frames and bulkheads by brackets. When a transverse frame terminates at a stringer or deck, a bracket or similar construction is to be fitted. When a frame is running through the supporting structure, both sides of the web plate of the frame are to be connected to the structure by direct welding, collar plate or lug. When a bracket is installed, it is to have at least the same thickness as the web plate of the frame and the edge is to be appropriately stiffened against buckling.

(3) For ice class IA Super in all region, for ice class IA in the forward and midship regions and for ice classes IB, IC and ID in the forward regions, followings are to apply in the ice strengthening area.

(A) Frames which are at a small angle to the shell, are to be supported against tripping by brackets, intercostals, stringers or similarly at a distance preferably not exceeding 1.3 m.

(B) The frames are to be attached to the shell by double continuous welds. No scalloping is allowed except when crossing shell plate butts.

(C) The web thickness of the frames is to be at least one half of the thickness of the shell plating and at least 9 mm.

(D) Where there is a deck, tanktop or bulkhead in lieu of a frame, the plate thickness of this is to be as per the preceding in (C), to a depth corresponding to the height of adjacent frames.

Table 3.20.11 Vertical extension of the ice strengthening of framing

Ice Class	Region		Above UIWL (m)	Below LIWL (m)
IA Super	forward	from stem to 0.3L abaft it	1.2	to double bottom or below top of floors
		abaft 0.3L from stem	1.2	1.6
	midship		1.2	1.6
	aft		1.2	1.2
IA IB IC	forward	from stem to 0.3L abaft it	1.0	1.6
		abaft 0.3L from stem	1.0	1.3
	midship		1.0	1.3
	aft		1.0	1.0
ID	forward	from stem to 0.3L abaft it	1.0	1.6
		abaft 0.3L from stem	1.0	1.3

2. Transverse frames

(1) The section modulus Z of a main or intermediate transverse frame specified in **403. 1** is to be not less than that obtained from the following formula. Where less than 15 % of the span of the frame is situated within the ice strengthening zone for frames, ordinary frame scantlings may be used.

$$Z = \frac{P_d S h l}{m_t \sigma_y} \times 10^6 \quad \text{(cm3)}$$

P_d = as specified in **401. 1.**

S = frame spacing (m).

h = as specified in **Table 3.20.9.**

l = span of the frame (m).

m_t = as given by the following formula : $m_t = \dfrac{7m_0}{7-5h/l}$

m_0 = as specified in **Table 3.20.12.** The boundary conditions are those for the main and intermediate frames. Load is applied at mid span.

σ_y = as specified in **402. 2.**

(2) The upper end of the strengthening part of a main frame and of an intermediate frame are to be attached to a deck or an ice stringer as specified in **404.** Where a frame terminates above a deck or a stringer (hereinafter, referred to as the lower deck in this section) which is situated at or above the upper limit of the ice belt, the part of the frame above the lower deck is to be in accordance with the followings:

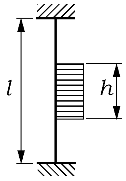
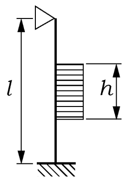
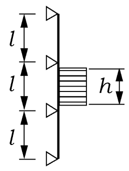
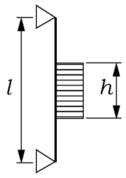
(A) the part of the main frame and the intermediate frame may have the scantlings required by the ordinary frame

(B) the upper end of the main frame and the intermediate frame is to be connected to a deck which situated above the lower deck (hereinafter, referred to as the higher deck in this section). However, the upper end of the intermediate frame may be connected to the adjacent main frames by a horizontal stiffener having the same scantlings as the main frame. Where a intermediate frame is outside the forward region and the higher deck is situated more than 1.8 m above the ice belt, an upper termination of such an intermediate frame may be decided as appropriately.

(3) The lower end of the strengthened part of a main frame and of an intermediate ice frame is to

be attached to a deck, tanktop or ice stringer specified in **404.** Where an intermediate frame terminates below a deck, tanktop or ice stringer which is situated at or below the lower limit of the ice belt, the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the frames.

Table 3.20.12 Value of m_0

Boundary condition	m_0	Example
Both ends fixed 	7.0	Frames in a bulk carrier with top side tanks
One side fixed and one side simple support 	6.0	Frames extending from the tank top to a single deck
Multi point simple support 	5.7	Continuous frames between several decks or stringers
Both ends simple support 	5.0	Frames extending between two decks only

3. Longitudinal frames

(1) The spacing of longitudinal frames in the extension specified in **403. 1** is not to exceed 0.35 m for ice classes IA Super and IA, and is to be in no case exceed 0.45 m. Where deemed as necessary by the Society, larger frame spacing may be permitted.

(2) The section modulus Z and shear area A of a longitudinal frame in the extension specified in **403. 1** are not to be less than that obtained from the following formula:

$$Z = \frac{f_3 f_4 P_d h l^2}{m \sigma_y} \times 10^6 \quad \text{(cm3)}, \qquad A = \frac{\sqrt{3} f_3 P_d h l}{2 \sigma_y} \times 10^4 \quad \text{(cm2)}$$

f_3 = factor which takes account of the load distribution to adjacent frames given by following formula:

$$f_3 = \left(1 - \frac{0.2h}{S}\right)$$

h = as specified in **Table 3.20.9.**

S = frame spacing (m).

f_4 = factor which takes account of the concentration of load to the point of support ; f_4 = 0.6

P_d = as specified in **401. 1.**

l = span of the longitudinal frame (m).

σ_y = as specified in **402. 2.**

m = Boundary condition factor is to be taken as 13.3. Where the boundary conditions deviate significantly from those of a continuous beam, a smaller boundary factor is to be adapted.

404. Ice stringers

1. The section modulus Z and the shear area A of a stringer situated within the ice belt are to be not less than that obtained from the following formula:

$$Z = \frac{f_5 P_d h l^2}{m \sigma_y} \times 10^6 \ (\mathrm{cm}^3), \qquad A = \frac{\sqrt{3} f_5 P_d h l}{2\sigma_y} \times 10^4 \ (\mathrm{cm}^2)$$

P_d = as specified in **401. 1.**

h = as specified in **Table 3.20.9.** However, the product $P_d h$ is not to be taken as less than 0.3.

l = span of the stringer (m).

m = boundary condition factor; m = 13.3

f_5 = Factor which takes account of the distribution of load to the transverse frames is to be taken as 0.9.

σ_y = as specified in **402. 2.**

2. The section modulus Z and the shear area A of a stringer situated outside the ice belt but supporting ice strengthened frames are not to be less than that obtained from the following formula:

$$Z = \frac{f_6 P_d h l^2}{m \sigma_y}(1 - h_s/l_s) \times 10^6 \ (\mathrm{cm}^3), \qquad A = \frac{\sqrt{3} f_6 P_d h l}{2\sigma_y}(1 - h_s/l_s) \times 10^4 \ (\mathrm{cm}^2)$$

P_d = as specified in **401. 1.**

h = as specified in **Table 3.20.9.** However, the product $P_d h$ is not to be taken as less than 0.3.

l = span of the stringer (m).

m_s = boundary condition factor; m_s = 13.3

l_s = the distance to the adjacent ice stringer (m).

h_s = the shortest distance from the considering stringer to the ice belt (m).

f_6 = Factor which takes account of load to the transverse frames is to be taken as 0.95.

σ_y = as specified in **402. 2.**

3. Narrow deck strips abreast of hatches and serving as ice stringers are to comply with the section modulus and shear area requirements in **Par 1** and **2** respectively. In the case of very long hatches, the product $P_d h$ may be taken as less than 0.3 but in no case less than 0.2. Regard is to be paid to the deflection of the ship's sides due to ice pressure in way of very long hatch openings, when designing weatherdeck hatchcovers and their fittings.

405. Web frames

1. The load F transferred to a web frame from an ice stringer or from longitudinal framing is not to be less than that obtained by the following formula. However, In case the supported stringer is outside the ice belt, the load F may be reduced by multiplying $(1-h_s/l_s)$.

$$F = P_d\, hS \text{ (MN)}$$

P_d = ice pressure (MPa) as specified in **401. 1** in calculating C_a however, l_a is to be taken as $2S$.

h = as specified in **Table 3.20.9.** However, the product $P_d h$ is to be more than 0.3.

S = web frame spacing (m).

h_s, l_s: As specified in **404. 2.**

2. When a web frame can be represented by the structure model shown in **Fig 3.20.3** the section modulus Z and shear area A may be obtained from the following formula:

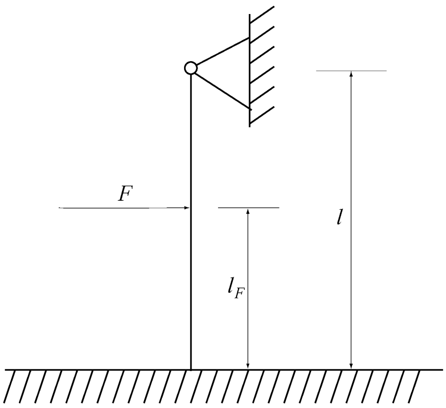


Fig 3.20.3 Structural model of web frame

$$Z = \frac{k_2 F l}{\sigma_y \sqrt{1-(\gamma A_k/A_a)^2}} \times 10^6 \text{ (cm}^3\text{)}, \qquad A = \frac{\sqrt{3}\,\alpha k_1 F}{\sigma_y} \times 10^4 \text{ (cm}^2\text{)}$$

l = span of web frame (m).

k_1 = the value is not to be less than that obtained from the following formula, whichever is greater. For the lower part of the web frame the smallest l_F within the ice belt is to be used. For the upper part the biggest l_F within the ice belt is to be used.

$$k_1 = 1 + 0.5(l_F/l)^3 - 1.5(l_F/l)^2 \;, \qquad k_1 = 1.5(l_F/l)^2 - 0.5(l_F/l)^3$$

l_F = distance from the lower support of the web frame to the stringer or longitudinal in question (m).

α and γ = as given in **Table 3.20.13.** For intermediate values of A_f/A_w is to be obtained by linear interpolation.

F = as specified in **Par 1.**

σ_y = as specified in **402. 2.**

k_2 = as given in the following formula : $k_2 = 0.5(l_F/l)^3 - 1.5(l_F/l)^2 + (l_F/l)$

A_k = required shear area (cm^2) obtained by using

$$k_1 = 1 + 0.5(l_F/l)^3 - 1.5(l_F/l)^2$$

A_a = actual cross sectional area of the web frame (cm^2)

Table 3.20.13 Value of α and γ

A_f/A_w	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
α	1.50	1.50	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04
γ	0.00	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

Note:
A_f = cross section area of free flange (cm^2)
A_w = cross section area of web plate (cm^2)

3. For other web frame configurations and boundary conditions specified in **Par 2,** a direct stress calculation is to be carried out. The concentrated load on the web frame is specified in **Par 1.** The point of application is in each case to be chosen in relation to the arrangement of stringers and longitudinal frames so as to obtain the maximum shear forces and bending moments. Allowable stresses are specified in **Table 3.20.14.**

406. Bow

1. Stem

(1) A sharp edged stem as shown in **Fig 3.20.4** or equivalent improves the manoeuvability of the ship in ice and is recommended particularly for smaller ships with a length below 150 m.

(2) The plate thickness of a shaped plate stem and in the case of a blunt bow, any part of the shell which forms an angle of 30 degrees or more to the centre line in a horizontal plane, is to be obtained from the formula in **402. 2** using the following values ;

S = spacing of elements supporting the plate (m).

P_{PL} = as specified in **401.** (MPa).

l_a = spacing of vertical supporting elements (m).

(3) The stem and the part of a blunt bow specified in **Par 2** is to be supported by floors or brackets spaced not more than 0.6 m apart and having a thickness of at least half the plate thickness.

(4) The reinforcement of the stem is to be extended from the keel to a point 0.75 m above UIWL or, in case an upper forward ice belt is required in **402. 1** to the upper limit of this.

Table 3.20.14 Allowable stresses

Stress	Allowable stress
Shear stress (τ)	$\sigma_y / \sqrt{3}$
Bending stress (σ_b)	σ_y
Equivalent stress ($\sigma = \sqrt{\sigma_b^2 + 3\tau^2}$)	σ_y
Note: σ_y = as specified in **206. 2.**	

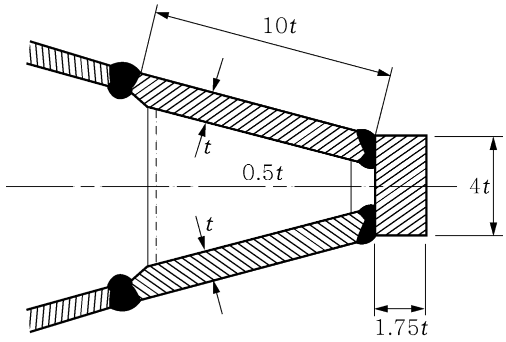


Fig 3.20.4 Sharp edged stem

2. Arrangements for towing

(1) A mooring pipe with an opening not less than 250 by 300 mm, a length of at least 150 mm and an inner surface radius of at least 100 mm is to be fitted in the bow bulwark at the centre line.
(2) A bitt or other means for securing a towline, dimensioned to stand the breaking force of the towline of the ship is to be fitted.
(3) On ships with a displacement not exceeding 30,000 tons the part of the bow which extends to a height of at least 5 m above the UIWL and at least 3 m back from the stem, is to be strengthened to take the stresses caused by fork towing. For this purpose intermediate frames are to be fitted and the framing is to be supported by stringers or decks.

407. Stern

1. The clearance between the propeller blade tip and the stern frame is to be sufficient to prevent from occurring high loads on the blade tip.

2. On twin and triple screw ships, the ice strengthening of the shell and framing are to be extended to the double bottom for 1.5 m forward and aft of the side propellers.

3. On twin and triple screw ships, the shafting and stern tubes of side propellers are to be normally enclosed within plated bossings. If detached struts are used, their design, strength and attachment to the hull are to be duly considered.

4. A wide transom stern extending below the UIWL will seriously impede the capability of the ship to back in ice. Therefore a transom stern is not to be extended below the UIWL, if this can be avoided. If unavoidable, the part of the transom stern below the UIWL is to be kept as narrow as possible. The part of a transom stern situated within the ice belt is to be strengthened as for the midship region.

408. Bilge keel

1. The connection of bilge keels to the hull is to be so designed that the risk of damage to the hull, in case a bilge keel is ripped off, is minimized.

2. It is recommended that bilge keels are cut up into several shorter independent lengths.

Section 5 Rudder and Steering Arrangements

501. Rudder and steering arrangements

1. The scantlings of rudder post, rudder stock, pintles and steering gear, etc. are to comply with requirements in **Pt 4, Ch 1** and **Pt 5, Ch 7.** In this case, the maximum service speed of ship to be used in these calculations is not to be taken less than that given in the **Table 3.20.16.**

2. For the ice classes IA Super and IA, the rudder stock and the upper edge of the rudder are to be protected against ice pressure by the ice knife or equivalent means.

3. For ships of ice classes IA Super and IA, the rudders and steering arrangements are to be designed as follows to endure the loads that work on the rudders by the ice when backing into an ice ridge.
(1) Relief valves for hydraulic pressure is to be effective.
(2) The components of the steering gear are to be dimensioned to stand the yield torque of the rudder stock.
(3) Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

Section 6 Propulsion Machinery

601. Application

The requirements in this Section apply to propulsion machinery covering open- and ducted-type propellers with controllable pitch or fixed pitch design for the ice classes IA Super, IA, IB, IC and ID. The given loads are the expected ice loads for the whole ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. This requirements also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice interaction. However, the load models in the strength calculation of this Section do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially) or load case when ice block hits on the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters have to be estimated with suitable methods, but ice load formulae are not available in this Section.

602. Symbols

c = chord length of blade section (m)

$c_{0.7}$ = chord length of blade section at 0.7R propeller radius (m)

CP = controllable pitch

D = propeller diameter (m)

d = external diameter of propeller hub (at propeller plane) (m)

$D_{\lim}$ = limit value for propeller diameter (m)

EAR = expanded blade area ratio

F_b = maximum backward blade force for the ship's service life (kN)

F_{ex} = ultimate blade load resulting from blade loss through plastic bending (kN)

F_f = maximum forward blade force for the ship's service life (kN)

F_{ice} = ice load (kN)

$(F_{ice})_{\max}$ = maximum ice load for the ship's service life (kN)

FP = fixed pitch

h_0 = depth of the propeller centerline from lower ice waterline (m)

H_{ice} = thickness of maximum design ice block entering to propeller (m)

I = equivalent mass moment of inertia of all parts on engine side of component under consideration (kgm^2)

I_t = equivalent mass moment of inertia of the whole propulsion system (kgm^2)

k = shape parameter for Weibull distribution

LIWL = lower ice waterline (m)

m = slope for S-N curve in log/log scale

M_{BL} = blade bending moment (kNm)

MCR = maximum continuous rating

n = propeller rotational speed (rev./s)

n_n = nominal propeller rotational speed at MCR in free running condition (rev./s)

N_{class} = reference number of impacts per propeller rotational speed per ice class

N_{ice} = total number of ice loads on propeller blade for the ship's service life

N_R = reference number of load for equivalent fatigue stress (10^8 cycles)

N_Q = number of propeller revolutions during a milling sequence

$P_{0.7}$ = propeller pitch at 0.7R radius (m)

$P_{0.7n}$ = propeller pitch at 0.7R radius at MCR in free running condition (m)

$P_{0.7b}$ = propeller pitch at 0.7R radius at MCR in bollard condition (m)

Q = Torque (kNm)

Q_{emax} = maximum engine torque (kNm)

$Q_{\max}$ = maximum torque on the propeller resulting from propeller-ice interaction (kNm)

Q_{motor} = electric motor peak torque (kNm)

Q_n = nominal torque at MCR in free running condition (kNm)

Q_r = maximum response torque along the propeller shaft line (kNm)

Q_{smax} = maximum spindle torque of the blade for the ship's service life (kNm)

R = propeller radius (m)

r = blade section radius (m)

T = propeller thrust (kN)

T_b = maximum backward propeller ice thrust for the ship's service life (kN)

T_f = maximum forward propeller ice thrust for the ship's service life (kN)

T_n = propeller thrust at MCR in free running condition (kN)

T_r = maximum response thrust along the shaft line (kN)

t = maximum blade section thickness (m)

Z = number of propeller blades

α_i = duration of propeller blade/ice interaction expressed in rotation angle (deg)

γ_ε = the reduction factor for fatigue; scatter and test specimen size effect

γ_ν = the reduction factor for fatigue; variable amplitude loading effect

γ_m = the reduction factor for fatigue; mean stress effect

ρ = a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles

$\sigma_{0.2}$ = proof yield strength of blade material (MPa)

$\sigma_{\exp}$ = mean fatigue strength of blade material at 10^8 cycles to failure in sea water (MPa)

σ_{fat} = equivalent fatigue ice load stress amplitude for 10^8 stress cycles (MPa)

σ_{fl} = characteristic fatigue strength for blade material (MPa)

σ_{ref} = reference stress $\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$ (MPa)

σ_{ref2} = reference stress (MPa)

$\sigma_{ref2} = 0.7 \cdot \sigma_u$ or $\sigma_{ref2} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$ whichever is less

σ_{st} = maximum stress resulting from F_b or F_f (MPa)

σ_u = ultimate tensile strength of blade material (MPa)

$(\sigma_{ice})_{bmax}$ = principal stress caused by the maximum backward propeller ice load (MPa)

$(\sigma_{ice})_{fmax}$ = principal stress caused by the maximum forward propeller ice load (MPa)

$(\sigma_{ice})_{\max}$ = maximum ice load stress amplitude (MPa)

Table 3.20.15 Definition of loads

	Definition	Use of the load in design process
F_b	The maximum backward force on a propeller blade resulting from propeller/ice interaction for the ship's service life, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line. See **Figure 3.20.5**.	Design force for strength calculation of the propeller blade.
F_f	The maximum forward force on a propeller blade resulting from propeller/ice interaction for the ship's service life, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line.	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum spindle torque on a propeller blade resulting from propeller/ice interaction for the ship's service life, including hydrodynamic loads on that blade.	In designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum thrust on propeller (all blades) resulting from propeller/ice interaction for the ship's service life. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.
T_f	The maximum thrust on propeller (all blades) resulting from propeller/ice interaction for the ship's service life. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules.
$Q_{\max}$	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on 0.8R. Spindle arm is to be taken as 2/3 of the distance between the axis of blade rotation and leading/trailing edge (whichever is he greater) at the 0.8R radius.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure should not cause damage to other components.
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller.	Design thrust for propeller shaft line components.

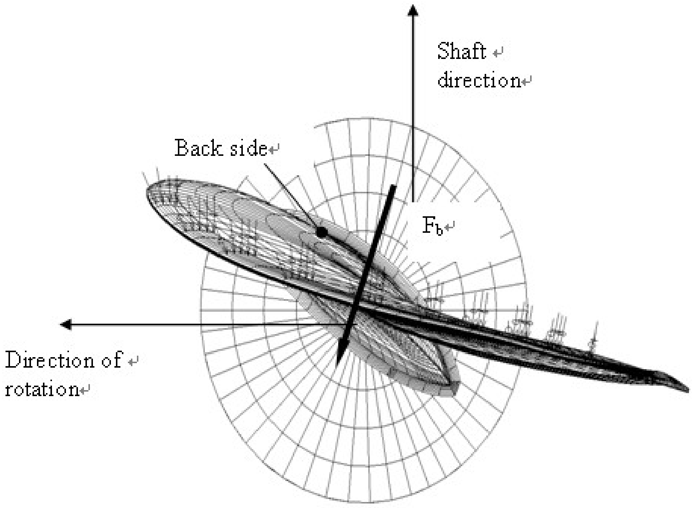


Fig 3.20.5 Direction of the backward blade force resultant taken perpendicular to chord line at radius 0.7R. (Ice contact pressure at leading edge is shown with small arrows)

603. Design ice conditions

In estimating the ice loads of the propeller for ice classes, different types of operation as given in **Table 3.20.16** were taken into account. For the estimation of design ice loads, a maximum ice block size is determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice} \cdot 2H_{ice} \cdot 3H_{ice}$. The thickness of the ice block (H_{ice}) is given in **Table 3.20.17**.

Table 3.20.16 Type of operation of the ship per ice classes

Ice class	Operation of the ship
IA Super	Operation in ice channels and in level ice. The ship may proceed by ramming
IA, IB, IC, ID	Operation in ice channels

Table 3.20.17 The thickness of the ice block (H_{ice})

Ice class	IA Super	IA	IB	IC	ID
Thickness of the design maximum ice block entering the propeller (H_{ice})	1.75 m	1.5 m	1.2 m	1.0 m	1.0 m

604. Materials

1. Materials exposed to sea water

Materials of components exposed to sea water, such as propeller blades, propeller hubs, and thruster body, are to have an elongation of not less than 15 % on a test specimen, the gauge length of which is five times the diameter. A Charpy V impact test is to be carried out for materials other than bronze and austenite steel. An average impact energy value of 20 J taken from three tests is to be obtained at minus 10 ℃.

2. Materials exposed to sea water temperature

Materials exposed to sea water temperature are to be of ductile material. An average impact energy value of 20 J taken from three tests is to be obtained at minus 10 ℃. This requirement applies to blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. This does not apply to surface hardened components, such as bearings and gear teeth.

605. Design loads

1. The given loads are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction.

2. The values of the parameters in the formulae in this Section is to be given in the units shown in **602.**

3. If the propeller is not fully submerged when the ship is in ballast condition, the propulsion system is to be designed according to ice class IA for ice classes IB, IC and ID.

4. Design loads on propeller blades

F_b is the maximum force experienced during the ship's service life that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is the maximum force experienced during the ship's service life that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead. F_b and F_f originate from different propeller/ice interaction phenomena, not acting simultaneously. Hence they are to be applied to one blade separately.

(1) Maximum backward blade force F_b for open propellers

when $D \leq D_{\lim}$, $F_b = -27 \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D^2$ (kN)

when $D > D_{\lim}$, $F_b = -23 \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D \cdot H_{ice}^{1.4}$ (kN)

where,

$D_{\lim} = 0.85 \cdot [H_{ice}]^{1.4}$ (m)

n is the nominal rotational speed (at MCR free running condition) for a CP propeller and 85 % of the nominal rotational speed (at MCR free running condition) for a FP propeller.

(2) Maximum forward blade force F_f for open propellers

when $D \leq D_{\lim}$, $F_f = 250 \cdot \left[\frac{EAR}{Z}\right] \cdot D^2$ (kN)

when $D > D_{\lim}$, $F_f = 500 \cdot \left[\frac{1}{(1-\frac{d}{D})}\right] \cdot H_{ice} \cdot \left[\frac{EAR}{Z}\right] \cdot D$ (kN)

where,

$D_{\lim} = \left[\frac{2}{(1-\frac{d}{D})}\right] \cdot H_{ice}$ (m).

(3) Loaded area on the blade for open propellers
Load cases 1-4 have to be covered, as given in **ANNEX 3-5 Table 1** of the Guidance, for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 also has to be covered for FP propellers.

(4) Maximum backward blade force F_b for ducted propellers

when $D \le D_{\text{lim}}$, $F_b = -9.5 \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot [n \cdot D]^{0.7} \cdot D^2$ (kN)

when $D > D_{\text{lim}}$, $F_b = -66 \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot [n \cdot D]^{0.7} \cdot D^{0.6} \cdot [H_{ice}]^{1.4}$ (kN)

where,

$D_{\text{lim}} = 4 \cdot H_{ice}$

n is the nominal rotational speed (at MCR in free running condition) for a CP propeller and 85 % of the nominal rotational speed (at MCR in free running condition) for an FP propeller

(5) Maximum forward blade force F_f for ducted propellers

when $D \le D_{\text{lim}}$, $F_f = 250 \cdot \left[\frac{EAR}{Z}\right] \cdot D^2$ (kN)

when $D > D_{\text{lim}}$, $F_f = 500 \cdot \left[\frac{EAR}{Z}\right] \cdot D \cdot \frac{1}{\left[1 - \frac{d}{D}\right]} \cdot H_{ice}$ (kN)

where,

$D_{\text{lim}} = \frac{2}{\left[1 - \frac{d}{D}\right]} \cdot H_{ice}$ (m)

(6) Loaded area on the blade for ducted propellers
Load cases 1 and 3 have to be covered as given in **ANNEX 3-5 Table 2** of the Guidance for all propellers, and an additional load case (load case 5) for an FP propeller, to cover ice loads when the propeller is reversed.

(7) Maximum blade spindle torque Qsmax for open or ducted propellers
The spindle torque Q_{smax} around the axis of the blade fitting is to be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as in **ANNEX 3-5 Table 1** and **Table 2** of the Guidance.
If the above method gives a value which is less than the default value given by the formula below, the default value is to be used.

Default Value $Q_{smax} = 0.25 \cdot F \cdot c_{0.7}$ (kNm)

where,

$c_{0.7}$ is the chord length of the blade section at 0.7R radius and F is either F_b or F_f, whichever has the greater absolute value.

(8) Load distributions for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{\max}$), as given in **Fig 3.20.6**, is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{\max}} \geq \frac{F}{(F_{ice})_{\max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{\max}}\right)^k \cdot \ln(N_{ice})\right)}$$

where k is the shape parameter of the spectrum, N_{ice} is the number of load cycles in the spectrum, and F_{ice} is the random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{\max}$. The shape parameter $k = 0.75$ is to be used for the ice force distribution of an open propeller blade and the shape parameter $k = 1.0$ for that of a ducted propeller blade.

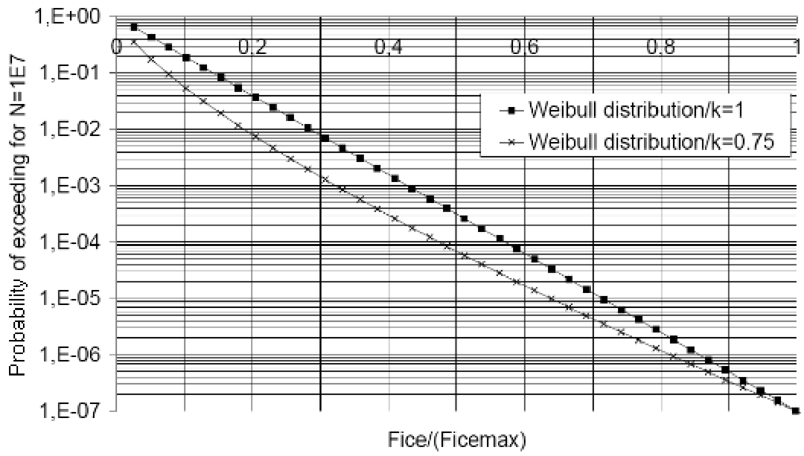


Figure 2.30.6 The Weibull-type distribution (probability that (F_{ice} exceeds $(F_{ice})_{max}$) that is used for fatigue design.

(9) Number of ice loads

The number of load cycles per propeller blade in the load spectrum is to be determined according to the formula:

$$N_{ice} = k_1 \cdot k_2 . k_3 . k_4 \cdot N_{class} n,$$

where,

Reference number of loads for ice classes N_{class}

Class	IA Super	IA	IB	IC	ID
impacts for the ship's service life $/n$	$9 \cdot 10^6$	$6 \cdot 10^6$	$3.4 \cdot 10^6$	$2.1 \cdot 10^6$	$2.1 \cdot 10^6$

Propeller location factor k_1

Location	Center propeller	Wing propeller
k_1	1	1.35

Propeller type factor k_2

type	open	ducted
k_2	1	1.1

Propulsion type factor k_3

type	fixed	azimuthing
k_3	1	1.2

The submersion factor k4 is determined from the equation

$$k_4 = 0.8 - f \quad \text{when } f < 0$$
$$= 0.8 - 0.4 \cdot f \quad \text{when } 0 \le f \le 1$$
$$= 0.6 - 0.2 \cdot f \quad \text{when } 1 < f \le 2.5$$
$$= 0.1 \quad \text{when } f > 2.5$$

where the immersion function f is:

$$f = \frac{h_0 - H_{ice}}{D/2} - 1$$

where h_0 is the depth of the propeller centerline at the lower ice waterline (LIWL) of the ship.

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

5. Axial design loads for propellers

(1) Maximum ice thrust on propeller T_f and T_b for propellers

The maximum forward and backward ice thrusts are:

$$T_f = 1.1 \cdot F_f \quad \text{(kN)}$$
$$T_b = 1.1 \cdot F_b \quad \text{(kN)}$$

(2) Design thrust along the propulsion shaft line for propellers
The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater absolute value of the forward and backward direction loads is to be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction $T_r = T + 2.2 \cdot T_f$ (kN)

In a backward direction $T_r = 1.5 \cdot T_b$ (kN)

If hydrodynamic bollard thrust, T, is not known, T is to be taken as follows:

Table 3.20.18 Propeller bollard thrust T

Propeller Type	T
CP propellers (open)	$1.25 \cdot T_n$
CP propellers (ducted)	$1.1 \cdot T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85 \cdot T_n$
FP propellers driven by diesel engine (ducted)	$0.75 \cdot T_n$

T_n = nominal propeller thrust at MCR at free running open water conditions

6. Torsional design loads

(1) Design ice torque on propeller $Q_{\max}$ for open propellers
$Q_{\max}$ is the maximum torque on a propeller resulting from ice/propeller interaction.

when $D \le D_{\lim}$, $Q_{\max} = 10.9 \cdot [1-\frac{d}{D}] \cdot [\frac{P_{0.7}}{D}]^{0.16} \cdot [nD]^{0.17} \cdot D^3$ (kNm)

when $D > D_{\lim}$, $Q_{\max} = 20.7 \cdot [1-\frac{d}{D}] \cdot [\frac{P_{0.7}}{D}]^{0.16} \cdot [nD]^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1}$ (kNm)

where

$D_{\lim} = 1.8 \cdot H_{ice}$ (m).

n is the rotational propeller speed in bollard condition. If not known, n is to be taken as follows:

Table 3.20.19 The rotational propeller speed at bollard condition value n

Propeller type	Rotational speed n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0.85 \cdot n_n$

Here, n_n is the nominal rotational speed at MCR in free running condition.

For CP propellers, propeller pitch, $P_{0.7}$ is to correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at MCR in free running condition.

(2) Design ice torque on propeller $Q_{\max}$ for ducted propellers
$Q_{\max}$ is the maximum torque on a propeller resulting from ice/propeller interaction.

when $D \le D_{\lim}$, $Q_{\max} = 7.7 \cdot [1-\frac{d}{D}] \cdot [\frac{P_{0.7}}{D}]^{0.16} \cdot [nD]^{0.17} \cdot D^3$ (kNm) when $D > D_{\lim}$, $Q_{\max} = 14.6 \cdot [1 - \frac{d}{D}] \cdot [\frac{P_{0.7}}{D}]^{0.16} \cdot [nD]^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1}$ (kNm)

where

$D_{\lim} = 1.8 \cdot H_{ice}$ (m)

n is the rotational propeller speed in bollard condition. If not known, n is to be taken as follows:

Table 3.20.20 The rotational propeller speed at bollard condition value n

Propeller type	Rotational speed n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0.85 \cdot n_n$

Here, n_n is the nominal rotational speed at MCR in free running condition.

For CP propellers, propeller pitch, $P_{0.7}$ is to correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at MCR in free running condition.

(3) Ice torque excitation for propellers
The propeller ice torque excitation for shaft line transient torsional vibration analysis is to be described by a sequence of blade impacts which are of a half sine shape; see **ANNEX 3-5 Fig 2** of the Guidance.
The torque resulting from a single blade ice impact as a function of the propeller rotation angle is then

$Q(\varphi) = C_q \cdot Q_{\max} \cdot \sin(\varphi(180/\alpha_i))$ when $\varphi = 0 ... \alpha_i$

$Q(\varphi) = 0$ when $\varphi = \alpha_i .....360$

where C_q and α_i parameters are given in table below. α_i is duration of propeller blade/ice interaction expressed in propeller rotation angle.

Table 3.21.21 C_q and α_i parameters

Torque excitation	Propeller-ice interaction	C_q	α_i
Case 1	Single ice block	0.75	90
Case 2	Single ice block	1.0	135
Case 3	Two ice blocks (phase shift 360/2/Z deg.)	0.5	45

The total ice torque is obtained by summing the torque of single blades, taking into account the

phase shift 360deg./Z. In addition, at the beginning and at the end of the milling sequence a linear ramp functions for 270 degrees of rotation angle shall be used.
The number of propeller revolutions during a milling sequence is to be obtained with the formula:

$$N_Q = 2 \cdot H_{ice}$$

The number of impacts is $Z \cdot N_Q$ for blade order excitation.

(4) Design torque along propeller shaft line
If there is not any relevant first blade order torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the following estimation of the maximum torque can be used.

$$Q_r = Q_{emax} + Q_{\max} \cdot \frac{I}{I_t} \quad \text{(kNm)}$$

Where, I is equivalent mass moment of inertia of all parts on engine side of component under consideration and It is equivalent mass moment of inertia of the whole propulsion system, all the torques and the inertia moments are to be reduced to the rotation speed of the component being examined.
If the maximum torque, Q_{emax} , is not known, it is to be taken as follows:

Table 3.20.22 the maximum torque Q_{emax}

Propeller type	Q_{emax}
Propellers driven by electric motor(FP and CP)	Q_{motor}
CP propellers driven by prime movers other than electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75 \cdot Q_n$

Here, Q_{motor} is the electric motor peak torque.

If there is a first blade order torsional resonance within the designed operating rotational speed range extended 20 % above the maximum and 20 % below the minimum operating speeds, the design torque (Q_r) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line.

7. Blade failure load

The ultimate load resulting from blade failure as a result of plastic bending around the blade root is to be calculated with the formula below. The ultimate load is acting on the blade at the 0.8 R radius in the weakest direction of the blade. For calculation of the extreme spindle torque, the spindle arm is to be taken as 2/3 of the distance between the axis of blade rotation and the leading/trailing edge (whichever is the greater) at the 0.8 R radius.

$$F_{ex} = \frac{300 \cdot c \cdot t^2 \cdot \sigma_{ref}}{0.8 \cdot D - 2 \cdot r} \quad \text{(kN)}$$

where,

$\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$

c, t, and r are, respectively, the length, thickness, and radius of the cylindrical root section of the blade at the weakest section outside the root filet.

606. Design

1. Design principle

The strength of the propulsion line is to be designed according to the pyramid strength principle. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

2. Propeller blade

(1) Calculation of blade stresses
The blade stresses is to be calculated for the design loads given in Section **605. 4**. Finite element analysis is to be used for stress analysis for final approval for all propellers. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area ($r/R < 0.5$). The root area dimensions based on following formula can be accepted even if the FEM analysis would show greater stresses at the root area.

$$\sigma_{st} = C_1 \cdot \frac{M_{BL}}{100 \cdot ct^2} \text{ (MPa)}$$

where,

constant C_1 is the $\frac{actual\ stress}{stress\ obtained\ with\ beam\ equation}$.

If the actual value is not available, C_1 should be taken as 1.6.

$M_{BL} = (0.75 - r/R) \cdot R \cdot F$, for relative radius $r/R < 0.5$

F is the maximum of F_b and F_f, whichever is greater absolute value.

(2) Acceptability criterion
The following criterion for calculated blade stresses has to be fulfilled.

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.5$$

where,

σ_{st} is the calculated stress for the design loads. If FEM analysis is used in estimating the stresses, von Mises stresses are to be used.

σ_{ref2} is the reference stress, defined as:

$\sigma_{ref2} = 0.7 \cdot \sigma_u$ or $\sigma_{ref2} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$, whichever is less.

(3) Fatigue design of propeller blade
The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution shall be calculated and the acceptability criterion for fatigue should be fulfilled as given in this Section. The equivalent stress is normalized for 10^8 cycles.
If the following criterion is fulfilled, fatigue calculations according to this Section are not required.

$$\sigma_{\exp} \geq B_1 \cdot \sigma_{ref}^{B_2} \cdot \log(N_{ice})^{B_3}$$

where, B_1, B_2 and B_3 coefficients for propellers are given in the table below.

Table 3.20.23 B_1, B_2 and B_3 coefficients

	Open propeller	Ducted propeller
B_1	0.00270	0.00184
B_2	1.007	1.007
B_3	2.101	2.470

For calculation of equivalent stress two types of S-N curves are available.
- Two slope S-N curve (slopes 4.5 and 10), see **Fig 3.20.7**.
- One slope S-N curve(the slope can be chosen), see **Fig 3.20.8**.

The type of the S-N curve is to be selected to correspond to the material properties of the blade. If S-N curve is not known, the two slope S-N curve is to be used.

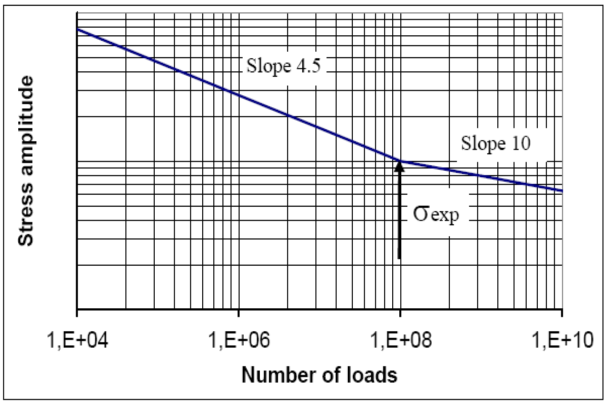


Fig 3.20.7 Two-slope S-N curve

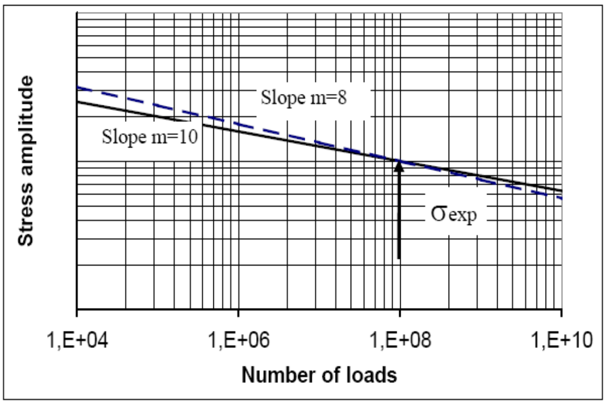


Fig 3.20.8 Constant-slope S-N curve

(A) Equivalent fatigue stress
The equivalent fatigue stress for 10^8 stress cycles which produces the same fatigue damage as the load distribution is:

$$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{\max}$$

where,

$(\sigma_{ice})_{\max} = 0.5 \cdot [(\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max}]$

$(\sigma_{ice})_{\max}$ is the mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied

$(\sigma_{ice})_{f\max}$ is the principal stress resulting from forward load

$(\sigma_{ice})_{b\max}$ is the principal stress resulting from backward load

In calculation of $(\sigma_{ice})_{\max}$, case 1 and case 3 (or case 2 and case 4) in **ANNEX 3-5** of the Guidance are considered as a pair for $(\sigma_{ice})_{f\max}$, and $(\sigma_{ice})_{b\max}$ calculations. Case 5 is excluded from the fatigue analysis.

(B) Calculation of ρ parameter for two-slope S-N curve
The parameter ρ relates the maximum ice load to the distribution of ice loads according to

the regression formulae.

$$\rho = C_1 \cdot (\sigma_{ice})_{\max}^{C_2} \cdot \sigma_{fl}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where,

$\sigma_{fl} = \gamma_\varepsilon \cdot \gamma_\nu \cdot \gamma_m \cdot \sigma_{\exp}$,

where,

γ_ε is the reduction factor for scatter and test specimen size effect

γ_ν is the reduction factor for variable amplitude loading

γ_m is the reduction factor for mean stress

$\sigma_{\exp}$ is the mean fatigue strength of the blade material at 10^8 cycles to failure in seawater.

The following values should be used for the reduction factors if actual values are not available: γ_ε = 0.67, γ_ν = 0.75, and γ_m = 0.75.

The coefficients C_1, C_2, C_3, and C_4 are given in **Table 3.20.24**.

Table 3.20.24 The coefficients C_1, C_2, C_3, and C_4

	Open propeller	Ducted propeller
C_1	0.000711	0.000509
C_2	0.0645	0.0533
C_3	- 0.0565	- 0.0459
C_4	2.22	2.584

(C) Calculation of ρ parameter for constant-slope S-N curve

For materials with a constant-slope S-N curve(see **Fig 3.20.8**), the ρ factor is to be calculated with the following formula:

$$\rho = \left(G \cdot \frac{N_{ice}}{N_R}\right)^{1/m} (\ln(N_{ice}))^{-1/k}$$

where,

k is the shape parameter of the Weibull distribution k = 1.0 for ducted propellers and k = 0.75 for open propellers.

N_R is the reference number of load cycles (=10^8)

Values for the G parameter are given in **Table 3.20.25**.

Linear interpolation may be used to calculate the G value for other m/k ratios than given in the **Table 3.20.25**.

Table 3.20.25 Value for the G parameter for different m/k ratios

m/k	G	m/k	G	m/k	G
3	6	5.5	287.9	8	40320
3.5	11.6	6	720	8.5	119292
4	24	6.5	1871	9	362880
4.5	52.3	7	5040	9.5	1.133E6
5	120	7.5	14034	10	3.623E6

(4) Acceptability criterion for fatigue
The equivalent fatigue stress at all locations on the blade has to fulfil the following acceptability criterion.

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geq 1.5$$

where,

$$\sigma_{fl} = \gamma_\varepsilon \cdot \gamma_\nu \cdot \gamma_m \cdot \sigma_{\exp}$$

where,

γ_ε is the reduction factor for scatter and test specimen size effect

γ_ν is the reduction factor for variable amplitude loading

γ_m is the reduction factor for mean stress

$\sigma_{\exp}$ is the mean fatigue strength of the blade material at 10^8 cycles to failure in seawater.

The following values should be used for the reduction factors if actual values are not available: γ_ε = 0.67, γ_ν = 0.75, and γ_m = 0.75.

3. Propeller bossing and CP mechanism

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft is to be designed to withstand the maximum and fatigue design loads, as defined in **605**. The safety factor against yielding is to be greater than 1.3 and that against fatigue greater than 1.5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending as defined in **605. 7** is to be greater than 1.0 against yielding.

4. Propulsion shaft line

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, are to be designed to withstand the propeller/ice interaction loads as given in **605.** The safety factor is to be at least 1.3.

(1) Shafts and shafting components
The ultimate load resulting from total blade failure as defined in **605. 7** should not cause yielding in shafts and shaft components. The loading shall consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for bending and torsional stresses.

5. Azimuthing main propulsors

In addition to the above requirements, special consideration is to be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of loading cases has to reflect the way of operation of the ship and the thrusters. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller have to be considered. Furthermore, loads resulting from the thrusters operating at an oblique angle to the flow have to be considered. The steering mechanism, the fitting of the unit, and the body of the thruster are to be designed to withstand the loss of a blade without damage. The loss of a blade is to be considered for the propeller blade orientation which causes the maximum load on the component being studied. Typically, top-down blade orientation places the maximum bending loads on the thruster body.

Azimuth thrusters are to also be designed for estimated loads caused by thruster body/ice interaction. The thruster body has to stand the loads obtained when the maximum ice blocks, which are given in **603.**, strike the thruster body when the ship is at a typical ice operating speed. In addition, the design situation in which an ice sheet glides along the ship's hull and presses against the thruster body should be considered. The thickness of the sheet should be taken as the thickness of the maximum ice block entering the propeller, as defined in **603.**

6. Vibrations

The propulsion system is to be designed in such a way that the complete dynamic system is free from harmful torsional, axial, and bending resonances at a 1-order blade frequency within the designed running speed range, extended by 20 percent above and below the maximum and minimum operating rotational speeds. If this condition cannot be fulfilled, a detailed vibration analysis has to be carried out in order to determine that the acceptable strength of the components can be achieved.

607. Alternative design procedure

1. Scope

As an alternative to **605.** and **606.**, a comprehensive design study may be carried out to the satisfaction of the society. The study has to be based on ice conditions given for different ice classes in **603.** It has to include both fatigue and maximum load design calculations and fulfil the pyramid strength principle, as given in **606. 1.**

2. Loading

Loads on the propeller blade and propulsion system are to be based on an acceptable estimation of hydrodynamic and ice loads.

3. Design levels

(1) The analysis is to indicate that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin.
(2) Cumulative fatigue damage calculations are to indicate a reasonable safety factor. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.
(3) Vibration analysis is to be carried out and is to indicate that the complete dynamic system is free from harmful torsional resonances resulting from propeller/ice interaction.

Section 7 Miscellaneous Machinery Requirements

701. Starting arrangements

1. The capacity of the air receivers is to be sufficient to provide without reloading not less than 12 consecutive starts of the propulsion engine, if this has to be reversed for going astern, or 6 consecutive starts if the propulsion engine does not have to be reversed for going astern.

2. If the air receivers serve any other purposes than starting the propulsion engine, in addition to the capacity required by **Par 1**, they are to have a sufficient capacity for these purposes.

3. The capacity of the air compressors is to be sufficient for charging the air receivers from at-mo-spheric to full pressure in one (1) hour as specified in **Pt 5, Ch 6, 1101.**, except for a ship with the ice class IA Super, if its propulsion engine has to be reversed for going astern, in which case the compressor is to be able to charge the receivers in half an hour.

702. Sea inlet and cooling water systems

1. The cooling water system is to be designed to ensure supply of cooling water when navigating in ice.

2. To satisfy **Par 1**, at least one cooling water inlet chest is to be arranged as follows. However, the ship with ice class ID may not comply with the requirements in (2), (3) and (5).

(1) The sea inlet is to be situated near the centerline of the ship and well aft if possible.
(2) As guidance for design, the volume of the chest is to be about 1 m^3 for every 750 kW engine output of the ship including the output of auxiliary engines necessary for the ship's service.
(3) The chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.
(4) A pipe for discharge cooling water, allowing full capacity circulate, is to be connected to the chest.
(5) The open area of the strainer plates is not to be less than four (4) times the inlet pipe sectional area.

3. If there are difficulties to meet the requirements of **Par 2** (2) and (3), two smaller chests may be arranged for alternating intake and discharge of cooling water. In this case, the requirements in **Par 2** (1), (4) and (5) are to be complied with.

4. Heating coils may be installed in the upper part of the sea chest.

5. Arrangements for using ballast water for cooling purposes may be useful as a reserve in ballast condition but cannot be accepted as a substitute for sea inlet chest as described above. ⚓

CHAPTER 21 ADDITIONAL REQUIREMENTS TO SHIPS FOR NAVIGATION IN POLAR WATERS

The ships constructed of steel and intended for navigation in ice-infested polar waters are to be specially considered as deemed appropriate by this Society. ⚓

CHAPTER 22 VESSELS FOR POLAR AND ICE BREAKING SERVICE

The vessels for polar and ice breaking service are to be specially considered as deemed appropriate by this Society. ⚓

KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 3

Hull Structures

GA-03-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF the Guidance

This "Guidance relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 3 "HULL STRUCTURES"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date : 10 January 2011

Chapter 15 DEEP TANKS

Section 2 Bulkheads of Deep Tank
- 202. and 203. 4 have been newly added.

Effective Date : 1 July 2011

Chapter 1 GENERAL

Section 8 Corrosion protection coating
- 803. has been amended.

Chapter 4 PLATE KEELS AND SHELL PLATINGS

Section 1 General
- 103. has been amended.

Chapter 5 DECKS

Section 3 Deck plating
- 307. has been newly added.

Chapter 7 DOUBLE BOTTOMS

Section 1 General
- 101. 8 has been amended.

Chapter 20 STRENGTHENING FOR NAVIGATION IN ICE

Section 2 Ice strengthening
- 201. has been amended.

Section 5 Rudder and steering arrangements
- has been newly added.

Chapter 21 ADDITIONAL REQUIREMENTS TO SHIPS FOR NAVIGATION IN POLAR WATERS

Section 1 Polar class descriptions and application
- 104. has been amended.

Annex 3-2 GUIDANCE FOR THE DIRECT STRENGTH ASSESSMENT

III Guidance for the Hold Analysis

- 3. 5 (C) has been amended.

Annex 3-4 GUIDANCE FOR THE HULL CONSTRUCTION MONITORING PROCEDURE

- 3. (3) (E) has been amended.
- 4. (1) (F) has been deleted.
- 4. (3) (D) has been amended.

CONTENTS

<ANNEX>

CHAPTER 1 GENERAL

Section 1 Definitions

101. Application

L, B, D, D_s, d and other significant scantlings have two significant figures and third figure is raised to a unit. However, scantling depth D and scantling draft d for freeboard have three significant figures and fourth figure is raised to a unit.

102. Length

1. When the length of ship is measured, the end of stern is from the midpart of the rudder stock regarded as which has not a rudder post when it is not elongated from the upper part of stern post to heel part. In case of simplex rudder, end of stern is from the midpart of rudder stock.

2. For the length of ship for freeboard, when 96 % of the length is larger than L_{pp}, end part of L is the 0.96 L_{WL} abaft part from the end of stern.

3. For ships which have not rudder post or rudder stock, (for example, ships having Voith-Schneider propeller) L is the 96 % of length for freeboard and end of stern is as follows above mentioned **Par 2.**

4. When the difference is not much than 300 mm between designed load line and draft of assigned freeboard, the length of ship and overall length of load line are regarded as a designed load line. And when the difference is not less than 300 mm, those are regarded as assigned draft.

5. When the difference is not much than 300 mm between the scantling draft (d_s) and designed load line, the length of ship and overall length of load line are regarded as a designed load line. And when the difference is not less than 300 mm, those are regarded as d_s.

104. Breadth

For ships having inclined shipline, breadth(B) used of the Rules is as following;

1. Double bottom

b in **Fig 3.1.1** is to be used instead of breadth B

2. Longitudinal strength

B_w on the same line to load line is to be used instead of breadth B

3. Equipment number

The breadth of ship B is to be used.

106. Depth

1. For the depth of ships having a rounded gunwale, depth is the distance to the conjunction point of the elongated line to end point of R and elongated line to inside face of side plate.(See **Fig 3.1.2**)

2. For the ships having multiple deck, "freeboard deck", specified in **114. 3** of the Rules, only used for calculating depth in accordance with the Rules. Freeboard deck used for assigning load line may use the upper deck than the above mentioned deck.

107. Depth for strength computation

If the lowest point of sheer is not located in the center of L, depth for strength calculation (D_s) is the minimum depth to strength deck between 0.4L of the midship.

Section 2 General

201. Application

For the ships classed for restricted service area, special consideration for hull construction and equipment of the ship is to be as followings.

1. Decreasing for scantlings of structural members is in accordance with **Table 3.1.1** in this Guidance and for the other members may be properly decreased in accordance with **Table 3.1.1.** However, for scantlings of the beams be loaded the cargo on, the weather deck beams be loaded timber cargoes on, the inner bottom and longitudinals attached to inner bottom and deep tanks, is not to be decreased.

2. The height of sills of access opening is to be in accordance with the following **Table 3.1.2.** However, ships engaged in international voyage are not applied to.

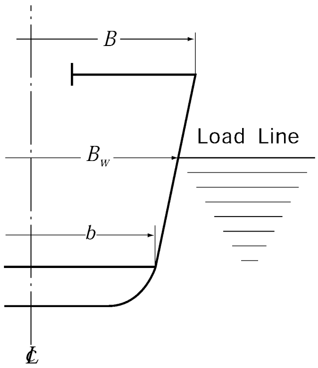


Fig 3.1.1

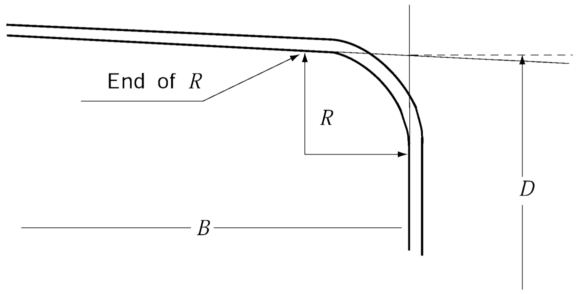


Fig 3.1.2

Table 3.1.1 Minimum dimension and lightening of the members

Items		Coastal services	Smooth water services	Minimum dimension
Longitudinal strength	Wave load(M_w & F_w)	20 %	30 %	—
	Z_{min}	10 %	15 %	—
Shell plating (including plate keels)		5 %	10 %	6 mm (excluding superstructure)
Min. thickness of deck		1 mm	1 mm	5 mm
Section modulus of frame		10 %	20 %	30 cm^3
Section modulus of deck beam		15 %	15 %	—
Section modulus of girder under deck		15 %	15 %	—
Plate thickness of double bottom		1 mm	1 mm	5.5 mm
Plate thickness. of single bottom		0.5 mm	10% or 1 mm whichever is smaller	—
Plate thickness of B.H.D of superstructure end and section modulus of B.H.D stiffeners		10 %	1 0 %	—

Note:
1. For the ships engaging in international services may not be lightened the thickness of B.H.D of superstructure end and section modulus of B.H.D stiffeners.
2. Z_{min} & M_w : refer to **Table 3.3.1** of the Rules
   F_w : refer to **Ch 3, 301** of the Rules.

Table 3.1.2 Height of door sills of hatch coaming and access doors.

Service area \ Type \ Position		General hatch opening	Small hatch opening(Area)		Elevator door E/R entrance	Access door of superstructure end	Ventilation tunnel
			$0.45 \sim 1.5\ m^2$	Not exceeding 0.45 m2			
Smooth sea water area	I	600	450	380	450	380	900
	II	450	380	230	300	300	760
Fresh water area	I	450	380	230	300	300	760
	II	300	230	180	100	100	450

3. Equipment and equipment number is to be in accordance with **Pt 4, Ch 8** of the Rules.

203. Ships of unusual form or proportion, or intended for carriage of special cargoes

1. Timber carrier

(1) Ships marked timber load line, when the difference between timber load line and d in **110.** of the Rules is not much than 300 mm, may be use L, Δ and C_b corresponding to the value of d. However, if the difference is not less than 300 mm, ships is to be used L, Δ and C_b corresponding to the timber load line.

(2) Ships intended for carrying timber cargoes without timber load line mark, is to be complied with the following (3).

(3) For the hull structure of timber carrier is to be protected with complying to the followings. However, for timber carrier only carrying the packaged timber, the followings may be properly considered excepting (H).

(A) Welding structure (**Ch 1, Sec 5** of the Rules)
For the welding of the member impacted by the cargoes, it is to be double continuous welding(at least F2). However, when the bottom ceilings are provided, welding for structural member of double bottom tank top is not to be continuous welding.

(B) Deck girders and hatch end girders (**Ch 11** of the Rules)
For deck girders and hatch end girders of side hatch, tripping bracket having 1.5 m spacing is to be provided and free edges are to be flanged.

(C) Protection of watertight bulkhead (**Ch 14** of the Rules)
Hold bulkhead of ships of 130 m or less in length is preferably not to be of corrugated type but of plane type. One side of plane type bulkhead not fitted with stiffeners and on both sides of corrugated type bulkhead, special protection is to be made by providing square section wooden bars(250 mm × 250 mm) or steel angle bars, etc. at proper intervals. Protection of bulkhead stiffeners is to be in accordance with the following (F).

(D) The structure of hatch opening, machinery opening(**Pt 4, Ch 2** of the Rules) and hatch coamings of other deck opening is to be strongly constructed.

(E) Bulwarks (**Pt 4, Ch 4** of the Rules)
It is recommended that area of freeing ports provided on bulwarks is to be as small as possible in way of hatchway and the area is to be increased in other parts so as to maintain the total required freeing port area.

(F) Protection of hold frames
Protection method of hold frames is to be in accordance with the following. However, this protection may be dispensed with for ships exceeding 130 m in length.

(a) Hold frames are to be stiffened by one of the followings.

(i) Longitudinal stiffeners or tripping brackets are to be fitted at intervals of about 2 m.

(ii) Angle bars are to be fitted longitudinally at intervals of about 1.5 m on flange surface of hold frames.

(iii) Flat bars of about 150 mm wide × 10 mm thick are to be fitted longitudinally at intervals of about 0.5 m on flange surface of hold frames.

(b) Angle bars or flat bars (in case of flat bars, at least 2 tiers) are to be fitted longitudinally on flange surface of tank side brackets or of the lower bracket of hold frames of bulk carrier type ships. However, the above requirements may be dispensed with where thickness and breadth of flange of hold frames of bulk carrier type ships are not less than that determined by the followings.

(i) Thickness of bracket t is in accordance with **604.** of the Rules. However, the length of bracket arms is to be in accordance with **Fig 3.1.3.**

(ii) Breadth of free edges of bracket is to be obtained from the following formula.

$$b = 128\sqrt{d_0 l} \quad \text{(mm)}$$

d_0 = depth of throat of bracket as specified in **Fig 3.1.3.** (m)

l = length of flange of bracket as specified in **Fig 3.1.3.** (m)

(iii) For abaft and aft peaks and other parts, where the frames is provided beneath of hatch, it is to be properly compensated.

(iv) Where the projected part is large as like as deep frames in the hold, special consideration is to be given for the dimension and provision of tripping bracket.

(G) Painting
For the inside of hold, all hull structural members below the point of 150 mm above the top of tank side brackets (including shell plate and piping) are to be coated with tarepoxy paint or other similar paint of good quality not easily peeling off.

(H) Air pipes, ladders, weathertight doors and equipment fitted on hull structural members which are liable to cause damage due to impact of cargoes are to be properly protected.

(I) Protection of hatch covers
Hatch covers are to be protected from timber by dunnage, etc. and to be fitted with the devices to prevent from moving due to the ship's motion such as rolling, pitching, etc. In case of hatch covers with gasket, the devices for preventing gasket from excessive compression by timber loads are to be provided.

2. Ships having an unusual large freeboard and an unusual large height from the load line to strength deck.

(1) "Ships having an unusual large freeboard" is the ships having a actual summer freeboard f_s (corresponding to the assigned load line) which is not less than the sum of minimum summer freeboard f (See **Fig 3.1.4**) and standard height of superstructure h_s (See **Reg 33.** of "**1966 International Convention on Load Line**").

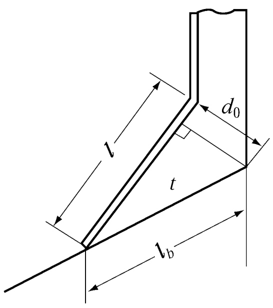


Fig 3.1.3 Measurements of bracket arm

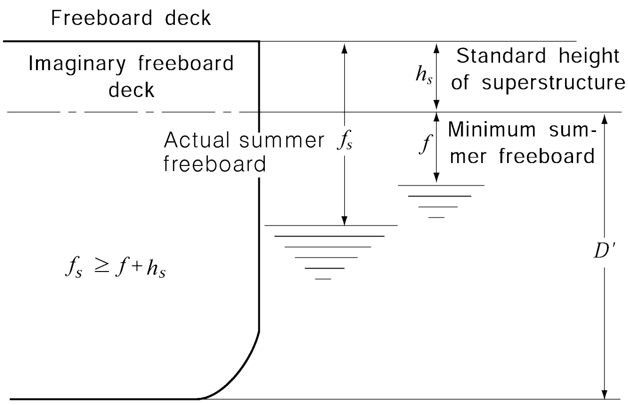


Fig 3.1.4 Ships having specially large freeboard

(2) The dimension of member is to be comply with the followings in addition to the Rules. However, for the Type B ship in the **1966 International Convention on Load Line,** under mentioned treatments are not apply to ships whose assigned freeboards are B-60 or B-100 type.

(A) Single bottom
For the sectional area of floor, the value of D may be replaced instead of D' for the formula specified in **Ch 6, 403** of the Rules.

(B) Frames (**Ch 8** of the Rules)
Where the deck supporting frames above an imaginary freeboard deck, those frames may be regarded as superstructure frames

(C) Deck Load (**Ch 10** of the Rules)
In the provision of "h" specified in **Ch 10, Table 3.10.3** in the Rules, a weather deck may be regarded as follows in accordance with the vertical distance from an imaginary freeboard deck to the weatherdeck at side. In other Chapters of the Rules, this deck load "h" may be treated in the same manner.

$h_s \le H_D < 2h_s$ = Superstructure deck of first tier above an imaginary freeboard deck

$2h_s \le H_D < 3h_s$= Superstructure deck of second tier above an imaginary freeboard deck

$3h_s \le H_D$ = Superstructure deck of third tier above an imaginary freeboard deck

(D) Plate keels and shell platings (**Ch 4** of the Rules)
The thickness of side shell platings above than freeboard deck (imaginary freeboard deck for which is regarded as a freeboard deck) is in accordance with **Ch 4, 103** of the Guidance.

(E) Hatch openings and bulwarks (**Pt 4, Ch 2** and **Ch 4** of the Rules)
For the following items, provision to providing on freeboard deck may be released to provision to providing on superstructure deck and provision to providing on superstructure deck may be released to upper deck.
(a) Height of hatch coamings, scantlings and height of hatch covers
(b) Sill height of openings in the exposed machinery space casings
(c) Sill height of openings in deckhouses enclosing deck openings or sills of companionways.
(d) Height of ventilation duct coamings
(e) Height of air pipe
(f) Type of side scuttles

206. Direct strength calculation

1. When the scantlings of hull structural members is decided by the direct strength calculation specified in **206.** of the Rules, it is to be in accordance with **Annex 3-2 "Guidance for the Direct Strength Assessment".** However, if it is not applicable to comply with this Guidance, the analysis method, loading and allowable stress are to be in accordance with the discretion of the Society.

2. Buckling stress of each structural member is to be reviewed based on the results of direct strength calculation. Analysis method and allowable stress are to be in accordance with **Annex 3-2 "Guidance for the Direct Strength Assessment".**

3. If it is deemed to be necessary by the Society that fatigue analysis of the connection parts of ship structure, discontinuous parts of the structure and stress concentrated parts are to be reviewed, data for the analysis method and loading is to be submitted.

209. Structural testing, leak testing and hose testing

"where deemed necessary by the Society" in note number [3] of **Table 3.1.1** of the Rules means where the quality in relation to the construction techniques and the welding procedures adopted is not certified and where hydrostatic testing or hydropneumatic testing is specially required in the Rules and the Guidelines.

Section 4 Materials

401. Standards of material

1. When the stainless steels are used for plate, use of the materials and their scantling are to be subject to the followings.

(1) Stainless steel being used in the structural members is to be complied with **Pt 2, Ch 1, 305.** and **309.** of the Rules.
(2) This section is to be applied to structural members using stainless steels irrelevant to corrosion prevention is provided or not.

(3) When the stainless steel are used in the structural members, it is to be complied with buckling strength criteria in **Ch 3, Sec 4** in the Guidance and Rules.

(4) Material factor(K_s) are obtained from the following formula but not less than 0.72

$$K_s = f\{8.81(\sigma_s/1000)^2 - 7.56(\sigma_s/1000) + 2.29\}$$

σ_s : The minimum value of yield strength or proof stress of stainless steel or stainless clad steel specified in **Pt 2, Ch 1, 305.** and **309.** of the Rules. (N/mm^2)

f : To be given by the following formula. Where T is more than 100℃, the value is at the discretion of the Society.

$$f = 0.0025(T-60) + 1.00$$

T : The maximum cargo temperature in (°C) to be contacted by the materials. Where the temperature is less than 60°C, T is to be taken as 60°C.

Where the members do not come in contact with the sea water the values of following (A) and (B) may be reduced from the scantlings required by the relevant requirements.

(A) For stainless steel, the values is to be given as follows.
- Where the scantling is required of the thickness of plate: 1.0 mm
- Where the scantling is required of the section modulus: 5%

(B) For stainless clad steel, the values is to be given as follows.
- Where the scantling is required of the thickness of plate: 0.5 mm

403. High tensile steels

1. Where high tensile steels are used for the longitudinal strength members, it is to be in accordance with the followings.

(1) Application
For the mid part of ships having strength deck and bottom with longitudinal structure, where the section modulus of vertical section is reduced by the using high tensile steels in accordance with **403.** of the Rules, longitudinal strength members are to in accordance with the followings

(2) Extents of use of high tensile steels
High tensile steels are to be used in the following parts.

(A) Longitudinal strength members within the ranges from the strength deck or the bottom down or up to the points specified below respectively. (See **Fig 3.1.5** and **3.1.6**)

(a) Strength deck

$$b_D = y_D\left(1 - \frac{1}{f_D}\right) \quad \text{(m)}$$

y_D = distance from the neutral axis of the cross section of hull to the strength deck (m)

(b) Bottom

$$b_B = y_B\left(1 - \frac{1}{f_B}\right) \quad \text{(m)}$$

y_B = distance from the neutral axis of the cross-section of hull to the top of keel (m)

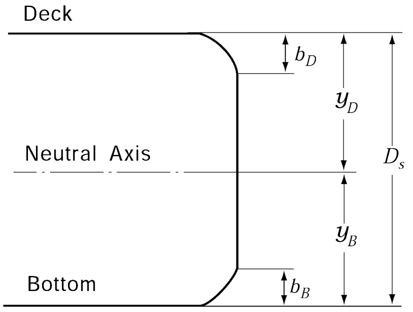


Fig 3.1.5 For the case that high tensile steels are used for deck and bottom

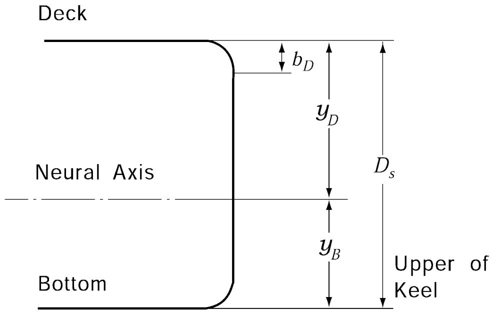


Fig 3.1.6 For the case that high tensile steels are used for deck

(B) Longitudinal strength members on strength deck
(C) Portions as shown in **Fig 3.1.7** of deck inside the line of openings
(D) Hatch coamings and their horizontal stiffeners within the extents shown in **Fig 3.1.8.**

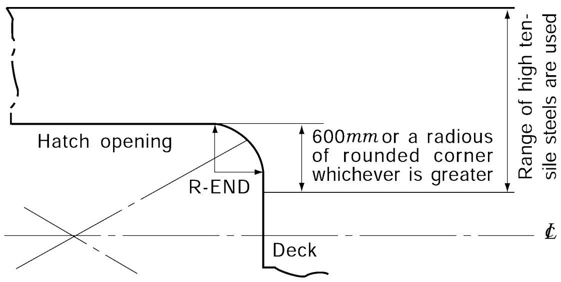


Fig 3.1.7. Deck

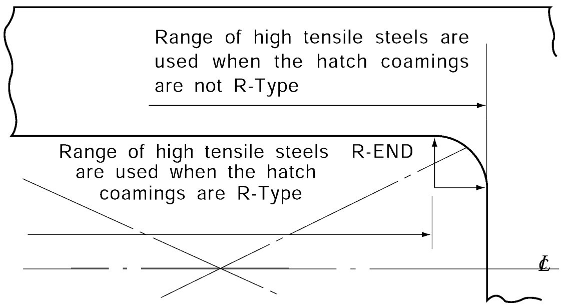
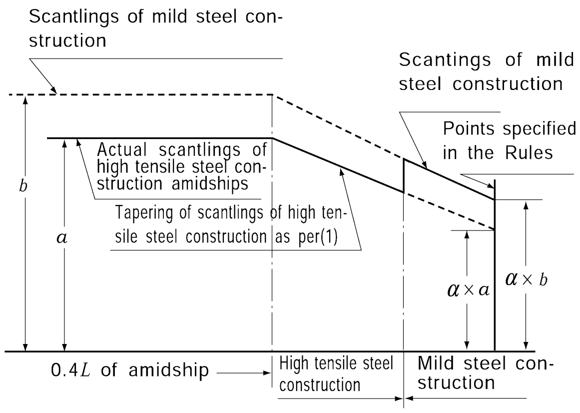


Fig 3.1.8 Hatch coaming

(E) Gutter bars and bilge keels welded to high tensile steel materials. Where bilge keels are welded to shell plating need not be of high tensile steel.
(F) Doubling plates fitted to the longitudinal strength members of high tensile steel for reinforcing openings, etc.
(G) It is recommended that the range of $0.5L$ amidship be constructed of high tensile steel. If the range of $0.5L$ amidship is not covered by high tensile steel, special consideration should be given to the continuity of section modulus of hull girder between the range of $0.4L$ and $0.5L$ amidship.

(3) Tapering of longitudinal strength members
(A) The manner of tapering of longitudinal strength members of high tensile steel is to comply with the provisions of the Rules, assuming that the entire hull be constructed of high tensile steel.
(B) Where the midship part is constructed of high tensile steel, the scantlings of mild steel members forward of and abaft the midship part are to be in accordance with **Fig 3.1.9.**
(C) At the connection of high tensile and mild steel materials, due consideration should be so given to the continuity of strength that appreciable difference of plate thickness may be avoided.



α = lightening at the point specified of the Rules
a = real dimension of high tensile steels at the midship
b = dimension of members used mild steels. thickness t and area A are to be followings.

(A) Thickness of shell plating and longitudinal bulkheads

$$t = \frac{1}{\sqrt{K}}(a - t_c) + t_c \ (mm)$$

t_c : oil tankers = 2.0 mm
others = 1.5 mm

(B) Sectional area of longitudinal strength members of the strength deck

$$A = \beta a$$

β is in accordance with **Table 3.1.3.** However, in case the effective sectional area of longitudinal strength members of the strength deck in the middle of L has been determined, where mild steel construction is assumed, the value may be given as follows;

$$\beta = \frac{\text{Effective sectional area of strength deck at the middle of } L\text{, where mild steel construction is assumed}}{\text{Effective sectional area of strength deck at the middle of } L\text{, for ships made of high tensile steels}}$$

(C) Sectional modulus of stiffeners of longitudinal frames, beams and bulkheads

$$Z = a/K$$

Fig 3.1.9

Table 3.1.3

Material \ Ship	Oil tanker	Others
HT32	1.27	1.34
HT36	1.38	1.45

2. The followings are to be considered when high tensile steels used.

(1) When the steels having different stiffness are used for ship structure, stress of low stiffness steel nearby high stiffness steel is specially considered.

(2) When the girder is constructed with high tensile steel, stiffness of girder or scantlings of tripping brackets are to be specially considered for preventing to occur excessive stress to tripping brackets.

(3) For the members constructed with high tensile steels, special consideration is to be given to the members for preventing of excessive stress concentration.

(4) When the high tensile steels used in a wide scope, detailed strength review is to be given and submitted the results to the Society.

405. Application of steels

1. The steels used for the rounded gunwale are to be treated as shear strake. In such a case, width of a strake plate is to be not less than 1,300 mm for ship length L up to 100 m and 2,600 mm for L being not less than 250 m. When the ship length is between 100 m and 250 m, breadth is not to be less than the value which is obtained by interpolation.

2. Where the steels with the thickness above 50 mm up to 100 mm used for hull structures, the steels are to be provided in **Pt 2, Ch 1** Rules in accordance with **Table 3.1.4** of the Rules and **3.1.4** of the Guidance.

Table 3.1.4 Steel grades (50 mm < t ≤ 100 mm)

Thickness(mm) \ Class	I		II		III	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*
$50 < t \le 60$	*D*	*DH*	*E*	*EH*	*E*	*EH*
$60 < t \le 100$	*E*	*EH*	*E*	*EH*	*E*	*EH*

Note:
The symbols in the table mean the grades of steel as follows:
DH : *DH* 32, *DH* 36 and *DH* 40, *MS* : Mild steels
EH : *EH* 32, *EH* 36 and *EH* 40, *HT* : High tensile steels

406. Special requirements for application of steels

1. For the ships carrying low temperature cargo, the application of steels which is exposed to low temperature cargo is in accordance with **Table 3.1.5.** However, if the structure can be released the thermal stress, it is to be in accordance with the discretion by the Society.

Table 3.1.5 (1)

Designed temp T (°C)	Thickness of steels t (mm)						
	$t \le 10$	$10 < t \le 15$	$15 < t \le 20$	$20 < t \le 25$	$25 < t \le 30$	$30 < t \le 40$	$40 < t \le 50$
$-10 \le T$	*A*			*B*		*D*	*E*
$-20 \le T < -10$	*B*	*D*		*E*			
$-30 \le T < -20$	*E*				*RL* 24*A*		*RL* 24*B*
$-40 \le T < -30$	*RL* 24*A*			*RL* 24*B*			(2)
$-50 \le T < -40$	*RL* 24*B*			(2)			

NOTE
(1) For the members having designed temperature under -50°C, or strength deck exposed low temp, they may be needed steels having more higher tenacity by due to thickness of plate and structure.
(2) It is to be in accordance with the discretion by the Society.

2. The application of steels for ships designed to operate in area with low air temperatures is to comply with the following requirements:

(1) For ships intended to operate in areas with low air temperatures (below and including -20°C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in (5). Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes Ⅰ, Ⅱ and Ⅲ, as given in **Table 3.1.6,** depending on the categories of structural members(SECONDARY, PRIMARY and SPECIAL). For non-exposed structures and structures below the lowest ballast water line, see **405.** of the Rules.

Table 3.1.6 Application of material classes and grades – Structures exposed at low temperatures

Structural member category	Material class	
	Within 0.4L amidships	Outside 0.4L amidships
○ SECONDARY: - Deck plating exposed to weather, in general - Side plating above BWL - Transverse bulkheads above BWL	I	I
○ PRIMARY: - Strength deck plating [1] - Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings - Longitudinal bulkhead above BWL - Top wing tank bulkhead above BWL	II	I
○ SPECIAL: - Sheer strake at strength deck [2] - Stringer plate in strength deck [2] - Deck strake at longitudinal bulkhead [3] - Continuous longitudinal hatch coamings [4]	III	II

Notes :
[1] Plating at corners of large hatch openings to be specially considered. Class Ⅲ or grade E, EH 32, EH 36 and EH 40 to be applied in positions where high local stresses may occur.
[2] Not to be less than grade E, EH 32, EH 36 and EH 40 within 0.4L amidships in ships with length exceeding 250 m
[3] In ships with a breadth exceeding 70 m at least three deck strakes to be class Ⅲ.
[4] Not to be less than grade D, DH 32, DH 36 and DH 40.

(2) The material grade requirements for hull members of each class depending on thickness and design temperature are defined in **Table 3.1.7.** For design temperatures t_D < -55°C, materials are to be in accordance with the discretion of the Society.

(3) Single strakes required to be of class Ⅲ or of grade E, EH 32/EH 36/EH 40 and FH 32/FH 36/FH 40 are to have breadths not less than the values given by the following formula, maximum 1800 mm.

$$b = 5L + 800 \quad \text{(mm)}$$

(4) Plating materials for stern frames, rudder horns, rudders and shaft brackets are not to be of lower grades than those corresponding to the material classes given in **405. 3** of the Rules.

(5) The design temperature is to be taken as the lowest mean daily average air temperature in the area of operation. For seasonally restricted service the lowest value within the period of operation applies.

Table 3.1.7 Material grade requirements for classes I, II and III at low temperatures

Class I

Plate thickness in (mm)	-20/-25 °C		-26/-35 °C		-36/-45 °C		-46/-55 °C	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*
$t \leq 10$	*A*	*AH*	*B*	*AH*	*D*	*DH*	*D*	*DH*
$10 < t \leq 15$	*B*	*AH*	*D*	*DH*	*D*	*DH*	*D*	*DH*
$15 < t \leq 20$	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
$20 < t \leq 25$	*D*	*DH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
$25 < t \leq 30$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$30 < t \leq 35$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$35 < t \leq 45$	*D*	*DH*	*E*	*EH*	*E*	*EH*	-	*FH*
$45 < t \leq 50$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*

Class II

Plate thickness in (mm)	-20/-25 °C		-26/-35 °C		-36/-45 °C		-46/-55 °C	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*
$t \leq 10$	*B*	*AH*	*D*	*DH*	*D*	*DH*	*E*	*EH*
$10 < t \leq 20$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$20 < t \leq 30$	*D*	*DH*	*E*	*EH*	*E*	*EH*	-	*FH*
$30 < t \leq 40$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*
$40 < t \leq 45$	*E*	*EH*	-	*FH*	-	*FH*	-	-
$45 < t \leq 50$	*E*	*EH*	-	*FH*	-	*FH*	-	-

Class III

Plate thickness in (mm)	-20/-25 °C		-26/-35 °C		-36/-45 °C		-46/-55 °C	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*	*MS*	*HT*
$t \leq 10$	*D*	*DH*	*D*	*DH*	*E*	*EH*	*E*	*EH*
$10 < t \leq 20$	*D*	*DH*	*E*	*EH*	*E*	*EH*	-	*FH*
$20 < t \leq 25$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*
$25 < t \leq 30$	*E*	*EH*	*E*	*EH*	-	*FH*	-	*FH*
$30 < t \leq 35$	*E*	*EH*	-	*FH*	-	*FH*	-	-
$35 < t \leq 40$	*E*	*EH*	-	*FH*	-	*FH*	-	-
$40 < t \leq 50$	-	*FH*	-	*FH*	-	-	-	-

Notes :

The symbols in the table mean the grades of steel as follows :

AH : *AH* 32, *AH* 36 and *AH* 40,
DH : *DH* 32, *DH* 36 and *DH* 40,
EH : *EH* 32, *EH* 36 and *EH* 40,
FH : *FH* 32, *FH* 36 and *FH* 40
MS : Mild steels,
HT : High tensile steels

Section 5 Welding

501. General

1. Arrangement

When the ship having hatchs are fall under the following (1) to (4), detailed review of the fatigue strength for strength deck at hatch corner and end parts of hatch is to be completed and the cross section is not to be changed radically or scantlings of hatch side coaming are to be increased.

(1) Ships with hatch in the mid part, where the breadth of the hatch exceeds $0.7B$.
(2) Ships having strength deck which is constructed with high tensile steels in accordance with **403.** of the Rules.
(3) Ships with unusual high hatch coamings
(4) Ships with strength deck constructed with special shape or hatch opening constructed with special structure.

Section 8 Corrosion Control

803. Corrosion protection coating

1. Corrosion protection coating for sea water ballast tanks and double-side skin spaces arranged in bulk carriers

(1) Where ships engaging in international voyage and not less than 500 gross tonnage are relevant to (A) or (B), all dedicated seawater ballast tanks and double-side skin spaces arranged in bulk carriers of 150 m in length and upward are to be in accordance with **IMO Res. MSC. 215(82) PSPC**(Performance Standard for Protective Coatings). However, tankers or bulk carrier whose keels are laid after 1 July 2008 and before the date specified in (A) are to be in accordance with **IMO Res. 798(19)**.
(A) for which the building contract is placed on or after 1 July 2008 (in the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 January 2009); or
(B) the delivery of which is on or after 1 July 2012.

(2) Maintenance of the protective coating system shall be included in the overall ship’s maintenance scheme. The effectiveness of the protective coating system shall be verified during the life of a ship by the Administration or an organization recognized by the Administration, based on the guidelines developed by the Organization. ⚓

CHAPTER 2 STEMS AND STERN FRAMES

Section 1 Stems

101. Plate stems

1. The thickness of plate stems may be same as that of side shell plating at the level of freeboard deck and same as that of forecastle-side shell in the range of forecastle.

2. Where the plate stem with a large radius of curvature at its fore end is not fitted with a centreline stiffener or is not reinforced by using thicker plate than that in accordance with **101. 1** of the Rules, horizontal breast-hooks are to be provided at a space not exceeding 600 mm apart for reinforcement.

Section 2 Stern Frames

202. General

1. Welding of cast steel stern frames

(1) When cast steel stern frames is constructed with dividing 2 or 3 pieces, shape of weld is based on **Fig 3.2.1.**

(2) Connection of cast steel stern frame and shell plating is in accordance with **Fig 3.2.2.** However, if the welding procedure is approved, it may be in accordance with that procedure.

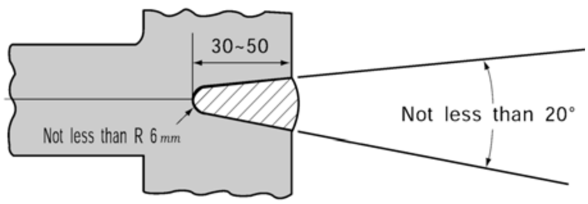


Fig 3.2.1 Welding of cast steel stern frames

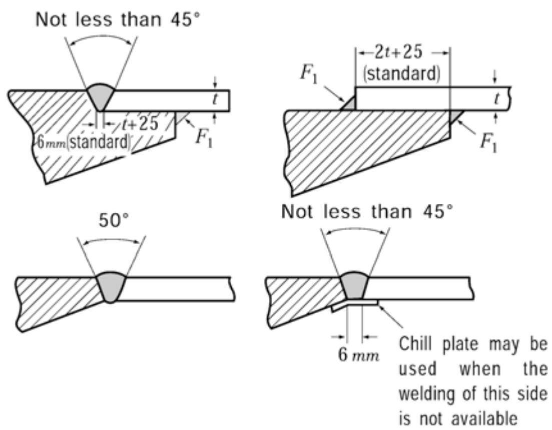


Fig 3.2.2 Connection with shell plating and cast steel stern frames

203. Propeller post

1. Connection of cast steel boss and plate parts of built up stern frame

The connection of cast steel boss and built-up stern frame is to be well grooved and welded with full penetrations at the root as shown in **Fig 3.2.3.**

2. Length of shaft hole of propeller boss

The length of shaft hole of the propeller boss is to be greater than 1.25 times the inside diameter of the boss hole.

3. Round bars used for built-up stern frame

In case that a round bar is used as the aft edge of a built-up stern frame, its radius is, as a standard, to be more than 70 % of R prescribed in **Table 3.2.1** of the Rules. At the connection of round bar to cast steel part or at the connection of round bars, the depth of bevel for welding is to be at least 1/3 of the diameter of round bar. The thickness of ribs fitted to the stern frame is, as a standard, to be 75 % of the stern frame plate. (See **Fig 3.2.4**)

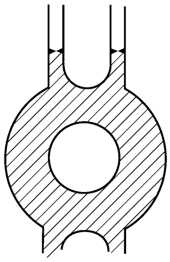


Fig 3.2.3 Connection with steel and propeller boss

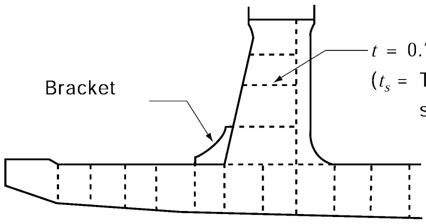


Fig 3.2.4

205. Shoe Piece

1. Connection of shoe pieces and propeller posts

The top plate of shoe piece is to be extended forward beyond the aft end of propeller post. A bracket of the same thickness as the stem frame is to be fitted at the connection of the shoe piece and the aft end of propeller post to keep a sufficient continuity of strength. (See **Fig 3.2.4**)

2. Steel bolts for fixing zinc slabs to the shoe piece must not be directly screwed into the shoe piece but they are to be directly welded to the shoe piece or screwed into steel plates welded to the shoe piece.

3. Shoe pieces of built-up construction are to be made watertight and the inside coated with effective coating material. Where no coating is applied to the inside of built-up shoe piece, the thickness of the shoe piece is to be increased by 1.5 mm.

206. Heel Piece

1. Determination of length of heel pieces

(1) In built-up stern frames, the length of heel pieces may be equal to twice the frame spacing at the position of heel pieces providing that the thickness of flat keels connected to the heel pieces is increased by about 5 mm.
(2) The length of heel piece is to be measured as shown in **Fig 3.2.5.**

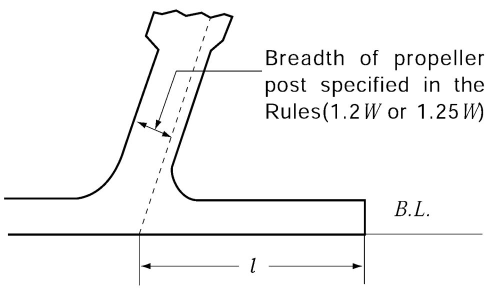


Fig 3.2.5 Measurements of l

(3) The thickness of ribs fitted to the heel piece is, as a standard, to be 75% of the ribs. ⚓

CHAPTER 3 LONGITUDINAL STRENGTH

Section 1 General

101. Application

1. Transverse section modulus of ship which is completed corrosion control with an approved measure

For deck or longitudinal strength members which is consist with one of a cargo tanks, ballast tanks, if they are completed the approved measure of corrosion control in accordance with **Ch 1, 801.** of the Rules, transverse section modulus may be reduced 5% to the value of specified in **201.** of the Rules. However, transverse minimum second moment of inertia ($I_{\min}$) is not to be less than the value specified in **Table 3.3.1** of the Rules.

2. Transverse section modulus of ships with unusual proportion

For the ships with $L/B \leq 5$ or $B/D_s \geq 2.5$, all strength excepting longitudinal strength is to be adequately considered.

3. Ships with especially large hatches

For ships breadth of whose hatches exceeds $0.7B$ in midship part, according to the requirements in **Pt 7, Ch 4, Sec 2,** bending and torsional strength is to be specially considered.

4. Ships with large flare and high speed ships

According to the value of K_v and K_f obtained from the following (1) and (2), wave induced longitudinal bending moment M_w is to be increased.

$$K_v = \frac{0.2V}{\sqrt{L}}, \qquad K_f = \frac{A_d - A_w}{Lh_B}$$

where

A_d = projected area onto a horizontal plane of exposed deck from the fore end extending to 0.2L aft of fore end including the part forward of fore end (m^2), Where a forecastle is provided, the horizontal project area of the forecastle is overlapped to the fore mentioned area.

A_w = water plane area corresponding to designed maximum load line within the forward $0.2L$ (m^2)

h_B = vertical distance from designed maximum load line to exposed deck at the side of fore end (m)

(1) In case that K_v exceeds 0.28
C_2 specified in **Fig 3.3.2** of the Rules is to be replace with the value given in **Table 3.3.1** in accordance with K_v and x(m) which is the distance from aft end of L to the position of considered hull transverse section. Where the K_v and/or x become intermediate, the value is to be determined by interpolation.

(2) In case that $(K_v + K_f)$ exceeds 0.4
C_2 specified in **Fig 3.3.2** of the Rules is to be replaced with the value given in **Table 3.3.2.** for the under M_w (-) condition. However, where the $(K_v + K_f)$ and/or x become intermediate, the value is to be determined by interpolation.

Table 3.3.1 Coefficient of C_2

K_v \ x	$0.65L$	$0.75L$	$1.0L$
0.28	1.0	5/7	0.0
0.32 over	1.0	0.80	0.0

Table 3.3.2 Coefficient of C_2

$K_v + K_f$ \ x	$0.65L$	$0.75L$	$1.0L$
0.4	1.0	5/7	0.0
0.5 over	1.0	0.80	0.0

103. Loading manual

1. "a ships may not be provided with a loading manual where deemed unnecessary by the Society" in **103. 1** of the Rules means the ships with length less than 90 m (L_f) in which the deadweight does not exceed 30 % of the displacement at the summer loadline draft and with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern.

2. The loading manual to be approved by the Society according to **103.** of the Rules, are to be prepared in accordance with **Annex 3-1 "Guidance for Preparation and Survey of Loading Manual".** They are to be written with a language easily understood by the shipmaster and if it is not English, English version is to be attached.

3. In addition, Bulk carriers of 150 m in length and above in L_f, where one or more cargo holds are bounded by the side shell only, which were contracted for construction before 1st July 1998 are to be provided with an approved loading manual with Guidance for typical loading/unloading sequences where the vessel is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, alternate conditions and relevant part load conditions where applicable. (see **Table 4** of **Annex 3-1**) The followings are to be included in the guidance.

(1) The minimum acceptable number of typical sequences is ;
  (A) one homogeneous full load condition
  (B) one full load alternate hold condition, if the ship is approved for alternate hold loading.
  (C) one part load condition where relevant, such as block loading or two port unloading.
(2) The shipowner/operator should select actual loading/unloading sequences, where possible, which may be port specific or typical.
(3) The results of the calculations of bending moments, shear force for each step from initial loading to full loading
(4) For each load condition in above mentioned in (1), the summary for all steps is to include the followings.
  (A) How much cargo is filled in each hold during the different steps.
  (B) How much ballast is discharged from each ballast tank during the different steps.
  (C) The maximum still water bending moment and shear at the end of each step
  (D) The ship's trim and draught at the end of each step
(5) Approved guidance for loading /unloading is to be attached to loading manual or to be placed on board ship in annex of the manual.
(6) The form of guidance for loading/unloading is referred to **Table 4** in **Annex 3-1.**

4. Application for providing of loading manual is to be in accordance with **Table 3.3.3.**

104. Longitudinal strength loading instruments

1. "a ships may not be provided with a loading manual where deemed unnecessary by the Society" in **104. 1** of the Rules means the ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern and with suitable Guidance are included in loading manual

2. Bulk carriers, ore carriers and combination carriers of 150 m in length and above, which are contracted for construction before 1st July 1998 are to be provided with an approved loading instruments for longitudinal strength with satisfaction of the requirements of this Society.

3. Application for providing of loading instruments for longitudinal strength is to be in accordance with **Table 3.3.3.**

4. The followings are to be included in loading instruments for longitudinal strength for bulk carriers, ore carriers and combination carriers of 150 m in length and above, which are contracted for construction on or after 1st July 1998.

(1) the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position.
(2) the mass of cargo and double bottom contents of any two adjacent holds as a function of the draught at mid-part of these holds.
(3) the still water bending moment and shear forces in the hold flooded conditions in accordance with **Pt 7, Ch 3, Sec 10** of the Rules.

Table 3.3.3 For the case of ships, loading manual and longitudinal loading instruments are to be installed

Application \ Kind of ship		Category 1-1		Category 1-2		Category 1-3		Category 2	
		Loading Manual	Longitudinal loading instruments	Loading Manual	Longitudinal loading instruments	Loading Manual	Longitudinal loading instruments	Loading Manual	Longitudinal loading instruments
①	Ships under survey during (after) construction before 1992/11/1	$L_f \geq 100$ m	NA	$L_f \geq 100$ m	NA(C)	$L_f \geq 100$ m	NA	NA	NA
②	Ships under survey during (after) construction after 1992/11/1	$L_f \geq 100$ m	NA	$L_f \geq 100$ m	NA(C)	$L_f \geq 65$ m	NA	NA	NA
③	Ships under survey during (after) construction before 1993/5/1	$L_f \geq 100$ m	$L_f \geq 100$ m	$L_f \geq 100$ m	$L_f \geq 120$ m	$L_f \geq 65$ m	$L_f \geq 65$ m	NA	NA
④	Ships under survey during (after) construction before 1998/7/1	$L_f \geq 65$ m	$L_f \geq 65$ m	$L_f \geq 65$ m	$L_f \geq 65$ m(A)	$L_f \geq 65$ m	$L_f \geq 65$ m	$L_f \geq 65$ m(B)	NA
⑤	Ships contracted for construction on or after 1st January 2003.	$L_f \geq 65$ m	$L_f \geq 100$ m	$L_f \geq 65$ m	$L_f \geq 100$ m(A)	$L_f \geq 65$ m	$L_f \geq 100$ m	$L_f \geq 65$ m(B)	NA

1. All ships engaged in under the coastal services may not be installed the loading manual and longitudinal loading instruments.
2. Kind of ships
   (1) Category 1-1 = For ships having large opening on the deck and are to be considered for combined stress of bending moment and torsional moment
   (2) Category 1-2 = For ships having non-homogeneous cargo and ballast loading
   (3) Category 1-3 = Chemical tankers and Ships carrying liquified gases in bulk.
   (4) Category 2 = For ships having homogeneous cargo and ballast loading in usual as followings
      (A) ships having no loadline mark
      (B) ships not carrying out cargoes
      (C) cargo vehicle carrier
      (D) ships having homogeneous cargo loading
3. For the application ① to ⑤, they means application date for the ships under the survey of during construction and construction date for the ships under the survey after construction.
4. (A) : For the ships having not exceeding 120 m in length and reflected in design for non-homogeneous cargo loading, it is specified in category 2 and longitudinal loading instrument may be not installed.
5. (B) : For the ships in category 2 with not exceeding 90 m in length and dead weight is not exceed 30 % of fully loaded displacement, longitudinal loading instrument may be not installed.
6. (C) : For all bulk carriers, ore carriers and combination carriers, longitudinal loading instrument is to be installed until 1 Jan 1999.
7. For the ships exempted the installation of longitudinal loading instrument may be not installed, when the instruments is installed, they are to be complied with related regulations.

5. “Approval by the Society" in **104. 2** of the Rules means each of the followings.

(1) It is recommended that software for longitudinal strength loading instrument is taken design approval. Regardless of the design approval to be of the software for longitudinal strength loading instrument, test result of typical service condition is to be submitted to the Society for approval and the software installed on board ship is to be approved by Society in accordance with test result.

(2) Where type approved hardware is installed, one instrument may install, and otherwise two instruments are to be installed.

Section 2 Bending Strength

201. Bending strength at amidships

1. The calculation of Longitudinal bending moment in still water is to be as follows.

(1) When performing the calculation of longitudinal bending moment in still water (M_s) specified in **Table 3.3.1** of the Rules, the method of calculation used is, upon submission of necessary documents, to be approved before hand by the Society.

(2) For ships desired to be built under the survey of the Society's Surveyors, calculation sheets for longitudinal strength in still water corresponding to the actual loading plans and the set of data necessary for the calculation are to be submitted to the Society.

(3) In the Classification Survey longitudinal strength calculations in still water are to be performed at the time of completion of the ship on each type of operating condition, and the necessary sets of data and the results of these calculations are to be included in the loading manual specified in **301.** of the Rules.

202. Bending strength at sections other than amidship

For those ships categorized in the following (1) or (2), the coefficient C_2 in the formula for M_w, specified in **Table 3.3.1** of the Rules is obtained from the value in accordance with the dotted line in **Fig 3.3.2** of the Rules and the same provision is to be applied.

(1) Ships with C_b of less than 0.7

(2) Ships whose longitudinal bending moments in still water at the parts other than the midship part are equal to or greater than the value at the midship part

203. Calculation of hull section modulus

1. Unit of hull section modulus

The section modulus Z(cm^3)is to have five significant figures.

2. Members included in longitudinal strength

The ratio of inclusion of members effective for longitudinal strength is to be as follows.

(1) Intercostal plates may be included in 100% if the fillet welding complies with **Ch 1,** Notes 1 in **Table 3.1.7** of the Rules.

(2) For new building ship, the Area of doubling plate may be included **1007.** in the rate of inclusion of member and for the ship fitted during conversion or addition, it may be included 90 %.

(3) For side stringers, slots for frames are to be deducted.

(4) Scallops complying with the following conditions need not be deducted from the sectional area. (See **Fig 3.3.1**)

(A) d_s not exceeding $d/4$ nor exceeding $7t$, but maximum 75 mm

(B) S more than $5b$ and more than $10d_s$

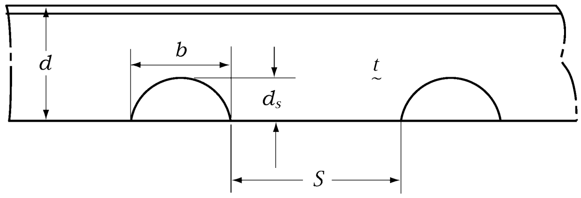


Fig 3.3.1 S, b and d_s of scallops

(5) Lightening holes and draining holes in longitudinals or longitudinal girders need not be deducted from the sectional area provided that the height of the holes does not exceed 25 % of the web depth.
(6) As for the longitudinal continuous decks between hatch ways of ships having 2 or 3 rows of cargo hatches, the ratio of sectional area to be included in the calculation of section modulus of hull girder is to be obtained from **Table 3.3.4.**
(7) Where sectional area of longitudinals, which are unable to be continued due to the arrangement of small hatch openings, etc., are compensated by adjacent ones, they may be included in the calculation of section modulus of hull girders.

Table 3.3.4 Ratio of inclusion of sectional area

ξ \ l/L \ No of holds	2			3 and over		
	0.10	0.20	0.30	0.10	0.15	0.20
0.0	0.96	0.85	0.70	0.96	0.91	0.85
0.5	0.65	0.57	0.48	0.89	0.80	0.69
1.0	0.48	0.43	0.36	0.83	0.73	0.62
2.0	0.32	0.29	0.25	0.73	0.63	0.53
3.0	0.24	0.22	0.18	0.65	0.57	0.47
4.0	0.19	0.17	0.14	0.59	0.51	0.43
5.0	0.16	0.14	0.12	0.53	0.47	0.39

NOTE:
1. ξ is to be in accordance with followings

$$\xi = \frac{ab^3}{lI_c}\left\{\frac{1+2\mu}{6(2+\mu)} \times 10^4 + 2.6\frac{I_c}{a_c b^2}\right\}$$

I_c = moment of inertia of deck between hatches, including hatch coaming(cm^4)
a_c = effective shear area of deck between hatches (cm^2)
a = sectional area of continuous deck between hatches(one side) (cm^2)
l = length of hatch (m)
μ and b = as specified in **Fig 3.3.2** (m)
2. ξ or l/L may obtained from the interpolation.
3. When the value of ξ is over 5.0, it may be obtained extrapolation.

(8) The car deck platings of Pure Car Carriers, in case they are intermittently welded in lap joint, are not to be included in the calculation.

4. Openings in strength deck

Openings in strength decks outside the line of hatch openings are to be treated as mentioned below.

(1) Where the shape and dimensions do not meet the conditions in **Table 3.3.5** reinforcement by menas of rings, thicker plates, etc. is required (See **Fig 3.3.3** and **3.3.4**)

(2) Where the intervals between centres of holes do not meet the conditions in **Fig 3.3.5** reinforcement as per (1) above is needed.

Table 3.3.5 Opening

	Elliptic hole	Circular hole
Oil tanker	$\frac{a}{b} \leq \frac{1}{2}$, $a \leq 0.06B$ (max. 900 mm)	$a \leq 0.03B$ (max. 450 mm)
Cargo ships	$\frac{a}{b} \leq \frac{1}{2}$, $a \leq 0.03B(B - b_H)$ (max. 450 mm)	$a \leq 0.015(B - b_H)$ (max. 200 mm)

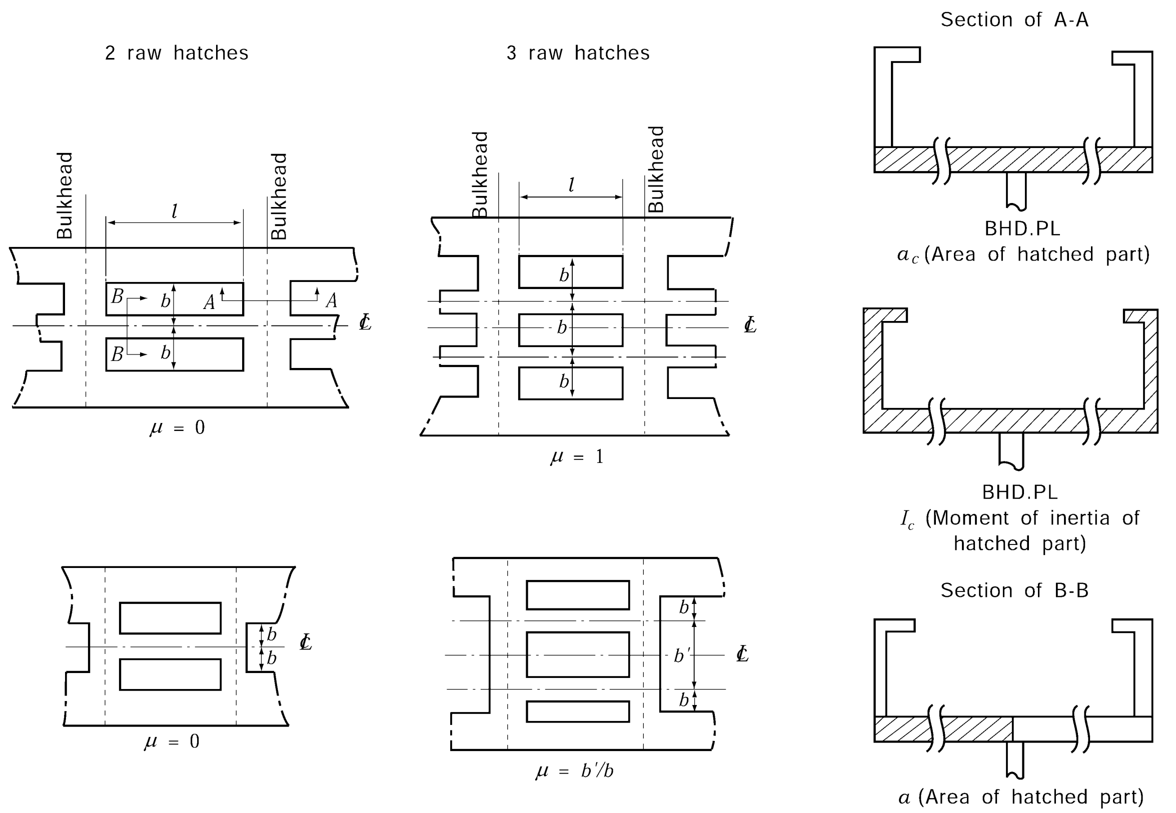


Fig 3.3.2 l, b and μ

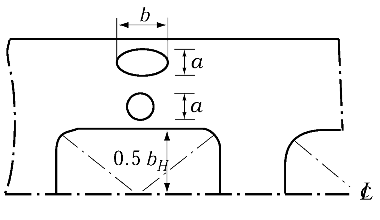


Fig 3.3.3 Where elliptical hole and circular hole are in same cross-section

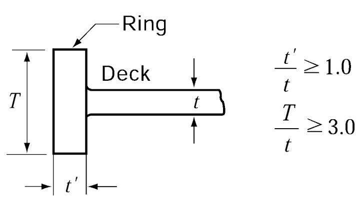


Fig 3.3.4 Reinforcements by ring

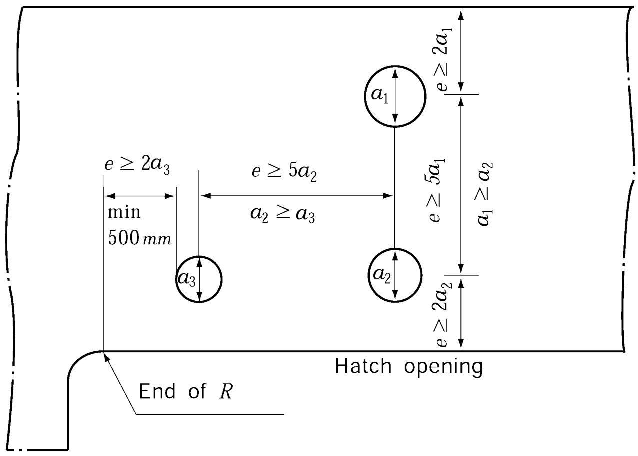


Fig 3.3.5 Spacing of opening

Section 3 Shear Strength

301. Thickness of side shell of ships without the effective longitudinal bulkhead

1. Ships with bilge hopper tanks or top side tanks

Where the sloping plates of the bilge hopper tank and topside tank are joined to the side shell plating and are considered to be effective to carry a part of the shearing force, the shear current at the transverse section of the hull under consideration may be calculated directly and the thickness of the side shell plating forming a part of the bilge hopper tank and topside tank may be determined. However, when performing this direct strength calculation and determining the thickness of plating, shearing force given in (1) is made to act on the transverse section of the hull, and shearing stresses which develop in the side shell plating forming a part of the bilge hopper tank and topside tank and in the sloping plates are obtained, and these values are to be less than the allowable stress given in (2).

(1) The value of shearing force acting on the transverse section of hull is obtained from the following formula, whichever is greater.

$$F = |F_s + F_w(+) - \Delta F_c| \quad \text{(kN)}, \qquad F = |F_s + F_w(-) - \Delta F_c| \quad \text{(kN)}$$

where

F_s, $F_w(+)$ and $F_w(-)$ = still water shear force and wave induced shear force specified in **Table 3.3.2**

ΔF_c = as specified in the following **2.**

(2) Allowable stress of sloping plate and side shell plate inside of bilge hopper tanks or topside tanks

$90/K$ (N/mm^2)

2. Modification of shearing force in still water in case where cargo is loaded in every other hold

Where a loaded hold (or a ballast hold) adjoins an empty hold by a transverse bulkhead, the shearing force in still water at the transverse section of hull under consideration may be determined as following F_c.

$F_c = F_s - \Delta F_c$ (kN)

F_c = still water shear force specified in **Table 3.3.2** (kN)

ΔF_c = the value obtained from the following formula by the distance form the transverse section and fore/aft end of hold

(1) At the bulkhead aft of hold

$$-C(F_{SF} - F_{SA} - F_T)$$

(2) At the bulkhead fore of hold

$$C(F_{SF} - F_{SA} - F_T)$$

(3) At a section in the hold

The value obtained by applying the linear interpolation of the values of (1) and (2) depending on the distance between the transverse section under consideration and the bulkhead aft or fore of the hold which contains the transverse section.

F_{SF}, F_{SA} = shearing force in still water(F_S) at the bulkhead aft and fore of the hold, respectively, in the loading condition concerned, applying the calculation method as specified in **301.** of the Rules(kN).

F_T = mass of ballast in the topside tank which is contained in the hold concerned (kN)

C = Coefficient which depends on the values of k as specified in **Pt 7, Ch 3, Sec 201, 4** of the Rules and B/l_h as given in the **Table 3.3.6.** For intermediate value of k linear interpolation is to be applied.

Table 3.3.6 Coefficient C

k \ B/l_h	0.4 under	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2	1.2–1.4	1.4–1.6	1.6–1.8	1.8–2.0	2.0–2.2	2.2–2.4	2.4 over
10.0	0.092	0.115	0.159	0.197	0.230	0.255	0.275	0.289	0.300	0.308	0.314	0.317
5.0	0.088	0.110	0.152	0.190	0.223	0.250	0.270	0.286	0.298	0.307	0.313	0.315
2.0	0.081	0.101	0.140	0.177	0.210	0.238	0.261	0.279	0.293	0.302	0.310	0.312
1.0	0.075	0.094	0.131	0.166	0.200	0.230	0.254	0.273	0.288	0.300	0.307	0.310
0.0	0.063	0.079	0.112	0.145	0.179	0.211	0.238	0.261	0.279	0.291	0.302	0.306

3. Simplified formula for Q/I

The ratio of Q and I specified in **301.** of the Rules may be simplified to $1/(90D_s)$.

302. Thickness of side shell and longitudinal bulkhead plating of ships having one to four rows of longitudinal bulkheads

For double hull ships with bilge hopper tanks, α_2 and R specified in **Table 3.3.2** of the Rules is in accordance with **Table 3.3.7** of the Guidance. However, the thickness of the side shell plating and slant plates forming bilge hoppers is not to be less than 1.2 times the values determined by the requirements of the Rules.

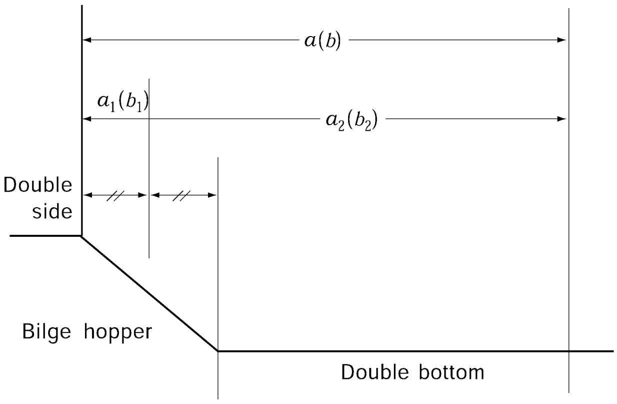


Fig 3.3.6 Measurements of a_1, a_2, b_1 and b_2

Table 3.3.7 α_2 and R of the ships having bilge hopper tanks

Type	Application		α_2	R
C	Side shell		$1-\dfrac{1.08k_2A_{DL}}{A_s+A_{DL}}$	$4.9(W_a(a_1+\beta a_2)+W_c c)S$
	Longitudinal bulkhead	Bilge hopper slant plate	$\dfrac{1.19k_2A_{DL}}{A_s+A_{DL}}$	
		Others	$\dfrac{1.08k_2A_{DL}}{A_s+A_{DL}}$	
D	Side Shell		$1-\dfrac{1.07k_2A_{DL}}{A_s+A_{DL}}$	$4.9(W_b(a_1+\beta a_2)+W_c c)S$
	Outer longitudinal bulkhead	Bilge hopper slant plate	$\dfrac{1.15k_2A_{DL}}{A_s+A_{DL}}$	
		Others	$\dfrac{1.07k_2A_{DL}}{A_s+A_{DL}}$	
	Centre longitudinal bulk		2	$9.8W_b b_2 S$
E	Side Shell		$1-\dfrac{1.06k_2A_{DL}}{A_s+A_{DL}}$	$4.9(W_b(b_1+0.5b_2)+W_c c)S$
	Outer longitudinal bulkhead	Bilge hopper slant plate	$\dfrac{1.11k_2A_{DL}}{A_s+A_{DL}}$	
		Others	$\dfrac{1.06k_2A_{DL}}{A_s+A_{DL}}$	
	Inner longitudinal bulkhead		1	$9.8(\beta W_a a+0.5W_b b_2)S$

a_1, a_2, b_1 and b_2 : as specified in **Fig 3.3.6**
A_s, A_{DL}, W_a, W_b, W_c, S, a, c, β and k_2 : as specified in **Table 3.3.2** of the Rules

Section 4 Buckling Strength

401. Apllication

Carlings (100×10 FB as standard type) are to be fitted in the longitudinal direction at the carling spaces which satisfy the following formula, on the part of midships, of strength deck plating of transverse framing system, and/or of side shell plating of transverse framing system connecting with strength deck and bottom both having same system as side shell plating. Where, however, an approval by the Society is obtained, the following requirements may not be applied.

$$16.6\left(\frac{t}{10S}\right)^2\left(1+\frac{S^2}{C^2}\right)^2 \geqq \alpha\gamma$$

t = thickness of deck or shell plating (mm)

C = spacing of carling (m)

S = spacing of transverse beams (m)

α = as given by the followings:

$$\frac{-(M_{S\min}+M_W(-))}{Z_D}\times 10^3 \ (\text{N/mm}^2) \quad \text{for strength deck}$$

$$\frac{(M_{S\max}+M_W(+))}{Z_B}\times 10^3 \ (\text{N/mm}^2) \quad \text{for bottom shell}$$

$M_{S\min}$ and $M_{S\max}$ = min. and max. values respectively, of longitudinal bending moment in still water as required in **201.** of the Rules

$M_W(-)$ and $M_W(+)$ = as specified in **201.** of the Rules

Z_D and Z_B = actual section moduli of transverse section of hull whose values are determined against the strength deck and ship bottom according to the requirements in **203.** of the Rules

γ : 1.0 for strength deck plating and bottom shell plating, and the value given by the following for side shell plating:

$\frac{y_1}{y_D}$ = for members located above the neutral axis of athwartship considered

$\frac{y_1}{y_B}$ = for members located below the neutral axis of athwartship considered

y_D = vertical distance from neutral axis to deck (m)

y_B = vertical distance from base line to neutral axis (m)

y_1 = vertical distance from neutral axis to upper edge of each strake (m), but need not be greater than y_D

y_2 = vertical distance from neutral axis to lower edge of each strake (m), but need not be greater than y_B

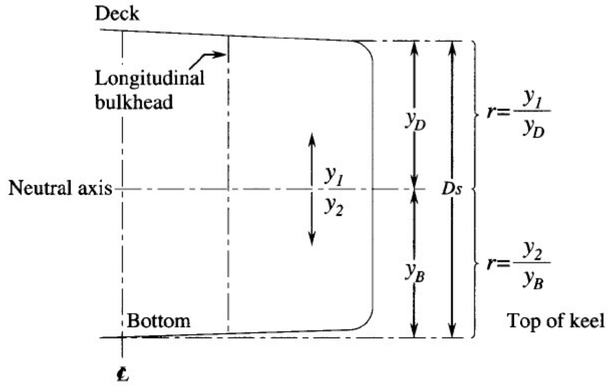


Fig 3.3.7

403. Elastic buckling stress

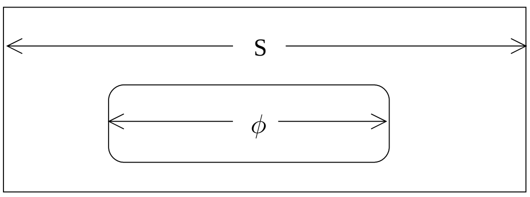
1. When examining the buckling strength of plate with an opening, the elastic buckling stress σ_E' or τ_E' obtained from following formulae is to be used in place of σ_E or τ_E for determination of critical buckling stress in **404.** of the Rules:

$$\sigma_E' = \gamma \sigma_E \quad (\mathrm{N/mm^2})$$
$$\tau_E' = \gamma \tau_E \quad (\mathrm{N/mm^2})$$

γ = reduction factor due to the opening, given by the following. When the opening is reinforced properly, it may be taken as 1.0:

$$\gamma = \frac{1}{\{1+\phi/(2S)\}^{2}}$$

ϕ = span of the major axis of the opening
S = span of the side of the panel along the major axis of the opening



2. Elastic buckling stress for longitudinal frames is to be obtained from the following formulae
(1) Buckling of pillars without torsion
Elastic buckling stress of pillar σ_E (N/mm^2) for pillar buckling mode is to be obtained from the following formula.

$$\sigma_E = 0.001E\frac{I_a}{Al^2} \quad (\mathrm{N/mm^2})$$

I_a and A = second moment of inertia (cm^4) and sectional area (cm^2) of longitudinal frame including plate flange. The breadth of flange is in accordance with **Ch 1, Sec 602** of the Rules.

l = length of longitudinal frame (m)

(2) Buckling of pillars with torsion
Elastic buckling stress of pillar σ_E (N/mm^2) for torsional buckling mode is to be obtained from the following formula.

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p l^2}\left(m^2 + \frac{k^2}{m^2}\right) + 0.385 E \frac{I_t}{I_p} \quad (\text{N/mm}^2)$$

k = coefficient, it is to be obtained from the following formula.

$$k = \frac{C l^4}{\pi^4 E I_W} \times 10^6$$

m = the number of half-waves of buckling mode is to be in accordance with the value of k in **Table 3.3.8.**

I_t = St. Venant moment of inertia for the section (cm^4), as specified in **Table 3.3.9.** However, flange of plate is not considered.

I_p = polar moment of inertia of connection point with plate, as specified in **Table 3.3.9.** However, flange of plate is not considered.

I_w = sectorial moment of inertia for the section of connection point with plate (cm^6), as specified in **Table 3.3.9.**

l = the length of tripping brackets (m)

S = spacing between tripping brackets (m)

C = coefficient of spring stiffness of tripping brackets supporting plate panels, as obtained from the following formula

$$C = \frac{k_p E t_p^3}{3S\left(1 + \frac{1.33 k_p h_w t_p^3}{1000 S t_w^3}\right)} \times 10^{-3}$$

k_p = coefficient obtained from the following formula. However, it is not less than 0 and may not be less than 0.1 for the inverted angles with flange compensated

$$k_p = 1 - \frac{\sigma_{act}}{\sigma_E}$$

σ_{act} = compression stress acting on longitudinal frames, as specified in **402. 1** of the Rules.

σ_E = elastic buckling stress of supporting plate, as specified in (1) of item **1.**

t_p = thickness of plate excepting standard deduction specified in **Table 3.3.3** of the Rules.

Table 3.3.8 The number of half-waves of buckling mode

	$0 < k \le 4$	$4 < k \le 36$	$36 < k \le 144$	$(m-1)^2 m^2 < k \le m^2(m+1)^2$
m	1	2	3	m

Table 3.3.9 I_t, I_p and I_w

Sectional shape	I_t (cm^4)	I_p (cm^4)	I_w (cm^6)
Flat steel	$\dfrac{h_w t_w^3}{3} \times 10^{-4}$	$\dfrac{h_w^3 t_w}{3} \times 10^{-4}$	$\dfrac{h_w^3 t_w^3}{36} \times 10^{-4}$
T section steel	$\dfrac{1}{3}\left(h_w t_w^3 + b_f t_f^3\left(1 - 0.63\dfrac{t_f}{b_f}\right)\right) \times 10^{-4}$	$\left(\dfrac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) \times 10^{-4}$	$\dfrac{t_f b_w^3 h_w^2}{12} \times 10^{-6}$
L section steel or bulb section steel			$\dfrac{b_f^3 h_w^2}{12(b_f + h_w)^2}\left[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w\right] \times 10^{-6}$

Notes:
h_w : web height (mm)
t_w : web thickness excluding standard deduction specified in **Table 3.3.3** of the Rules (mm)
b_f : flange breadth (mm)
t_f : thickness of flange excluding standard deduction specified in the Rules. For bulb section steel, it is a average thickness.

(3) Buckling of web and flange

(A) Ideal elastic buckling stress for the web of longitudinal frames is to be obtained from the following formula

$$\sigma_E = 3.8E\left(\frac{t_w}{h_w}\right)^2 \quad (\text{N/mm}^2)$$

t_w = thickness of webs (mm)
h_w = depth of webs (mm)

(B) The ratio of breadth of flange to longitudinal frames b_f and thickness of flange t_f is not more than 15. However, t_f is the half-breadth for T type section and breadth of L type section flange. ⚓

CHAPTER 4 PLATE KEELS AND SHELL PLATINGS

Section 1 General

103. Consideration for ship with unusually large freeboard

Where the distance from the designed maximum load line to strength deck is usually large, the thickness of side shell plating of superstructures and in the range between the imaginary freeboard deck specified in **Ch 1, Sec 203, 2** (1) of the Guidance and the strength deck (hereinafter referred to as "super structure side plating") is obtained from the followings. However, where this requirement is applied, the requirements in **Sec 301.** of the Rules do not need to be applied to shell plate above the freeboard deck.

(1) The thickness of superstructure side shell plating from the freeboard deck (or imaginary freeboard deck in ships where the imaginary deck is regarded as the freeboard deck) to the level at a height of $2h_s$ above the freeboard deck is to be obtained from the formulas in **302.** of the Rules, where $(d - y + 0.05L' + h_1)$ may be replaced by $\{(d - y + 0.05L' + h_1)D\}/(D + 2h_s)$. In this formula, h_s is decided by the L and is to be obtained from the followings,

L = 90 m ----------- 1.95

$L \geq$ 125 m ----------- 2.30

(2) The thickness of superstructure side plating from the level at a height equal to twice h_s as per (1) above the freeboard deck to the strength deck is not to be less than that obtained from the following formula, but need not be greater than that obtained from (1).

$$t = 0.7\sqrt{L+50} \quad \text{(mm)}$$

(3) The thickness of superstructure side plating from the freeboard deck to the level at a height h_s as per (1) above the freeboard deck forward from $0.25L$ aft from the F.P. is not to be less than obtained from (1) above or **501.** of the Rules. whichever is greater.

Section 3 Shell Plating below Strength Deck

303. Sheer strakes for midship part

Attentions to be paid as to sheer strakes

(1) The upper edges of sheer strakes are to be properly smoothed.

(2) Bulwarks are not to be directly welded to sheer strakes in the range of $0.6L$ amidships. Further, fixtures, such as eye plates, are not to be directly welded on the upper edge of sheer strake, except in the fore and aft end parts.

(3) Special care should be taken where fixtures, gutter bar ends, etc. are directly welded to the curved parts of round gunwales.

(4) At least for $0.6L$ amidship the manner of the welding construction of T type joints between sheer strakes and stringer plates of strength deck is, in general, to be as shown in **Fig 3.4.1** as a standard. However, where the thickness of stringer plates is less than 13 mm, fillet weld of F1 grade may be acceptable without edge preparation.

305. Bilge plate

1. Where, in the midship part, longitudinal frames are omitted in the bilge part, the distance from the end of bilge curvature to the nearest longitudinal frame outside the curved part is not to exceed 1/2 of the spacing of longitudinal frames.

2. In determining the thickness of bilge strake in the midship part according to the formula in **305. 1** of the Rules, the following condition is to be met.

$$\frac{1000R}{t} \geq 2\left(\frac{l}{R}\right)^2$$

where R = radius of bilge circle (m)

l = spacing of solid floor, bottom transverse or bilge brackets (m)

t = thickness of bilge strake (mm)

3. The bilge strake in the midship part are to be carefully worked so that deformations of the bilge circle may not exceed 1/3 of thickness of bilge strake amidships.

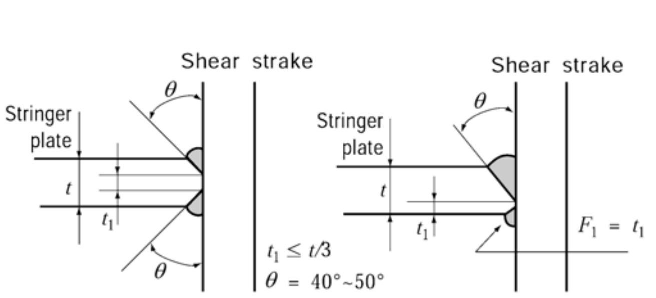


Fig 3.4.1 Welding construction of joints between sheer strakes and stringer plates of strength deck

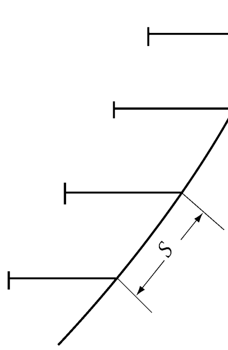


Fig 3.4.2 Measurements and shell plating stiffened in a spacing S

4. Where bilge keel plates are fitted, the plates welded directly to bilge strakes are to be of same kind of bilge strakes. However, grade of the plates may be generally of A-grade in any kind of steel plating.

Section 4 Special Requirements for Shell Plating

401. Shell plating at a location where flare is specially large

For pure car carriers, the thickness of shell plate above the load line for 0.1L forward is not to be less than that obtained from the following formula:

$$S\sqrt{\frac{\psi P}{\sigma_y} \times 10^3} \quad \text{(mm)}$$

S = spacing of frames, or spacing of girders or longitudinal shell stiffeners, whichever is the smaller. (mm)

σ_y = specified yield stress of materials (N/mm^2)

ψ = as obtained from following formula

$$\psi = \frac{3\eta^2 - 2\sqrt{1+3\eta^2} + 2}{12\eta^2}$$

η = spacing of frames, or spacing of girders or longitudinal shell stiffeners, whichever is the greater(m), divided by S.

P = slamming impact pressure as specified in **Ch 8, 108.**(kPa)

402. Shell plating stiffened in a spacing remarkably different from the frame spacing

Where the spacing of stiffening members on shell plating is remarkably different from the spacing, actual spaces is to be used in calculating the thickness of shell plating.(See **Fig 3.4.2**)

404. Strengthened bottom forward

In ships of which L and C_b are not more than 150 m and 0.7 respectively and $V/\sqrt{L}$ is 1.4 and over, the thickness of shell plating at the strengthened bottom forward is not to be less than the value determined in accordance with **404.** of the Rules using slamming pressure in **Ch 7, Sec 801, 2** (2) (A).

405. Spectacle bossings and stern frame

In case where the spacing of transverse frames in the aft-peak exceeds 610 mm or the length of ship exceeds 200 mm, the thickness of shell plating adjacent to stem frame or in way of spectacle bossing is to be equivalent to the standards given by **Table 3.4.1.**

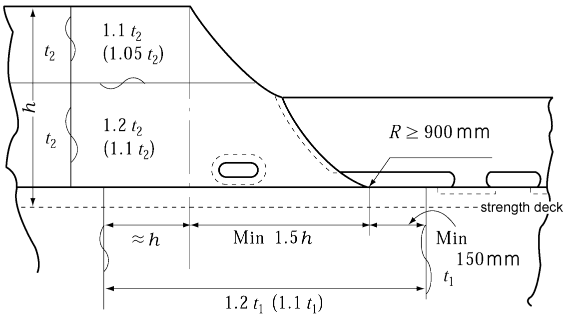
Table 3.4.1 Standard thickness of shell plating adjacent to stern frame or in way of spectacle bossing

Spacing of trans frame (mm)	Length of Ship L (m)				
	90	150	200	250	300
610	12.5	18.0	22.5	26.0	29.0
700	14.5	20.0	24.5	27.0	30.0
800	17.0	22.5	27.0	29.5	32.0
900	20.0	25.0	30.0	32.5	35.0
Notes : When the value is between the above values, it may be obtained by the interpolation.					

Section 6 Compensation at end of Superstructure

601. Strengthening method

(1) The side shell plating of superstructure is to be well extended beyond the end of superstructure to terminate with an ample radius($R \geq 900$ mm).
(2) Butt welding joint of sheer strake at the strength deck is to be off at least 150 mm from the R-end.
(3) The rate of thickening of shell plating in the region of $0.4L$ amidships is to be as shown in **Fig 3.4.3** and **3.4.4** The rate of thickening is to be zero in the region of $0.2L$ from the fore and aft ends of the ship, and at the intermediate points, the ratio is to be determined by linear interpolation.
(4) Where the superstructure is set in, increasing of thickness of shell plating is not needed.



Notes:
1. t_1 : thickness of shear strake
2. t_2 : thickness of superstructure side plating
3. Figures without brackets ( ) show the case where the superstucture deck is regarded as the strength deck
4. Figures in brackets ( ) show the case where the superstucture deck is not the strength deck

Fig 3.4.3 Construction of end part of superstructure(without expansion joints)

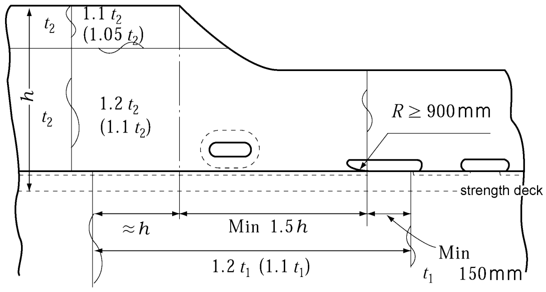


Fig 3.4.4 Construction of end part of superstructure(with expansion joints)

Section 7 Local Compensation of Shell Plating

701. Opening in shell

1. Opening of shell plate of 300 mm or more in size are to be compensated by doubling plate or increasing thickness.

2. In the end parts of hull, proper modification may be accepted for the manners of compensation for opening.

3. The radius at the corners of openings is to be at least 100 mm.

702. Thickness of sea chest

As for compensation for openings which is acting for sea water suction, **701.** of the Guidance is to be referred to.

703. Locations of openings

As for compensation for openings, **701** of the Guidance is to be referred to. ⚓

CHAPTER 5 DECKS

Section 1 General

101. Steel deck plating

Steel decks are not plated

1. Stringer plate

Decks not fully plated are to have stringer plates of an appropriate breadth and of a thickness not less than that determined for deck plating in accordance with the requirements in **Sec 3** of the Rules for the positions concerned. The stringer plates of effective decks are to be effectively connected to the shell plating.

2. Tie plates

Tie plates are to be provided along the hatch sides, in way of pillars, on the under-deck girders and under deckhouse coamings. These tie plates are to have an appropriate breadth and a thickness not less than that determined for deck plating in accordance with the requirements in **Sec 3** of the Rules for the positions concerned.

3. In way of transverse bulkheads and at the ends of deck openings

In way of transverse bulkheads and at the ends of deck openings, the deck is to be suitably plated with steel plates.

102. Watertightness of decks

Where the rudder stock penetrates the deck lower than the point located 1.5 m above the load line, special attention is to be given to the watertightness at the penetration.

104. Compensation for openings

All corners of openings in decks, such as hatchways, are to be well rounded and reinforced, as necessary, by increasing of thickness the deck plating or by means of doubling plates.

(1) Regions where thicker plating or doubling plates are required
Strength deck = within $0.75L$
Effective 2nd deck = within $0.6L$
3rd deck and lower decks = In substance, no doubling needed
Superstructures and long deckhouse = Doubling needs within $0.6L$ for decks immediately above the strength deck

(2) Plate thickening and doubling plates may be properly reduced depending upon their locations. (See **Fig 3.5.1**)

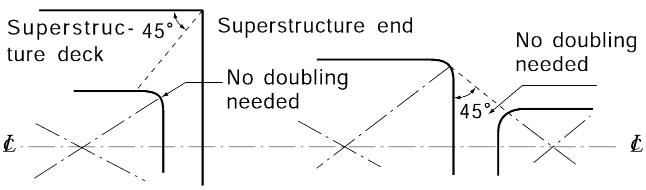


Fig 3.5.1

(3) The dimensions and thickness of doubling plates or ranges of thickening are to be determined in consideration of the degrees of stress concentration around the openings.

(4) The minimum value of R at the corners are to be as follows.
Within $0.5L$ midpart of strength deck = 250 mm
Elsewhere = 200 mm
The value of R at the 4 corners may be suitably reduced for small openings and small steel

ship. For companionways and similar small openings, the radius at the corners may be 150 mm in the strength deck outside the line of openings and 75 mm or so elsewhere.

(5) For corners of openings having radius not less than 600 mm or having elliptical or similar shape, neither doubling plates nor thickening of plating is required. The recommended corner shape is as shown in **Fig 3.5.2.**

(6) No welded joints are permitted at the corners of openings in the strength deck and the welded joints are to be off properly form the end of curvature. (See **Fig 3.5.3**)

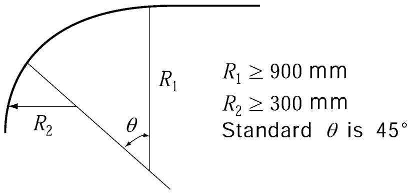


Fig 3.5.2

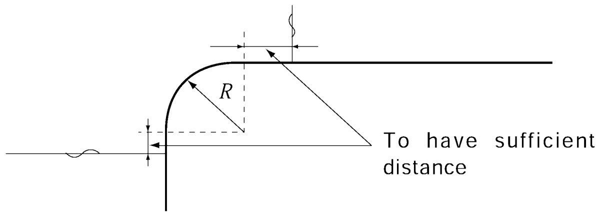


Fig 3.5.3

105. Rounded gunwales

Where round gunwales are made of steel plate of Grade D or Grade E, the inner radius of curvature is not to be less than 20 times the thickness of gunwale plate, except that the radius may be reduced down to 15 times the plate thickness where the width of sheer strake to be bent to form round gunwale is not less than the plate width of a strake prescribed in **Ch.1, Sec 405** of the Guidance plus 500 mm, or the method of bending work is specially approved by the Society.

Section 2 Effective Sectional Area of Strength Deck

202. Effective sectional area of strength deck

1. Tapers of stem/stern part to strength deck may tapered with average value of sectional area as **Fig 3.5.4.** However, thickness of plate is not be reduced rapidly.

2. Where rounded gunwales are provided, the sectional area is to be calculated assuming that the plate of round gunwale be horizontally extended to the ship's side.

204. Long poop

The effective sectional area of strength deck within long poop which is not deal with strength deck is to be in accordance with **Fig 3.5.5.**

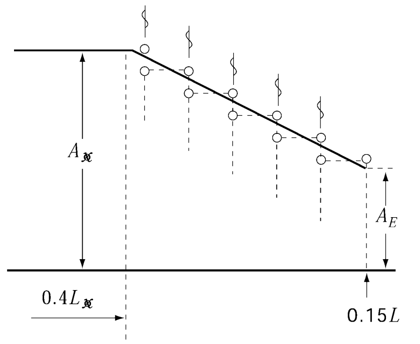
205. Superstructure deck designed as strength deck

When the poop deck is deal with strength deck, the sectional area of deck within poop is to be in accordance with **Fig 3.5.6.**

Section 3 Deck Plating

301. Thickness

When strength deck is framed longitudinally, deck inside the line of openings are desirable to be transversely framed as **Fig 3.5.7.**



$A_{갑}$: effective sectional area of strength deck in midship part of L

A_E : for ships with machinery in midship part 0.4 $A_{갑}$
for ships with machinery in aft end of ship 0.5 $A_{갑}$

Fig 3.5.4

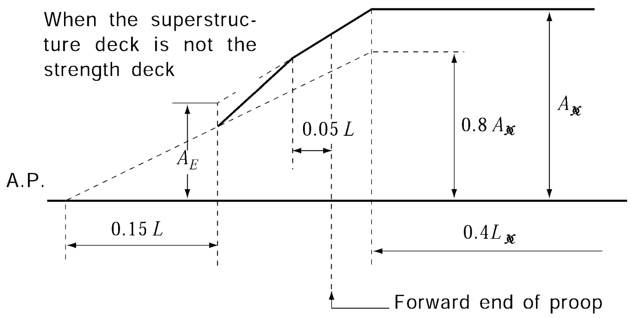


Fig 3.5.5

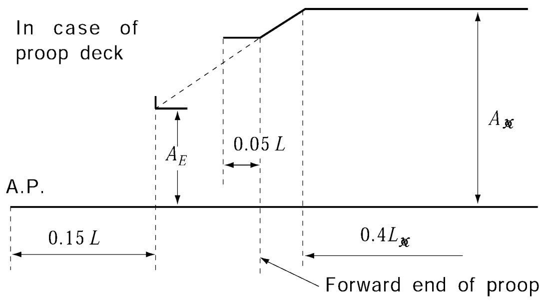


Fig 3.5.6

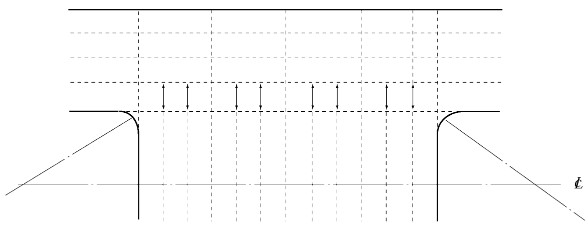


Fig 3.5.7

307. Deck plating for helicopter landing

1. For

$$t = 4.6\sqrt{K}\sqrt{\frac{(2S-b)}{(2S+a)} \times \frac{P}{9.81}} + 1.5 \qquad \text{(mm)}$$

where,

S : spacing between deck beam (m)

a, b : length of wheel print measured in parallel and perpendicular to beam (m)(See the **Fig 7.7.2** of **Guidance Pt 7, Ch 7**) Unless otherwise specified elsewhere, a × b is to be 0.3 m × 0.3 m.

P : As for the deck loads in the range where a helicopter takes off or lands, a load of 75 % of the helicopter maximum take-off weight(MTOW) is to be taken on each of two square areas. But where the emergency condition is considered, a load of 100 % of the MTOW is to be used. (kN)

K : material factor

2. When the scantling of stiffeners are calculated, simple support beam is to be assumed and allowable stress, 235/K (N/mm^2) and P obtained fram **1.** are to be used. But where the arrangement of stiffeners or etc. are considered, continuous beam may be assumed. ⚓

CHAPTER 7 DOUBLE BOTTOMS

Section 1 General

101. Application

1. For the ships subject to **SOLAS** or **Korean Ship Safety Act**., inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. And the inner bottom is not to be lower at any part than a plan parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

$$h = B/20$$

However, in no case is the value of h to be less than $0.76\ \mathrm{m}$, and need not be taken as more than $2.0\ \mathrm{m}$.

2. The method for flooding calculation as defined **Ch 7, 101. 2** to be followed by **IMO MSC 194(80), Reg.9, 8.**

3. A double bottom may be omitted in way of watertight tanks, including dry tanks of moderate size, provided it is satisfied for flooding calculation of **2.**

4. For ships with special structure, the scantlings of structural members are to be in accordance with the followings.

(1) Double hull ship (See **Fig 3.7.1**)
B may replaced with the $0.5(B+b)$.
(2) For ships with inclined sides
B may replaced with the length between intersection of extension of inner bottom plate and conjunction point with side shell plate (See **Fig 3.1.1**)
(3) For ships, the breadth of which becomes particularly narrow in fore and/or aft part in comparison with the breadth in midship part.
The distance b between the intersection of inner bottom and shell plating at centre of hold length may be used in place of B (See **Fig 3.7.2**)
(4) In spite of the (1) through (3), the scantlings may be determined by direct calculation method.

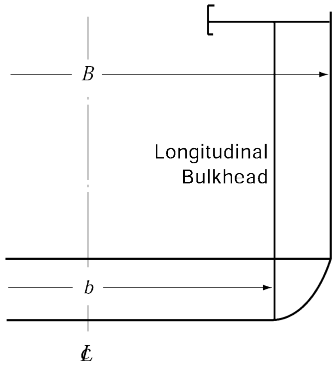


Fig 3.7.1

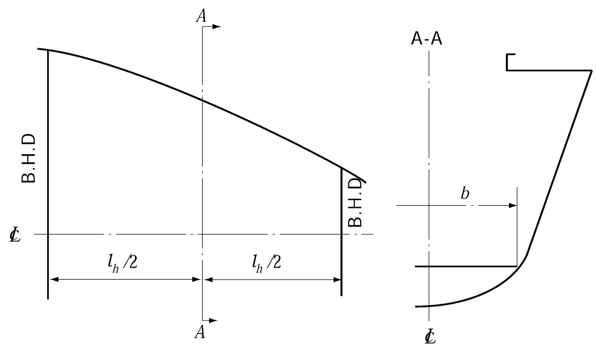


Fig 3.7.2 For ships, the breadth of which becomes particularly narrow in fore and/or aft part

5. In holds with pillars, the thickness of centre girder, side girders, solid floor, inner bottom plating and bottom shell plating may be reduced in accordance with the results of direct strength calculation.

6. Scantlings of structural members of double bottom for ships intended to carry out the steel coils are recommended to comply with the following requirement in addition to **Ch 7** of the Rules.

(1) This calculation method is a standard means of securing steel coils as like to **Fig 3.7.3.**

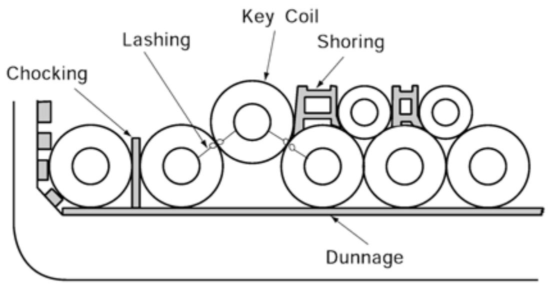


Fig 3.7.3 Standard means of securing steel coils

(2) Thickness of inner bottom plate in longitudinal framed structure is to be not less than the value obtained from the following formula.

$$t=\sqrt{1.65QK\{(1.65\beta-2.3)\alpha-6\beta+12.2\}}+0.5 \quad \text{(mm)}$$

α = aspect ratio of panel of inner bottom platings. When a exceeds 3.0, α is to be taken as 3.0

$$\beta=\frac{C}{a}$$

β = as obtained from the following formula.
a = spacing of floors (m)
C = distance between load points in ship length direction per panel of inner bottom (m). According to the value of n_2 and n_3, it is to be in accordance with **Table 3.7.1** of the Guidance.

Q = mass of steel coils which is supported by the one inner bottom panel. It is to be obtained from the following formulae. However, in case where steel coils are lined up in one tier with a key coil, Q is to be of 1.4 times to the formula.

$$Q=Wn_1\frac{n_2}{n_3} \quad \text{(ton)}$$

W = mass of a steel coil (ton)
n_1 = number of tiers of steel coils
n_2 = number of load points per panel of inner bottom plates, as given in **Table 3.7.2** according to the value of n_3 and $a\,/\,l_s$
n_3 = number of dunnages supporting one steel coil
l_s = breadth of steel coil (m)

Table 3.7.1. Spacing of longitudinal direction of loaded point to one panel (C)

n_2 \ n_3	2	3	4	5
1	Breadth of real dunnage			
2	$0.5l_s$	$0.3l_s$	$0.25l_s$	$0.2l_s$
3	$1.2l_s$	$0.67l_s$	$0.5l_s$	$0.4l_s$
4	$1.7l_s$	$1.2l_s$	$0.75l_s$	$0.6l_s$
5	$2.4l_s$	$1.53l_s$	$1.2l_s$	$0.8l_s$
6	$2.9l_s$	$1.87l_s$	$1.45l_s$	$1.2l_s$
7	$3.6l_s$	$2.4l_s$	$1.7l_s$	$1.4l_s$
8	$4.1l_s$	$2.73l_s$	$1.95l_s$	$1.6l_s$
9	$4.8l_s$	$3.07l_s$	$2.40l_s$	$1.8l_s$
10	$5.3l_s$	$3.60l_s$	$2.65l_s$	$2.0l_s$

Table 3.7.2 Number of points of loads in one panel (n_2)

n_2 \ n_3	2	3	4	5
1	$0 < a/l_s \leq 0.5$	$0 < a/l_s \leq 0.33$	$0 < a/l_s \leq 0.25$	$0 < a/l_s \leq 0.20$
2	$0.5 < a/l_s \leq 1.2$	$0.33 < a/l_s \leq 0.67$	$0.25 < a/l_s \leq 0.5$	$0.2 < a/l_s \leq 0.4$
3	$1.2 < a/l_s \leq 1.7$	$0.67 < a/l_s \leq 1.2$	$0.5 < a/l_s \leq 0.75$	$0.4 < a/l_s \leq 0.6$
4	$1.7 < a/l_s \leq 2.4$	$1.2 < a/l_s \leq 1.53$	$0.75 < a/l_s \leq 1.2$	$0.6 < a/l_s \leq 0.8$
5	$2.4 < a/l_s \leq 2.9$	$1.53 < a/l_s \leq 1.87$	$1.2 < a/l_s \leq 1.45$	$0.8 < a/l_s \leq 1.2$
6	$2.9 < a/l_s \leq 3.6$	$1.87 < a/l_s \leq 2.4$	$1.45 < a/l_s \leq 1.7$	$1.2 < a/l_s \leq 1.4$
7	$3.6 < a/l_s \leq 4.1$	$2.4 < a/l_s \leq 2.73$	$1.7 < a/l_s \leq 1.95$	$1.4 < a/l_s \leq 1.6$
8	$4.1 < a/l_s \leq 4.8$	$2.73 < a/l_s \leq 3.07$	$1.95 < a/l_s \leq 2.40$	$1.6 < a/l_s \leq 1.8$
9	$4.8 < a/l_s \leq 5.3$	$3.07 < a/l_s \leq 3.60$	$2.40 < a/l_s \leq 2.65$	$1.8 < a/l_s \leq 2.0$
10	$5.3 < a/l_s \leq 6.0$	$3.60 < a/l_s \leq 3.93$	$2.65 < a/l_s \leq 2.90$	$2.0 < a/l_s \leq 2.4$

(4) Section modulus of inner bottom longitudinal frames is not to be less than the value required in the extent of elastic in accordance with the following conditions.
(A) Boundary condition : Fixed at solid floor, simply supported at strut
(B) Allowable stress

$$\sigma = 8.2(24 - 11.4Kf_B)/K \quad (\text{N/mm}^2)$$

(C) Loading condition : Concentrated load at the position of dunnages where the steel coils are loaded just on longitudinals.
(5) Compressive buckling strength against steel coil load is to be examined for solid floor and girder plates.

7. Where the double bottom is constructed, intersection of exterior edge of margin plate and side shell of bilge is to be through the point which is the distance with $B/2$ from the midship on the base line and is to be in the above horizontal surface which is through the intersection of oblique line with 25° angle from the base line and side shell (See **Fig 3.7.4**)

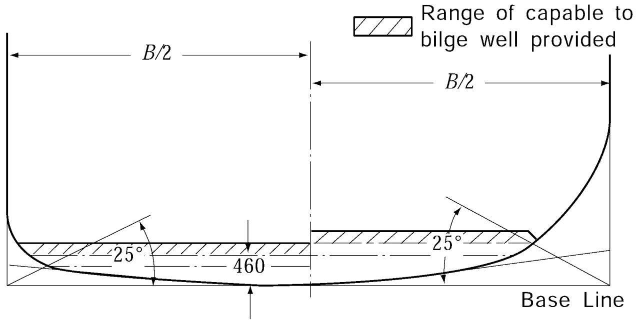


Fig 3.7.4 Structure of double bottom and position of bilge well

8. With respect to the provisions of **101. 7** of the Rules, where the ratio of cargo weight per unit area (kN/m^2) of the inner bottom plating to d is less than 5.40, double bottom structures are to be in accordance with **203. 1**, **302. 1**, **501. 2** and **505. 1**. Where cargo loads can not be treated as evenly distributed loads, scantlings of double bottom structures are to be determined by taking account of load distribution for particular cargoes. Where concentrated loads act on specific points of double bottoms, scantlings of center girders, side girders, floors, inner bottom plates and bottom plates and their stiffeners are to be determined by an appropriate strength assessment such as direct calculations.

103. Drainage

1. Bilge well on the double bottom constructed in passenger ship, in addition to **103.** of the Rules, is not to be constructed under the horizontal surface specified in **101. 7.** of the Guidance. (See **Fig 3.7.4**)

2. Small wells constructed in the double bottom in connection with drainage arrangements of holds are not to be extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel.

3. Other wells (e.g., for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this Chapter.

4. For the ships subject to **SOLAS** or **Korean Ship Safety Act.**, except a well at the end of the shaft tunnel, the vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than 0.5m.

107. Strengthening under boilers

Considering the corrosive environment due to high temperature, thickness of all members under boiler is to be increased according to the following standards. However, where the effective means for preventing corrosion or overheating are provided, increasing of thickness is not be needed. Above mentioned effective preventing for overheating means the case which temperature of the upper surface of inner bottom plate is 40°C or less in usual condition.

Structural member	Increasement
Centre girder	3.0 mm
Side girder	
Solid floors	
Inner bottoms	3.5 mm
Vertical stiffener	1.5 mm
Section modulus of reverse frames of open floors and inner bottom longitudinals	15 %
Section modulus of frames of open floors and bottom longitudinal	7 %
Sectional area of vertical strut	10 %

Section 2 Centre Girders and Side Girders

201. Arrangement and construction

1. Where side girders are unable to extend forward and/or aftward because of the breadth of double bottom becoming narrow in fore and/or aft part, the side girders are to be sufficiently lapped over the adjacent girders in order to keep continuity of strength.

2. Girders or half height girders are to be provided under longitudinal bulkheads for proper strengthening of double bottom.

203. Thickness

1. Where the ratio of load per square meter of double bottom (kN/m^2) to d is less than 5.40, C_1 in the formula in **203.** (1) of the Rules is to be obtained from the following formula.

$$C_1{}' = nab$$

n = coefficient, as obtained from the following

(1) For holds adjacent to each other and being loaded or empty simultaneously; Where B/l_H is 1.4 and over, it is to be taken as 1.4, and where B/l_H is less than 0.4, it is to be taken as 0.4

$$n = \frac{1}{1.4}\left(3 - \frac{B}{l_H}\right)$$

(2) Other cargo holds : n = 1.0

l_H = as specified in **203.** of the Rules

a = as obtained from the following formula

$$a = 1.35 - \frac{h\gamma}{d}$$

h = as specified in **403. 2** of the Rules

γ = as specified in **101. 6** of the Rules

b = coefficient,

for the longitudinal framed construction = 17

for the transversely framed construction = 20

2. For the double hull construction, C_1 specified in **203.** (1) is to be obtained from the following formulae.

$$C_1'' = na(b - \beta b')$$

n = coefficient, As specified in **Table 7.3.2** of the Rules
a = as specified in **1.** above. But not to be less than 0.8
b = as specified in **1.** above.
b' = for the longitudinal framed construction = 4
for the transversely framed construction = 5
β = coefficient to be obtained from the following formula. However, where the hold is unusually long or where the sides are constructed on the transverse framing system and the spacing of side transverses is unusually large, special consideration is to be given.

$$\beta = \frac{1}{1 + \frac{2t_0 d_0^2 H_s}{3t_s d_s^2 B_0}}$$

t_0 = mean thickness of inner bottom plating and bottom shell plating (mm)
t_s = mean thickness of longitudinal bulkhead and side shell plating
d_0, d_s, B_0 and H_s = distance (m), shown in **Fig 3.7.5**

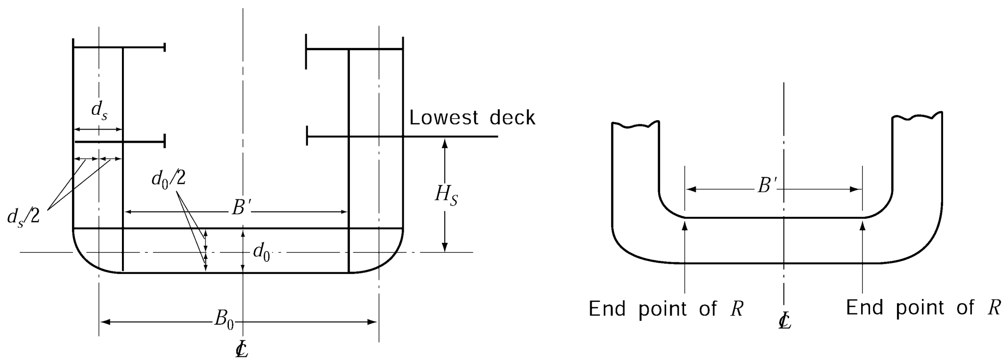


Fig 3.7.5 Double side structure

204. Brackets

The thickness, size, form, etc. of brackets specified in **204.** of the Rules are to be determined by taking into consideration of the height of centre girders and their buckling strength. As the examples, **Fig 3.7.6** is shown.

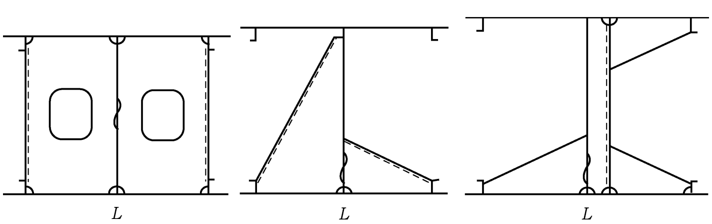


Fig 3.7.6 Forms of docking brackets

Section 3 Solid Floors

302. Thickness

1. Where the ratio of load per square metre of double bottom to d is less than 5.40, the coefficient C_2 in the formula in **302.** (1) of the Rules is to be obtained from the following formula.

$$C_2' = ab$$

a = as specified in **203. 1** of the Rules
b = value is specified in **Table 3.7.3** of the Guidance according to the value of B/l_H
l_H = as specified in **203.** of the Rules

Table 3.7.3 Coefficient b

<table>
<tr><td colspan="2">B/l_H</td><td>Not less than
Not more than 0.4</td><td>0.4
0.6</td><td>0.6
0.8</td><td>0.8
1.0</td><td>1.0
1.2</td><td>1.2</td></tr>
<tr><td colspan="2">Longitudinal structure</td><td rowspan="2">36</td><td rowspan="2">34</td><td rowspan="2">31</td><td rowspan="2">28</td><td rowspan="2">23</td><td rowspan="2">21</td></tr>
<tr><td rowspan="2">Trans. Structure</td><td>When solid floors are provided in each frame</td></tr>
<tr><td>When solid floors are provided between 2 frames or over</td><td>25</td><td>24</td><td>21</td><td>20</td><td>16</td><td>15</td></tr>
</table>

2. The thickness of solid floors of ships of double hull construction is to be obtained according to the following prescriptions.

(1) B' and B'' in the formula in **302.** (1) of the Rules are to be as follows.
B' = distance between longitudinal bulkheads at the top of inner bottom plating at amidship (m) (See **Fig 3.7.5**)
B'' = distance between longitudinal bulkheads at the top of inner bottom plating at the position of solid floor (m)

(2) The coefficient C_2 in the formula in **302.** (1) of the Rules is to be obtained from the following formula.

$$C_2 = a(b + \beta b')$$

a = as specified in **203. 1** of the Guidance. However, it is not to be less than 0.8
b = value is specified in **Table 3.7.3** of the Guidance according to the value of B/l_H
b' = value is specified in **Table 3.7.4** of the Guidance according to the value of B/l_H
β = as specified in **203. 2** of the Guidance
l_H = as specified in **203.** of the Rules

Table 3.7.4 Coefficient b'

<table>
<tr><td colspan="2">B/l_H</td><td>Not less than
Not more than 0.4</td><td>0.4
0.6</td><td>0.6
0.8</td><td>0.8
1.0</td><td>1.0
1.2</td><td>1.2</td></tr>
<tr><td colspan="2">Longitudinal structure</td><td rowspan="2">1</td><td rowspan="2">3</td><td rowspan="2">6</td><td rowspan="2">9</td><td rowspan="2">14</td><td rowspan="2">15</td></tr>
<tr><td rowspan="2">Trans. Structure</td><td>When solid floors are provided in each frame</td></tr>
<tr><td>When solid floors are provided between 2 frames or over</td><td>1</td><td>2</td><td>4</td><td>6</td><td>9</td><td>11</td></tr>
</table>

Section 4 Bottom Longitudinals

403. Section modulus

1. Where the apparent specific gravity γ of cargoes in loaded holds exceeds 0.9, the coefficient C in the formula in **403. 1.** of the Rules is to be as follows

(1) where no strut as per **404.** of the Rules is provided midway between the floors-------100
(2) where a strut as per **404.** of the Rules is provided midway between the floors
Under deep tanks-------------- 62.5
Elsewhere------------------------ $30\gamma + 20$
In no case is C to be less than 50.
γ = As specified in **101. 7.** of the Rules.

2. In case where the width of vertical stiffeners fitted on solid floors and vertical struts is unusually large, the coefficient C in **403. 1.** and **2.** of the Rules may be multiplied by the value obtained from the following formula.

$$\left(1-\frac{a}{l}\right)^2\left(1-\frac{b}{l}\right)$$

l = distance between floors (m)

a = width of vertical stiffeners on floors (m). a is to be zero, if the vertical stiffeners are not well fixed to longitudinals by means of lug connection.

b = width of vertical strut (m) (See **Fig 3.7.7**)

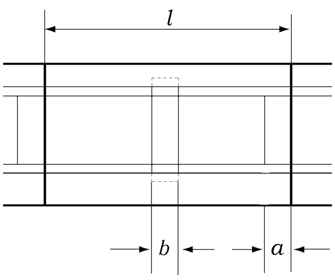


Fig 3.7.7

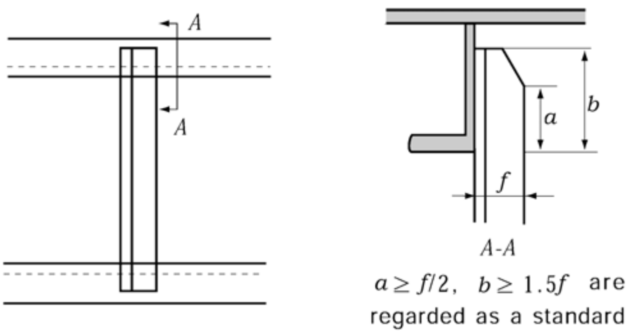


Fig 3.7.8 Details of lap of strut and longitudinal frame

404. Struts

Depth of lapped parts of vertical struts over web of longitudinals is to be of 1.5 times as large as the breadth of face plates of struts as a standard. Where the sufficient depth of lapped parts is unable to be taken due to weld ability, throat of fillet weld is to be properly increased. (See **Fig 3.7.8**)

Section 5 Inner Bottom Plating, Margin Plates and Bottom Shell Plating

501. Thickness of inner bottom plating

1. Where the height of centre girder is less than $B/16$, the thickness of inner bottom plating and bottom shell plating are to be increased so that the moment of inertia of the double bottom obtained from the following formula may be equivalent to that corresponding to the case where the centre girder has the required height.

$$I = 1.23 \frac{t_1 t_2}{t_1 + t_2} d_0^2$$

d_0 = height of centre girder (m)

t_1 = thickness of bottom shell plating (mm)

t_2 = thickness of inner bottom plating (mm)

2. Where the ratio of load per square metre of double bottom to d is less than 5.40, the coefficient C in the formula of **501. 1.** of the Rule is to be obtained from the following formula.

$$C' = ab$$

a = as specified in **203. 1.** of the Guidance

b = coefficient b_0 or αb_1 as specified in the followings according to the value of B/l_H

$B/l_H < 0.8$; b_0

$0.8 \leq B/l_H < 1.2$; αb_1 or b_0, whichever is greater.

$1.2 \leq B/l_H$; αb_1

l_H = as specified in **203.** of the Rules.

b_0 and b_1 = as specified in **Table 3.7.5** according to the value of B/l_H. However, for the transversely framed construction, the value b_1 specified in the Table, is to be multiplied by 1.1.

α = as obtained from the following formula

$$\alpha = \frac{13.8}{24 - 11.4 f_B K}$$

Table 3.7.5 Coefficient b_0 and b_1

B/l_H	Not less than	0.4	0.6	0.8	1.0	1.2	1.4	1.6
	Not much than 0.4	0.6	0.8	1.0	1.2	1.4	1.6	
b_0	5.5	4.9	4.1	2.8	2.0	—	—	—
b_1	—	—	—	2.8	2.6	2.4	2.2	1.8

3. For the ships with double hull construction, C in the formula t_1 in **501. 1.** of the Rules, is to be obtained from the following formula, whichever is greater.

$$C_1 = a(b_0 - \beta b'_0)$$
$$C_2 = a\alpha(b_1 - \beta b'_1)$$

a = coefficient, is to be in accordance with **203. 1.** of the Guidance. However, it is not to be less than 0.8

b_0, b_1 and α = as obtained from the above mentioned **2.**

b'_0 and b'_1 = as specified in **Table 3.7.6** according to the value of B/l_H. However, for the transversely framed construction, the value b'_1 specified in the Table, is to be multiplied by 1.1.

l_H = as specified in **203.** of the Rules

β = It is to be in accordance with **203. 2** of the Guidance.

Table 3.7.6 Coefficient b'_0 and b'_1

B/l_H	Not less than	0.4	0.6	0.8	1.0	1.2	1.4	1.6
	Not much than 0.4	0.6	0.8	1.0	1.2	1.4	1.6	
b'_0	3.1	2.5	1.8	1.0	0.5	—	—	—
b'_1	—	—	—	1.1	1.1	0.8	0.7	0.4

4. In case forklift is used for unloading operation, thickness of inner bottom plate is to be also in accordance with **Ch 5, 305.** of the Rules.

5. Butt joints of inner bottom plating in the midship part are generally not to be arranged at the knuckle line of the inner bottom.

505. Bottom shell plating

1. Where the ratio of load per square metre of double bottom to d is less than 5.40, the thickness of bottom shell plating is to be determined as follows.

In the region of double bottoms under cargo holds, the thickness of bottom shell plating is not to be less than obtained from the formula in **Ch 4, 304.** of the Rules or from the first formula in **Ch 7, 501. 3** of the Rules whichever is greater. In applying the latter formula, coefficient C' is described in **501. 3** of the Guidance. However, In applying the first formula in **501. 1** of the Rules, α is to be obtained from the following formula.

$$\alpha = \frac{13.8}{24 - 15.0 f_B K}$$

2. In the region of double hull construction, the thickness of bottom shell plating is not to be less than obtained from the formula in **Ch 4, 304.** of the Rules or from the first formula in **501, 3.** of the Rules whichever is greater. In applying the latter formula, coefficient C described in **501. 2** of the Guidance. However, In applying the first formula in **501. 1** of the Rules, α is to be obtained from the following formula.

$$\alpha = \frac{13.8}{24 - 15.0 f_B K}$$

Section 8 Construction of Strengthened Bottom Forward

801. Application

1. Here, the ballast condition means the ordinary ballast condition where only the ballast tanks such as clean ballast tanks, segregated ballast tanks and ballast holds are ballasted. This ballast condition excludes an exceptional case where cargo tanks are ballasted only in the heavy weather condition to assure the safety of the ship.

2. In ships of which L and C_b are not more than 150 m and 0.7 respectively and $V/\sqrt{L}$ is 1.4 and over, the construction of bottom forward is to be as required in the followings.

(1) Construction

Construction of strengthened bottom forward is to be in accordance with **803.** of the Rules. However, the vertical stiffeners for the solid floors specified in **803. 3** of the Rules are to be provided on all shell stiffeners. Where the bottom longitudinals or longitudinal shell stiffeners are extended through the solid floors, slots are to be reinforced with collar plates.

(2) Scantlings of longitudinal shell stiffeners or bottom longitudinals

(A) In ships having bow draught not more than $0.025L$ at the ballast condition, the section modulus (Z) of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward is not to be less than that obtained from the following formula

$$Z = 0.53\,Pal^2 \quad (\text{cm}^3)$$

l = spacing of solid floor (m)

a = 0.774 l (m) However, where the spacing of longitudinal shell stiffeners or bottom longitudinals is not more than $0.774l$, is to be taken as the spacing (m).

P = slamming pressure obtained from the following formula

$$P = \frac{2.48LC_1C_2C_3C_4}{\beta} \quad (\text{kPa})$$

C_1 = as specified in **Table 3.3.7** of the Guidance. For the intermediate value $V/\sqrt{L}$ is to be obtained by linear interpolation.

Table 3.7.7 Coefficient C_1

$V/\sqrt{L}$	1.4	1.5	1.6	1.7	1.8
C_1	0.31	0.33	0.36	0.38	0.40

C_2 = coefficient obtained from the following formula

$V/\sqrt{L} \leq 1.0$; 0.4
$1.0 < V/\sqrt{L} \leq 1.3$; $0.667V/\sqrt{L} - 0.267$
$1.3 \leq V/\sqrt{L}$; $1.5V/\sqrt{L} - 1.35$

β = slope of ship's bottom obtained from the following formula, but C_2/β is greater than 11.43, it is to be taken as 11.43.

$$\beta = \frac{0.0025L}{b}$$

b = horizontal distance measured at the station $0.2L$ from the stem, from the centre line of ship to the intersection of the horizontal line $0.0025L$ above the top of keel with the shell plating (m) (See **Fig 3.7.2**)

C_3 = as obtained from the following formula

$$C_3 = 1.9 - 0.9\left(\frac{d_f}{0.025L}\right)$$

d_f = minimum bow draught at the ballast conditions.

C_4 = coefficient obtained from the followings.

$x_1 \leq x$; 1.0

$x < x_1$; $0.5 + \frac{0.5x}{x_1}$

x = length to longitudinal direction from end of stem to transverse section (m)

x_1 = as obtained from the followings

$C_b < 0.7$; $0.1L$

$0.7 \leq C_b < 0.8$; $(0.1 - 0.5(C_b - 0.7))L$ (m)

$0.8 \leq C_b$; $0.05L$

(B) In ships having bow draught more than $0.025L$ but less than $0.037L$ at the ballast condition, the section modulus of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward is to be obtained by the linear interpolation from the values given by the requirements in (A) and the values in **403. 1** of the Rules.

(3) Thickness of solid floors

Thickness of solid floors is obtained from the following (A) and (B), whichever is greater.

(A) The thickness of solid floors in 1/2 spacing of both sides of bottom longitudinals is to be obtained from the following formula. (See **Fig 3.7.9**)

$$t = \frac{PSbK}{196(b - d_1)} + 1.5 \quad \text{(mm)}$$

P = slamming pressure given by (2)(A). In ships having bow draught more than $0.025L$ but less than $0.037L$ at the ballast condition, this requirement is to be applied using actual bow draught at the ballast condition.

S = spacing of solid floors (m)

b = breadth of panel (m)

d_1 = sum of breadth of panel opening (m), where the opening compensated with double plates, sectional area may be properly considered.

(B) Thickness of solid floors is to be obtained from the following formula.

$$t = 1.1\sqrt[3]{PSb^2} + 1.5 \quad \text{(mm)}$$

P and S = as specified in (A)

b = spacing of bottom longitudinal (m)

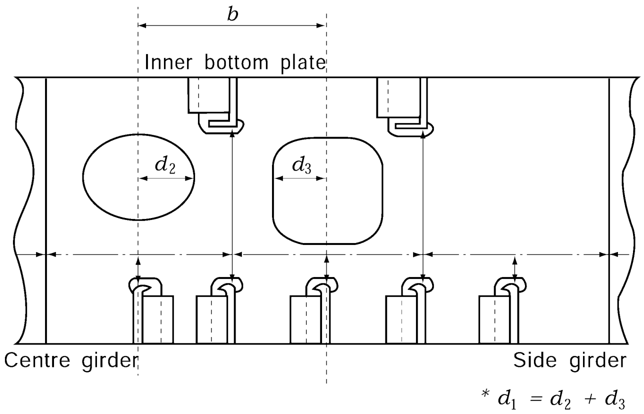


Fig 3.7.9 Solid floor of strengthened bottom forward

3. With respect to the requirements of **801.** of the Rules, ships of which L and C_b are 150 m or more and 0.7 or more respectively may apply to the followings.

(1) Slamming impact pressure P specified in **804. 1** of the Rules**,** may be given by the following formula. In this case, the slamming impact pressure is to be calculated at the mid-span point for each longitudinal shell stiffeners or bottom longitudinals.

$$P = 1.14\frac{\nu^2}{\beta} \quad \text{(kPa)}$$

β = as given by the following formula. In no case, the value of $1/\beta$ is greater than 11.43.

$$\beta = \frac{0.0025L}{b}$$

b = in considering transverse section, horizontal distance (m) from the ship's center line to the intersection of the horizontal line of 0.025L above the ship's base line and the ship's moulded line of shell.

ν = relative speed (m/s)between the ship's bottom of considered position and sea surface as given by the following formula.

$$\nu = C_0\left(\frac{2\pi}{T_P}\left(\sqrt{C_4} + 0.45H_w\cos\phi + 0.18\cos\lambda\,\sin\phi\right) + 0.51C_7\,V\sin\phi\right)$$

C_0 = as given by the following formula.

$$C_0 = 1 - 0.015\left(\frac{L-150}{150}\right)$$

C_4 = as given by the following formula. In no case, the value is less than zero.

$$C_4 = (l + 0.05L)^2\phi_0^2 - (0.025L')^2$$

l = longitudinal distance (m) from the midship to the considered position.

ϕ_0 = pitch angle (rad) as given by the following formula.

$$\phi = \frac{3.3(C_7 V + 5)^{0.2}}{L^{1.2}\sqrt{C_b}} H_W$$

H_W = significant wave height (m) as given by the following formula. However, this value may not be greater than the maximum value of 0.055L and 11.5.

$$H_W = C_5 C_6$$

C_5 = as given by the following formula.

$$L \le 300 \ : \ C_5 = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$$

$$300 < L \le 350 \ : \ C_5 = 10.75$$

$$350 < L \ : \ C_5 = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$$

C_6 = As given by the following formula.

$$C_6 = \sqrt{\frac{L + \lambda - 25}{L}}$$

C_7 = as given by the following formula. In any case, this value is not to be less than 0 and not to be greater than 1.

$$C_7 = \frac{V/\sqrt{L} - 1.1}{0.4}$$

λ = wave length as given by the following formula.

$$\lambda = 0.6\left(1.5 + \frac{(0.0075L + 0.025L')}{2d}\right)L \quad \text{(m)}$$

T_P = natural period of pitch motion as given by the following formula.

$$T_P = \sqrt{\frac{2\pi\lambda}{g}} \quad \text{(sec)}$$

ϕ = as given by the following formula. However, this value may not be greater than $0.015 + \phi$

$$\phi = 0.015 + \tan^{-1}\left(\frac{0.025L'}{l + 0.05L}\right) \quad \text{(rad)}$$

(2) For the examination of the position within ballast tanks which are to be filled up by sea water in the ballast conditions, the slamming impact pressure P specified in (1) above may be reduced by ΔP as given by the following formula. In this case, it is to be stated in the ship's loading manual that such ballast tanks are to be filled up in the heavy weather condition.

$$\Delta P = 5h \quad \text{(kPa)}$$

h = depth of the ballast tank (m)

4. In way of strengthened bottom forward, structural arrangements other than those specified in **803.** of the Rules may be adapted subject to the following (1) to (3).

(1) The thickness of solid floors in the longitudinal stiffened system and girders in the transverse stiffened system is to apply to the provisions of **801. 2** (3). For the thickness of solid floors in the longitudinal stiffened system, the slamming impact pressure P may be corrected by multiplying the coefficient C_9 specified in (3) the below.

(2) The thickness of solid floors and girders is not to be less than the value obtained by the following (A) and (B), whichever is the greater.

(A) $t_1 = K\dfrac{C_8 PSl}{226(d_0 - d_1)} + 2.5$ (mm)

P = the considered slamming impact pressure as specified in **804. 1** of the Rules, **801. 2**. or 801.3. In ships having bow draught more than 0.025 L' but less than 0.037 L' at the ballast condition, the slamming impact pressure is to be obtained by linear interpolation from the above value and the value obtained by the following formula as the pressure when the bow draught is 0.037 L'. The slamming impact pressure is not to be less than the value obtained by the following formula.

$$P = 1.015L \quad \text{(kPa)}$$

C_8 = as given by the following formula. In any case, this value is not to be less than 0.1 and not to be greater than 1.

$$C_8 = \frac{3}{A}$$

A = area (m^2) considered in the strength examination, in this case, as given by the following formula

$$A = S \times l$$

S = spacing (m) at solid floors or girders for themselves under the consideration

l = spacing (m) at girders or solid floors for members crossing those under the consideration

d_0 = depth (m) of the floors or the girders at the considered position

d_1 = depth (m) of the opening in the floors or the girders at the considered position.

(B) The value given by the requirements of **302.** (2) of the Rules, using the value of t_1 as given by the above (a), in the mentioned requirements. For the application to girders, the wording 'solid floors' specified in **302.** (2) of the Rules is to be read as 'girders'.

(3) For scantlings of longitudinal shell stiffeners and bottom longitudinals, the slamming impact pressure P may be corrected by multiplying the coefficient C_9 as given by the following formula. In any case, the coefficient C_9 is not to be less than 0.1 and not to be greater than 1.

$$C_9 = \frac{3}{l}$$

l = as given in **804. 1** of the Rules

802. Definition

In ships of which L and C_b are less than 150 m and 0.7 respectively and bow draught is less than $0.02L$ at the ballast condition, the area of strengthened bottom forward of the ship is to be expended as follows.

(1) The after end of strengthened area is to be extended the following distance a afterwards from the position required in **Table 3.7.11** of the Rules.

$a = 0$, where $C_b = 0.7$

$a = 0.05L$, where $C_b < 0.6$

For intermediate values of C_b, a is to be obtained by linear interpolation.

(2) In addition to (1) above, bottom areas of which tangential slope to the base line is less than 25° are required to be strengthened. (See **Fig 3.7.10**). ⚓

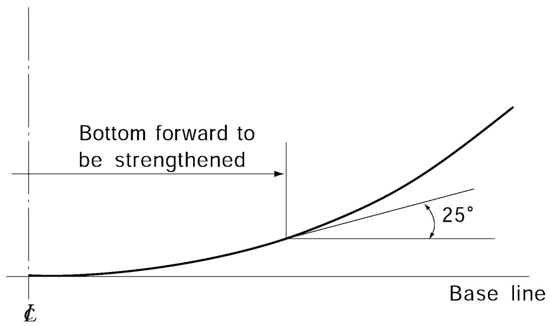


Fig 3.7.10 Range of transverse direction of strengthened bottom forward

CHAPTER 8 FRAMES

Section 1 General

108. Frames at a location where flare is specially large

1. For pure car carriers, the plastic section modulus Z_p of transverse frames and side longitudinals, which are fitted in the bow flare position considered to endure large wave impact pressure, above the load line for 0.1 L forward is not to be less than that obtained from the following formula.

Required plastic section modulus : $Z_p = \frac{PSl_s^2}{16\sigma_y \cos\theta_s} \times 10^3$ (cm^3)

Where,

S = frame spacing (m)

l_s = unsupported length of frame as obtained from the following formula (m)

$$l_s = l - l_{b1} - l_{b2}$$

l = refer to **Fig 3.8.1**

l_{b1} and l_{b2} = bracket length for span correction as obtained from the following formulae

$$l_{b1} = b_1(1 - \frac{h_0}{h_1}) \times 10^{-3}$$

$$l_{b2} = b_2(1 - \frac{h_0}{h_2}) \times 10^{-3}$$

b_1, b_2, h_0, h_1 and h_2 = refer to **Fig 3.8.1**

σ_y = specified yield stress of the material (N/mm^2)

θ_s = frame list angle to side shell (deg), refer to **Fig 3.8.2**

P = slamming impact pressure as obtained from the following formula (kPa)

$$P = \frac{1}{2}\rho C_e K_P (\frac{\nu_n}{\cos\beta_0})^2$$

ρ = sea water density, 1.025 (t/m^3)

β_0 = relative impact angle between wave surface and a point under consideration on ship's surface as obtained from the following formula (deg)

$$\beta_0 = \phi + \phi_h^* - 35$$

ϕ = as obtained from the following formula (deg)

$$\phi = \tan^{-1}(\frac{1}{\tan\beta_k \cos\gamma})$$

β_k = as obtained from the following formula (deg)

$$\beta_k = \beta_{k1} - \sqrt{40-\beta} \quad (\beta \le 40^o)$$
$$\beta_k = \beta_{k1} + \sqrt{\beta-40} \quad (\beta > 40^o)$$

β = shell angle at the section under consideration (deg) (see **Fig 3.8.3**)
β_{k1} = as obtained from the following formula (deg)

$$\beta_{k1} = 40\{1.2(0.8-X/L)(1.2-X/L)+1\} - 0.02(D_z-d)(D_z-d-20)$$

X = longitudinal distance from the aft end of L to the section under consideration (m)
D_z = vertical distance from base line at the middle of L to the section under consideration (m)

γ = shell angle at the section under consideration (deg) (see **Fig 3.8.3**)
ϕ_h^* = angle of heel as obtained from the following formula

$$\phi_h^* = 0 \qquad \text{(where, } \frac{(D_1-d)^2}{BdC_b} \le 0.5\text{)}$$
$$\phi_h^* = \{7.8\frac{(D_1-d)^2}{BdC_b} - 3.9\}\cos\gamma \text{ (deg)} \qquad \text{(where, } \frac{(D_1-d)^2}{BdC_b} > 0.5\text{)}$$

D_1 = vertical distance, at the midship, from the top of keel to the top of uppermost continuous deck beam (m)

K_P= coefficient obtained from the formula in **Table 3.8.1**
C_e = coefficient obtained from the following formula

$$C_e = \frac{\beta_0}{40} + 0.25 \qquad \text{(where, } \beta_0 \le 30^o\text{)}$$
$$C_e = 1.0 \qquad \text{(where, } \beta_0 > 30^o\text{)}$$

ν_n = maximum relative velocity between wave surface and a point under consideration on ship's surface as obtained from the following formula (m/s)

$$\nu_n = \frac{\nu_x \tan\beta_k + \nu_z \tan\alpha \tan\beta_k}{\sqrt{\tan^2\alpha + \tan^2\beta_k + \tan^2\alpha \tan^2\beta_k}}$$

ν_x = longitudinal relative velocity at a point under consideration on ship's surface as obtained from the following formula (m/s)

$$\nu_x = (1-C_1)\nu_{xo}$$

C_1 = coefficient obtained from the formula in **Table 3.8.2**

ν_{x0} = longitudinal relative velocity at the waterline as obtained from following formula (m/s)

$$\nu_{x0} = \nu_s + C_2\sqrt{Lg}$$

ν_s = 0.36 V (m/s)
V = speed of ship (kt)
g = gravity acceleration, 9.81 (m/s^2)
C_2 = coefficient obtained from the formula in **Table 3.8.2**

ν_z = relative velocity at a point under consideration on ship's surface in the direction of ship's depth as obtained from the following formula (m/s)

$$\nu_z = (1 - C_3)\nu_{zo}$$

C_3 = coefficient obtained from the formula in **Table 3.8.2**
ν_{z0} = relative velocity at the waterline in the direction of ship's depth as obtained from the following formula (m/s)

$$\nu_{z0} = C_4\sqrt{Lg}$$

C_4 = coefficient obtained from the formula in **Table 3.8.2**

α = as obtained from the following formula

$$\alpha = \tan^{-1}\left(\frac{\tan\beta_k}{\tan\gamma}\right)$$

Z_P = plastic section modulus of frame, where the frame is joined to shell plate with a right angle, as obtained from the following formula. (cm^3)

$$Z_P = 0.1A_f h + \frac{1}{2000}h^2 t_w$$

A_f = sectional area of flange (cm^2)
h = depth of web plate (mm)
t_w = thickness of web plate (mm)

Table 3.8.1 Coefficient K_p

β_0	K_p
$\beta_0 < 3^0$	255.85
$3^0 \le \beta < 4^0$	$758.60\ e^{-0.3623\beta_0}$
$4^0 \le \beta < 6^0$	$453.91\ e^{-0.2339\beta_0}$
$6^0 \le \beta < 10^0$	$335.41\ e^{-0.1835\beta_0}$
$10^0 \le \beta < 15^0$	$173.61\ e^{-0.1176\beta_0}$
$15^0 \le \beta < 18^0$	$80.523\ e^{-0.0664\beta_0}$
$18^0 \le \beta_0$	$1+\frac{\pi}{4}cot^2\beta_0$

Table 3.8.2 Coefficient C_1, C_2, C_3 and C_4

C_1	$(4.40\xi - 6.31)\zeta$
C_2	$0.100\xi + 0.435F_n - 0.162$
C_3	$(\frac{6.37}{\xi - 0.449} + 10.73)\zeta^2$
C_4	$(-1.270F_n + 0.410)\xi + 0.758F_n - 0.038$

Note :

ξ = $x/(L/2)$, however, ξ is to be greater than 0.8
x = longitudinal distance to the section under consideration from the midship (m)
ζ = $z/(L/2)$, however, ζ is to be greater than 0
z = height from the load line to the section under consideration (m)
F_n = $\nu_s/\sqrt{Lg}$

2. For pure car carriers, the scantling of web frames supporting side longitudinals, which are fitted in the bow flare position considered to endure large wave impact pressure, above the load line for 0.1 L forward is to be in accordance with requirements of side stringers supporting transverse frames in **Ch 9, 104.**

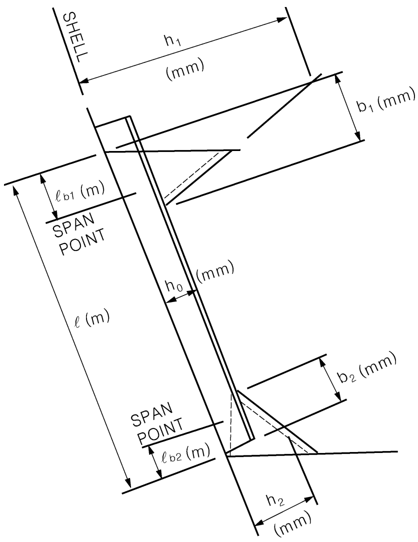


Fig 3.8.1 Modified Span Length of Frames

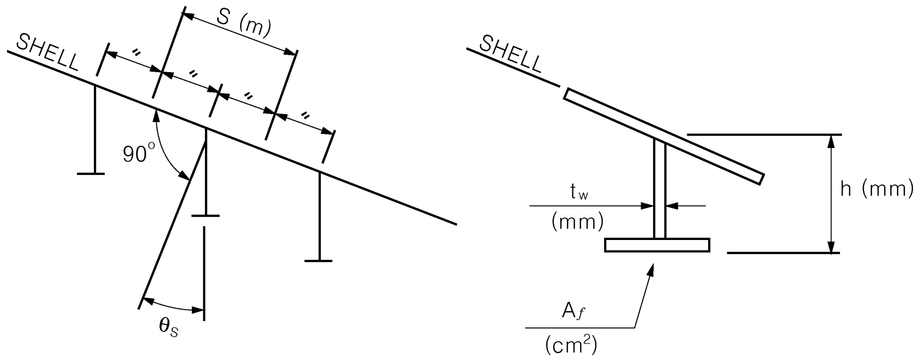


Fig 3.8.2

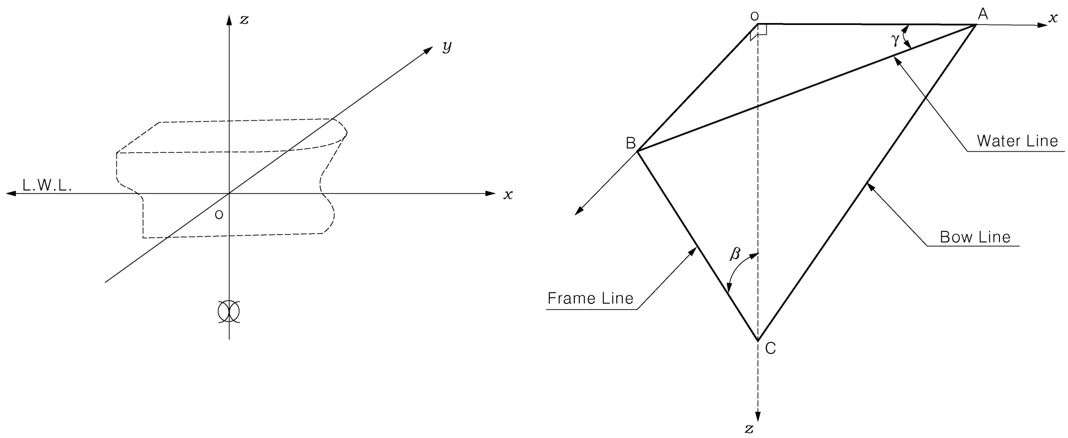


Fig 3.8.3 Shell Angle

Section 3 Hold Frames

302. Scantlings of transverse hold frames

The scantlings of hold frames which are considered to support the loads from steel coils at ship's rolling are recommended to be determined in accordance with not only **302.** of the Rules but also mentioned below based on calculation in elastic range.

(1) Boundary condition ; Simply supported at deck and fixed at inner bottom
(2) Allowable stress ; $196/K$ (N/mm^2)
(3) Loading condition ; Hydraulic pressure of ship's side by h specified in **Table 3.8.1** of the Rules and mass of steel coils(P) calculated by the following formula
(A) In case of loading steel coils lined up in one tier.

$$P = \frac{C_1 \, Wk \, \sin\theta}{n} \quad \text{(ton)}$$

W = mass of one steel coil (ton)

θ = maximum heeling angle (deg)

n = number of frame supporting one steel coil

k = coefficient according to acceleration direction due to ship's rolling, to be normally taken 1.0

C_1 = coefficient according to the arrangements of key coil as obtained from the followings.

Where the key coils are arranged at second from ship side -- 4.0

Where the key coils are arranged towards center line than second steel coil form ship side -- 2.5

(B) In case of loading steel soils lined up in two tiers

$$P = \frac{C_2\ Wm\ \sin\theta}{n} \quad \text{(ton)}$$

$W,\ \theta,\ n$ = as specified in (A)

m = total number of steel coils loaded in the relevant transverse frame section

C_2 = coefficient defined according to arrangement of steel coil, in general, to be taken 0.7. However, where steel coils in lower tier are arranged so closely that the contact pressure of each other is considered large enough to be reduced, the value may be reduced.

303. Transverse hold frames supported by web frames and side stringers

Where the arrangement of side stringers are not complies with **303. 2** of the Rules, the scantlings of frames are to be applied in **303. 1.** of the Rules. However, if it is reviewed and decided the scantlings with proper manner, the scantlings of frames may not be applied in **303. 1** of the Rules. (see **Fig 3.8.4**)

(1) Where the difference between unsupported spans of any adjacent frames is more than 25 %

(A) In case that the value of $l_2/l \geq 1.25$, $l_2/1.25$ is to be used instead of l.

(B) In case that the value of $l_3/l_2 \geq 1.25$ and $l_2/l < 1.25$, modification is not required.

(2) Where the difference between the largest and smallest span is more than 50 %.

(A) In case the lowest span is smallest, (maximum span)/1.5 to be used instead of l.

(B) In other cases than above, no modification required.

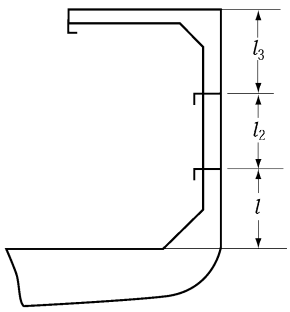


Fig 3.8.4 Transverse hold frames supported by side stringers specially arranged

Section 5 Tween Deck Frames

502. Scantlings of tween deck frames

Where ends of tween deck frames are connected with brackets, the size of which is bigger than $l/8$, the requirements of **502.** of the Rules may be applied as the manner shown in **Fig 3.8.5.**

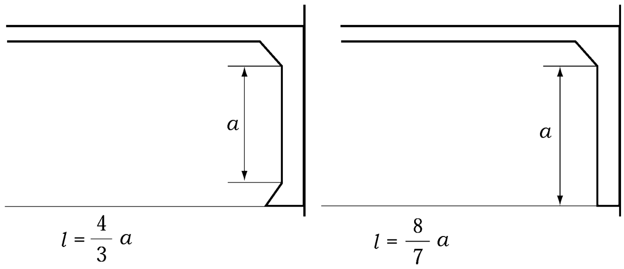


Fig 3.8.5 Frames between decks fixed by the bracket

503. Special consideration to tween deck frames

1. In ships having multi-decks like as Pure Car Carriers, where freeboard is less than the value given in **Table 3.8.1,** the tween deck frames above freeboard deck are to be generally reinforced according to the ship's length as follows.

Table 3.8.1 Standard freeboard

Length of ship L(m)	$L < 75$	$75 \leq L < 125$	$125 \leq L$
Standard freeboard (m)	0.36	0.40	0.46

(1) Range of reinforcement is at least up to the between deck frames of the first tier counted from freeboard deck.

(2) The section modulus of tween deck frames is applied to the following requirements.

(A) Tween deck frame is arranged toward of forward the collision bulkhead : It is to be applied to **Ch 13, 204 .1** of the Rules.

(B) Tween deck frame is arranged afterward of abaft aft peak bulkhead : It is to be applied to **Ch 13, 302.** of the Rules.

(C) Others : It is to be applied (2) in **Table 3.8.4** in **502.** of the Rules. However for coefficient C of **Table 3.8.4** in **502.** of the Rules, 0.57, 0.74 and 0.89 should be substituted for 0.44, 0.57 and 0.74 respectively.

2. Tween deck frames, which are fitted in the bow flare position considered to endure large wave impact pressure, are to be properly strengthened taking care of the effectiveness of their end connections. ⚓

CHAPTER 9 WEB FRAMES AND SIDE STRINGERS

Section 1 General

104. Web frames and side stringers at a location where flare is specially large

1. For pure car carriers, the thickness t_{wG} of web plate and section modulus Z_G, of side stringers supporting transverse frames and web frames supporting these side stringers, which are fitted in the bow flare position considered to endure large wave impact pressure, above the load line for 0.1 L forward are not to be less than those obtained from the following formulae.

Required thickness of web plate : $t_{wG} = \dfrac{433 P S_G l_G}{d_{wG}\,\sigma_y \cos\theta_G}$ (mm)

Required section modulus : $Z_G = \dfrac{P S_G l_G^2}{24\sigma_y \cos\theta_G} \times 10^3$ (cm^3)

where,

P = slamming impact pressure as specified in **Ch 7, 108.** (kPa)

S_G = spacing of girder (m)

l_G = unsupported length of girder taking into account geometry of girder at end parts (m). Where form of girder at end parts is arc form such as **Fig 3.8.1** this length is to be modified considering it triangle, as follows.

(1) To join R-ENDs together. (AB)
(2) To draw tangent line $A'B'$ with arc, parallel to AB.
(3) To put point A'' so that $AA'' = (2/3)AA'$ and to put B'' so that $BB'' = (2/3)BB'$, and triangle $OA''B''$ is considered as bracket of triangle.

$$l_G = l - l_{b1} - l_{b2}$$

l : refer to **Fig 3.8.1**

l_{b1} and l_{b2} = bracket length for span correction as obtained from the following formulae (m)

$$l_{b1} = b_1\left(1 - \frac{d_{wG}}{h_1}\right) \times 10^{-3}$$

$$l_{b2} = b_2\left(1 - \frac{d_{wG}}{h_2}\right) \times 10^{-3}$$

b_1, b_2, h_1 and h_2 : refer to **Fig 3.9.1**

d_{wG} = depth of web plate (mm)

σ_y = specified yield stress of the material (N/mm^2)

θ_s = angle between girder and vertical axis of shell plate (deg). Refer to **Fig 3.9.2**

Z_G = section modulus of girder as obtained from the following formula. (cm^3)

$$Z_G = 0.1 A_{fG} d_{wG} + \frac{1}{3000} d_{wG}^2 t_{wG}$$

A_{fG} = sectional area of flange (cm^2)

2. Buckling strength of girder webs at end parts in above **1.** is to be in accordance with followings (1) and (2).

(1) Shearing stress τ for the web plates of girders at end parts is not to exceed the critical value τ_{cr}^* obtained from the following.

$$\tau_{cr}^* = \tau_{cr} \quad (\text{N/mm}^2), \text{ where } \quad \tau_{cr} \le \frac{\tau_F}{2}$$

$$\tau_{cr}^* = \tau_F\left(1 - \frac{\tau_F}{4\tau_{cr}}\right) \quad (\text{N/mm}^2), \quad \text{where} \quad \tau_{cr} > \frac{\tau_F}{2}$$

$$\tau_F = \frac{\sigma_y}{\sqrt{3}}$$

σ_y = specified yield stress of the material (N/mm^2)

τ_{cr} = shear buckling stress for web plates of girders at end parts as obtained from the following formula

$$\tau_{cr} = 0.9 k_s E\left(\frac{t_{wG}^*}{d_{wG}^*}\right) \quad (\text{N/mm}^2)$$

k_s = coefficient as obtained from Table 3.9.1 depending on a_G/d_{wG}^*. For intermediate values of a_G/d_{wG}^*, k_s is to be obtained by linear interpolation.

a_G = length of web plate at end parts (mm) See **Fig 3.9.3**

E = modulus of elasticity, 2.06×10^5 (N/mm^2)

t_{wG}^* = thickness of web plate of girder at end parts (mm)

d_{wG}^* = mean depth of web plate of girder at end parts (mm)

τ = shear stress for web plate at end parts as obtained from the following formula

$$\tau = \frac{250 P S_G l}{d_{wG}^* t_{wG}^* \cos\theta_G} \quad (\text{N/mm}^2)$$

Table 3.9.1 Coefficient k_s

a_G/d_{wG}^*	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
k_s	64	38	25	19	15	12	10	9	8	7

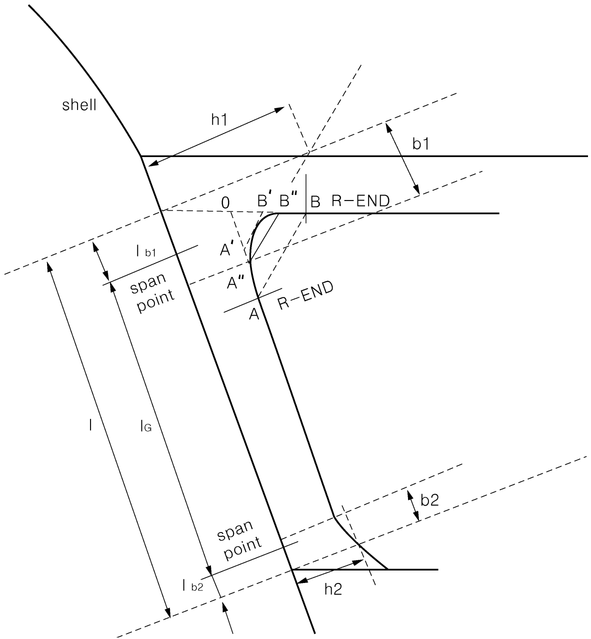


Fig 3.9.1

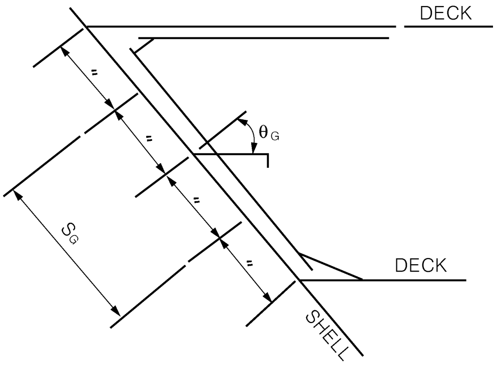


Fig 3.9.2

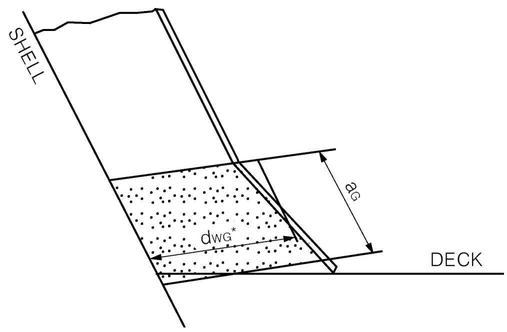


Fig 3.9.3

(2) Bending stress σ_b for the web plates at end parts is not to exceed the critical value σ^*_{bcr} obtained from the following.

$$\sigma^*_{bcr} = \sigma_{bcr} \quad (\text{N/mm}^2), \quad \text{where } \sigma_{bcr} \le \frac{\sigma_y}{2}$$

$$\sigma^*_{bcr} = \sigma_y\left(1 - \frac{\sigma_y}{4\,\sigma_{bcr}}\right) \ (\text{N/mm}^2), \quad \text{where } \sigma_{bcr} > \frac{\sigma_y}{2}$$

σ_y = yield stress of the material (N/mm^2)

σ_{bcr} = bending buckling stress (N/mm^2) of web as obtained from following

$$\sigma_{bcr} = 0.9\,k_b\,E\left(\frac{t^*_{wG}}{d^*_{wG}}\right)^2 \qquad (\text{N/mm}^2)$$

k_b = coefficient as obtained from **Table 3.9.2** depending on a_G/d^*_{wG}. For intermediate values of a_G/d^*_{wG}, k_b is to be obtained by linear interpolation.

σ_b = bending stress working on web as obtained from the following formula

$$\sigma_b = \frac{P S_G l_G^2}{24 Z^*_G \cos\theta_G} \times 10^3 \quad (N/mm^2)$$

Z^*_G = sectional modulus of web plate at end parts (cm^3)

$$Z^*_G = 0.1 A_{fG} d^*_{wG} + \frac{1}{3000} d^{*2}_{wG} t^*_{wg}$$

Table 3.9.2 Coefficient k_b

a_G/d^*_{wG}	0.5 and under	0.6	0.7	0.8	0.9 and over
k_b	12	10	8.8	8.0	7.8

Section 5 Cantilever Beams

503. Connections

1. To prevent the buckling of end brackets of cantilever beams connected with web frames, stiffeners are to be fitted to the brackets with at suitable spacing in order to make their panels smaller as shown in **Fig 3.9.4.**

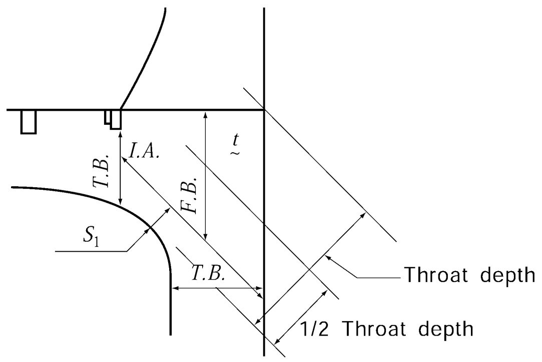


Fig 3.9.4 Compensation of bracket

2. Within the range of 1/2 of the throat depth of the end bracket from the side of face plate, stiffeners such as inverted angle are to be arranged in the direction of compression at the spacing(S_1) obtained from the following formula as the standard.

$$S_1 = 35(t - 2.5) \quad (mm)$$

t = thickness of bracket (mm) ⚓

CHAPTER 10 BEAMS

Section 1 General

102. Connections of ends of beams

1. The standards of end connection of longitudinal beams are as shown below.

2. The standards of end connection of transverse beams by means of brackets are as shown below.

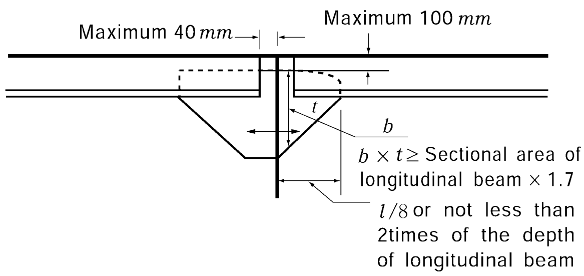


Fig 3.10.1

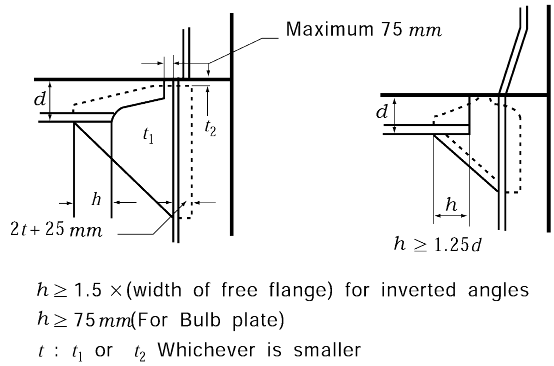


Fig 3.10.2

106. Long machinery opening

Where the length of machinery opening is not less than 20 m, a cross tie is to be provided at middle of opening.

Section 2 Deck Load

201. Value of h

The value of h is to be prescribed in suitable documents like as loading manual specified in **Ch 3, 103.** of the Rules to aid the ship's master.

Section 3 Longitudinal Beams

303. Section modulus

The section modulus of longitudinal beams outside the line of hatchway openings of the strength deck for the parts forward and afterward the midship part of ship may be determined by the interpolation between the requirements of **303. 1** and **2** of the Rules. In general the interpolation may be made at the mid position of each building block in ship lengthwise. However, where the length of block is over 15 m, it may be properly divided.

Section 4 Transverse Beams

402. Proportion

1. In case where the span/depth ratio of transverse beams exceeds 30 in strength decks or 40 in effective decks and superstructure decks, the second moduli of beams are to be increased in the corresponding ratios.

2. In bulk carrier, ore carrier, etc. over 200 m in their length, the slenderness ratio of transverse beams inside the line of hatchway openings of the strength deck is recommended that is to be below 60. ⚓

CHAPTER 11 DECK GIRDERS

Section 1 General

103. Construction

1. At the upper and lower ends of pillars and other places where concentrated loads are expected, girders are to be fitted with tripping brackets and slots in girders are to be fitted with collars. Under the end bulkheads of superstructures, only collars are required. Collars are also to be fitted at the slots near the toe of end bracket.

2. Butt joints of girder webs are to be avoided at corners of slots. Butt joints of face plates are to be likewise avoided at knuckled parts. If butt joints of face plates are inevitably placed at knuckled parts, butt straps are to be provided as shown in **Fig 3.11.1.** The depth of slots is not to exceed $0.4d_G$. If this limit is exceeded, collars are to be fitted with the depth not exceeding $0.5d_G$. These requirements may be suitably modified for superstructures.

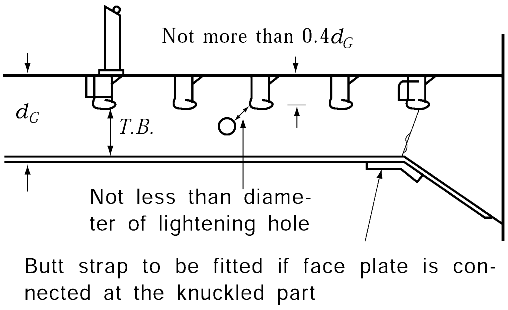


Fig 3.11.1

3. Sizes of lightening holes are to be as follows.

Where slots are provided, $d \le \frac{d_G}{4}$

Where slots are not provided, $d \le \frac{d_G}{3}$

d_G = depth of girder

d = diameter of lightening holes

4. In RO-RO ships, etc., the scantlings of girders may be determined by the direct strength calculation.

5. Where the value obtained from the following formulas equal to or greater than 1.6, special consideration is to be given to the beams on the shell side or bulkhead side in the region of mid-span of girders because of added stress due to forced deflection.

$$\frac{I_b l^4}{I_g S b^3}$$

I_b and I_g = actual moment of inertia of beams and girders (cm^4)

b and l = span of beams and girders (m)

S = spacing of beams (m)

104. End connection

1. Where a girder stops at a bulkhead, a bracket is to be fitted on the reverse side. (See **Fig 3.11.2**)

2. Continuity of deck girders

(1) The depth of bracket is, as a standard, to be equal to twice the depth of web. If the depth of bracket is smaller than this standard, suitable equivalent means, such as gusset plate, is to be provided.(See **Fig 3.11.3**)

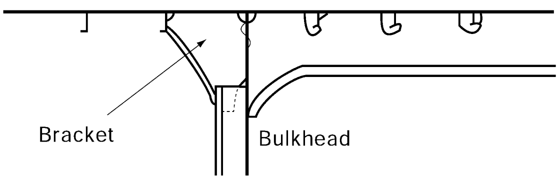


Fig 3.11.2

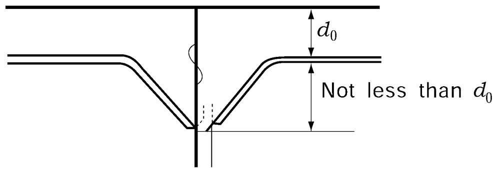


Fig 3.11.3

(2) Girders to be considered for the section modulus calculation of hull girder are to penetrate bulk-heads as a whole including the web and face plate, or to be so connected at the ends as to give an equivalent effectiveness. (See **Fig 3.11.4**)

(3) Where deck girders are discontinuous, they are be sufficiently overlapped. (See **Fig 3.11.5**) ⫝

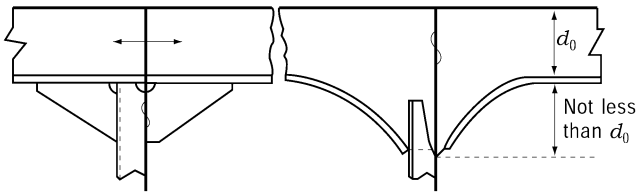


Fig 3.11.4

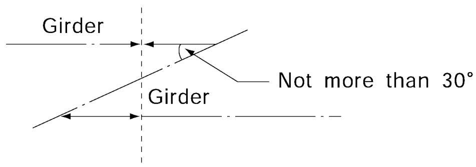


Fig 3.11.5

CHAPTER 12 PILLARS

Section 1 General

102. Pillars in holds

Compensation of under pillars is to be as shown in **Fig 3.12.1.**

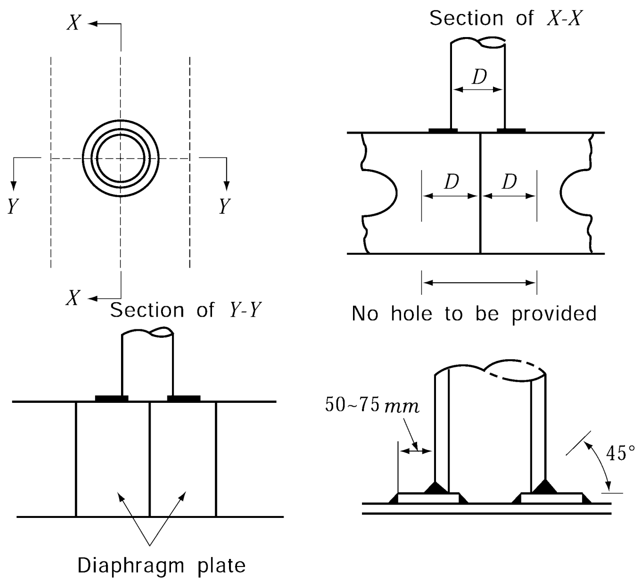


Fig 3.12.1 Compensation of under pillars

Section 2 Scantling of Pillars

201. Sectional area

Sectional area of pillars which is regarded as fixed ends may be obtained from the following formula.

$$A = \frac{0.223\,W}{2.72 - \dfrac{0.5\,l}{k_0}} \quad (\mathrm{cm}^2)$$

CHAPTER 13 ARRANGEMENTS TO RESIST PANTING

Section 1 General

102. Swash plate

Scantlings of swash plates which are used for deep tanks at fore and aft peak tanks are to be complied with **203. 2** (2) of the Rules.

103. Stringers fitted up with extremely small angle

In case the angle between webs of girders and shell plating is not more than 75°, substantially the following treatment (1) and (2) are to be required (See **Fig 3.13.1**). And where the webs of girder is inclined provided to shell plating, actual section modulus of girder is to be calculated against neutral axis parallel to shell plating.
(1) Face plate is to be fitted on the side of open bevel
(2) Tripping brackets are to be fitted in suitable spacing

Section 2 Arrangements to Resist Panting forward the Collision Bulkhead

204. Longitudinal framing

For the applying **204. 2** (2) of the Rules, where the side transverses are supported by side stringers or panting stringers, d_2 in the formula for the depth of side stringers is not applied.

Section 4 Arrangements to Resist Panting between Both Peaks

401. Abaft collision bulkhead

The reinforcement is recommended such that, between the $0.15L$ from the fore end, side stringers are provided in line with stringer plates or side stringers in way of the fore peak tank in association with web frames provided at a suitable interval. Even in case where it is impracticable to provide with frame and side stringer, at least the reinforcement as the followings is to be provided.

1. Appropriate range of scantlings of hold frames abaft the collision bulkhead are to be reinforced to not less than the value in **302.** of the Rules by gradually increasing scantlings of hold frames from the prescribed **Table 3.8.1** of the Rules.

2. Solid brackets are to be provided and firmly connected with collision bulkhead and hold frame abaft the collision bulkhead at appropriate positions in way of depth of ship. ⚓

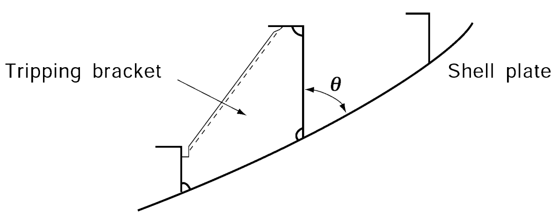
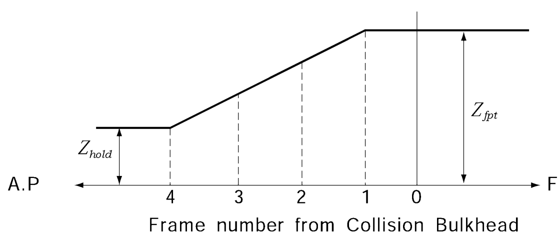


Fig 3.13.1 In case the angle between webs of girders and shell plating is small



Z_{hold} : the section modulus of hold frames required in **Table 3.8.1** of the Rules

Z_{fpt} : the section modulus of frames forward collision bulkhead obtained from the formula in **302.** of the Rules

Fig 3.13.2

CHAPTER 14 WATERTIGHT BULKHEAD

Section 2 Arrangements of Watertight Bulkheads

201. Collision bulkheads

1. In ships with bow doors, the collision bulkhead under the deck just above the freeboard deck is to comply with the **201., 202.** and **205.** of the Rules.

2. The expression "accepted by the Society" means that an application submitted together with calculations verifying that no part of the bulkhead deck will be immersed even when the compartment forward of collision bulkhead is flooded under the loading condition (without trim) corresponding to the load line.

204. Hold bulkheads

1. The expression "to the approval of the Society" in **204. 2** of the Rules means that the ships are complied with the International convention or relative Laws of flag state for damage stability and subdivision regulation, for other ships are to be complied with the following **2.**

2. Omission standard

(1) The arrangement of watertight bulkheads may be different from that specified of the Rules, provided that, under the loading condition corresponding to the load line, the final waterline will not exceed the upper surface of bulkhead deck at side even after any one compartment, except the machinery space, has been flooded. In this case, the ratio of flooding used in the flooding calculations are to be as follows.

Cargo Space
empty hold ………………………………………… 0.95
loaded with general cargoes ……………………… 0.60
loaded with timber…………………………………… 0.55
loaded with ore……………………………………… 0.50

loaded with car or containers……………………… $0.95 - 0.35 \times \dfrac{V_C}{V_0}$

Where, V_C is the volume occupied by cars and/or containers, and V_0 the moulded volume of the compartment.

Deep tanks
filled out with liquid ……………………………… 0
empty tanks ………………………………………… 0.95

(2) In case the spacing between bulkheads is not more than $0.7\sqrt{L}$ (m), these bulkheads are regarded as one bulkhead

3. For the ships which is not less than 186 m in length, the number of hold bulkheads is not to be less than that determined by the above mentioned **2.**

207. Chain lockers

This Requirement is applicable to ships with a length of 24 m and above built in accordance with the **1966 Load Line Convention** or the **1988 Protocol to the Load Line Convention** and the keels of which are laid or which are at a similar stage of construction on or after **1 July 2003.**

- Spurling pipes and cable lockers are to be watertight up to the weather deck. Bulkheads between separate cable lockers (see **Fig 3.14.1 Arrangement 1**), or which form a common boundary of cable lockers (see **Fig 3.14.1 Arrangement 2**), need not however be watertight.
- Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.
- Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances to minimize water ingress.

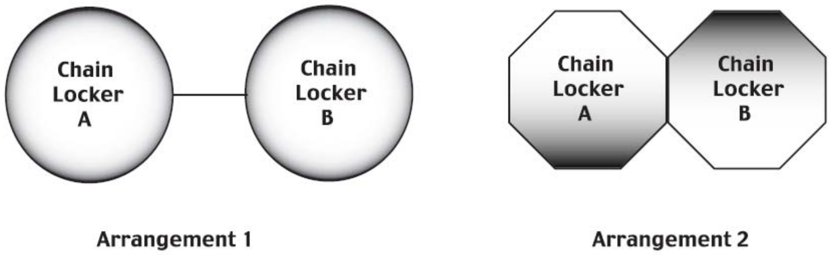


Fig 3.14.1 Arrangements of chain Locker

Section 3 Construction of Watertight Bulkhead

303. Stiffeners

1. Scantlings of bulkheads stiffeners just under deck girders

The scantlings of bulkhead stiffeners supporting under deck girders are to comply with the following formula.

$$C\frac{Z_0}{Z}+\frac{W}{A}\le C$$

Z_0 = required section modulus of stiffener (cm^2)
Z = actual section modulus (cm^3)
A = sectional area of stiffener (cm^2)
(including effective breadth)
W = axial load of stiffener obtained from the following formula.

$$W = Sbh \quad \text{(kN)}$$

S = distance between mid-spaces of adjacent girders supported by stiffeners (See **Fig 3.14.2**)
b and h = as specified in **Ch 11, 201.** of the Rules. However, in ships having two or more decks, W may not be considered.
C = 17.7

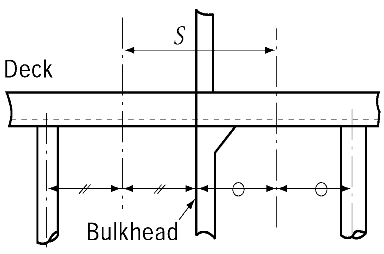


Fig 3.14.2 Measurements of S

2. Scantlings of bulkheads stiffeners just under cargo gears and deck girders.

The scantlings of bulkhead stiffeners just under cargo gears and deck girders are to comply with the above **1.** using the value obtained from following formula as axial load to stiffener. Where the stiffeners support only tare weight of cargo gears, the first term in the formula may be of zero.

$$W = Sbh + P \quad \text{(kN)}$$

S, b, h = as specified in above **1.**

P = tare weight of cargo gears (kN)

In case of derrick systems, it may be acceptable to use the value shown in **Table 3.14.1** of the Guidance.

Table 3.14.1 Tare weight of derrick system

Arrangement of derrick booms \ Type of derrick post	Independent Type	Gate Type
Booms arranged only on fore or aft side	$2.0w$	$2.3w$
Booms arranged on both sides	$2.7w$	$3.0w$
Note; w is a safe working load (kN) of each boom. However, in case of booms are arranged in both sides, average value is to be taken		

3. Scantlings of brackets of stiffeners is to be in accordance with **3.14.2.**

4. Where a deck terminates at the bulkhead, the stiffeners are to have ribs at the level of the deck. (See **Fig 3.14.4**)

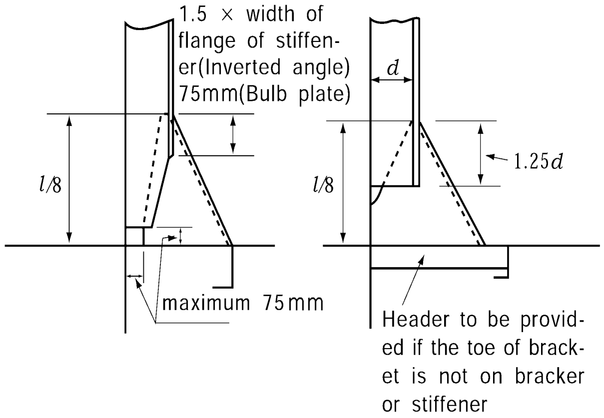


Fig 3.14.3

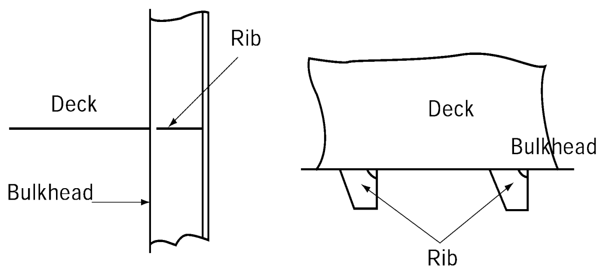


Fig 3.14.4 Rib

304. Corrugated bulkheads

1. Section modulus of corrugated bulkheads

(1) Where the end connection of corrugated bulkhead is specially strong, the coefficient C in **304.** of the Rules may be the value taken from **Table 3.14.2** in calculating the section modulus per half pitch. The term "specially strong end connection" means one of the followings.

(A) connection of upper end of corrugated bulkhead to deck, where the m_1 specified below is greater than 0.2

(B) connection of upper end of corrugated bulkhead to stool, where the m_2 specified below is greater than 0.6

(C) connection of lower end of corrugated bulkhead to stool, where the plate thickness of stool is not less than 1/2 of the thickness of face plate of corrugated bulkhead.

2. Construction of corrugated bulkheads

(1) Stiffeners are to be provided at the ends of under deck girders.

(2) Where the brackets are fixed to the bulkhead plate, pads or headers are to be fitted at the bracket toe.

(3) The angle of corrugation is to be not less than 45

(4) Girders fitted to corrugated bulkheads are to be balanced girders, except where the strength of such girders is at least equivalent to that of girders fitted to flat bulkheads. In calculating the actual section modulus of girder, the depth of girder is taken as shown in **Fig 3.14.7.** The bulkhead plate of corrugated bulkhead is not to be included into the section modulus of the girder as effective attached plate.

(5) The lower end of corrugated bulkhead is to be constructed as shown **Fig 3.14.8** (A) or (B). The construction of the upper end is recommended to follow the construction of the lower end.

Table 3.14.2 Value of C

Col	One end / Another end	Supported by girder	Upper end connected to deck	Upper end connected to stool
1	Supported by girder, or lower end connected to deck or to double bottom	As per Rules	$\dfrac{4}{2+m_1+\dfrac{Z_2}{Z_0}}$	$\dfrac{4}{2+m_2+\dfrac{Z_2}{Z_0}}$
2	Lower end connected to stool	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2+\dfrac{Z_1}{Z_0}+\dfrac{Z_H}{Z_0}}$	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2+m_1+\dfrac{Z_H}{Z_0}}$	$\dfrac{4.8\left(1+\dfrac{l_H}{l}\right)^2}{2+m_2+\dfrac{Z_H}{Z_0}}$
		However, it is not to be less than the value of column 1.		

NOTE:

Z_0, Z_1, Z_2, lH and l are to be in accordance with the Rules

m_1 = It is to be obtained from the following formula for the upper.

$$\frac{1}{Z_0}\left\{Z_S+\left(\frac{l_L+d_0}{l_L-d_0}+1.0\right)Z_L\right\}$$

Z_S = the section modulus of the continuous stiffener at the upper end (cm^3)

l_L, Z_l = span and section modulus of the longitudinal member connected to the upper end (See **Fig 3.14.5**)

d_0 = as specified of the Rules

m_2 = as obtained from the following formula, whichever is smaller.

$$\frac{1}{Z_0}\times\frac{1.050At}{n}, \qquad 3.6\left(\frac{l}{l_0}\right)^2-3$$

A = area enclosed into upper stool (See **Fig 3.14.6**)

t = average plate thickness of upper stool (mm) (See **Fig 3.14.6**)

n = number of pitches of corrugation supported by upper stool (m) (See **Fig 3.14.6**)

l_0 = distance between insides of upper and lower stool (m) (See **Fig 3.14.6**)

Z_H = section modulus per half pitch of lower end of lower stool (See **Fig 3.14.6**)

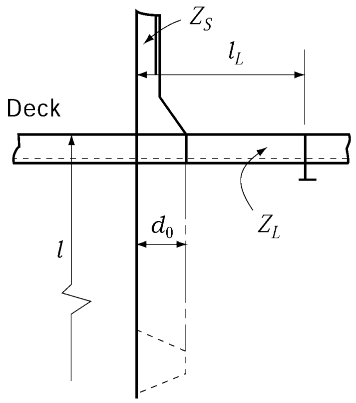


Fig 3.14.5

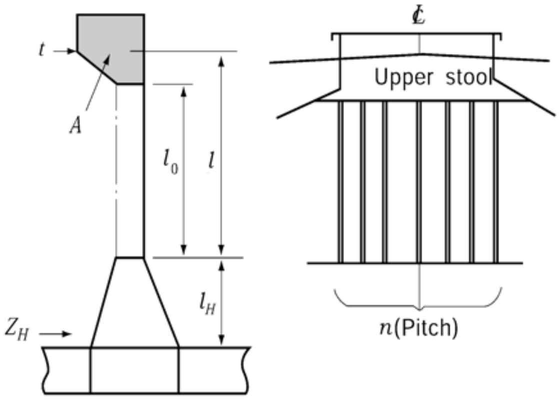


Fig 3.14.6

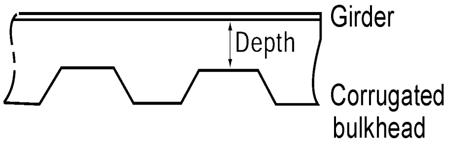


Fig 3.14.7 Measurements of depth of girder

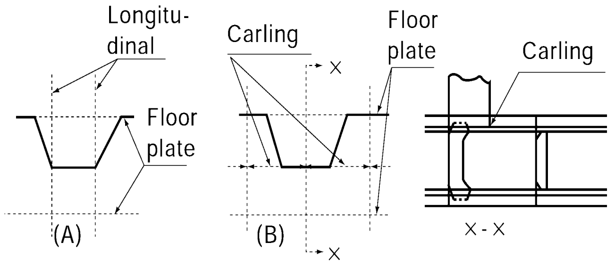


Fig 3.14.8

Section 4 Watertight Door

401. General

1. Watertight doors are categorized as the following (1) to (4) corresponding to its purpose and frequency of use.

(1) Watertight doors which are to be Permanently Closed at Sea:
Such doors are open in port and closed before the ship leaves port. The time of opening/closing such doors is to be entered in the log-book. (e.g. Bulkhead doors for loading/unloading)

(2) Watertight doors which are to be Normally Closed at Sea:
Such doors are kept closed at sea but may be used if authorized by the officer of the watch and to be closed again after use.

(3) Watertight doors which are Normally Open at Sea:
Such doors may be left open provided those are always ready to be immediately closed.

(4) Watertight doors which are Used at Sea:
Such doors are normally used and may be left open provided those are ready to be immediately closed.

402. Type of watertight doors

Watertight doors provided in watertight bulkheads are to be sliding type as far as practicable. If hinged doors are used, they are to be accessible at any time and, further, to be protected against damages due to cargoes, etc. by suitable means.

403. Strength and watertightness

The term of “where deemed necessary by the Society” in **403. 1** of the Rules means cases other than those specified in the following (1) to (3):

(1) Prototype of such doors which have been tested by design water pressure.

(2) Design of such doors has been verified to have enough strength and watertightness by direct structural analysis: Where those watertight doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis, is to be carried out.

(3) Doors complying with a standard deemed appropriate by the Society.

404. Control

1. Where it is necessary to operate the power unit for remote operation of the watertight door required by **404.** of the Rules, means to operate the power unit are also to be provided at remote control stations.

2. Remote controls required by **404.** of the Rules, are to be in accordance with the followings.

(1) The operating console at the navigation bridge is to have a “master switch” with following two modes of control. This switch is normally to be in the “local control” mode. The “remote control” mode is only used in an emergency or for testing purposes. Special consideration is to be given to the reliability of the “master switch”.

(a) A “local control” mode: This mode is to allow any door to be locally opened and locally closed after use without automatic closure.

(b) A “remote control” mode: This mode is to permit doors to be able to opened locally but is to be automatically reclose the doors upon release of the local control mechanism.

(2) The operating console at the navigation bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is opened or closed. A red light is to indicate a door is fully opened and a green light is to indicate a door is fully closed. When the door is being closed remotely, the red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

3. Where remote control is required by **404.** of the Rules, signboard/instructions are to be placed in way of the door advising how to act when the door is in “remote control” mode.

4. With respect to the provisions of **404.** of the Rules, where a watertight door is located adjacent to a fire door, both doors are to be capable of independent operation, remotely if required and from both sides of the each door.

5. The wording “navigation bridge” stated in **404.** of the Rules means the place always served by a watch officer and it normally represents the navigation bridge deckhouse.

6. With respect to the provisions of **404. 1** of the Rules, an operation capability of the ship listed of 30 degrees to either side is to be verified by prototype tests, etc.

7. With respect to the provisions of **404. 1** of the Rules, power operated doors are also to be capable of being opened and closed by power, as well as to by manual.

405. Indication

1. For watertight doors with dogs/cleat for securing watertightness, position indicators required by **405. 1** of the Rules are to be provided to show whether all dogs/cleats fully and properly engage or not.

2. With respect to the provisions of **405. 1** of the Rules, a position indicator may not be required for doors which are designed to confirm easily whether the doors are open or closed and, if applicable, all dogs/cleats fully and properly engage or not.

3. The door position indicating system required by **405.** of the Rules is to be of self-monitoring type and the means for testing of the indicating system are to be provided at the position where the indicators are fitted.

4. An indication required by **405. 2** of the Rules is to be placed locally showing that the door is in the “remote control” mode specified in **404. 2** (i.e. red light).

406. Alarm

An audible alarm required by **406.** of the Rules is to sound from the door begins to move and continue to sound until the door is completely closed.

407. Source of power

The term of “electrical installations” stated in **407. 2** of the Rules means electrical motors for opening and closing the doors and their control components, indicators whether the doors are opened or closed, audible alarms, limit switches to confirm the door position and their associated cables.

408. Notice

Locking device for closing apparatus itself or a box of operation device by the key is acceptable as "a device which prevents unauthorized opening" required in **408. 2** of the Rules.

409. Sliding doors

The section modulus of stiffeners adjacent to both sides of sliding doors (the one asterisked in **Fig 3.14.9**) are to be determined by the formula for stiffeners of deep tank bulkheads. the upper end of h in the formula is to be the bulkhead deck at the centreline of hull. ⚓

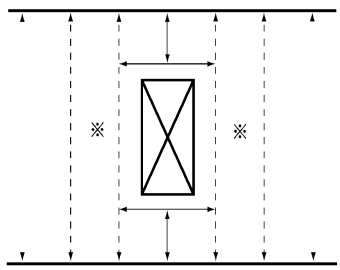


Fig 3.14.9

CHAPTER 15 DEEP TANKS

Section 1 General

103. Swash bulkhead

1. The length of deep tanks is not to exceed the following limits.

(1) Where longitudinal bulkhead is not provided or longitudinal bulkhead is provided in the centreline only; 0.15 L_f (m) or 10 m, whichever is greater.

(2) Where two or more bulkheads are provided
0.2 L_f (m). However, 0.15 L_f (m) in the bow and stern parts of bulk carriers. Further, where the breadth of wing tank is less than $4L+500$ (mm), the inner wall is not be regarded as a longitudinal bulkhead.

2. Swash bulkhead

(1) Except in the bow and stern parts, longitudinal bulkheads are to be provided through the whole breadth from side to side in deep tanks of the ship. However, when it can be confirmed by the safety data of ship that such bulkheads will be unnecessary.

(2) In fresh water tanks, fuel oil tanks or other tanks which may not be kept completely full during navigations, swash bulkheads or deep girders are to be provided in the centreline as well as in positions approximately $B/4$ distant from the ship's sides, except when it can be confirmed by the data on the rolling period of the ship and the inherent period of oscillation of water or oil in the tanks, that they will be unnecessary.

Section 2 Bulkheads of Deep Tank

203. Bulkhead plates

In the provision of h specified in **202.** in the Rules, for side shell plating, a water head corresponding to the minimum draught amidship $d_{\min}$ (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of keel is to be $d_{\min}$, value at point $d_{\min}$ above the top of keel, 0, and value at an intermediate point is to be obtained by linear interpolation.

203. Bulkhead stiffeners

1. For stiffeners having "strongly connected bracket" the span may be taken as $4l'/3$ for calculating, if the arm length of brackets exceed $l/8$. (See **Fig 3.15.1**).

2. End connection of stiffeners at the top of deep tanks stiffeners of deep tank bulkheads, which are not in line with stiffeners of tween deck bulkheads at the top of the tank, are to have bracket ends.

3. Scantlings of bulkheads stiffeners supporting under deck girders are to be calculated according to **Ch 14, 303. 1** of the Guidance, taking C as 9.81

4. In the provision of h specified in **203.** in the Rules, for side shell plating, a water head corresponding to the minimum draught amidship $d_{\min}$ (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of keel is to be $d_{\min}$, value at point $d_{\min}$ above the top of keel, 0, and value at an intermediate point is to be obtained by linear interpolation.

204. Girders supporting bulkhead stiffeners

1. Girders fitted to corrugated bulkheads are to be balanced girders. In case it is difficult to form a balanced girder, the neutral axis of the girder is to be brought as close as possible to the bulkhead plate.

207. Corrugated bulkheads

1. For the under of the corrugated bulkheads, solid floors are to be provided like as **Fig 3.15.2** or reinforced by means of brackets.

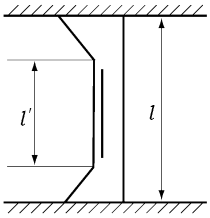


Fig 3.15.1

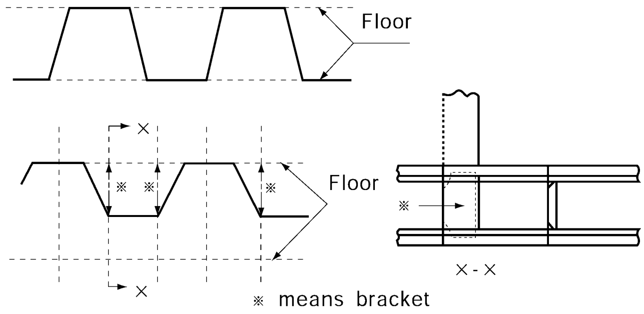
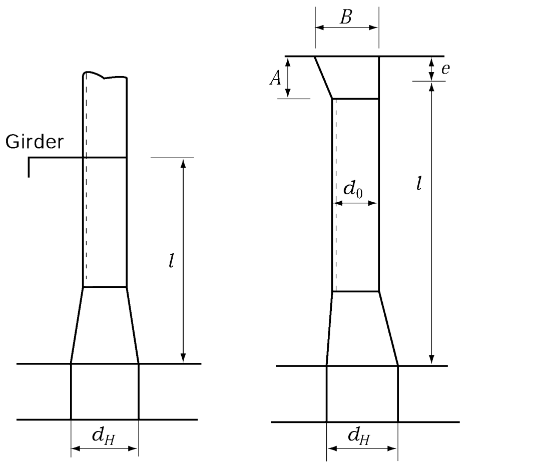


Fig 3.15.2

2. Section modulus of corrugated bulkheads

Where the width d_H in the direction of ship's length of stool of a corrugated bulkhead at the inner bottom is less than 2.5 times the web depth d_0 of corrugated bulkhead, the span l between supports is to be measured as shown in **Fig 3.15.3.** Further, the section modulus per half pitch of corrugated bulkhead and the section modulus of lower stool at the inner bottom are to be obtained from the formula in **207. 2** of the Rules, using the value of C specified in **Table 3.15.1.** ⚓



$$e = A - \frac{d_0}{2B} \cdot A$$

Fig 3.15.3 When $d_H/d_0 < 2.5$, Measurements of l

Table 3.15.1 Coefficient C

upper end support	Supported by girder	Connected to deck	Connected to stool
Section modulus of corrugated bulkhead	1.00	0.85	0.78
Section modulus of stool at bottom	1.00	1.50	1.35

CHAPTER 16 SUPERSTRUCTURES

Section 3 Access Opening in Superstructure End Bulkheads

301. Closure for access opening

Where the sill of access opening is to make hindrance to the passage of heavy spare parts, etc., removable sill may be provided subject to approval by the Society. ⚓

CHAPTER 18 MACHINERY SPACES AND ENGINE CASING

Section 2 Main Engine Foundation

202. Double bottom

1. Scantlings of members of double bottom structure in machinery space are based on the following standards.

(1) The thickness of centreline girder is not less than the value obtained from the following formula

$$t = 0.05L + 4.7 \quad \text{(mm)}$$

(2) The thickness of side girders and solid floors is not less than the value obtained from the following formula. If man holes are provided in girder plates, its number is to be minimized as far as possible.

$$L < 100\,m \ : \ t = 0.6\sqrt{L} + 3.0 \quad \text{(mm)}$$
$$L \geq 100\,m \ : \ t = 0.035L + 5.5 \quad \text{(mm)}$$

2. Girder plates beneath seat plates of main engine are in general to be penetrated through inner bottom plates. Where they are unable to be penetrated, inner bottom plates are to be suitably thicker than required and girder plates are to be welded with edge preparation.

3. Where main engines are directly installed on inner bottom plates, the compartments beneath main engine are recommended to be cofferdams. In case they are used as deep tanks, cap nuts, packing, etc. are to be fitted with in order to keep water/oil tightness at foundation bolts. ⚓

CHAPTER 20 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 General

101. Application

1. For ships trading in Northern Baltic in the winter under the control of the Regulations "*Finnish-Swedish Ice Class Rules 2008*", attention is to be paid to the following restrictions :

(1) The administrations of Sweden and Finland (hereafter the Administrations) provide icebreaker assistance to ships bound for ports in respective countries in the winter season. Depending on the ice conditions, restrictions in regard to the size and ice class of ships entitled to icebreaker assistance are enforced.
(2) Ships entitled to assistance under the restrictions of the preceeding (1) are requested to follow the instructions by the icebreakers when operating in icebound waters and will receive assistance when such is needed.
(3) The Administrations can not take responsibility for the safety of ships which enter ice bound waters ignoring the size and ice class restrictions or any instructions by the icebreakers.
(4) Merely the compliance with these regulations must not be assumed to guarantee any certain degree of capability to advance in ice without icebreaker assistance nor to withstand heavy ice jamming.
(5) It should be noted that small ships will have somewhat less ice going capability as compared with larger ships having the same ice class.
(6) If a ship, because of very unconventional proportions, hull form or propulsion arrangements, or any other characteristics, in practice turns out to have exceptionally poor ice going capability, the Administrations may lower its ice class.
(7) It shall be noted that for ships of moderate size (displacement not exceeding 30,000 tons) fork towing in many situations is the most efficient way of assisting in ice.
(8) Ships with a bulb protruding more than 2.5 m forward of the forward perpendicular are often difficult to tow in this way. The Administrations reserve the right to deny assistance to such ships if the situation so warrants.
(9) An ice strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_0. The design height(h) of the area actually under ice pressure at any particular point of time is, however, assumed to be only a fraction of the ice thickness. The values for h_0 and h are given in **Table 3.20.1.**

Table 3.20.1 Values for h_0 and h

Ice Class	h_0(m)	h(m)
IA Super	1.00	0.35
IA	0.80	0.30
IB	0.60	0.25
IC	0.40	0.22

Section 2 Ice Strengthening

201. Classification of ice strengthening

1. The comparison between ice classes specified in **Ch 20, 201.** of the Rules and those in the Finnish-Swedish Ice Class Rules 2008 is given in **Table 3.20.2.**

2. The correspondence of ice classes specified in **Ch 20, 201.** of the Rules with those in the Arctic Shipping Pollution Prevention Regulation is as given in **Table 3.20.3.**

Table 3.20.2 The correspondence of ice classes between the Rules and the Finnish-Swedish Ice Class Rules 2008

Ice Class of the Rules	Ice Class of the Finnish-Swedish Ice Class Rules 2008
IA Super	IA Super
IA	IA
IB	IB
IC	IC
*	II
Note : ID class of the Rules is not equal to II class of the Finnish-Swedish Ice Class rule, because ID class requires strengthening of forward region.	

Table 3.20.3 The correspondence of ice classes between the Rules and the Arctic Shipping Pollution Prevention Regulation

Ice Class of the Rules	Ice Class of the Arctic Shipping Pollution Prevention Regulations
IA Super	Type A
IA	Type B
IB	Type C
IC	Type D
ID	Type D

202. Definitions

1. Ice Class Draught Marking

The ship's sides are to be provided with a warning triangle and with a draught mark at the maximum permissible ice class draught amidships (see **Fig 3.20.2**). The purpose of the warning triangle is to provide information on the draught limitation of the vessel when it is sailing in ice for masters of icebreakers and for inspection personnel in ports.

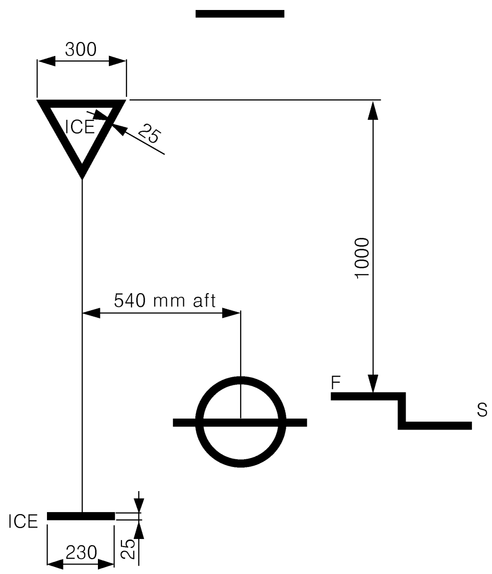


Fig 3.20.1 Ice class draught marking

(1) The upper edge of the Warning Triangle is to be located vertically above the “ICE” mark, 1000 mm higher than the Summer Load Line in fresh water but in no case higher than the deck line. The sides of the triangle are to be 300 mm in length.
(2) The ice class draught mark is to be located 540 mm abaft the centre of the load line ring or 540 mm abaft the vertical line of the timber load line mark, if applicable.
(3) The marks and figures are to be cut out of 5 - 8 mm plate and then welded to the ship's side. The marks and figures are to be painted in a red or yellow reflecting colour in order to make the marks and figures plainly visible even in ice conditions.
(4) The dimensions of all figures are to be the same as those used in the load line mark.

2. "Built" specified in **204.** of the Rules means the keel of ships has been laid or which has been at a similar stage of construction.

Section 4 Hull Structural Design

402. Shell plating

1. With respect to the provisions of **402. 2** of the Rules, value of factor f_2 for the longitudinal framing in larger frame spacing specified in **403. 3** (1) of the Rules, is not to be greater than 1.418.

403. Frames

3. Longitudinal frames

(1) With respect to the provisions of **403. 3** (1) of the Rules, the effective flange used in calculating the section modulus of the longitudinal frame in larger frame spacing is to be taken at most $0.15l$. An attention is to be paid to the provisions of **402.**
(2) With respect to the provisions of **403. 3** (2) of the Rules, boundary condition factor m for frames in conditions deviating from those of continuous beam is to be determined in accordance with the followings:
(A) For conditions deemed as those fixed at both ends : m=12
(B) For conditions deemed as those simple supported at both ends : m=8
(C) For conditions other than (A) or (B), boundary condition factor m is to be determined by calculation using simple beam theory, but in no case that m is not to be greater than 13.3.

404. Ice stringers

1. With respect to the provisions of **404.** of the Rules, boundary condition factor m for ice stringers in conditions deviating from those of continuous beam is to be determined in accordance with **403. 3** (2).

Section 5 Rudder and Steering Arrangements

501. Rudder and steering arrangements

1. The value that given in the **501. 1** of the Rules are following speed.

IA Super	20 kts
IA	18 kts
IB	16 kts
IC	14 kts

Section 6 Propulsion Machinery

605. Design loads

1. In application to **605. 7** of the Rules, for the c, t and r, refer to **Fig 3.20.2.**

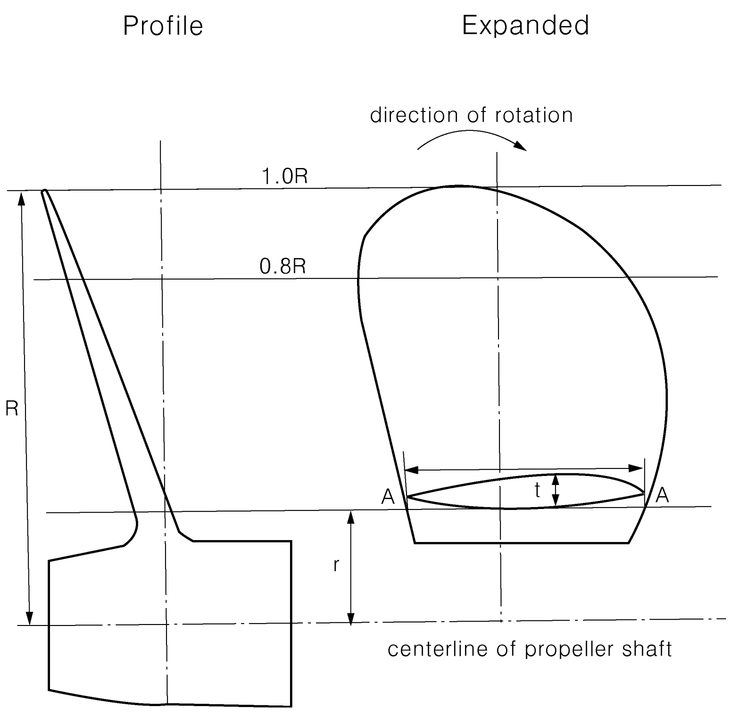


Fig 3.20.2 Dimension of propeller section for calculation of blade failure load

Section 7 Miscellaneous Machinery Requirements

702. Sea inlet and cooling water systems

1. In applying **702. 2** (3) of the Rules, the height of sea chest is not less than the value obtained from the following formula.

$$H = 1.5\sqrt[3]{V}$$

V = volume of sea chest specified in **702. 2** (2) of the Rules and, inlet pipe is to be not located higher than $H/3$ from the uppermost of sea chest.

2. "full capacity of cooling water" in **702. 2** (4) of the Rules is means that the cooling water is used for the following purposes

(1) Main propulsion system(main engine, power train, shafts)
(2) prime movers for generator
(3) main boiler and primary equipments of auxiliary boiler

3. In applying **702. 3** of the Rules, if the volume and height are not comply with **702. 2** (2) and (3) of the Rules, inlet and outlet pipes of cooling water is to be connected to sea chest. ⚓

CHAPTER 21 ADDITIONAL REQUIREMENTS TO SHIPS FOR NAVIGATION IN POLAR WATERS

Section 1 Polar Class Descriptions and Application

101. Application

1. This Guidance for Polar Ships is to apply to ships constructed of steel and intended for navigation in ice-infested polar waters, except ice breakers (see **101. 3**)

2. Ships that comply with the requirements in **Sec 2** and **Sec 3** can be considered for a Polar Class notation as listed in **Table 3.21.1**. The requirements of **Sec 2** and **Sec 3** are in addition to the open water requirements of this Society. If the hull and machinery are constructed such as to comply with the requirements of different polar classes, then both the hull and machinery are to be assigned the lower of these classes in the classification certificate. Compliance of the hull or machinery with the requirements of a higher polar class is also to be indicated in the classification certificate or an appendix thereto.

3. Ships that are also to receive an “Icebreaker” notation may have additional requirements and are to receive special consideration. “Icebreaker" refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters, and having a class certificate endorsed with this notation.

102. Polar classes

1. The Polar Class (PC) notations and descriptions are given in **Table 3.21.1**. It is the responsibility of the Owner to select an appropriate Polar Class. The descriptions in **Table 3.21.1** are intended to guide owners, designers and administrations in selecting an appropriate Polar Class to match the requirements for the ship with its intended voyage or service.

2. The Polar Class notation is used throughout this chapter to convey the differences between classes with respect to operational capability and strength.

Table 3.21.1 Polar class descriptions

Polar Class	Ice Description (based on WMO Sea Ice Nomenclature)
PC 1	Year-round operation in all Polar waters
PC 2	Year-round operation in moderate multi-year ice conditions
PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions.
PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

103. Upper and lower ice waterlines

1. The upper and lower ice waterlines upon which the design of the vessel has been based is to be indicated in the classification certificate. The upper ice waterline (UIWL) is to be defined by the maximum draughts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum draughts fore, amidships and aft.

2. The lower ice waterline is to be determined with due regard to the vessel's ice-going capability in the ballast loading conditions(e.g. propeller submergence).

104. Subdivision and stability

1. For the ships to apply this Guidance, the followings are to be examined, considering the navigation features in ice-infested polar waters within approved limitations, in addition to the requirements regarding the stability and subdivision for the ships navigating in open waters.

(1) Intact stability when operated in ice-infested polar waters

(A) Account should be taken of the effect of icing in the stability calculations.

(B) Suitable calculations should be carried out and/or tests conducted to demonstrate the following:

(a) the ship, when operated in ice within approved limitations, during a disturbance causing roll, pitch, heave or heel due to turning or any other cause, should maintain sufficient positive stability; and

(b) ships of Polar Classes 1 to 3 and icebreakers of all classes, when riding up in ice and remaining momentarily poised at the lowest stem extremity, should maintain sufficient positive stability.

(C) Sufficient positive stability in paragraphs (A). (a) and (b) means that the ship is in a positive state of equilibrium with a positive metacentric height of at least 150 mm, and a line 150 mm below the edge of the freeboard deck as defined in the applicable LL Convention, is not submerged.

(D) For performing stability calculations on ships that ride up onto the ice, the ship should be assumed to remain momentarily poised at the lowest stem extremity as follows:

(a) for a regular stem profile, at the point at which the stem contour is tangent to the keel line;

(b) for a stem fitted with a structurally defined skeg, at the point at which the stem contour meets the top of the skeg;

(c) for a stem profile where the skeg is defined by shape alone, at the point at which the stem contour tangent intersects the tangent of the skeg; or

(d) for a stem profile of novel design, the position should be specially considered.

(2) Damage stability to be expected when operated in ice-infested polar waters

(A) All Polar Class ships should be able to withstand flooding resulting from hull penetration due to ice damage of the extent set out in paragraph (B) and location set out in paragraph (C), and the residual stability following ice damage should be such that the factor si, as defined in **SOLAS** regulation II-1/7.2, has si = 1 for all loading conditions.

(B) The dimensions of an ice damage penetration should be taken as:

(a) longitudinal extent 0.045 of deepest ice waterline length if centred forward of the point of maximum beam on the waterline, and 0.015 of waterline length otherwise;

(b) depth 760 mm measured normal to the shell over the full extent of the damage; and

(c) vertical extent the lesser of 0.2 of deepest ice draft, or of longitudinal extent.

(C) The centre of the ice damage may be located at any point between the keel and 1.2 times the deepest ice draft. The vertical extent of damage may be assumed to be confined between the keel and 1.2 times the deepest ice draft. For ships of Polar Classes 6 and 7 not carrying polluting or hazardous cargoes, damage may be assumed to be confined between watertight bulkheads, except where such bulkheads are spaced at less than the damage dimension.

(3) Security of subdivision and watertightness when operated in ice-infested polar waters

(A) Subject to (B) and (C), no Polar Class ship should carry any pollutant directly against the outer shell. Any pollutant should be separated from the outer shell of the ship by double skin construction of at least 760 mm in width.

(B) All Polar Class ships should have double bottoms over the breadth and the length between forepeak and afterpeak bulkheads. Double bottom height should be in accordance with the rules of the Classification Societies inforce. Double bottoms should not be used for the carriage of pollutants except where a double skin construction complying with paragraph (A) is provided, or where working liquids, are carried in way of main machinery spaces in tanks not exceeding 20 m^3 individual volume.

(C) Double bottoms in ships of Polar Classes 6 and 7 may be used for the carriage of any working liquids where the tanks are aft of midships and within the flat of bottom.
(D) All Polar Class ships with icebreaking bow forms and short forepeaks may dispense with double bottoms up to the forepeak bulkhead in the area of the inclined stem, provided that the watertight compartments between the forepeak bulkhead and the bulkhead at the junction between the stem and the keel are not used to carry pollutants.

Section 2 Structural Requirements for Polar Class Ships

201. Application

1. These requirements are to be applied to polar class ships according to **Sec 1.**

202. Hull areas

1. The hull of all polar class ships is divided into areas reflecting the magnitude of the loads that are expected to act upon them. In the longitudinal direction, there are four regions: Bow, Bow Intermediate, Midbody and Stern. The Bow Intermediate, Midbody and Stern regions are further divided in the vertical direction into the Bottom, Lower and Icebelt regions. The extent of each Hull Area is illustrated in **Fig 3.21.1.**

2. The upper ice waterline (UIWL) and lower ice waterline(LIWL) are as defined in **103. 1.**

3. **Fig 3.21.1** notwithstanding, at no time is the boundary between the Bow and Bow Intermediate regions to be forward of the intersection point of the line of the stem and the ship baseline.

4. **Fig 3.21.1** notwithstanding, the aft boundary of the Bow region need not be more than 0.45 L aft of the forward perpendicular (FP).

5. The boundary between the bottom and lower regions is to be taken at the point where the shell is inclined 7° from horizontal.

6. If a ship is intended to operate astern in ice regions, the aft section of ships is to be designed using the Bow and Bow Intermediate hull area requirements.

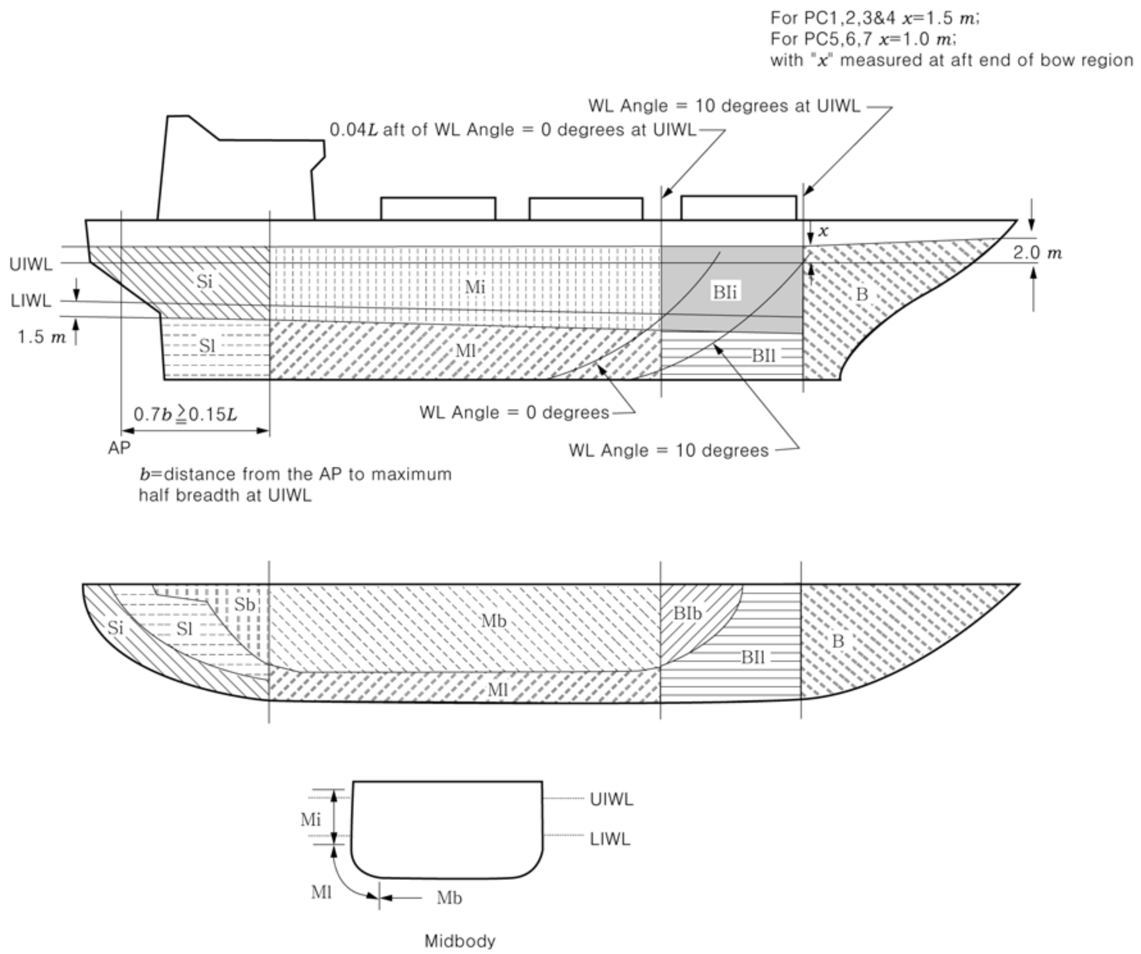


Fig 3.21.1 Hull area extents

203. Design ice loads

1. General

(1) For ships in all Polar Classes, a glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.
(2) The design ice load is characterized by an average pressure(P_{avg}) uniformly distributed over a rectangular load patch of height(b) and width(w).
(3) Within the Bow area of all polar classes and within the Bow Intermediate Icebelt area of polar classes PC6 and PC7, the ice load parameters(P_{avg}, b and w) are functions of the actual bow shape. To determine the ice load parameters, it is required to calculate the following ice load characteristics for sub-region of the bow area; shape coefficient (fa_i), total glancing impact force (F_i), line load (Q_i) and pressure (P_i).
(4) In other ice-strengthened areas the ice load parameters (P_{avg}, b_{NonBow} and w_{NonBow}) are determined independently of the hull shape. Accordingly, calculation of the glancing impact force (F_{NonBow}) and line load (Q_{NonBow}) are based on a standard hull shape coefficient ($fa = 0.36$) and a fixed load patch aspect ratio ($AR = 3.6$).
(5) Design ice forces calculated according to **203. 2** are only valid for vessels with icebreaking forms. Design ice forces for any other bow forms are to be specially considered by this Society.
(6) Ship structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads, based on accelerations determined by this Society, are to be considered in the design of these ship structures.

2. Glancing impact load characteristics

The parameters defining the glancing impact load characteristics are reflected in the Class Factors listed in **Table 3.21.2**.

Table 3.21.2 Class factors

Polar Class	Crushing Failure Class Factor (CF_C)	Flexural Failure Class Factor (CF_F)	Load Patch Dimensions Class Factor (CF_D)	Displacement Class Factor (CF_{DIS})	Longitudinal Strength Class Factor (CF_L)
PC1	17.69	68.60	2.01	250	7.46
PC2	9.89	46.80	1.75	210	5.46
PC3	6.06	21.17	1.53	180	4.17
PC4	4.50	13.48	1.42	130	3.15
PC5	3.10	9.00	1.31	70	2.50
PC6	2.40	5.49	1.17	40	2.37
PC7	1.80	4.06	1.11	22	1.81

(1) Bow area

(A) In the Bow area, the force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline. The influence of the hull angles is captured through calculation of a bow shape coefficient (fa). The hull angles are defined in **Fig 3.21.2.**

(B) The waterline length of the bow region is generally to be divided into 4 sub-regions of equal length. The force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) are to be calculated with respect to the mid-length position of each sub-region (each maximum of F, Q and P is to be used in the calculation of the ice load parameters P_{avg}, b and w).

(C) The Bow area load characteristics are determined as follows:

(a) Shape coefficient, fa_i, is to be taken as

$$fa_i = \min(fa_{i,1}\,; fa_{i,2}\,; fa_{i,3})$$

where,

$$fa_{i,1} = (0.097 - 0.68(x/L - 0.15)^2) \times \alpha_i \,/ \sqrt{\beta_i'}$$

$$fa_{i,2} = 1.2 \times CF_F / (\sin\beta_i' \times CF_C \times D^{0.64})$$

$$fa_{i,3} = 0.60$$

i = sub-region considered

L = ship length measured at the upper ice waterline (UIWL) (m)

x = distance from the forward perpendicular (FP) to station under consideration (m)

α = waterline angle (deg), see **Fig 3.21.2**

β' = normal frame angle (deg), see **Fig 3.21.2**

D = ship displacement (kt), not to be taken less than 5 kt

CF_C = crushing failure class factor from **Table 3.21.2**

CF_F = flexural failure class factor from **Table 3.21.2**

(b) Force, F

$$F_i = fa_i \times CF_C \times D^{0.64} \quad \text{(MN)}$$

where

i = sub-region considered

fa_i = shape coefficient at x/L of sub-region i

CF_C = crushing failure class factor from **Table 3.21.2**

D = ship displacement (kt), where $D_{\min} = 5$ kt

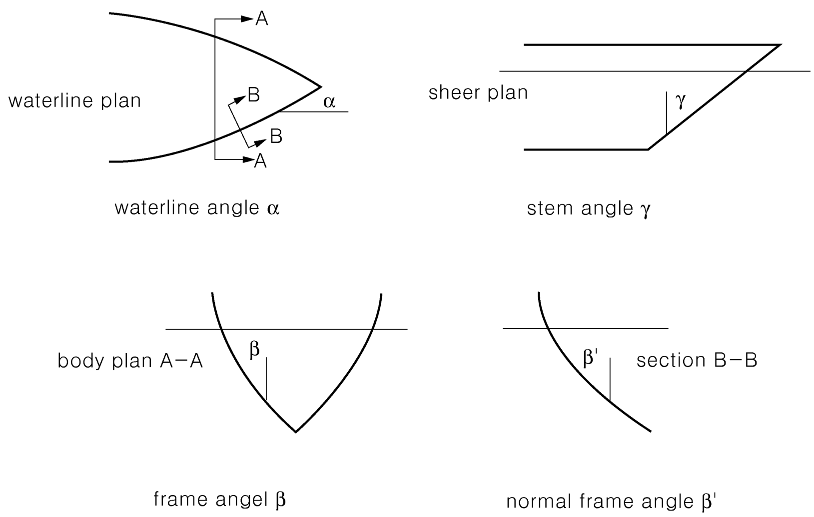
(c) Load patch aspect ratio, AR

$$AR_i = 7.46 \times \sin\beta_i' \geq 1.3$$

where

i = sub-region considered

β_i' = normal frame angle of sub-region i (deg)



Note: β' = normal frame angle at upper ice waterline [deg]

α = upper ice waterline angle [deg]

γ = buttock angle at upper ice waterline (angle of buttock line measured from vertical) [deg]

$\tan\beta = \tan\gamma \tan\alpha$

$\tan\beta' = \tan\beta \cos\alpha$

Fig 3.21.2 Definition of hull angles

(d) Line load, Q

$$Q_i = F_i^{0.61} \times CF_D / AR_i^{0.35} \quad \text{(MN/m)}$$

where

i = sub-region considered

F_i = force of sub-region i (MN)

CF_D = load patch dimensions class factor from **Table 3.21.2**

AR_i = load patch aspect ratio of sub-region i

(e) Pressure, P

$$P_i = F_i^{0.22} \times CF_D^2 \times AR_i^{0.3} \qquad \text{(MPa)}$$

where

i = sub-region considered

F_i = force of sub-region i (MN)

CF_D = load patch dimensions class factor from **Table 3.21.2**

AR_i = load patch aspect ratio of sub-region i

(2) Hull areas other than the bow

(A) In the hull areas other than the bow, the force (F_{NonBow}) and line load (Q_{NonBow}) used in the determination of the load patch dimensions (b_{NonBow}, w_{NonBow}) and design pressure (P_{avg}) are determined as follows:

(a) Force, F_{NonBow}

$$F_{NonBow} = 0.36 \times CF_C \times DF \qquad \text{(MN)}$$

where,

CF_C = crushing failure class factor from **Table 3.21.2**

DF = ship displacement factor

= $D^{0.64}$ if $D \le CF_{DIS}$

= $CF_{DIS}^{0.64} + 0.10(D - CF_{DIS})$ if $D > CF_{DIS}$

D = ship displacement (kt), not to be taken less than 10 kt

CF_{DIS} = displacement class factor from **Table 3.21.2**

(b) Line Load, Q_{NonBow}

$$Q_{NonBow} = 0.639 \times F_{NonBow}^{0.61} \times CF_D \qquad \text{(MN/m)}$$

where,

F_{NonBow} = force from Equation 9 (MN)

CF_D = load patch dimensions class factor from **Table 3.21.2**

3. Design load patch

(1) In the Bow area, and the Bow Intermediate Icebelt area for ships with class notation PC6 and PC7, the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, defined as follows:

$$w_{Bow} = F_{Bow} / Q_{Bow} \qquad \text{(m)}$$
$$b_{Bow} = Q_{Bow} / P_{Bow} \qquad \text{(m)}$$

where

F_{Bow} = maximum F_i in the Bow area (MN)

Q_{Bow} = maximum Q_i in the Bow area (MN/m)

P_{Bow} = maximum P_i in the Bow area (MPa)

(2) In hull areas other than those covered by (1), the design load patch has dimensions of width, w_{NonBow}, and height, b_{NonBow}, defined as follows:

$$w_{NonBow} = F_{NonBow} / Q_{NonBow} \qquad \text{(m)}$$
$$b_{NonBow} = w_{NonBow} / 3.6 \qquad \text{(m)}$$

where

F_{NonBow} = force determined using Equation 9 (MN)

Q_{NonBow} = line load determined using Equation 10 (MN/m)

4. Pressure within the design load patch

(1) The average pressure, P_{avg}, within a design load patch is determined as follows:

$$P_{avg} = F/(b \times w) \quad \text{(MPa)}$$

where

F = F_{Bow} or F_{NonBow} as appropriate for the hull area under consideration (MN)

b = b_{Bow} or b_{NonBow} as appropriate for the hull area under consideration (m)

w = w_{Bow} or w_{NonBow} as appropriate for the hull area under consideration (m)

(2) Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in **Table 3.21.3** are used to account for the pressure concentration on localized structural members.

Table 3.21.3 Peak pressure factors

Structural Member		Peak Pressure Factor (PPF_i)
Plating	Transversely-Framed	$PPF_p = (1.8 - S) \geq 1.2$
	Longitudinally-Framed	$PPF_p = (2.2 - 1.2 \times S) \geq 1.5$
Frames in Transverse Framing Systems	With Load Distributing Stringers	$PPF_m = (1.6 - S) \geq 1.0$
	With No Load Distributing Stringers	$PPF_m = (1.8 - S) \geq 1.2$
Load Carrying Stringers Side and Bottom Longitudinals Web Frames		$PPF_s = 1$ if $S_w \geq 0.5 \times w$ $PPF_s = 2.0 - 2.0 \times S_w / W$ if $S_w < (0.5 \times w)$
where, S = frame or longitudinal spacing (m) S_w = web frame spacing (m) w = ice load patch width (m)		

5. Hull area factors

(1) Associated with each hull area is an Area Factor that reflects the relative magnitude of the load expected in that area. The Area Factor (AF) for each hull area is listed in **Table 3.21.4.**

(2) In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.

(3) Due to their increased manoeuverability, ships having propulsion arrangements with azimuthing thruster(s) or “podded” propellers shall have specially considered Stern Icebelt (S_i) and Stern Lower (S_l) hull area factors.

Table 3.21.4 Hull area factors (AF)

Hull Area		Area	Polar Class						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_l	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Icebelt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_l	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern (S)	Icebelt	S_i	0.75	0.70	0.65	0.60	0.50	0.40	0.35
	Lower	S_l	0.45	0.40	0.35	0.30	0.25	0.25	0.25
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Note to Table 3: * See 203.1.(3)
** Indicates that strengthening for ice loads is not necessary.

204. Shell plate requirements

1. The required minimum shell plate thickness, t, is given by:

$$t = t_{net} + t_s \quad \text{(mm)}$$

where

t_{net} = plate thickness required to resist ice loads according to **Ch 21, 204. 2** of the Guidance. (mm)

t_s = corrosion and abrasion allowance according to **Ch 21, 211** of the Guidance. (mm)

2. The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing.

(1) In the case of transversely-framed plating ($\Omega \geq 70°$, see **Fig 3.21.3**), including all bottom plating, i.e. plating in hull areas BI_b, M_b and S_b, the net thickness is given by:

$$t_{net} = 500 \times S((AF \times PPF_p \times P_{avg}) / \sigma_y)^{0.5} / (1 + S/2b) \quad \text{(mm)}$$

(2) In the case of longitudinally-framed plating ($\Omega \leq 20°$), when $b \geq S$, the net thickness is given by:

$$t_{net} = 500 \times S((AF \times PPF_p \times P_{avg}) / \sigma_y)^{0.5} / (1 + S/2a) \quad \text{(mm)}$$

(3) In the case of longitudinally-framed plating ($\Omega \leq 20°$, see **Fig 3.21.3**), when $b < S$, the net thickness is given by:

$$t_{net} = 500 \times S((AF \times PPF_p \times P_{avg}) / \sigma_y)^{0.5} (2b/S - (b/S)^2)^{0.5} / (1 + S/2a) \quad \text{(mm)}$$

(4) In the case of obliquely-framed plating($70° > \Omega > 20°$), linear interpolation is to be used.

where,

Ω = smallest angle (deg.) between the chord of the waterline and the line of the first level framing as illustrated in **Fig 3.21.3**

S = transverse frame spacing in transversely framed ships or longitudinal spacing in longitudinally-framed ships (m)

AF = Hull Area Factor from **Table 3.21.4**

PPF_p = Peak Pressure Factor from **Table 3.21.3**

P_{avg} = average patch pressure according to **203. 4** (1) (MPa)

σ_y = minimum yield stress of the material (N/mm^2)

b = height of design load patch (m), where $b \le (a - S/4)$ in the case of **204. 2** (1)

a = distance between frame supports, i.e. equal to the frame span as given in **205. 1** (5), but not reduced for any fitted end brackets (m). When a load-distributing stringer is fitted, the length a need not be taken larger than the distance from the stringer to the most distant frame support.

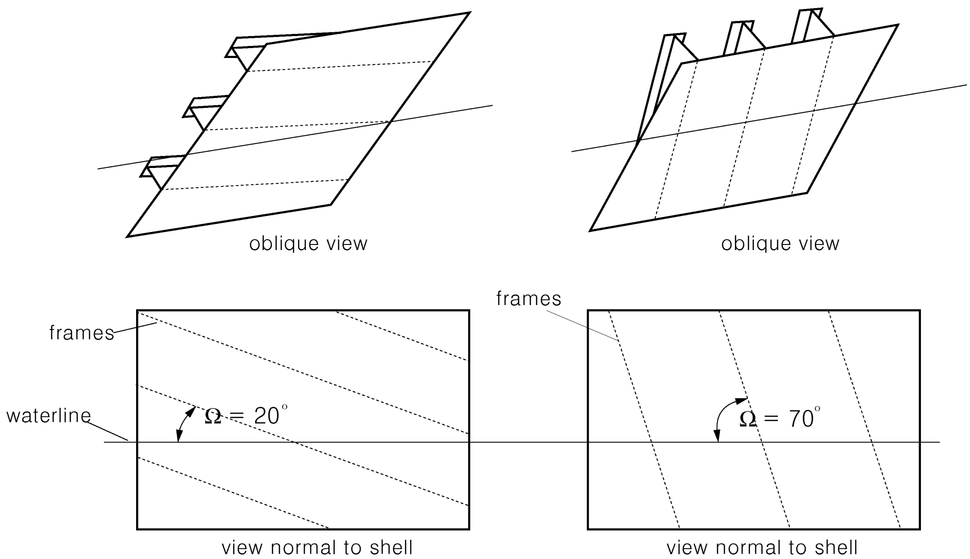


Fig 3.21.3 Shell framing angle Ω

205. Framing

1. General

(1) Framing members of Polar class ships are to be designed to withstand the ice loads defined in **203.**

(2) The term "framing member" refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, see **Fig 3.21.1.** Where load-distributing stringers have been fitted, the arrangement and scantlings of these are to be in accordance with the requirements of this society.

(3) The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area.

(4) The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections are to be in accordance with the requirements of each member society.

(5) The design span of a framing member is to be determined on the basis of its moulded length. If brackets are fitted, the design span may be reduced in accordance with the usual practice of each member society. Brackets are to be configured to ensure stability in the elastic and post-yield response regions.
(6) When calculating the section modulus and shear area of a framing member, net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member, i.e. web area including portion of flange, if fitted, but excluding attached shell plating.
(7) The actual net effective shear area, A_w, of a framing member is given by:

$$A_w = h t_{wn} \sin\varphi_w / 100 \quad (\text{cm}^2)$$

h = height of stiffener (mm) (see **Fig 3.21.4**)
t_{wn} = net web thickness (mm)
= $t_w - t_c$
t_w = as built web thickness (mm) (see **Fig 3.21.4**)
t_c = corrosion deduction (mm) to be subtracted from the web and flange thickness (as specified this society, but not less than t_s as required by **207. 3**).
φ_w = smallest angle between shell plate and stiffener web, measured at the midspan of the stiffener. (see **Fig 3.21.4**) The angle may be taken as 90 degrees provided the smallest angle is not less than 75 degrees.

(8) When the cross-sectional area of the attached plate flange exceeds the cross-sectional area of the local frame, the actual net effective plastic section modulus, Z_p, is given by:

$$Z_p = A_{pn} t_{pn} / 20 + \frac{h_w^2 t_{wn} \sin\varphi_w}{2000} A_{fn} (h_{fc} \sin\varphi_w - b_w \cos\varphi_w) / 10 \quad (\text{cm}^3)$$

h, t_{wn}, t_c and w are as given in **205. 1** (7) and S as given in **204. 2**
A_{pn} = net cross-sectional area of attached plate (cm^2) (equal to $t_{pn} * S * 10$, but not to be taken greater than the net cross-sectional area of the local frame)
t_{pn} = fitted net shell plate thickness (mm) (shall comply with t_{net} as required by **204. 2**)
h_w = height of local frame web (mm) (see **Fig 3.21.4**)
A_{fn} = net cross-sectional area of local frame flange (cm^2)
h_{fc} = height of local frame measured to centre of the flange area (mm) (see **Fig 3.21.4**)
b_w = distance from mid thickness plane of local frame web to the centre of the flange area (mm) (see **Fig 3.21.4**)

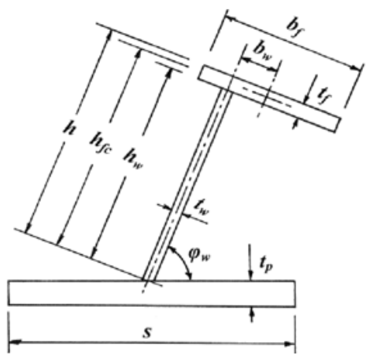


Fig 3.21.4 Stiffener geometry

When the cross-sectional area of the local frame exceeds the cross-sectional area of the attached plate flange, the plastic neutral axis is located a distance z_{na} above the attached shell plate, given by:

$$Z_{na} = (100A_{fn} + h_w t_{wn} - 1000 t_{pn} S)/(2t_{wn}) \quad \text{(mm)}$$

and the net effective plastic section modulus, Z_p, is given by:

$$Z_p = t_{pn} S Z_{na} \sin\varphi_w + \left(\frac{((h_w - Z_{na})^2 + Z_{na}^2) t_{wn} \sin\varphi_w}{2000}\right) + A_{fn}((h_{fc} - Z_{na})\sin\varphi_w - b_w \cos\varphi_w)/10 \quad (\text{cm}^3)$$

(9) In the case of oblique framing arrangement (70 deg > Ω > 20 deg, where Ω is defined as given in **204. 2**), linear interpolation is to be used.

2. Transversely framed side structures and bottom structures

(1) The local frames in transversely-framed side structures and bottom structures (i.e. hull areas B_{fb}, M_b and S_b) are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. Plastic strength is defined as the magnitude of mid-span load that causes the development of a plastic collapse mechanism.

(2) The actual net effective shear area of the frame, A_w, as defined **205. 1** (7), is to comply with the following condition: $A_w \geq A_m$, where:

$$A_m = 100^2 \times 0.5 \times LL \times S \times (AF \times PPF_m \times P_{avg})/(0.577\sigma_y) \quad (\text{cm}^2)$$

where

LL = length of loaded portion of span
= lesser of a and b (m)
a = main frame span (m)
b = height of design ice load patch according to **203. 3** (1) or (2) (m)
S = main frame spacing (m)
AF = Hull Area Factor from **Table 3.21.4**
PPF_m = Peak Pressure Factor from **Table 3.21.3**
P_{avg} = average pressure within load patch according to **203. 4** (1) (MPa)
σ_y = minimum yield stress of the material (N/mm^2)

(3) The actual net effective plastic section modules of the plate/stiffener combination, Z_p, as defined in **205. 1.** (8) is to comply with the following condition: $Z_p \geq Z_{pm}$, where Z_{pm} is to be the greater calculated on the basis of two load conditions: a) ice load acting at the midspan of the main frame, and b) the ice load acting near a support. The A_1 parameter in the equation reflects the two conditions:

$$Z_{pm} = 100^3 \times LL \times Y \times S \times (AF \times PPF_t \times P_{avg})\, a \times A_1/(4\sigma_y) \quad (\text{cm}^3)$$

where

LL, a, b, S, AF, PPF_t, P_{avg} and σ_y, are given in **205. 2** (2)
$Y = 1 - 0.5(LL/a)$
A_1 = maximum of

$$A_{1A} = \frac{1}{\left(1 + \frac{j}{2} + k_w \frac{j}{2}((1 - a_1^2)^{0.5} - 1)\right)}$$

$$A_{1B}= \frac{1-1/(2a_1Y)}{0.275+1.44\,k_z^{0.7}}$$

j = 1 for framing with one simple support outside the ice strengthened areas
= 2 for framing without any simple supports

a_1 = A_t/A_w

A_t : minimum shear area for main frame (cm^2)

A_w : fitted shear area of main frame (cm^2) (calculated according to **205. 1** (7)) (cm^2)

k_w = $1/(1+2A_{fn}/A_w)$ with A_{fn} as given in **205. 1** (8)

k_z = z_p/Z_p in general
= 0.0 when the frame is arranged with end bracket

z_p = sum of individual plastic section modulus of flange and shell plate as fitted (cm^3)

$$= (b_f\frac{t_{fn}^2}{4}+b_{eff}\frac{t_{pn}^2}{4})/1000$$

b_f = flange breadth (mm) (see **Fig 3.21.4)**

t_{fn}= net flange thickness (mm)
= t_f-t_c (t_c as given **205. 1.** (7))

t_f = as-built flange thickness (mm) (see **Fig 3.21.4**)

t_{pn}= the fitted net shell plate thickness (mm) (not to be less than t_{net} as given in **204. 2**)

b_{eff}= effective width of shell plate flange (mm)

Z_p = plastic section modulus of transverse frame (cm^2) (calculated according to **205. 1** (8))

(4) The scantlings of the main frame are to meet the structural stability requirements of **5.**

3. Side longitudinals (longitudinally framed ships)

(1) Side longitudinals are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. Plastic strength is defined as the magnitude of midspan load that causes the development of a plastic collapse mechanism.

(2) The actual net effective shear area of the frame, A_w, as defined **205. 1** (7), is to comply with the following condition: $A_w \geq A_L$, where:

$$A_L= 100^2\times\frac{0.5b_1\times c\times LL\times(AF\times PPF_s\times P_{avg})}{0.577\sigma_y}\quad (\text{cm}^2)$$

where

AF = Hull Area Factor from **Table 3.21.4**

PPF_s = Peak Pressure Factor from **Table 3.21.3**

P_{avg} = average pressure within load patch according to **203. 4** (1) (MPa)

$b_1 = k_0\,b_2$

$k_o = 1-0.3/b'$

$b' = b/S$

b = height of design ice load patch from **203. 3** (1) or (2) (m)

S = main frame spacing (m)

$b_2 = b(1-0.25b')$ if $b' < 2$
$= S$ if $b' \geq 2$

a = longitudinal design span as given **205.1** (5)

σ_y = minimum yield stress of the material (N/mm^2)

(3) The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in **205. 1** (8) is to comply with the following condition: $Z_p \geq Z_{pL}$:

$$(Z_{pL}) = 100^3 \times \frac{b_1 \times a^2 \times A_4 \times (AF \times PPF_s \times P_{avg})}{8\,\sigma_y} \quad (\text{cm}^3)$$

where

$AF, PPF_s, P_{avg}, b_1, a$, and σ_y are as given in **205. 3** (2)

$$A_4 = \frac{1}{2 + k_{wl}((1-a_4^2)^{0.5} - 1)}$$

$$a_4 = \frac{A_l}{A_{1FIT}}$$

A_l = minimum shear area for longitudinal as given in **205. 3** (2) (cm^2)

A_{iFIT} = net effective shear area of longitudinal (cm^2) (calculated according to **205. 3** (2))

$k_{wl} = 1/(1+2A_{fn}/A_{iFIT})$ with A_{fn} as given in **205. 1** (8)

(4) The scantlings of the longitudinals are to meet the structural stability requirements of **5.**

4. Web frame and load carrying stringers

(1) Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in **203.** The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimised.

(2) Web frames and load-carrying stringers are to be dimensioned such that the combined effects of shear and bending do not exceed the limit state(s) defined by each member society. Where these members form part of a structural grillage system, appropriate methods of analysis are to be used. Where the structural configuration is such that members do not form part of a grillage system, the appropriate peak pressure factor (PPF) from **Table 3.21.3** is to be used. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

(3) The scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of **5.**

5. Structural stability

(1) To prevent local buckling in the web, the ratio of web height (h_w) to net web thickness (t_w) of any framing member is not to exceed:

For flat bar sections: $h_w / t_w \leq 282 / \sigma^{0.5}$

For bulb, tee and angle sections: $h_w / t_w \leq 805 / \sigma^{0.5}$

where

h_w = web height

t_w = net web thickness

σ_y = minimum yield stress of the material (N/mm^2)

(2) Framing members for which it is not practicable to meet the requirements of (1) (e.g. load carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by the following equation:

$$t_w = \frac{2.63 \times 10^{-3}\, c_1\, \sigma_y}{5.34 + 4(c_1 / c_2)^2} \quad \text{(mm)}$$

where

t_w = net web thickness (mm)

c_1 = $h_w - 0.8h_f$ (mm)

h_w = web height of stringer / web frame (mm) (see **Fig 3.21.5**)

h_f = height of framing member penetrating the member under consideration (0 if no such framing member) (mm) (see **Fig 3.21.5**)

c_2 = spacing between supporting structure oriented perpendicular to the member under consideration (mm) (see **Fig 3.21.5**)

σ_y = minimum yield stress of the material (N/mm^2)

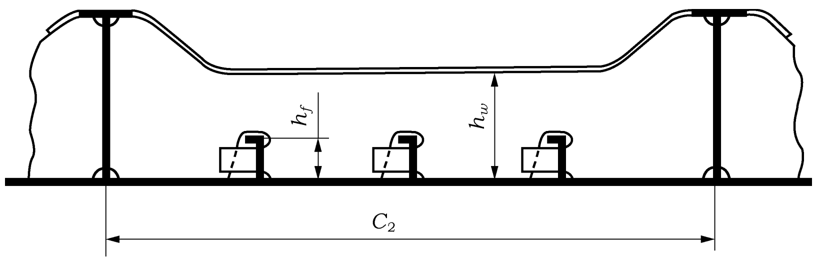


Fig 3.21.5 Parameter definition for web stiffening

(3) In addition, the following is to be satisfied:

$$t_w \geq 0.35\, t_{net} \sqrt{\frac{\sigma_y}{235}}$$

where

σ_y = minimum upper yield stress of the material (N/mm^2)

t_w = net thickness of the web

t_{net} = thickness of the shell plate in way the framing member

(4) To prevent local flange buckling of welded profiles, the following are to be satisfied:

(a) The flange width (b_f) shall not be less than five times the net thickness of the web (t_w).

(b) The flange outstand (b), shall meet the following requirement:

$$\frac{b}{t_f} \leq \frac{155}{\sqrt{\sigma_y}}$$

where

t_f = net thickness of flange

σ_y = minimum upper yield stress of the material (N/mm^2)

206. Plated structures

1. Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. These requirements are applicable to an inboard extent which is the lesser of:

(1) web height of adjacent parallel web frame or stringer; or

(2) 2.5 times the depth of framing that intersects the plated structure

2. The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

3. The stability of the plated structure is to adequately withstand the ice loads defined in **203.**

207. Corrosion/abrasion additions and steel renewal

1. Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar ships.

2. The values of corrosion/abrasion additions, t_s, to be used in determining the shell plate thickness for each Polar Class are listed in **Table 3.21.5.**

3. Polar ships are to have a minimum corrosion/abrasion addition of $t_s = 1.0$ mm applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.

4. Steel renewal for ice strengthened structures is required when the gauged thickness is less than $t_{net} + 0.5$ mm.

Table 3.21.5 Corrosion/Abrasion additions for shell plating

Hull Area	t_s (mm)					
	With Effective Protection			Without Effective Protection		
	PC1 - PC3	PC4 & PC5	PC6 & PC7	PC1 - PC3	PC4 & PC5	PC6 & PC7
Bow; Bow Intermediate Icebelt	3.5	2.5	2.0	7.0	5.0	4.0
Bow Intermediate Lower; Midbody & Stern Icebelt	2.5	2.0	2.0	5.0	4.0	3.0
Midbody & Stern Lower; Bottom	2.0	2.0	2.0	4.0	3.0	2.5
Other Areas	2.0	2.0	2.0	3.5	2.5	2.0

208. Materials

1. Plating materials for hull structures are to be not less than those given in **Tables 3.21.7** and **3.21.8** based on the as built thickness of the material, the Polar ice class notation assigned to the ship and the Material Class of structural members given in **Table 3.21.6.**

2. Material classes specified in **Ch 2, Table 3.1.4** of the Rules are applicable to polar ships regardless of the ship's length. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed shell plating of polar ships are given in **Table 3.21.6.** Where the material classes in **Table 3.21.6**, below, and those in **Ch 2, Table 3.1.4** of the Rules differ, the higher material class is to be applied.

3. Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 m below the lower waterline, as shown in **Fig 3.21.6**, are to be obtained from **Ch 2, Table 3.1.9** of the Rules based on the Material Class for Structural Members in **Table 3.21.7**, above, regardless of Polar Class.

4. Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m below the lower ice waterline, as shown in **Fig 3.21.6**, are to be not less than given in **Table 3.21.8.**

5. Steel grades for all inboard framing members attached to weather exposed plating are to be not less than given in **Table 3.21.8.** This applies to all inboard framing members as well as to other contiguous inboard members (e.g. bulkheads, decks) within 600 mm of the exposed plating.

6. Castings are to have specified properties consistent with the expected service temperature for the cast component.

Table 3.21.6 Material classes for structural members of polar ships

Structural Members	Material Class
Shell plating within the bow and bow intermediate icebelt hull areas (B, BIi)	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in **Ch 2**, **Table 3.1.4**, structural members outside $0.4\,L$ amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm of the shell plating	I
Weather-exposed plating and attached framing in cargo holds of ships which by nature of their trade have their cargo hold hatches open during cold weather operations	I
All weather and sea exposed SPECIAL, as defined in **Ch 2**, **Table 3.1.4**, structural members within $0.2\,L$ from FP	II

Table 3.21.7 Steel grades for weather exposed plating

Thickness, t (mm)	Material Class I				Material Class II				Material Class III					
	PC1-5		PC6&7		PC1-5		PC6&7		PC1-3		PC4&5		PC6&7	
	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT
$t \leq 10$	B	AH	B	AH	B	AH	B	AH	E	EH	E	EH	B	AH
$10 < t \leq 15$	B	AH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$15 < t \leq 20$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$20 < t \leq 25$	D	DH	B	AH	D	DH	B	AH	E	EH	E	EH	D	DH
$25 < t \leq 30$	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
$30 < t \leq 35$	D	DH	B	AH	E	EH	D	DH	E	EH	E	EH	E	EH
$35 < t \leq 40$	D	DH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
$40 < t \leq 45$	E	EH	D	DH	E	EH	D	DH	F	FH	E	EH	E	EH
$45 < t \leq 50$	E	EH	D	DH	E	EH	D	DH	F	FH	F	FH	E	EH

Notes :

1) Includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0.3 m below the lowest ice waterline.

2) Grades D, DH are allowed for a single strake of side shell plating not more than 1.8 m wide from 0.3 m below the lowest ice waterline.

Table 3.21.8 Steel grades for inboard framing members attached to weather exposed plating

Thickness t, mm	PC1 - PC5		PC6 & PC7	
	MS	HT	MS	HT
$t \leq 20$	B	AH	B	AH
$20 < t \leq 35$	D	DH	B	AH
$35 < t \leq 45$	D	DH	D	DH
$45 < t \leq 50$	E	EH	D	DH

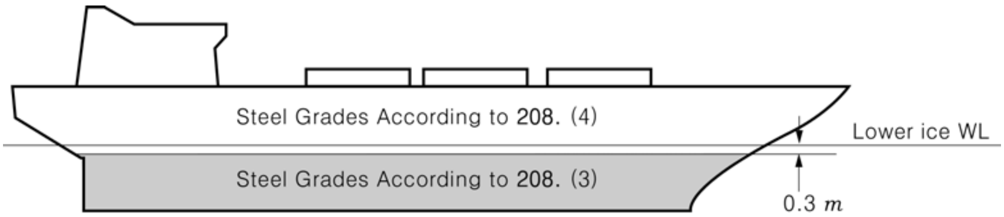


Fig 3.21.6 Steel grade requirements for submerged and weather exposed shell plating

209. Longitudinal strength

1. Application

Ice loads need only be combined with still water loads. The combined stresses are to be compared against permissible bending and shear stresses at different locations along the ship's length. In addition, sufficient local buckling strength is also to be verified.

2. Design vertical ice force at the bow

The design vertical ice force at the bow, F_{IB}, is to be taken as:

$$F_{IB} = \min(F_{IB,1}\,;F_{IB,2}) \quad \text{(MN)}$$

where

$$F_{IB,1} = 0.534 K_I^{0.15} \sin^{0.2}\gamma_{stern}(DK_h)^{0.5}\, CF_L \quad \text{(MN)}$$

$$F_{IB,2} = 1.2\, CF_F \quad \text{(MN)}$$

K_I = indentation parameter = K_f / K_h

(1) for the case of a blunt bow form

$$K_f = \left(\frac{2CB^{(1-e_b)}}{(1+e_b)}\right)^{0.9} \tan(\gamma_{stem})^{-0.9(1+e_b)}$$

(2) for the case of wedge bow form ($\alpha_{stem} < 80$ deg), $e_b = 1$ and the above simplifies to

$$K_f = \left(\frac{\tan(\alpha_{stem})}{\tan^2(\gamma_{stem})}\right)^{0.9}$$

$K_h = 0.01 A_{wp}$ (MN/m)

CF_L = Longitudinal Strength Class Factor from **Table 3.21.2**

e_b = bow shape exponent which best describes the waterplane (see **Fig 3.21.7** and **3.21.8**)

= 1.0 for a simple wedge bow form

= 0.4 to 0.6 for a spoon bow form

= 0 for a landing craft bow form

An approximate e_b determined by a simple fit is acceptable.

γ_{stem} = stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline (deg) (buttock angle as per **Fig 3.21.2** measured on the center-line)

$$C = \frac{1}{2\,(L_B\,/\,B)^{e_b}}$$

B = ship moulded breadth (m)

L_B = bow length used in the equation $y = B/2\ (x/L_B)^{e_b}$ (m) (see **Fig 3.21.7** and **3.21.8**)

D = ship displacement (kt), where $D_{\min}$ = 10 kt

A_{wp} = ship waterplane area (m^2)

CF_F = Flexural Failure Class Factor from **Table 3.21.2**

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

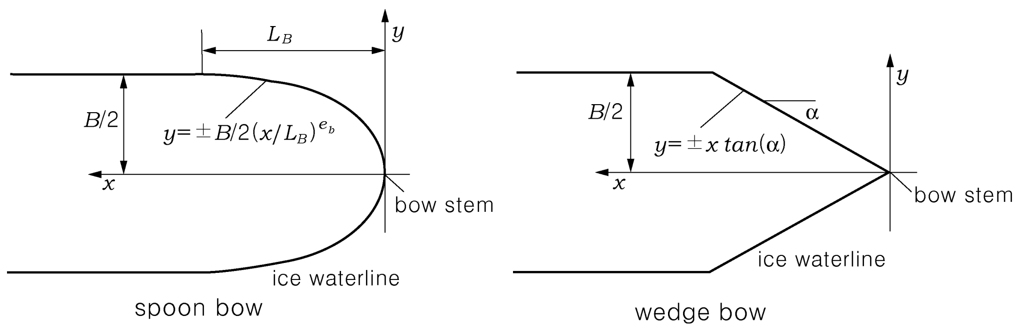


Fig 3.21.7 Bow shape definition

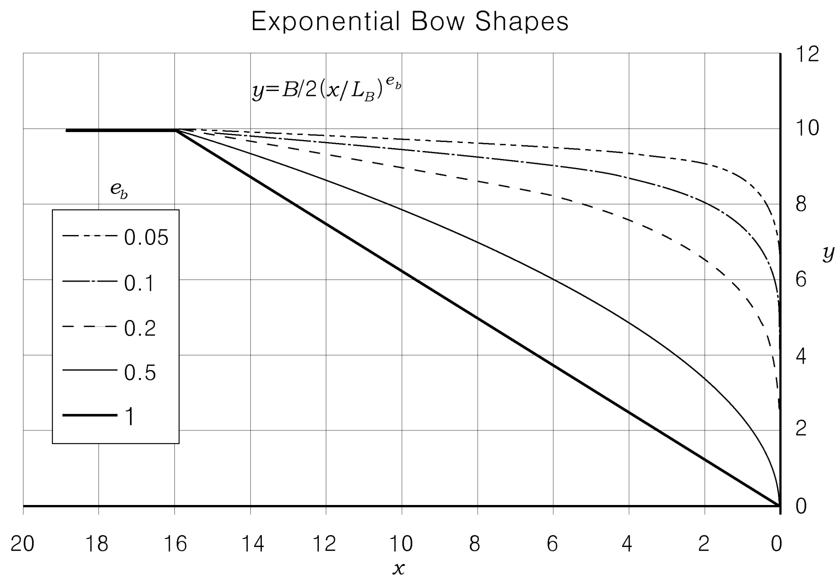


Fig 3.21.8 Illustration of e_b effect on the bow shape for B = 20 and L_B =16

3. Design vertical shear force

(1) The design vertical ice shear force, F_I, along the hull girder is to be taken as:

$$F_I = C_f \, F_{IB} \quad (MN)$$

where

C_f = longitudinal distribution factor to be taken as follows:

(a) Positive shear force

$C_f = 0.0$ between the aft end of L and $0.6\,L$ from aft

$C_f = 1.0$ between $0.9L$ from aft and the forward end of L

(b) Negative shear force

$C_f = 0.0$ at the aft end of L

$C_f = -0.5$ between $0.2L$ and $0.6L$ from aft

$C_f = 0.0$ between $0.8L$ from aft and the forward end of L

Intermediate values are to be determined by linear interpolation

(2) The applied vertical shear stress, τ_a, is to be determined along the hull girder in a similar manner as in **Ch 3, 402. 2** of the Rules by substituting the design vertical ice shear force for the design vertical wave shear force.

4. Design vertical ice bending moment

(1) The design vertical ice bending moment, M_I, along the hull girder is to be taken as:

$$M_I = 0.1 C_m \, L \sin^{-0.2}(\psi) \, F_{IB} \quad \text{(MN-m)}$$

where

L = ship length (Rule Length as defined in **Ch 1, 102.** of the Rules) (m)

ψ = stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline (deg)

F_{IB} = design vertical ice force at the bow (MN)

C_m = longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

$C_m = 0.0$ at the aft end of L

$C_m = 1.0$ between $0.5L$ and $0.7L$ from aft

$C_m = 0.3$ at $0.95L$ from aft

$C_m = 0.0$ at the forward end of L

Intermediate values are to be determined by linear interpolation

Where applicable, draught dependent quantities are to be determined at the waterline corresponding to the loading condition under consideration.

(2) The applied vertical bending stress, σ_a, is to be determined along the hull girder in a similar manner as in **Ch 1, 402. 1.** of the Rules, by substituting the design vertical ice bending moment for the design vertical wave bending moment. The ship still water bending moment is to be taken as the maximum hogging moment.

5. Longitudinal strength criteria

(1) The strength criteria provided in **Table 3.21.9** are to be satisfied. The design stress is not to exceed the minimum yield stress.

Table 3.21.9 Longitudinal strength criteria

Failure Mode	Applied Stress	Permissible Stress (when $\sigma_y/\sigma_u \le 0.7$)	Permissible Stress (when $\sigma_y/\sigma_u > 0.7$)
Tension	σ_a	$\eta \times \sigma_y$	$\eta \times 0.41(\sigma_u + \sigma_y)$
Shear	τ_a	$\eta \times \frac{\sigma_y}{\sqrt{3}}$	$\eta \times \frac{0.41(\sigma_u + \sigma_y)}{\sqrt{3}}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners $\sigma_c/1.1$ for stiffeners	
	τ_a	τ_c	

where

σ_a = applied vertical bending stress (N/mm^2)

τ_a = applied vertical shear stress (N/mm^2)

σ_y = minimum upper yield stress of the material (N/mm^2)

σ_u = ultimate tensile strength of material (N/mm^2)

σ_c = critical buckling stress in compression, according to **Ch 3, Sec 4** of the Rules (N/mm^2)

τ_c = critical buckling stress in shear, according to **Ch 3, Sec 4** of the Rules (N/mm^2)

η = 0.8

210. Stem and stern frames

The stem and stern frame are to be designed according to the requirements of this Society. For PC6/PC7 vessels requiring IA SUPER/IA equivalency, the stem and stern requirements of **Ch 20, 406. 1** and **407.** of the Rules may need to be additionally considered.

211. Appendages

1. All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

2. Load definition and response criteria are to be determined by each member society.

212. Local details

1. For the purpose of transferring ice-induced loads to supporting structure (bending moments and shear forces), local design details are to comply with the requirements of each member society.

2. The loads carried by a member in way of cut-outs are not to cause instability. Where necessary, the structure is to be stiffened.

213. Direct calculations

1. Direct calculations are not to be utilised as an alternative to the analytical procedures prescribed in this unified requirement.

2. Where direct calculation is used to check the strength of structural systems, the load patch specified in **203.** is to be applied.

214. Welding

1. All welding within ice-strengthened areas is to be of the double continuous type.

2. Continuity of strength is to be ensured at all structural connections.

Section 3 Machinery Requirements for Polar Class Ships

301. Application

The contents of this Section apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the ship and the survivability of the crew.

302. Drawings & particulars to be submitted and system design

1. Drawings & particulars to be submitted

(1) Details of the environmental conditions and the required ice class for the machinery, if different from ship's ice class.
(2) Detailed drawings of the main propulsion machinery. Description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions.
(3) Description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions.
(4) Calculations and documentation indicating compliance with the requirements of this Section.

2. System design

(1) Machinery and supporting auxiliary systems shall be designed, constructed and maintained to comply with the requirements of "periodically unmanned machinery spaces" with respect to fire safety. Any automation plant (i.e. control, alarm, safety and indication systems) for essential systems installed is to be maintained to the same standard.
(2) Systems, subject to damage by freezing, shall be drainable.
(3) Single screw vessels classed PC1 to PC5 inclusive shall have means provided to ensure sufficient vessel operation in the case of propeller damage including CP-mechanism.

303. Materials

1. Materials exposed to sea water

Materials exposed to sea water, such as propeller blades, propeller hub and blade bolts shall have an elongation not less than 15% on a test piece the length of which is five times the diameter.

Charpy V impact test shall be carried out for other than bronze and austenitic steel materials. Test pieces taken from the propeller castings shall be representative of the thickest section of the blade. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at minus 10℃.

2. Materials exposed to sea water temperature

Materials exposed to sea water temperature shall be of steel or other approved ductile material.

An average impact energy value of 20 J taken from three tests is to be obtained at minus 10℃.

3. Material exposed to low air temperature

Materials of essential components exposed to low air temperature shall be of steel or other approved ductile material.

An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10℃ below the lowest design temperature.

304. Ice interaction load

1. Propeller ice interaction

These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow propellers and pulling type propellers shall receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ships service life for normal operational conditions. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules apply also for azimuthing (geared and podded) thrusters considering loads due to propeller ice interaction. However, ice loads due to ice impacts on the body of azimuthing thrusters have to be estimated with suitable methods, but ice load formulae are not available in this Section.

The loads given in section **304.** are total loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only. The different loads given here are to be applied separately.

F_b is a force bending a propeller blade backwards when the propeller mills an ice block while rotating ahead.

F_f is a force bending a propeller blade forwards when a propeller interacts with an ice block while rotating ahead.

2. Ice class factors

The Table below lists the design ice thickness and ice strength index to be used for estimation of the propeller ice loads.

Table 3.21.10 Ice class factors

Ice Class	H_{ice} [m]	S_{ice} [-]	S_{qice} [-]
PC1	4.0	1.2	1.15
PC2	3.5	1.1	1.15
PC3	3.0	1.1	1.15
PC4	2.5	1.1	1.15
PC5	2.0	1.1	1.15
PC6	1.75	1	1
PC7	1.5	1	1

H_{ice} : Ice thickness for machinery strength design
S_{ice} : Ice strength index for blade ice force
S_{qice} : Ice strength index for blade ice torque

3. Design ice loads for open propeller

(1) Maximum backward blade force, F_b

when $D < D_{\lim}$, $F_b = -27 \cdot S_{ice} \cdot [nD]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot [D]^2$ (kN)

when $D \geq D_{\lim}$, $F_b = -23 \cdot S_{ice} \cdot [nD]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot [H_{ice}]^{1.4} \cdot [D]$ (kN)

where,

$D_{\lim} = 0.85 \cdot [H_{ice}]^{1.4}$

n is the nominal rotational speed(at MCR free running condition) for CP-propellers and 85% of the nominal rotational speed(at MCR free running condition) for a FP-propeller (regardless driving engine type).

F_b is to be applied as a uniform pressure distribution to an area on the back(suction) side of the blade for the following load cases.

(A) Load case 1 : from 0.6 R to the tip and from the blade leading edge to a value of 0.2 chord length,

(B) Load case 2 : a load equal to 50 % of the F_b is to be applied on the propeller tip area outside of 0.9 R,

(C) Load case 5 : for reversible propellers a load equal to 60% of the F_b, is to be applied from 0.6 R to the tip and from the blade trailing edge to a value of 0.2 chord length.

See load cases 1, 2, and 5 in **Table 1** of **Annex 3-5**

(2) Maximum forward blade force, F_f

when $D < D_{\lim}$, $F_f = 250 \cdot \left[\frac{EAR}{Z}\right] \cdot [D]^2$ (kN)

when $D \geq D_{\lim}$, $F_f = 500 \cdot \left[\frac{1}{(1-\frac{d}{D})}\right] \cdot H_{ice} \cdot \left[\frac{EAR}{Z}\right] \cdot [D]$ (kN)

where,

$D_{\lim} = \left[\frac{2}{(1-\frac{d}{D})}\right] \cdot H_{ice}$ (m)

d = propeller hub diameter (m)

D = propeller diameter (m)

EAR = expanded blade area ratio

Z = number of propeller blades

F_f is to be applied as a uniform pressure distribution to an area on the face(pressure) side of the blade for the following load cases.

(A) Load case 3 : from 0.6 R to the tip and from the blade leading edge to a value of 0.2 chord length,

(B) Load case 4 : a load equal to 50 % of the F_f is to be applied on the propeller tip area outside of 0.9 R,

(C) Load case 5 : for reversible propellers a load equal to 60% of the F_f , is to be applied from 0.6 R to the tip and from the blade trailing edge to a value of 0.2 chord length.

See load cases 3, 4, and 5 in **Table 1** of **Annex 3-5**

(3) Maximum blade spindle torque Q_{smax}

Spindle torque Q_{smax} around the spindle axis of the blade fitting shall be calculated both for the load cases described in (1) & (2) for F_b , F_f. If the spindle torque values are less than the default value given below, the default minimum value shall be used.

Default Value $Q_{smax} = 0.25 \cdot F \cdot c_{0.7}$ (kNm)

where,

$c_{0.7}$ = the length of the blade chord at 0.7 R radius (m)

F is either F_b or F_f which ever has the greater absolute value.

(4) Maximum propeller ice torque applied to the propeller

When $D < D_{\lim}$,

$$Q_{\max} = 105 \cdot \left[1 - \frac{d}{D}\right] \cdot S_{qice} \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot \left[\frac{t_{0.7}}{D}\right]^{0.6} \cdot [nD]^{0.17} \cdot D^3 \quad \text{(kNm)}$$

When $D \geq D_{\lim}$,

$$Q_{\max} = 202 \cdot \left[1 - \frac{d}{D}\right] \cdot S_{qice} \cdot [H_{ice}]^{1.1} \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot \left[\frac{t_{0.7}}{D}\right]^{0.6} \cdot [nD]^{0.17} \cdot D^{1.9} \quad \text{(kNm)}$$

where,

$D_{\lim} = 1.81 \cdot H_{ice}$

S_{qice} = Ice strength index for blade ice torque

$P_{0.7}$ = propeller pitch at 0.7 R (m)

$t_{0.7}$ = max thickness at 0.7 radius

n is the rotational propeller speed, [rps], at bollard condition. If not known, n is to be taken as follows:

Table 3.21.11 The rotational propeller speed at bollard condition value n

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0.85 \cdot n_n$

Where n_n is the nominal rotational speed at MCR, free running condition.
For CP propellers, propeller pitch, $P_{0.7}$ shall correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at MCR free running condition.

(5) Maximum propeller ice thrust applied to the shaft

$$T_f = 1.1 \cdot F_f \quad \text{(kN)}$$

$$T_b = 1.1 \cdot F_b \quad \text{(kN)}$$

4. Design ice loads for ducted propeller

(1) Maximum Backward Blade Force, F_b

when $D < D_{\lim}$, $F_b = -9.5 \cdot S_{ice} \cdot [EAR/Z]^{0.3} \cdot [nD]^{0.7} \cdot D^2$ (kN)

when $D \geq D_{\lim}$, $F_b = -66 \cdot S_{ice} \cdot [EAR/Z]^{0.3} \cdot [nD]^{0.7} D^{0.6} \cdot [H_{ice}]^{1.4}$ (kN)

where,

$D_{\lim} = 4 \cdot H_{ice}$

n is to be taken as in **304. 3** (1)

F_b is to be applied as a uniform pressure distribution to an area on the back side for the following load cases(See **Table 2** of **Annex 3-5**) :

(A) Load case 1 : On the back of the blade from 0.6 R to the tip and from the blade leading edge to a value of 0.2 chord length,

(B) Load case 5 : for reversible rotation propellers a load equal to 60% of the Fb is applied on the blade face from 0.6 R to the tip and from the blade trailing edge to a value of 0.2 chord length,

(2) Maximum forward blade force, F_f

when $D \le D_{\lim}$, $F_f = 250 \cdot \left[\frac{EAR}{Z}\right] \cdot [D]^2$ (kN)

when $D > D_{\lim}$, $F_f = 500 \cdot [EAR/Z] \cdot D \cdot \frac{1}{\left[1-\frac{d}{D}\right]} \cdot H_{ice}$ (kN)

where,

$D_{\lim} = \frac{2}{\left[1-\frac{d}{D}\right]} \cdot H_{ice}$ (m)

F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side for the following load case (see **Table 2** of **Annex 3-5**):

(A) Load case 3 : On the blade face from 0.6 R to the tip and from the blade leading edge to a value of 0.5 chord length

(B) Load case 5 : a load equal to 60% F_f is to be applied from 0.6 R to the tip and from the blade leading edge to a value of 0.2 chord length.

(3) Maximum propeller ice torque applied to the propeller

$Q_{\max}$ is the maximum torque on the propeller due to ice-propeller interaction.

When $D \le D_{\lim}$,

$$Q_{\max} = 74 \cdot \left[1-\frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot \left[\frac{t_{0.7}}{D}\right]^{0.6} \cdot [nD]^{0.17} \cdot S_{qice} \cdot D^3 \text{ (kNm)}$$

When , $D > D_{\lim}$

$$Q_{\max} = 141 \cdot \left[1-\frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot \left[\frac{t_{0.7}}{D}\right]^{0.6} \cdot [nD]^{0.17} \cdot S_{qice} \cdot D^{1.9} \cdot H_{ice}^{1.1} \text{ (kNm)}$$

where,

$D_{\lim} = 1.8 \cdot H_{ice}$ (m)

n is the rotational propeller speed [rps] at bollard condition. If not known, n is to be taken as follows:

Table 3.21.12 The rotational propeller speed at bollard condition value n

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0.85 \cdot n_n$

Where n_n is the nominal rotational speed at MCR, free running condition.
For CP propellers, propeller pitch, $P_{0.7}$ shall correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7 \cdot P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at MCR free running condition.

(4) Maximum blade spindle torque for CP-mechanism design, Q_{smax}
Spindle torque Q_{smax} around the spindle axis of the blade fitting shall be calculated for the load case described in **304. 1.** If the spindle torque values are less than the default value given below, the default value shall be used.

Default Value $Q_{smax} = 0.25 \cdot F \cdot c_{0.7}$ (kNm)

where,

$c_{0.7}$ = the length of the blade section at 0.7R radius (m)

F is either F_b or F_f which ever has the greater absolute value.

(5) Maximum propeller ice thrust (applied to the shaft at the location of the propeller)

$$T_f = 1.1 \cdot F_f$$

$$T_b = 1.1 \cdot F_b$$

5. Design loads on propulsion line

(1) Torque
The propeller ice torque excitation for shaft line dynamic analysis shall be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The torque due to a single blade ice impact as a function of the propeller rotation angle is then

$$Q(\varphi) = C_q \cdot Q_{\max} \cdot \sin(\varphi(180/\alpha_i)) \quad \text{when } \varphi = 0 ... \alpha_i$$

$$Q(\varphi) = 0 \quad \text{when } \varphi = \alpha_i .....360$$

where C_q and α_i parameters are given in table below.

Table 3.21.13 C_q and α_i parameters

Torque excitation	Propeller-ice interaction	C_q	α_i
Case 1	Single ice block	0.5	45
Case 2	Single ice block	0.75	90
Case 3	Single ice block	1.0	135
Case 4	Two ice blocks with 45 degree phase in rotation angle	0.5	45

The total ice torque is obtained by summing the torque of single blades taking into account the phase shift 360 deg./Z. The number of propeller revolutions during a milling sequence shall be obtained with the formula:

$$N_Q = 2 \cdot H_{ice}$$

The number of impacts is $Z \cdot N_Q$

See **Fig 1** in **Annex 3-5**

Milling torque sequence duration is not valid for pulling bow propellers, which are subject to special consideration. The response torque at any shaft component shall be analysed considering excitation torque $Q_{(\Phi)}$ at the propeller, actual engine torque, Q_e, and mass elastic system

Q_e = actual maximum engine torque at considered speed

Design torque along propeller shaft line

The design torque (Q_r) of the shaft component shall be determined by means of torsional vibration analysis of the propulsion line. Calculations have to be carried out for all excitation cases given above and the response has to be applied on top of the mean hydrodynamic torque in bollard condition at considered propeller rotational speed.

(2) Maximum response thrust

Maximum thrust along the propeller shaft line is to be calculated with the formula below. The factors 2.2 and 1.5 take into account the dynamic magnification due to axial vibration. Alternatively the propeller thrust magnification factor may be calculated by dynamic analysis.

Maximum Shaft Thrust Forwards $T_r = T_n + 2.2 \cdot T_f$ (kN)

Maximum Shaft Thrust Backwards $T_r = 1.5 \cdot T_b$ (kN)

T_n = propeller bollard thrust (kN)

T_f = maximum forward propeller ice thrust (kN)

If hydrodynamic bollard thrust, T_n is not known, T_n is to be taken as follows:

Table 3.21.14 Propeller bollard thrust

Propeller Type	T_n
CP propellers (open)	$1.25 \cdot T$
CP propellers (ducted)	$1.1 \cdot T$
FP propellers driven by turbine or electric motor	T
FP propellers driven by diesel engine (open)	$0.85 \cdot T$
FP propellers driven by diesel engine (ducted)	$0.75 \cdot T$

T = nominal propeller thrust at MCR at free running open water conditions

(3) Blade failure load for both open and nozzle propeller

The force is acting at 0.8 R in the weakest direction of the blade and at a spindle arm of 2/3 of the distance of axis of blade rotation of leading and trailing edge which ever is the greatest. The blade failure load is:

$$F_{ex} = \frac{0.3 \cdot c \cdot t^2 \cdot \sigma_{ref}}{0.8 \cdot D - 2 \cdot r} 10^3 \quad \text{(kN)}$$

where,

$\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$

where σ_u and $\sigma_{0.2}$ are representative values for the blade material.

c, t and r (See **Ch.20. 605. Fig.3.20.2** of the Guidance) are respectively the actual chord length, thickness and radius of the cylindrical root section of the blade at the weakest section outside root fillet. And typically will be at the termination of the fillet into the blade profile.

305. Design

1. Design principle

The strength of the propulsion line shall be designed for maximum loads in 304. such that the plastic bending of a propeller blade shall not cause damages in other propulsion line components with sufficient fatigue strength.

2. Azimuthing main propulsors

In addition to the above requirements special consideration shall be given to the loading cases which are extraordinary for propulsion units when compared with conventional propellers. Estimation of the loading cases must reflect the operational realities of the ship and the thrusters. In this respect, for example, the loads caused by impacts of ice blocks on the propeller hub of a pulling propeller must be considered. Also loads due to thrusters operating in an oblique angle to the flow must be considered. The steering mechanism, the fitting of the unit and the body of the thruster shall be designed to withstand the loss of a blade without damage. The plastic bending of a blade shall be considered in the propeller blade position, which causes the maximum load on the studied component.

Azimuth thrusters shall also be designed for estimated loads due to thruster body/ice interaction as per **Sec.2 211.**

3. Blade design

(1) Maximum blade stresses
Blade stresses are to be calculated using the backward and forward loads given in section **304. 3** & **4.** The stresses shall be calculated with recognised and well documented FE-analysis or other acceptable alternative method. The stresses on the blade shall not exceed the allowable stresses σ_{all} for the blade material given below.
Calculated blade stress for maximum ice load shall comply with the following:

$$\sigma_{calc} < \sigma_{all} = \sigma_{ref}/S$$

$S = 1.5$

σ_{ref} is reference stress, defined as:

$\sigma_{erf} = 0.7 \cdot \sigma_u$ or

$\sigma_{ref} = 0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$ which ever is less

Where σ_u and $\sigma_{0.2}$ are representative values for the blade material.

(2) Blade edge thickness
The blade edge thicknesses t_{ed} and tip thickness t_{tip} are to be greater than t_{edge} given by the following formula:

$$t_{edge} \geq xSS_{ice}\sqrt{\frac{3p_{ice}}{\sigma_{ref}}}$$

x = distance from the blade edge measured along the cylindrical sections from the edge and shall be 2.5% of chord length, however not to be taken greater than 45 mm.
In the tip area (above 0.975 R radius) x shall be taken as 2.5% of 0.975 R section length and is to be measured perpendicularly to the edge, however not to be taken greater than 45 mm.

S = safety factor
= 2.5 for trailing edges
= 3.5 for leading edges
= 5 for tip

S_{ice} = according to **304. 2**

p_{iec} = ice pressure
16 MPa for leading edge and tip thickness

σ_{ref} = according above **Par. 3** (1)

The requirement for edge thickness has to be applied for leading edge and in case of reversible rotation open propellers also for trailing edge. Tip thickness refers to the maximum measured thickness in the tip area above 0.975 R radius. The edge thickness in the area between position of maximum tip thickness and edge thickness at 0.975 radius has to be interpolated between edge and tip thickness value and smoothly distributed.

4. Prime movers

(1) The Main engine is to be capable of being started and running the propeller with the CP in full pitch.
(2) Provisions shall be made for heating arrangements to ensure ready starting of the cold emergency power units at an ambient temperature applicable to the polar class of the ship.
(3) Emergency power units should be equipped with starting devices with a stored energy capability of at least three consecutive starts at the design temperature in (2) above. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy shall be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

306. Machinery fastening loading accelerations

1. Essential equipment and main propulsion machinery supports shall be suitable for the accelerations as indicated in as follows. Accelerations are to be considered acting independently.

2. Longitudinal impact accelerations, a_l

Maximum longitudinal impact acceleration at any point along the hull girder,

$$= \left(\frac{F_{IB}}{\triangle}\right)\left\{[1.1\tan(\gamma+\phi)]+\left[7\frac{H}{L}\right]\right\} \quad (\mathrm{m/s^2})$$

3. Vertical acceleration, a_v

Combined vertical impact acceleration at any point along the hull girder,

$$= 2.5\left(\frac{F_{IB}}{\triangle}\right)F_X \quad (\mathrm{m/s^2})$$

F_X = 1.3 at FP
= 0.2 at midships

= 0.4 at AP
= 1.3 at AP for vessels conducting ice breaking astern
intermediate values to be interpolated linearly

4. Transverse impact acceleration, a_t

Combined transverse impact acceleration at any point along hull girder,

$$= 3F_i \frac{F_X}{\triangle} \quad (\mathrm{m/s^2})$$

F_X = 1.5 at FP
= 0.25 at midships
= 0.5 at AP
= 1.5 at AP for vessels conducting ice breaking astern
intermediate values to be interpolated linearly

where,

ϕ : maximum friction angle between steel and ice, normally taken as 10° [deg.]

γ : bow stem angle at waterline [deg.]

$\triangle$: displacement

L : length between perpendiculars (m)

H : distance in meters from the water line to the point being considered (m)

F_{IB}: vertical impact force, defined in **Sec.2 209. 2**

F_I : total force normal to shell plating in the bow area due to oblique ice impact, defined in **Sec.2 209. 3**

307. Auxiliary systems

1. Machinery shall be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means should be provided to purge the system of accumulated ice or snow.

2. Means should be provided to prevent damage due to freezing, to tanks containing liquids.

3. Vent pipes, intake and discharge pipes and associated systems shall be designed to prevent blockage due to freezing or ice and snow accumulation.

308. Sea chest and cooling water systems

1. Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chests inlets, shall be designed for the environmental conditions applicable to the ice class.

2. At least two sea chests are to be arranged as ice boxes for class PC1 to PC5 inclusive where. The calculated volume for each of the ice boxes shall be at least 1 m^3 for every 750 kW of the total installed power. For PC6 and PC7 there shall be at least one ice box located preferably near center line.

3. Ice boxes are to be designed for an effective separation of ice and venting of air.

4. Sea inlet valves are to secured directly to the ice boxes. The valve shall be a full bore type.

5. Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected direct to the shell.

6. Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load water line.

7. Efficient means are to be provided to re-circulate cooling seawater to the ice box. Total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

8. Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

9. Openings in ship sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm. Gratings of the ice boxes are to be provided with a means of clearing. Clearing pipes are to be provided with screw-down type non return valves.

309. Ballast tanks

1. Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the water line and where otherwise found necessary.

310. Ventilation systems

1. The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship.

2. Accommodation and ventilation air intakes shall be provided with means of heating.

3. The temperature of inlet air provided to machinery from the air intakes shall be suitable for the safe operation of the machinery.

311. Alternative design

1. As an alternative a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme. ⚓

CHAPTER 22 VESSELS FOR POLAR AND ICE BREAKING SERVICE

Section 1 General

101. Classification

1. The requirements in this section apply to ships containing icebreakers and to passenger and cargo vessels intended to operate unassisted in ice-infested waters of sub-Arctic, Arctic and/or Antarctic regions.

2. Vessels intended for ice breaking as their main purpose and built in compliance with the following requirements may be given one of the class notations Icebreaker ICE05 (or 10 or 15) for ICE class vessels, or Icebreaker PL10 (or 20 or 30) for POLAR class vessels, whichever is relevant.
Vessels built for another main purpose, while also intended for ice breaking, may be given the additional class notation ICE05 (or 10 or 15) or the notation PL10 (or 20 or 30).

3. Arctic class vessels intended for special services where intermediate ice condition values are relevant may, upon special consideration, be given intermediate notations (e.g. PL25).

4. For POLAR class vessels the design ambient air temperature on which the classification has been based will be given the special feature notation DAT(-x°C) The highest temperatures to be applied for year round operations are stated in **201.** For Arctic and/or Antarctic operations with area and seasonal restrictions higher design ambient air temperatures may be accepted as basis for the classification.

5. For vessels with the class notation Icebreaker, and for other POLAR class vessels the maximum operational speed on which the ramming design requirements have been based will be stated in the "Appendix to the classification certificate". The operational speed is in no case to be taken as smaller than stated in **103.** for the various class notations.

102. Scope

1. The following matters are covered by the classification:

- materials in structures exposed to low ambient air temperature
- subdivision, intact and damage stability
- hull girder longitudinal and transverse strength
- local hull structures exposed to ice loads
- rudders and steering gears
- propellers and propulsion machinery
- sea suctions for cooling water
- air starting systems

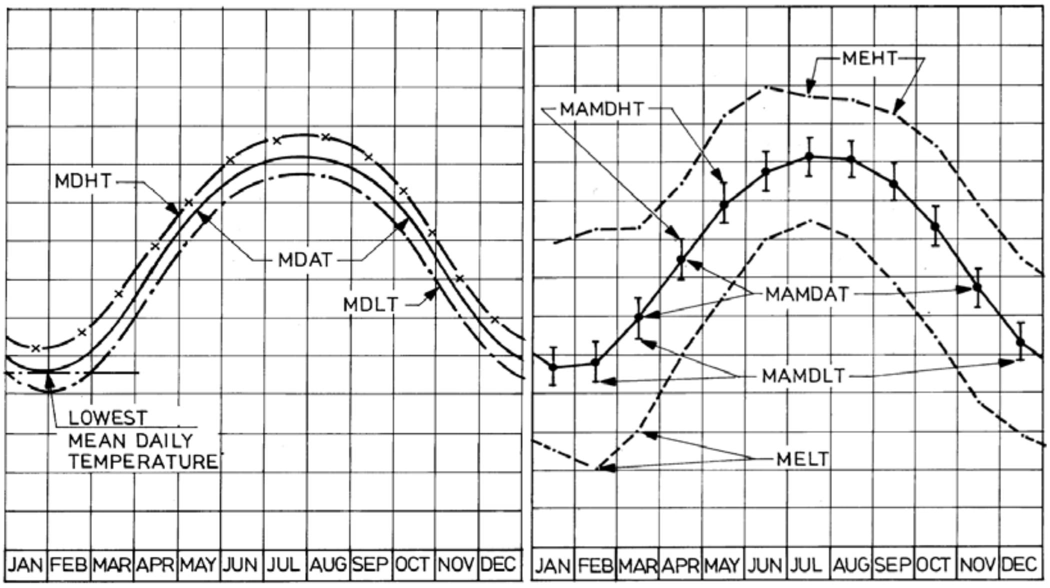


Fig 3.22.1 Commonly used definitions of temperatures

MDHT Mean daily high (or maximum) temperature
MDAT Mean daily average temperature
MDLT Mean daily low (or minimum) temperature
MAMDHT Monthly average of MDHT
MAMDAT Monthly average of MDAT
MAMDLT Monthly average of MDLT
MEHT Monthly extreme high temperature (ever recorded)
MELT Monthly extreme low temperature (ever recorded)
Mean: Statistical mean over observation period (at least 20 years).
Average: Average during one day and night.

103. Design principles and assumptions

1. Each class notation is related to a particular ice condition that the vessel is expected to encounter. Relevant design ice conditions are as given in **Table 3.22.1**. In case intermediate ice conditions are relevant (see **101. 3.**), nominal ice strength is to be related to the selected nominal ice thickness.

2. Vessels with the class notation Icebreaker, and other POLAR class vessels are expected to encounter pressure ridges and other ice features of significantly greater thickness than the average thicknesses specified in **Table 3.22.1**. Vessels with the class notation PL only are assumed not to make repeated ramming attempts if the ice fails to break during the first (accidental) ram unless the vessel's speed is kept well below the design ramming speed. Vessels with class notation Icebreaker may make several consecutive attempts to break the ice at maximum ramming speed. The design speed in ice infested waters when ramming may occur, V_{RAM}, is to be specified by the builder. In general this speed is not to be taken less than:

$$V_{RAM} = V_B + V_H \quad \text{(m/s)}$$

V_B = specified continuous speed, when breaking maximum average ice thickness

V_B = speed addition in thinner ice

= h_{ice} (see **Table 3.22.1**).

In no case the design ramming speed is to be taken less than:

V_{RAM} (minimum)

= 2.0 m/s (3.9 knots) for the notation PL10

= 3.0 m/s (5.8 knots) for the notation PL20

= 4.0 m/s (7.8 knots) for the notation PL30.

For vessels with the class notation Icebreaker the minimum speed is 2 m/s (3.9 knots) but not less than 1.5 times the speed specified above when POLAR class notation is also specified.

104. Definitions

1. General symbols and terms are also given in **Ch. 1.**

2. Symbols

L = rule length in **Ch. 1**

B = rule breadth in **Ch. 1**

D = rule depth in **Ch. 1**

T = rule draught in **Ch. 1**

$\triangle$ = rule displacement in **Ch. 1**

C_B = block coefficient in **Ch. 1**

$\triangle_f$ = displacement in t in fresh water (density 1.0 t/m^3) at ice class draught

P_s = maximum continuous output of propulsion machinery in kW

g_0 = standard acceleration of gravity ($\approx$ 9.81 m/s^2).

V_{RAM} = design speed in m/s when ramming may occur, see also **103. 2.**

σ_{ice} = nominal strength of ice in N/mm^2, see **Table 3.22.1**

h_{ice} = average ice thickness in m, see **Table 3.22.1**

E_{KE} = vessel's kinetic energy before ramming

= $1/2\triangle(V_{RAM})^2$ (kNm)

a, γ = bow shape angles, see **Fig 3.22.2**

C_{WL} = vessel's water line area coefficient on UIWL

s = stiffener spacing in m, measured along the plating.
Stiffener web thickness may be deducted

l = stiffener span in m, measured along the top flange of the member. For determining the section modulus and shear area of the stiffener, the depth of stiffener on crossing panel and 2/3 of the arm length of end bracket(s) (except at simply supported ends) may be deducted when deciding the span.
For curved stiffeners l may be taken as the chord length

S = girder span in m. The web height of in-plane girders may be deducted

t = rule thickness of plating in mm

t_k = corrosion addition in mm

t_w = rule web thickness in mm

Z = rule section modulus in cm^3

A_W = rule web area in cm^2, defined as the web thickness times the web height including thickness of flanges

A = rule cross-sectional area in cm^2

σ_y = minimum upper yield stress of material in N/mm^2. A steel may be taken as having σ_y = 235 N/mm^2

σ = nominal allowable bending stress in N/mm^2 due to lateral pressure

τ = nominal allowable shear stress in N/mm^2

UIWL(upper ice waterline) = the deepest waterline at which the ship is intended to operate in ice irrespective of water salinity.

LIWL(lower ice waterline) = the lowest waterline at which the ship is intended to operate in ice.

All design loading conditions in ice, including trim, shall be within the draught envelop limited by the UIWL and LIWL. The lower ice waterline should further be determined with due regard to the vessel's ice-going capability in the ballast loading conditions (e.g. propeller submergence).

Table 3.22.1 Ice conditions

Class notation	Type of ice encountered	Nominal ice strength σ_{ice}(N/mm^2)	Nominal ice thickness h_{ice}(m)	Limiting impact conditions
ICE-05 ICE-10 ICE-15	Winter ice with pressure ridges	4.2 5.6 7.0	0.5 1.0 1.5	No ramming anticipated
PL10 PL20 PL30	Winter ice with pressure ridges and multi-year ice-floes and glacial ice inclusions	7.0 8.5 10.0	1.0 2.0 3.0	Accidental ramming
Icebreaker	As above	As above	As above	Repeated ramming

3. External structure is defined, with respect to design temperature, as the plating with stiffening to a distance of 0.5 m from the shell plating, exposed decks and exposed sides and ends of superstructure and deckhouses.

4. Temperature terms (see also **Fig 3.22.1**):

Design temperature is a reference temperature used as a criterion for the selection of steel grades. The design temperature for external structures is defined as the lowest mean daily average air temperature in the area of operation. This temperature is considered to be comparable with the lowest monthly mean temperature in the area of operation -2 ℃. If operation is restricted to "summer" navigation the lowest monthly mean temperature comparison may only be applied to the warmer half of the month in question. The corresponding extreme low temperature is generally considered to be 20 ℃ lower than the design temperature.

Mean daily average temperature is the statistical mean average temperature for a specific calendar day, based on a number of years of observations (= MDAT).

Monthly mean temperature is the average of the mean daily temperature for the month in question (= MAMDAT).

Lowest mean daily temperature is the lowest value on the annual mean daily temperature curve for the area in question. For seasonally restricted service the lowest value within the time of operation applies.

Lowest monthly mean temperature is the monthly mean temperature for the coldest month of the year.

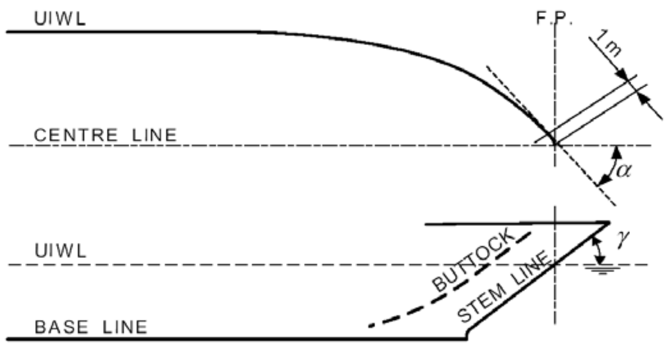


Fig 3.22.2 Bow shape angles

5. The hull structure (shell plating with stiffening) to be reinforced against local ice loads is divided into 7 different areas. The areas are defined as follows (see also **Fig 3.22.4**):

Bow area

Longitudinally from stem to a line parallel to and 0.04 L aft of the border line of flat side of hull forward. If the hull breadth is increased over a limited length forward of the flat side the bow area need normally not extend aftwards beyond the widest section of each waterline.

The bow area need not extend aftwards beyond 0.3 L from the forward perpendicular.

Vertically from a line defined by a distance z_{lm} below LIWL (aft) and the intersection between the keel line and the stem line (forward) to a line defined by the distances z_{ua} (aft) and z_{uf} (forward) above UIWL. For ships with an ice knife fitted, the line of the lower vertical extension may be drawn to a point 0.04 L aft of the upper end of the knife and further down to the base line (see also **Fig 3.22.3**).

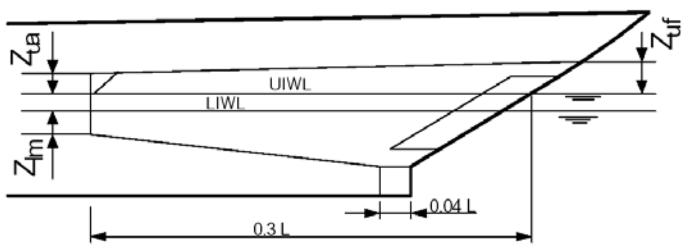


Fig 3.22.3 Extension of bow area

Stem area

The part of the bow area between the stem line and a line 0.06 L aft of the stem line or 0.125 B outboard from the centre line, whichever is first reached.

Vertically from a line defined by a distance z_{la} below LIWL, to a line defined by a distance z_{ua} above UIWL.

Midship area

Longitudinally from the stem area to the bow area.

Vertically from a line defined by a distance z_{lm} below LIWL, to a line defined by a distance z_{ua} above UIWL.

Bottom area

Longitudinally aft of 0.3 L from F.P. and transversely over the flat bottom including deadrise. For ships with bow ice knife, the bottom area may be extended forward to the ice knife.

Lower transition area

Transition area between the bottom area and the adjacent stern and midships areas respectively.

Stern area

Longitudinally from the stern to a line parallel to and 0.04 L forward of the border line of flat side of hull aft, or to a line 0.2 L aft of midships, whichever is the aftermost.

Vertically from a line defined by a distance z_{la} below LIWL, to a line defined by a distance z_{ua} above UIWL.

Lower bow area

The area below the bow area.

Values of z_{la}, z_{lm}, z_{ua} and z_{uf} are given for various class notations in **Table 3.22.2.**

Table 3.22.2 Vertical extent of ice reinforced areas

Class notation	Parameters for vertical extent (m)			
	z_{la}	z_{lm} 1)	z_{ua}	z_{uf}
ICE-05	1.7	1.1	0.8	1.5
ICE-10	2.2	1.6	1.0	2.0
ICE-15	4.6	3.7	1.9	2.5
PL10	2.9	2.3	1.4	2.2
PL20	6.0	4.6	2.8	3.7
PL30	11.9	9.2	4.2	5.2
1) z_{lm} (maximum) =	the vertical distance from the LIWL to the point on the frame contour amidships where the tangent is at 45 degrees.			

105. Documentation

1. UIWL and LIWL as well as the border line of flat side are to be indicated on the shell expansion plan together with the ice reinforced areas as given in **Fig 3.22.4.**

2. Maximum design ramming speed (V_{RAM}) in ice infested waters as well as design speed for continuous ice breaking operations (V_B) are to be stated on the midship section plan for ships with class notations PL or Icebreaker.

3. For documentation in connection with stability and watertight integrity, see **Sec 12.**

4. Applicable special limitations to the operation of the vessel in ice infested waters are to be stated in the ship's loading manual.

Possible limitations are:
- allowable draughts, maximum and minimum
- loading conditions with respect to strength and stability
- ambient temperature
- design speed
- ramming speed
- instruction for filling of ballast tanks
- astern operation in ice.

5. Where ice exposed plating is fitted with a special wear addition, the plate thickness including wear addition is to be given on the shell expansion plan in addition to the net thickness required by the rules.

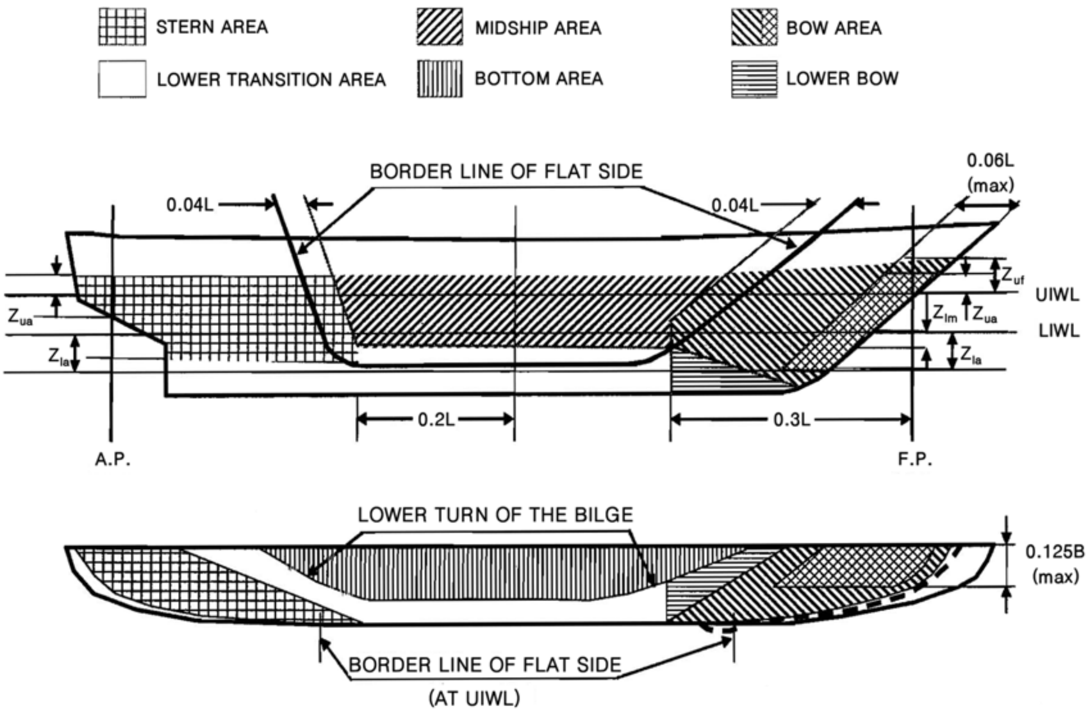


Fig 3.22.4 Ice reinforced areas

106. Marking and on board documentation

1. The maximum and minimum ice class draughts fore, amidships and aft shall be indicated in the 'Classification Certificate'.

2. If the "Summer Load Line" in fresh water is located at a higher level than the UIWL, ice class notation shall explicitly include the maximum amidships draughts. For such ships, the ship sides shall be provided with a warning triangle and with ice class draught marks at maximum permissible amidships draughts, see **Ch 20, Sec 2, 202. 1.**

3. For vessels not having load line markings, the warning triangle and ice draught mark is to be vertically aligned with the draught mark. The warning triangle is to be placed 1,000 mm above the draught mark, but in no case above the deck line.

Section 2 Materials and Corrosion Protection

201. Design temperatures

1. Steel grades to be used in hull structural members are to be determined based on the design temperature for the structure in question.

2. For PL class notation steel grades in exposed structures are to be based on air temperatures lower than those generally anticipated for world wide operation. Unless a service restriction notation is also given, limiting the navigation to specified areas and/or time of year, the design temperature is not to be taken higher than -30 °C (corresponding extreme low temperature -50 °C)

For operation in lower design temperature, this must be clearly specified.

3. For ICE class notation, no special consideration for low ambient air temperature are given unless specified by the builder.

202. Structural categories

1. Structural strength members or areas are classified in 4 different classes for the purpose of selecting required material grades. The classes are generally described as follows:

Class IV:
- Strakes in the strength deck and shell plating amidships intended as crack arrestors.
- Highly stressed elements in way of longitudinal strength member discontinuities.

Class III:
- Plating chiefly contributing to the longitudinal strength amidships.
- Fore ship substructures in vessels with notation Icebreaker and PL.
- Aft ship substructures in vessels equipped with podded propulsors and azimuth thrusters, and intended for continuous astern operation.
- Foundations and support structures for heavy machinery and equipment, including crane pedestals.
- Frames for windlass, emergency towing and chain stopper.

Class II:
- Structures contributing to longitudinal and/or transverse hull girder strength in general.
- Appendages of importance for the main functions of the vessel. Stern frames, rudder, propeller nozzels and shaft bracket. (To be class III for vessels with notations ICE, Icebreaker or PL)
- Gutter bars of oil spill coamings that attached to hull.
- Structures for subdivisions.
- Structures for cargo, bunkers and ballast containment.
- Internal members (stiffeners, girders) on plating exposed to external low temperatures where class III and IV is required.

Class I:
- Local members in general unless upgraded due to special considerations of loading rate, level and type of stress, stress concentrations and load transfer points and/or consequences of failure.
- Deckhouse structure not exposed to longitudinal stresses.
- Cargo hatch covers.

2. Hull girder plating in vessels of conventional design is normally classified as specified in **Table 3.22.3.**

3. The material class requirement may be reduced by one class for:
- laterally loaded plating having a thickness exceeding 1.25 times the requirement according to design formulas,
- laterally loaded stiffeners and girders having section modulus exceeding 1.5 times the requirement according to design formulas

4. Structural materials for stern frames, rudder horns, rudders and shaft brackets are not to be of lower grades than corresponding to class III.

Table 3.22.3 Classification of longitudinal and transverse strength members, plating

Structural member	Within 0.4 L amidships (Within 0.2 L aft of amidships and 0.3 L forward of amidships in vessels with notation Icebreaker or PL)	Elsewhere
Deck plating exposed to weather, in general Side plating Longitudinal bulkhead plating, in general Transverse bulkhead plating	II	I
Bottom plating including keel plate Strength deck plating 2) Continuous longitudinal members above strength deck excluding longitudinal hatch coamings Upper strake in longitudinal bulkhead Upper strake in top wing tank	III 5)	II
Sheer strake at strength deck 6) Stringer plate in strength 6) deck Deck strake at longitudinal bulkhead 1) Bilge strake 3) Continuous longitudinal hatch coamings 7)	IV	III 4)

1) In ships with breadth exceeding 70 m at least three deck strakes are to be class IV amidships.
2) Plating at corners of large hatch openings is to be specially considered. Class IV is to be applied in positions where high local stresses may occur.
3) May be of class III amidships in ships with a double bottom over the full breadth and with length less than 150 m.
4) May be class II outside 0.6 L amidships.
5) May be class II if relevant midship section modulus as built is not less than 1.5 times the rule midships section modulus, and the excess is not credited in local strength calculations.
6) Not to be less than grade E, EH32, EH36 and EH40 within 0.4 L amidships in ships with length exceeding 250 m.
7) Not to be less than grade D, DH32, DH36 and DH40.

(Note) Single strakes required to be of class IV or of grade E, EH32, EH36 and EH40 and within 0.4 L amidships are to have breadths not less than (800+5 L) mm, maximum 1,800 mm, unless limited by the geometry of the ship's design.

203. Selection of steel grades

1. Plating materials for various structural categories as defined in **202.** of exposed members above the ballast waterline of vessels with class notation PL are not to be of lower grades than obtained from **Fig 3.22.5** using the specified design temperatures.
Plating materials of non-exposed members are not to be of lower grade than obtained according to **Rule Ch 1, Table 3.1.5**.

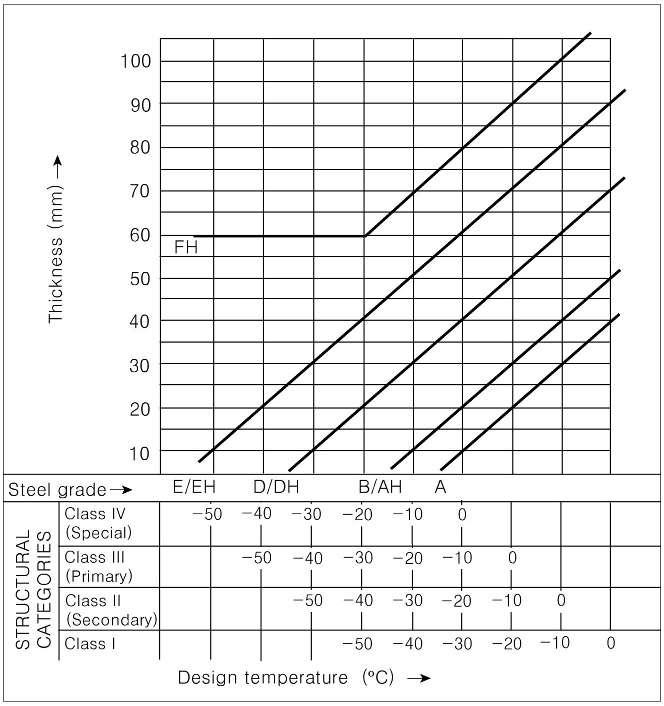


Fig 3.22.5 Required steel grades

Guidance note :

When the structural category is known, the material grade can be selected based on the design temperatures and plate thickness. As an example, when 30 mm plate should be applied for structural category III with a design temperature of -30°C, grade E, EH32, EH36 and EH40 are to be applied.

2. Forged steel or cast steel in structural members subjects to design temperatures lower than -10°C shall be impact tested at 5°C below the design temperature.

204. Coatings

1. Wear resistant coating is assumed used for the external surfaces of plating in ice reinforced areas.

205. Corrosion additions

1. Hull structures are in general to be given a corrosion addition t_k as required by the main class, see **Table 3.22.4**.

Table 3.22.4 Corrosion addition t_k

Compartment	Structure	
	Shell plating (mm)	Internal structure (mm)
Ballast tank	1.0	1.5
Dry cargo hold which may be used as ballast tank	0.5	1.0
Dry compartment	0.0	0.0

206. Equipment

1. Structural materials in windlasses (when exposed) are to be of class III. Design temperature to be

-20°C for PL class notations, 0°C elsewhere.

Section 3 Ship Design and Arrangement

301. Hull form

1. The bow is to be shaped so that it can break level ice effectively and at continuous speed, up to a thickness as indicated in **Table 3.22.1** for the various class notations.

2. Vessels with class notation Icebreaker, and other POLAR class vessels are to have a bow shape so that the bow will ride up on the ice when encountering pressure ridges or similar ice features that will not break on the first ramming.

3. Masts, rigging, superstructures, deck houses and other items on deck are to be designed and arranged so that excessive accumulation of ice is avoided. The rigging is to be kept at a minimum, and the surfaces of erections on deck are to be as even as possible.

4. Weathertight doors are to be suitably designed for use in low temperature environment with respect to:

- strength of cleats and the choice of steel with adequate ductility
- flexibility of packing material
- ease of maintenance, e.g. interior accessible grease fittings
- ease of operations, e.g. low weight and preference to central handwheel operated cleats.

5. Air pipe closures are to be designed so that icing or freezing will not make them inoperable.

6. Freeing ports are to be designed so that blocking by ice is avoided as far as possible and so that they are easily accessible for removal of ice should blocking occur.

302. Appendages

1. In vessels with class notation Icebreaker and in other POLAR class vessels an ice knife may be required forward to avoid excessive beaching and submersion of the deck aft. This requirement will be based on consideration of design speed and freeboard, and may result in additional requirements regarding accelerations and strength.

2. Ice horns are to be fitted directly abaft each rudder in such a manner that:

- the upper edge of the rudder is protected within two degrees to each side of midposition when going astern, and
- ice is prevented from wedging between the top of the rudder and the vessel's hull.

303. Mooring equipment

1. The housing arrangement for anchors is to be designed so that possible icing will not prevent the anchor from falling when released.

Section 4 Design Loads

401. Ice impact forces on the bow

1. The vertical design force component due to head on ramming (not applicable to vessels with class notation ICE only) is given by:

$$P_{ZR} = P_R F_{EL} \quad \text{(kN)}$$

$$P_R = 28\left(\frac{C_R E_{IMP}}{\tan\gamma}\right)^{0.6}(\sigma_{ice}\tan\alpha)^{0.4} \quad \text{in general}$$

For spoon bows :

$$\tan\alpha = 1.2\frac{B^{0.1}}{\sqrt{\cos\gamma}}$$

$$E_{IMP} = E_{KE}\frac{\tan^2\gamma}{\tan^2\gamma + 2.5}$$

$$F_{EL} = \sqrt{\frac{E_{IMP}}{E_{IMP} + C_L P_R{}^2}}$$

$$C_L = \frac{L^3}{3\times 10^{10} I_V}$$

C_R = 1 for the class notation **PL** only

= 2 for the class notation Icebreaker

E_{KE}, σ_{ice} , α and γ as defined in **104.**

L as defined in **104.**

I_V = moment of inertia in m^4 about the horizontal neutral axis of the midship section.

2. The total design force normal to the shell plating in the bow area due to an oblique impact with an ice feature is given by:

$$P_{OI} = \frac{P_{ZR}F_{SIDE}}{\cos\gamma} \quad \text{(kN)}$$

$$F_{SIDE} = \frac{1.9}{(\tan\alpha)^{0.4}}\left(\frac{\sigma_{ice}}{E_{KE}}\right)^{0.05} \quad \text{in general}$$

$$\tan\alpha = 1.2\frac{B^{0.1}}{\sqrt{\cos\gamma}} \quad \text{for spoon shaped bows}$$

P_{ZR} = vertical ramming load as given in **401. 1.**

L, B, E_{KE}, σ_{ice} , α and γ as defined in **104.**

402. Beaching forces

1. The vertical design force resulting from beaching on a large ice feature (not applicable to vessels with class notation ICE only) is in general given by :

$$P_{ZB} = G_B\sqrt{k_b E_{KE} L B} \quad \text{(kN)}$$

$$G_B = \sqrt{\frac{C_{WL}(C_{WL} - 0.5)}{(C_{WL} + 1)}}$$

$k_b = 2g_0(1 - r_{fw})$

r_{fw} = reduction factor due to energy lost in friction and waves

= 0.3.

E_{KE}, σ_{ice}, C_{WL}, γ, α, L, B and g_0 as defined in **104.**

2. For vessels with vertical ram bow the vertical design force in beaching need not be taken larger than :

$$P_{ZB} = \frac{10.6 C_{WL} B L X \tan\gamma}{1 + 15[0.55 - (X/L)]^2} \quad \text{(kN)}$$

X = horizontal distance from FP_{ICE} to centre of vertical ram bow in m

FP_{ICE} = intersection point of stem line and deepest ice-breaking waterline

C_{WL} = waterline area coefficient.

L and B as defined in **104.**

403. Ice compression loads amidships

1. All vessels are to withstand line loads acting simultaneously in the horizontal plane at the water level on both sides of the hull. These loads are assumed to arise when a vessel is trapped between moving ice floes.

2. The design line loads are to be taken as:

$$q = \frac{165}{\sin\beta}(h_{ice})^{1.5} \quad \text{(kN/m)}$$

h_{ice} = average ice thickness as defined in **104.**

β = angle of outboard flare at the waterlevel. Need not to be taken as less than 10 degrees.

404. Local ice pressure

1. All vessels are to withstand local ice pressure as defined for the different ice class notations and as applied to the different ice reinforced areas. The design pressure is to be applied over a corresponding contact area reflecting the type of load in question.

2. The basic ice pressure is in general to be taken as:

$$p_0 = 1{,}000 F_A \sigma_{ice} \quad (\text{kN/m}^2)$$

F_A = correction factor for ice reinforced area in question
= 1.0 for bow and stem area in general
= 0.6 for midship area in general
= 0.5 for midship area if ship breadth in bow area larger than ship breadth in midship area
= 0.2 for bottom area of vessels with notation Icebreaker or PL
= 0.1 for vessels with notation ICE only
= 0.6 for stern area in general
= 0.8 for stern area in ships with class notation Icebreaker
= 1.0 for the stern area in ships with the class notation Icebreaker or PL, 0.8 for ships with ICE notations, fitted with pod and or thruster propulsion units and designed for continuous astern operation. The stern area structure shall in general be dimensioned as outlined for bow structure.

For the transition areas 2/3 of the F_A -value for the adjacent area above may be used in general.

σ_{ice} as defined in **104.**

3. The design pressure is in general to be taken as:

$$p = F_B p_o \quad (\text{kN/m}^2)$$

F_B = correction factor for size of design contact area A_C

= $\frac{0.58}{(A_C)^{0.5}}$ for $A_C \le 1.0$ m^2

= $\frac{0.58}{(A_C)^{0.15}}$ for $A_C > 1.0$ m^2

A_C = h_o w (m^2)

h_o = h in general

= s, maximum for longitudinals

= l, maximum for non-longitudinal frames

= 1.4 l, maximum for connection area of non-longitudinal frames

= S, maximum for girders supporting longitudinals

= l, maximum for stringers supporting non-longitudinal frames

h = effective height of contact area in m

= 0.4 h_{ice} (m) in general

= 0.64 h_{ice} (m) in the stern area; for vessels with notation PL or Icebreaker, with pod or thruster propulsion units, and the assumed capability of continuous operation astern

= 0.8 h_{ice} (m) in stem area in general

= $\left(\frac{P}{645\,\sigma_{ice}}\right)^{0.6}\left(\frac{\tan^2\gamma + \tan^2\alpha}{\tan\alpha}\right)^{0.5}$

in stem area for vessels with class notation PL or Icebreaker

= 0.8 h_{stem}(m) in bow area outside stem area

h_{stem} = h as given for stem area.

For spoon bows : $\tan\alpha = 1.2\frac{B^{0.1}}{\sqrt{\cos\gamma}}$

P = the largest of P_{ZR} and P_{ZB} as given in **401.** and **402.**

w = critical width of contact area in m

= l for longitudinals

= s for non-longitudinal frames

= 1.4 l for connection area for longitudinals

= l for vertical girders supporting longitudinal main frames

= S for stringers supporting vertical main frames.

l, S, α and γ as defined in **104.**

The relations are illustrated in **Fig 3.22.6.**

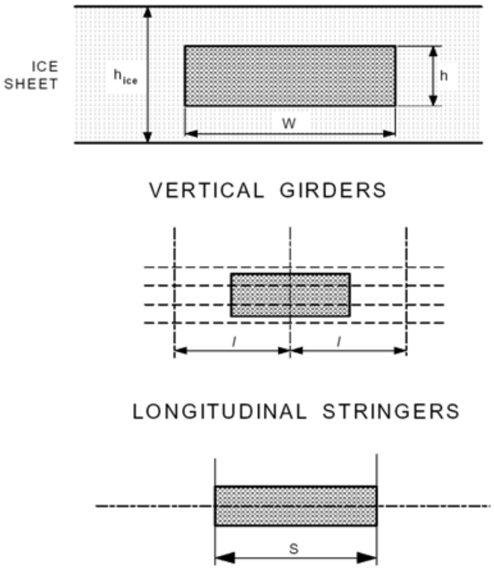


Fig 3.22.6 Design contact areas

405. Accelerations

1. Substructures, equipment and supporting structures are to withstand accelerations arising as a result of impacts with ice features.

2. The combined vertical acceleration at any point along the hull girder (not applicable to vessels with class notation ICE only) may be taken as:

$$a_V = \frac{2.5\,P_{ZR}}{\triangle} F_X \quad (\mathrm{m/s^2})$$

F_X = 1.3 at F.P.
= 0.1 at midships
= 0.4 at AP.

Linear interpolation is to be applied between specified positions.

P_{ZR} as derived in **401.**

$\triangle$ as defined in **104.**

a_v does not include the acceleration of gravity.

3. The combined transverse acceleration at any point along the hull girder may be taken as:

$$a_t = \frac{3\,P_{OI}}{\triangle} F_X \quad (\mathrm{m/s^2})$$

F_X = 1.5 at F.P.
= 0.25 at midships
= 0.5 at AP.

Linear interpolation is to be applied between specified positions

P_{OI} as derived in **401.**

$\triangle$ as defined in **104.**

4. The maximum longitudinal acceleration is taken to be the same at any point along the hull girder.

$$a_l = \frac{1.1 P_{ZR} \tan(\gamma + \phi)}{\triangle} + \frac{7 P_{ZR} H}{\triangle L} \quad (\text{m/s}^2)$$

ϕ = maximum friction angle (between steel and ice), normally taken as 10°

H = distance in m from lowest waterline to position considered.

P_{ZR} as derived in **401.**

$\triangle$, γ as defined in **104.**

Section 5 Global Strength

501. General

1. Hull girder shear forces and bending moments as stipulated in this subsection are to be combined with relevant stillwater conditions as stipulated for the main class. Wave load conditions as stipulated for the main class need not be regarded as occurring simultaneously with the shear forces and bending moments resulting from ramming and beaching.

2. The shear forces and bending moments are to be regarded as the design values at probability level equivalent to the maximum load in a service life of 20 years.

3. In addition to the maximum stress requirements given in this subsection, individual elements are to be checked with respect to buckling under the ramming and beaching load conditions, according to accept criteria as stipulated for the main class.

502. Longitudinal strength

1. The following requirements are applicable to vessels with class notation Icebreaker and other POLAR class vessels(i.e. not to vessels with class notation ICE only).

2. The design vertical shear force at any position of the hull girder due to ramming and/or beaching is given by:

$$Q_{ICE} = k_{iq} P \quad (\text{kN})$$

k_{ip} = 0.4 at F.P.

= 1.0 between 0.05L and 0.1 L from F.P.

= 0.4 between 0.7L and 0.2 L from A.P. 0.0 at AP.

= 0.0 at A.P.

Between specified positions k_{iq} is to be varied linearly. Values of k_{iq} may also be obtained from **Fig 3.22.7**.

P = P_{ZR} as given in **401.** or

= P_{ZB} as given in **402.** whichever is the greater.

The thickness requirements for side shell and possible longitudinal bulkhead platings are to be calculated for different cargo and ballast conditions as stipulated in **Ch 3, Sec 3** replacing Q_W with Q_{ICE} as calculated above.

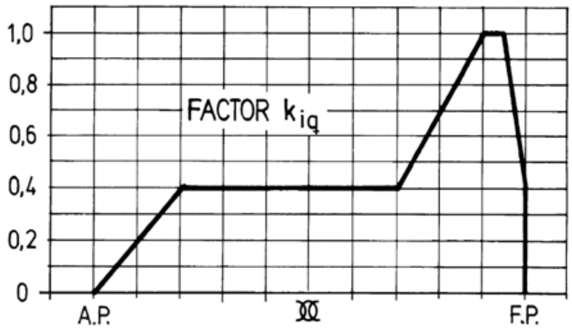


Fig 3.22.7 Distribution of vertical shear force due to ramming and beaching

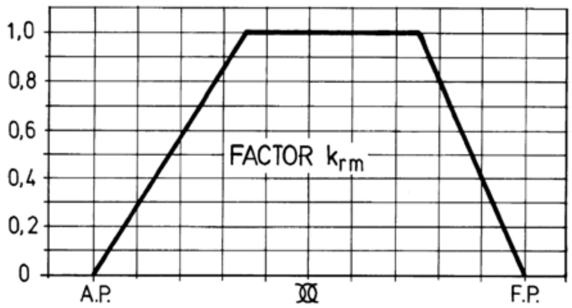


Fig 3.22.8 Distribution of vertical bending moment due to ramming

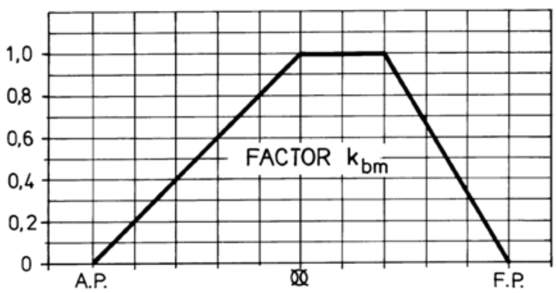


Fig 3.22.9 Distribution of vertical bending moment due to beaching

3. The design vertical sagging bending moment at any position of the hull girder due to ramming and/or beaching is given by:

$M_{ICE\,S} = 0.25\,k_{im}\,P\,L$ (kNm)

k_{im} = 0.0 at F.P. and A.P.

= 1.0 between 0.25 L from F.P. to 0.35 L from A.P. for ramming load condition

= 1.0 between 0.3 Land 0.5 L from F.P. for beaching load condition.

Between specified positions k_{im} is to be varied linearly. Values of k_{im} may also be obtained from **Fig 3.22.8** and **Fig 3.22.9** for ramming and beaching load conditions respectively.

P = P_{ZR} or P_{ZB} as given in **401.** or **402.** for ramming and beaching load conditions respectively.

L as defined in **104.**

4. The design vertical hogging bending moment at any position of the hull girder due to vibration following the initial ramming is given by:

$$M_{ICE\,H} = 0.6\,M_{ICE\,SR} \quad \text{(kNm)}$$

$M_{ICE\,SR}$ = as given in **3.** for ramming load condition.

5. The section modulus requirement about the transverse neutral axis is given by:

$$Z = \frac{M_S + M_{ICE}}{0.7\sigma_y} 10^3 \quad (\text{cm}^3)$$

M_S = design stillwater bending moments according to **Rules Ch 3, Sec 2.**

M_{ICE} design bending moment due to ramming and/or beaching, see **3.** and **4.**

The most unfavourable combinations of stillwater and ramming bending moments are to be applied.

σ_y = yield stress as defined in **104.**

6. The buckling strength of longitudinal strength members in bottom, side and deck as well as longitudinal bulkheads subject to compressive and/or shearing loads is to be checked according to **Rules Ch 3, Sec 4**.

503. Transverse strength amidships

1. The line loads specified in **403.** are to be applied at different water levels including UIWL and LIWL as found necessary depending on the structural arrangement of the vessel.

2. The line loads are to be applied over one full hold/tank length or as found necessary to assess the structural strength of transverse bulkheads and decks supporting the ice reinforced regions.

3. The calculations of transverse strength amidships are to be based on the most severe realistic combination of ice compression loads and static load conditions.

4. Recognised structural idealisation and calculation methods are to be applied. Effects to be considered are indicated in **Annex 3-2.**

5. The calculated stresses are not to exceed allowable stresses as stipulated in **Annex 3-2.**

504. Overall strength of substructure in the foreship

1. The total impact forces as stipulated in D100 may have a decisive effect on primary structural systems in the foreship. The loads are assumed to be evenly distributed in such a manner that local pressures will not exceed those stipulated for local members directly exposed to the load as given in **404. 2.**

2. The design ramming load (not applicable to vessels with class notation ICE only) taken as

$$P_{ZR} / \cos\gamma$$

is to be applied with its center on the stem line at the water line forward. The most unfavourable design draught forward is to be assumed with regard to positioning of the load.

3. The design bow side impact load taken as P_{OI} should be positioned at various positions within bow side area considered critical for the overall strength of the substructure.

Such parts of the bow side area which are aft of the border line of the flat side need normally not be considered with respect to P_{OI}.

4. Recognised structural idealisation and calculation methare to be applied. Effects to be considered are indicated in **Annex 3-2.**

5. The equivalent stress as defined in **Annex 3-2.** is not to exceed σ_y. This is normally achieved for girder type members when the bending stress is not exceeding 0.9 σ_y and the mean shear stress over a web cross-section is not exceeding 0.45 σ_y.

Section 6 Local Strength

601. General

1. The requirements in this subsection apply to members that may be directly exposed to local ice pressure.

2. The buckling strength of web plates and face plates in girders and stringers subject to ice loads is to be checked according to methods given in **Rules Ch 3, Sec 4** or equivalent.

3. In curved regions of ice exposed plating, the stiffening is normally to be in the direction of the maximum curvature.

4. Framing in ice reinforced areas are in general to have symmetrical cross-section with the web to the extent possible positioned at right angle to the plane of the plate. The bending efficiency and tripping capacity of frames are to be documented by calculations according to recognised methods as considered necessary.

5. Ice exposed knuckles are in general to be supported by carlings or equivalent structures.

6. Plate fields adjacent to stem and possible knuckles in the forward shoulder are to be supported so as to be of square shape or otherwise locally strengthened to equivalent standard.

602. Plating

1. The thickness of plating exposed to patch load is generally not to be less than:

$$t = 23k_a \frac{s^{0.75}}{{h_0}^{0.25}} \sqrt{\frac{k_w p_0}{m_p \sigma_y}} + t_k \quad \text{(mm)}$$

k_a = aspect ratio factor for plate field

= 1.1 - 0.25 s/l, maximum 1.0, minimum 0.85

k_w = influence factor for narrow strip of load (perpendicular to s)

= $1.3 - \frac{4.2}{(a/s+1.8)^2}$, maximum 1.0

m_p = bending moment factor

= $f(b/s)$, see **Table 3.22.5** (taking r as b/s)

a = s in general

= h_o for transversely stiffened panels

h_o = h (ee **404.**) or s, whichever is the smaller

b = s in general

= h_o for longitudinally stiffened plating

p_o = basic ice pressure in kN/m^2 as calculated in **404.**

t_k = corrosion addition as given in **205.**

s, l and σ_y as defined in **104.**

Table 3.22.5 Parameters for local strength formulas (general application)

r	m_p	m_e
0.05	27.4	132.3
0.10	14.25	67.9
0.15	9.87	46.5
0.20	7.69	35.8
0.25	6.40	29.5
0.30	5.57	25.3
0.35	4.95	22.3
0.40	4.50	20.2
0.45	4.09	18.5
0.50	3.77	17.2
0.60	3.31	15.4
0.70	3.02	14.1
0.80	2.83	13.4
0.90	2.72	13.0
1.00	2.68	12.9
For intermediate values of r the parameters may be obtained by linear interpolation.		

603. Longitudinal stiffeners

1. Stiffeners in the bow-, midship- and stern ice reinforced areas which are largely parallel to the waterline are defined as longitudinals.

2. The web sectional area of stiffeners in ice reinforced areas is not to be less than:

$$A_W = \frac{3.7(l-0.5s)h_0^{1-\alpha}p_o}{\tau \sin\beta l^\alpha} + A_K \quad (\text{cm}^2)$$

and the web thickness is not to be less than:

$$t_w = 1.5\left(\frac{p_o}{\sigma_y \sin\beta}\right)^{0.67}\left(\frac{h_w h_o}{t_s}\right)^{0.33} + t_k \quad (\text{mm})$$

for flanged profiles.

The section modulus is not to be less than:

$$Z = \frac{41 h_o^{1-\alpha} l^{2-\alpha} p_o w_k}{\sigma \sin\beta} \quad (\text{cm}^3)$$

The stiffener connection area a_o is not to be less than:

$$a_o = \frac{10cP}{\tau \sin\beta} = \frac{6.5\, c h_0^{1-\alpha}(l-0.5s)p_0}{\tau \sin\beta (1.4l)^\alpha} \quad (\text{cm}^2)$$

h_0 = h, see **404.**

= s, whichever is smaller

h_w = height of web in mm

p_o = basic ice pressure in kN/m^2 as calculated in **404.**

τ = 110 f_1

σ = 210 f_1

t_s = shell plate thickness in mm.

s, l and σ_y as defined in **104.**

$A_K = t_k h_w 10^{-2}$ (cm^2)

w_k = section modulus corrosion factor (= 1.2)

c = factor as given in **Table 3.22.6**

α = 0.5 for $A_C \leq 1.0$

= 0.15 for $A_C > 1.0$

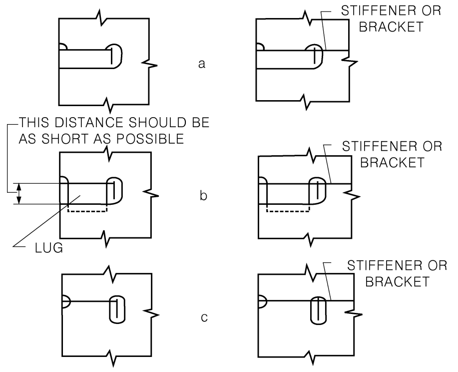
A_C = as defined in **404. 3.**

β = angle of web with shell plating.

= $\tan^{-1}(\frac{\tan\gamma}{\sin\theta})$, γ and θ as shown **Fig 3.22.10**

Table 3.22.6 Value of c

Type of connection (see figure)	Stiffener/bracket on top of stiffener		
	None	Single-sided	Double-sided
a	1.00	1.25	1.00
b	0.90	1.15	0.90
c	0.80	1.00	0.80



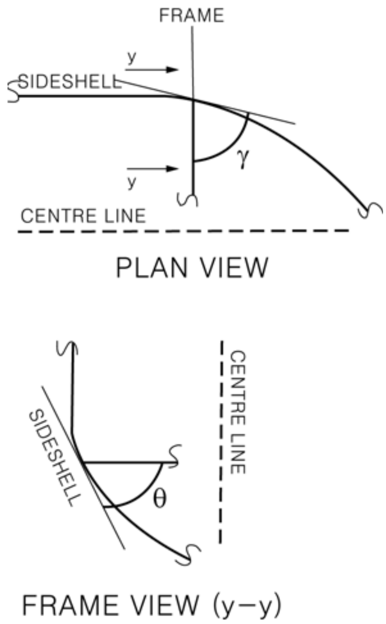


Fig 3.22.10 Determination of β angle

604. Other stiffeners

1. The web sectional area is not to be less than:

$$A_W = \frac{5.8k_s(h_o s)^{1-\alpha}(l-0.5s)p_o}{\tau l \sin\beta} + A_K \quad (\text{cm}^2)$$

and the web thickness is not to be less than:

$$t_w = 1.5\left(\frac{p_o}{\sigma_y \sin\beta}\right)^{0.67}\left(\frac{h_w s}{t_s}\right)^{0.33} + t_k \quad (\text{mm})$$

for flanged profiles.

The section modulus is not to be less than:

$$Z = \frac{520 l^2 s^{1-\alpha} p_o w_k}{m_e \sigma h_o^\alpha \sin\beta} \quad (\text{cm}^3)$$

For end connections with brackets, section modulus including bracket shall be at least 1.2 Z. the bracket thickness shall not be less than t_w.

The connection area a_0 is not to be less than:

$$a_0 = \frac{5.8cs^{1-\alpha}\left(1-0.1\frac{h_1^2}{l^2}\right)(l-0.5s)h_0^{1-\alpha}p_o}{tl\sin\beta} \quad (\text{cm}^2)$$

$$k_s = 1+0.5\frac{(C_1+0.5h_o)^3}{l^3} - 1.5\frac{(C_1+0.5h_o)^2}{l^2}$$

= 0.69 minimum

C_1 = arm length of bracket in m

h_o = h, see **404.**

= l, whichever is the smaller

h_1 = h

= 1.4 l, whichever is the smaller

h_w = web height in mm

m_e = bending moment factor

= $f(h_o/l)$, see **Table 3.22.5** (taking $r = h_o/l$) in general

= $\dfrac{8}{\left(2-\dfrac{h_o}{l}\right)\dfrac{h_o}{l}}$

for stiffener with simply supported ends

p_o = basic ice pressure in kN/m^2, see **404.**

τ = 0.45 σ_y

σ = 0.9 σ_y in general

= 0.8 σ_y when both ends are simply supported

t_s = shell plate thickness in mm.

s, l and σ_y as defined in **104.**

A_K = $t_k h_w 10^{-2}$ (cm^2)

w_k = section modulus corrosion factor, taken as 1.2.

c = factor as given in **Table 3.22.6**

α = 0.5 for $A_C \leq 1.0$

= 0.15 for $A_C > 1.0$

A_C = as given in **404. 3.**

β = angle of web with shell plating.

605. Girders

1. Within ice reinforced areas, girder structures supporting shell stiffeners are to be considered for ice loading. The ice load area to be applied for the girder system will depend on the structure considered, its position and orientation etc. The ice pressure load and load area are generally to be taken as given in **404. 3.**

2. For girders being part of a complex system of primary structures, analysis by direct calculation may be required. For such girder structures in the foreship, the requirements given in **504.** apply.

3. The following requirements apply to evenly spaced girder for which the ends may be considered as fixed, simply supported or constrained due to repetitive continuation of the girder beyond the support. The stiffness of supported members (frames or longitudinals) is assumed to be much smaller than the stiffness of the girder considered.
The web sectional area at any point along a girder is not to be less than:

$$A_W = \frac{5.8 k_s a b p_o}{\tau \sin\beta A_C{}^{\alpha}} + A_K \quad (\text{cm}^2)$$

and the section modulus is not to be less than:

$$Z = \frac{550\,S^2 b\,p_o w_k}{m_e\,\sigma \sin\beta\,{A_C}^{\alpha}}$$

k_s = shear factor, see **Table 3.22.7** (taking r as $(a+s)/S$)

s = spacing of secondary members in m

m_e = bending moment factor

= $f(a/S)$ in case of a continuous member, see **Table 3.22.5** (taking r as a/S)

= $\frac{24}{\left(3-\left(\frac{a}{s}\right)^2\right)\frac{a}{S}}$ in case of fixed ends

= $\frac{8}{\left(2-\left(\frac{a}{s}\right)\right)\frac{a}{S}}$ in case of simply supported ends

a = S in general

= h_o, maximum for girders supporting longitudinals

b = l in general

= h_o, maximum for girders supporting non-longitudinal frames

h_o = h, see **404.**

p_o = basic ice pressure in kN/m^2 as given in **404.**

τ = 0.45 σ_y

σ = 0.9 σ_y in general

= 0.8 σ_y when both ends are simply supported

α = 0.5 for $A_C \leq 1.0$

= 0.15 for $A_C > 1.0$

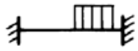
A_C = as given in **404. 3.**

β = angle of web with shell plating.

l and S as defined in **104.**

A_K and w_k, see **603. 2.**

Table 3.22.7 Shear factor k_s

r			
0.0	1.00	1.00	1.00
0.1	0.99	0.99	0.95
0.2	0.96	0.98	0.90
0.3	0.92	0.96	0.85
0.4	0.87	0.93	0.80
0.5	0.81	0.89	0.75
0.6	0.75	0.85	0.70
0.7	0.69	0.80	0.65
0.8	0.62	0.74	0.60
0.9	0.56	0.69	0.55
1.0	0.50	0.63	0.50
1.1	0.5-0.05 i	0.63-0.06 i	0.5-0.05 i
1.2	0.5-0.10 i	0.63-0.12 i	0.5-0.10 i
1.3	0.5-0.15 i	0.63-0.18 i	0.5-0.15 i
1.4	0.5-0.20 i	0.63-0.24 i	0.5-0.20 i
1.5	0.5-0.25 i	0.63-0.30 i	0.5-0.25 i
i = b/2s. maximum = 1.0			

Section 7 Hull Appendages and Steering Gears

701. General

1. Stemframes, rudders, propeller nozzles and steering gears are in general to be designed according to the rules given in **Pt 3.**

2. Additional requirements for ice reinforced vessels are given in the following. For vessels with-rudders which are not located behind the propeller, special consideration will be made with respect to the longitudinal ice load.

3. Plating materials in rudders, propeller nozzles and rudhorns are to be in accordance with **Sec 2**. Forged or cast materials in structural members subject to lower design temperatures than -10°C according to **201.** are to be impact tested at 5°C below design temperature.

4. The rudder stock and upper edge of the rudder are to be effectively protected against ice pressure.

5. Aft of the rudder an ice knife with depth minimum = 0.8 h_{ice} or an equivalent arrangement is to be arranged.

6. Exposed seals for rudder stock are assumed to be designed for the given environmental conditions such as:

- ice formation
- specified design temperature.

702. Ice loads on rudders

1. An ice load area is defined on the rudder with a length equal to the length of the rudder profile lr and height equal to the effective ice load height (h). The general design rudder force (F_R) is given by the following formula:

$F_R = 0.2(h\,l_r)^{0.85}\,K p_o$ (kN)

$$K = 1 + \frac{z}{z_{bl} - 0.01L}$$

z = distance from rudder bottom to centre of the assumed ice load area in m

z_{bl} = distance from rudder bottom to the ballast waterline in m

L = as defined in **Rules Ch 1, Sec 1**

p_o = as given in **404.**

The rudder force F_R gives rise to a rudder torque (M_{TR}) and a bending moment in the rudder stock (M_B), which both will vary depending on the position of the assumed ice load area, and on the rudder type and arrangement used.

In general the load giving the most severe combination of F_R, M_{TR} and M_B with respect to the structure under consideration is to be applied in a direct calculation of the rudder structure.

The design value of M_{TR} is given by:

M_{TR} = $F_R(0.6\,l_r - X_F)$ (kNm)

= $0.15\ FRl_r$ minimum

X_F = longitudinal distance in m from the leading edge of the rudder to the centre line of the rudder stock.

In lieu of direct calculation design values of M_B and F_R, applicable for the rudder stock diameter at the lower end, may normally be taken as :

Spade rudders :

F_R = $0.2(h\,l_r)^{0.85}p_o$ (kN)

M_B = $F_R H_B$ (kNm)

Semi spade rudders :

F_R = $0.2(h\,l_r)^{0.85}p_o$ (kN)

M_B = $0.5F_R H_P$ (kNm)

Balanced rudders :

F_R = $0.2(h\,l_r)^{0.85}\left(1 + \frac{H_B}{2z_{bl} - 0.02L}\right)p_o$ (kN)

M_B = $0.25F_R H_H$ (kNm)

H_B = distance (m) from lower end of rudder to middle of neck bearing

H_P = distance (m) from lower end of rudder to middle of pintle bearing

H_H = distance (m) from centre of heel bearing to centre of neck bearing

h = as given in **404. 3.**

2. An additional ice load area is defined on the uppermost part of the rudder including ice knife with a length equal to the rudder (including ice knife) (l_r) and height below the hull equal to the nominal ice height (h_{ice}). This gives rise to a force (F) given by:

$F \quad = kph_{ice}l_r$ (kN)

p = design ice pressure in kN/m^2 in stem area as given in **404.**
k = 0.7 in general
= 1.0 for vessels with class notations PL or Ice-breaker

The force F is to be divided between rudder and ice knife according to their support position. The force acting on the ice knife may generally be taken as:

$$F_K = \frac{F(X - X_F)}{(X_K - X_F)}$$

X = distance from leading edge of rudder to point of attack of the force F
= 0.5 l_r (m) minimum
= 0.67 l_r (m) maximum
X_K = distance in m from leading edge of rudder to centre of ice knife.

703. Rudder scantlings

1. The scantlings of rudders, rudder stocks and shafts, pinrudder horns and rudder actuators are to be calculated from the formulae given in **Pt 4, Ch 1**, inserting the rudder torque M_{TR}, bending moments M_B and rudder force F_R as given in **702. 1**, all reduced by factor 0.7.

2. Provided an effective torque relief arrangement is installed for the steering gear, and provided effective ice stoppers are fitted, the design rudder torque need not be taken greater than:

$$M_{TR} = M_{TRO}$$

M_{TRo} = steering gear relief torque in kNm.

3. For rudder plating the ice load thickness is to be calculated as given in **602.** using the design ice pressure as given for the stern area reduced linearly to half value at the lower end of the rudder.

4. Scantlings of rudder, rudder stock, rudder horn, rudder stoppers and ice knife as applicable are also to be calculated for the rudder force given in **702. 2.** acting on the rudder and ice knife, with respect to bending and shear. Allowable stresses as given in **604.**

704. Ice loads on propeller nozzles

1. A transverse ice load area positioned at the level of the nozzle center is defined on the nozzle with a length equal to the nozzle length and a height equal to the ice load height h given by:

h = 0.8 h_{ice} in general
= 0.6 h_{ice} for nozzle directly inside of protecting structures, e.g. other nozzle or propeller.

2. The following two alternative longitudinal ice load areas are to be considered:

- an area positioned at the lower edge of the nozzle with a width equal to 0.65 D and a height equal to the height of the nozzle profile
- an area on both sides of the nozzle at the propeller shaft level, with a transverse width equal to the height of the nozzle profile and with a height equal to 0.35 D. Both symmetric and asymmetric loading are to be checked.
  D = nozzle diameter.

3. The design ice pressure p (kN/m^2) for the stern area as given in **404.** is to be assumed for the ice load areas speciunder **704. 1.** and **704. 2.** giving rise to a force (F) given by:

$$F = kpA \quad \text{(kN)}$$

A = ice load area as defined in **704. 1.** and **704. 2.**

k = 0.7 in general

= 1.0 for vessels with class notations PL or Icebreaker.

705. Propeller nozzle scantlings

1. The scantlings of the propeller nozzle and its supports in the hull are to be calculated for theice loads given in **704,** with stresses not exceeding allowable values given in **604**. For nozzle plating the ice load thickness is to be taken as given in **602.** using the design ice pressure as given for the stern area.

706. Steering gear

1. The main steering gear is to be capable of putting the rudder over from 35° on one side to 30° on the other side in 20 seconds, when the vessel is running ahead at maximum service speed (corresponding to MCR) and at deepest ice draught.

2. For the additional class notation Icebreaker the above time is not to exceed 15 seconds.

3. The effective holding torque of the rudder actuator, at safety valve set pressure, is to be capable of holding the rudder in the preset position, when backing in ice, unless arranged in accordance with **703. 2.** and **706. 4.**
The holding torque means the rudder torque the actuator is cato withstand before the safety valve discharges.
The holding torque need normally not exceed the values given in **Table 3.22.8**.

Table 3.22.8 Values of holding torque

ICE-05 to -15	PL10 to -30	Icebreaker
0.5 M_{TR}	0.75 M_{TR}	M_{TR}

M_{TR} = as given in **702. 1.**

4. The torque relief arrangement, when installed, shall provide protection against excessive rudder ice peak torque, e.g. when backing towards ice ridges.
The arrangement is to be such that steering capability is either maintained or speedily regained after activation of such ar

5. All hydraulic rudder actuators are to be protected by means of relief valves. Discharge capacity at set pressure is not to be less than given in **Table 3.22.9**.

Table 3.22.9 Relief valve discharge capacity

	ICE-OS to -15	PL10 to -30	Icebreaker
Rudder speed (degrees/s)	4.5	5	6.5

6. Where practicable rudder stoppers working on the rudder blade or head are to be fitted.

707. Podded propulsors and azimuth thrusters

1. Vessels operating in ice and equipped with podded propulsor or azimuth thrusters are to be designed according to operational mode and purpose stated in the design specification. If not given, it shall be assumed that the vessel will be intended for continuous astern operation. This information is to be also stated in the ship's documents.

2. Ramming astern is not anticipated

3. The structure(housing, struts, bearings etc) of the pod/azimuth truster shall be dimensioned for basic ice pressures as given in **404.** for stern area in accordance with requested class notation and operational mode.

4. Documents of both local and global strength capacity of the pod/azimuth thruster are to be submitted to Society.

Section 8 Welding

801. General

1. The requirements in this subsection apply to members that may be directly exposed to local ice pressure and support structures for these. Otherwise weld dimensions are to be in acwith the rules for main class.

802. External welding

1. The welding of ice strengthened external plating to stiffand to webs and bulkheads fitted in lieu of stiffeners is in any case to have a double continuous weld with throat thickness which is not less than:

$$t = \frac{0.55\sqrt{s}\,p_o}{\sigma_{fw}} + 0.5t_k \text{ (mm)}$$

σ_{fw} = yield strength in $\mathrm{N/mm^2}$ of weld deposit.

= 355 $\mathrm{N/mm^2}$ for welding of normal strength steel.

= 375 $\mathrm{N/mm^2}$ for welding of high strength steels HT 32 and HT 36

= 390 $\mathrm{N/mm^2}$ for welding of high strength steel HT 40.

Need not be greater than:

= 0.45 x plate thickness for mild steel, and

= 0.50 x plate thickness for high strength steel.

If the welding method leads to deeper penetration than normal, the additional penetration can be included in the throat thickness.

Weld throat shall in no case be less than for main class requirements.

803. Fillet welds and penetration welds subject to high stresses

1. In structural parts where high tensile stresses due to local ice load act through an intermediate plate, the throat thickness of double continuous welds is not to be less than given by **Pt 2, Ch 2** with σ = 0.77 σ_i.

σ_i = calculated maximum tensile stress in abutting plate due to ice load in $\mathrm{N/mm^2}$.

2. Where high shear stresses in web plates due to local ice load, double continuous boundary fillet welds are to have throat thickness not less than given by **Pt 2, Ch 2** with $\tau = 0.77\tau_i$.

τ_i = calculated maximum shear stress due to ice load in $\mathrm{N/mm^2}$.

Section 9 Machinery Systems

901. Pneumatic starting arrangement

1. In addition to the requirements given in **Pt 5, Ch 6, Sec 10** for a vessel having a propulsion engine(s), which has to be reversed for going astern, the compressors are to have the capacity to charge the receivers in half an hour.

902. Sea inlets and discharges

1. The sea cooling water inlet and discharge for main and auxiliary engines is to be so arranged that blockage of strums and strainers by ice is prevented.
In addition, the requirements in **Pt 5, Ch 6, 301. 3** and **704.** are to be complied with.

2. At least one of the sea chests is to be sufficiently high to allow ice to accumulate above the pump suctions and cooling water tank inlet, arranged as follows:

(1) The sea inlet is to be situated near the centre line of the ship and well aft if possible. The inlet grids are to be specially strengthened.
(2) As a guidance for design the volume of the chest is to be about one cubic metre for every 750 kW engine output of the ship including the output of the auxiliary engines necessary for the ship's service.
(3) To allow for ice accumulation above the pump suction the height of the sea chest is not to be less than:

$$h_{\min} \geq 1.5 \sqrt[3]{V_s}$$

V_s = volume of sea chest according to item (2).

The suction pipe inlet is to be located not higher than $h_{\min}/3$ from top of sea chest.

(4) The area of the strum holes is to be not less than four (4) times the inlet pipe sectional area. Heating coils may be installed in the upper part of the chests.

3. A full capacity discharge branched off from the cooling water overboard discharge line is to be connected to the sea chests. At least one of the fire pumps is to be connected to this sea chest or to another sea chest with de-icing arrangement.

903. Sea cooling water arrangements

1. The sea cooling water inlets and discharges for main and auxiliary engines are to be connected to a cooling water double bottom tank having direct supply from the sea chests. The cross-sectional area of the supply line between each sea chest and the cooling water tank is to be twice that of all pump suctions connected to the tank.

2. Vessels with the class notation Icebreaker or PL are to comply with **903. 3** to **903. 7.**

3. The cooling water tank volume in m^3 is to be at least 0.01 times the output in kW of the main and auxiliary engines.

4. The sea water suction line strainers required in **Pt 5, Ch 6, Sec 7** are to be arranged outstream from the cooling water tank.

5. The sea water cooling pumps are to be of the self-priming type or connected to a central priming system.

6. The sea water cooling and ballast piping is to be arranged so that water in the cooling water tank can be circulated through the ballast tanks for the purpose of spare cooling capacity in the case of blocked sea chests.

7. Arrangements providing additional cooling capacity equivalent to that specified in **903. 1** through **903. 6** may be considered.

904. Ballast system

1. Arrangement to prevent freezing is to be provided for ballast tanks where found necessary.

Guidance note:
Double bottom tanks are normally not required to be provided with arrangement to prevent freezing.

Section 10 Propulsion Machinery and Propellers

1001. General

1. Special cold climate environmental conditions are to be taken into consideration in machinery design.

2. Propellers and its parts(propeller blades, blade bolts (if any), propeller hub, pitch control mechanism (if any), etc.) are to be of steel or bronze as specified in **Pt 2, Ch 1** of the Rules. Nodular cast iron of special qualities specified in **Pt 2, Ch 1, Sec 5, Table 2.1.77** of the Rules may be used for relevant parts in CP-mechanism. Other type of nodular cast iron with elongation ≥ 12% may be accepted upon special consideration for same purposes. Propeller shafts are subject to Charpy V-notch impact testing at -10°C and average energy value is to be minimum 27 J.

3. Grey cast iron is normally not accepted for components subject to ice shocks, as e.g. thrust bearing housings.

4. Shafting systems equipped with specially designed mechanical torque limiting devices are subject to special consideration. Such devices, when accepted, are to be provided with redundancy and are to be capable of restoring a lost function in 10 minutes when failure of system in use is occurred.
The torque limit is normally not less than 1.5 $K_{Aice}\ T_O$.
For K_{Aice} and T_O, see **1005.**

5. Ice induced vibrations (repetitive ice shocks) in the shafting system are to be considered.
Forced torsional vibration calculations are to include an evaluation of transient vibrations excited by ice on the propeller.

6. For non-reversible machinery plants, special means are to be provided for reversing the propellers stuck in ice.

7. The propulsion line is to be designed such that the blade failure load F_{ice} given in **1004. 4** is not to cause damage in the blade bolt connection, propeller hub, pitch mechanism, shaft connection, propeller shaft and thruster bearing.

Guidance Note :
Damage, in this context, means when the stresses in the highest loaded part of the considered cross section reaches yield stress. The local effect of stress raisers may be ignored.
Blade failure load(F_{ice}) is the load causing plastic bending of the propeller blade in a section just outside the root fillet.

1002. Engine output

1. The maximum continuous output of propulsion machinery is not to be less than:

$$P = 1.5 c_s c_p I N B \left[1 + 1.6\ T + 27 (0.1 I N / T^{0.25})^{0.5}\right] \quad \text{(kW)}$$

c_s = 1.0 for vessels with conventional «icebreaker stem»
= 0.9 + γ / 200 ; minimum 1.0, but need not exceed 1.2

c_p = 1.0 for controllable pitch propeller
= 1.1 for fixed pitch propeller

IN = ice class number (figure added to class notation)
B = moulded breadth at waterline (m), local increase in way of stem area is normally not to be taken into account
T = load draught (m)
γ = stem angle (see **Fig 3.22.2**).

2. When the vessel is provided with special means which will improve her performance in ice (e.g. air bubbling system), the input rating of machinery used for such purpose may be added to the actual rating of propulsion machinery.
The propeller rating is, however, not to be less than 85% of that required in **1002. 1.**

3. When the vessel is provided with a nozzle of efficient design, a reduction of required engine output corresponding to increase of thrust in ice conditions may be considered. The reduction is, however, not to exceed 20% of required output in **1002. 1** and **1002. 2.**

4. Additional reduction of the required output may be considered for a vessel having design features improving her performance in ice conditions. Such features are to be documented, either by means of model tests or full scale measurements.

1003. Determination of ice torque and loads

1. Ice torque (T_{ICE}), used for determination of scantlings in propellers and shafting systems, is to be taken as follows:

$$T_{ICE} = m\,D^2 \quad \text{(kNm)}$$

The factor m is given in **Table 3.22.10** as function of ice class:

Table 3.22.10 Values of m

Ice class	m	Icebreaker	m
ICE-05	16	ICE-05	21
ICE-10	21	ICE-10	30
ICE-15	27	ICE-15	30
PL	33	PL	40

D = propeller diameter in m.

2. For propellers running in nozzles of satisfactory design, the ice torque will be considered based on submitted documentation, e.g. measurements carried out on similar vessels.
However, if nothing else is documented, the following may be used:

$$T_{ICE} = (0.9 - 0.01\,m\,D^{-0.5})\,m\,D^2 \quad \text{(kNm)}$$

Large fragments of ice are not to have free access into or towards the front of the nozzle.

3. Axial loads in shaftline :

$F = T_H + 1.5F_{LE}$ (axial load, ahead)
$F = 0.8\,T_H + F_{LE}$ (axial load, astern)

The axial load F is to be applied on the propeller side of the thruster bearing.

T_H and F_{LE} according to **1004.** and **1005.**

1004. Propeller

1. The blade scantling requirements given in **Pt 3, Ch 20, 218.** apply, except as given below. In calculations involving the ice torque, T_{ICE} according to **1003.** is to be applied.
Propeller blade scantlings of martensitic - austenitic and ferritic - martensitic stainless steel may be specially considered.

2. Arrangement of propellers in ice classes ICE-15 and PL10 to PL30 is to be such that large fragments of ice do not have free access into the front of the propeller disc within 0.7 radius.

3. When the outer sections of the propeller blade is not subject to special consideration in accordance with **Pt 5, Ch 3, 303. 1** of the Guidance, the blade tip thickness at the radius 0.95 R is not to be less than:

$$t = (m + 2D)\sqrt{\frac{490}{\sigma_b}} \quad \text{(mm)}$$

m = the factor as function of ice class given in **1003. Table 3.22.10**

D and σ_b as given in **1004.4.**

σ_b is not to be taken higher than 2.5 σ_y.

For propellers running in nozzles blade tip thickness smaller than above may be accepted. The tip thickness, however, is not to be less than 3/4 of the above value.

The thickness of the blade edge and the propeller tip is not to be less than 50 % of minimum t as given above, measured at 1.25 t from the edge or tip, respectively. For propellers where the direction of rotation is not reversible, this requirement only applies to the leading edge and propeller tip.

4. The fitting of the propeller blades and the pitch control mechanism is to withstand a design static load not less than:

$$F_{ICE} = 0.3\frac{\sigma_n c_r t_r^2}{D\left[0.9 - R_R/R\right]}10^{-6} \quad \text{(kN)}$$

This load is to be applied on the blade at the radius 0.9 R and at an offset from blade centre axis of 2/3C_{TE} or 2/3C_{LE}, whichever is the greater.

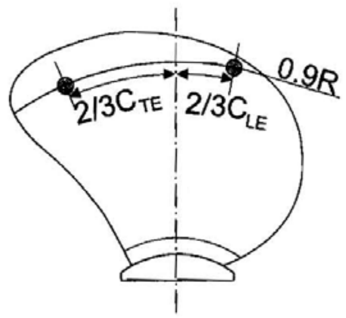


Fig 3.22.11

σ_n = $0.37\sigma_b + 0.6\sigma_y$

σ_b = ultimate tensile strength of the blade (N/mm^2)

σ_y = the blade yield stress or 0.2% offset point (N/mm^2)

c_r = the length of the blade section at R_R radius (mm)

t_r = the corresponding thickness (mm)

D = propeller diameter (m)

R = $D/2$ (m)

R_R = radius to a blade section taken at the termination of the blade root fillet (rounded upwards to the nearest $R/20$), ref. c_r and t_r (m)

C_{TE} = distance from axis of rotation of the blade to the tailing edge, measured along the cylinerical section at 0.9 R

C_{LE} = distance from axis of rotation of the blade to the leading edge, measured along the cylinerical section at 0.9 R

5. Propeller blade bolts are to have a section modulus, referred to an axis tangential to the bolt pitch diameter, not less than:

$$W_{BS} = 0.15 S c_r t_r^2 \frac{\sigma_n}{\sigma_y} \frac{0.9 - R_B/R}{0.9 - R_R/R} \quad (\text{mm}^3)$$

S = 1.0 for CP-propellers

= 1.25 for FP-propellers

σ_y = yield stress of bolt material (N/mm^2)

R_B = radius to bolt plan (m).

c_r, t_r and σ_n as given in **1004. 4.**

The bolts are to have a design which minimises stress concentrations in transition zones to threads and bolt head as well as in way of the threads, and reduces risk for plastic deformations in the threads.

6. For all parts in the pitch control mechanism, which are subject to variable ice loads, stress concentration is to be taken into consideration.

7. The blade fitting and other parts in the pitch control mechanism are to be designed to withstand all forces produced by the pitch control system at its maximum power. The forces are to be assumed to act towards one blade at a time.

Guidance note:
The pitch control mechanism is to be designed for the following dynamic ice loads:

$F_{LE} = T_{ICE}/0.9R$ (kN) at leading edge,

$F_{TE} = -0.5F_{LE}$ at trailing edge,

applied at the 0.9 radius perpendicular to the blade plane at the respective blade edges.
Number of load cycles to be considered is not to be taken less than one million for ice classes ICE-05 to ICE-15 and infinitive for PL10 to PL30 and class notation Icebreaker. The design pressure of the hydraulic system is not to be taken less than twice the pressure needed to produce the blade spindle torque based on the above forces. The forces are assumed to act on one blade at a time only.

8. Fitting of the propeller to the shaft is to be in accordance with the following;
(Considering 0℃ sea water temperature)

If the propeller is bolted to the propeller shaft, the bolt connection is to have at least the same bending stress as the propeller shaft.

(1) Flanged connection

(A) Torque transmission based on combinations of shear or guide pins or expansion devices and pre-stressed friction bolts is to fulfil :

(a) The friction torque T_F is to be at least twice the repetitive vibratory torque T_V, i.e.:

$$T_F = \frac{\mu D F_{bolts}}{2000} \geq 2T_V \quad \text{(Nm)}$$

µ = Coefficient of friction, 0.15 for steel against steel and steel against bronze, and 0.12 for steel against nodular cast iron. Other values may be considered for especially treated mating surfaces.

T_V = Vibratory torque for continuous operation in full speed range(~ 90-100% of rpm at maximum continuous power)

= $(K_{Aice} - 1) T_0$ (Nm)

D = Bolt pitch circle diameter (PCD) (mm)

F_{bolts} = The total bolt pre-stress force of all n bolts (N)

Bolt pre-stress limited as follows;

Bolts may have a pre-stress up to 70% of the yield strength in the smallest section. However, when using 10.9 or 12.9 bolts(refer to regulations for indication of thread strength in ISO) the thread lubrication procedure has to be especially evaluated, and only tightening by twist angle or better is accepted (e.g. by elongation measurement). If rolled threads, the pre-stress in the threads may be increased up to 90% of the yield strength. These percentages are given on the condition that the peak service stresses combined with the pre-stress do not exceed the yield strength.

T_0 = maximum continuous torque (kNm)

K_{Aice} = application factor due to ice shock(see **1005.**)

(b) Twice the peak torque T_{peak} minus the friction torque (see (a), above) is not to result in shear stresses beyond the shear yield strength $\sigma_y/(\sqrt{3})$ of the n ream fitted pins or expansion devices, i.e.:

$$2T_{peak} - T_F \leq \frac{\pi n D d_b^2 \sigma_y}{8 \cdot 10^3 \sqrt{3}} \quad \text{(Nm)}$$

$$T_{peak} = K_{Aice} \cdot T_0 \quad \text{(Nm)}$$

T_{peak} = higher value of $T + T_V$ or $K_{Aice} \cdot T_0$ (Nm)

T = mean torque at resonance

T_V = the highest value of vibratory torque in the entire speed range excluding critical speed range

D = Bolt pitch diameter(PCD) (mm)

d_b = Bolt shear diameter (mm)

(B) Torque transmission based on n flange coupling bolts mounted with a slight clearance (e.g.< 0.1 mm) and tightened to a specified pre-stress σ_{pre} is to fulfil the following requirements:

- the friction torque is to be at least twice the repetitive vibratory torque (including normal transient conditions) T_V (see (A)(a))
- bolt pre-stress limited as in (A)(a)
- the shear stress τ due to twice the peak torque minus the friction torque combined with the pre-stress σ_{pre} is not to exceed the yield strength σ_y, i.e.:

$$\sqrt{\sigma_{pre}^2 + 3\tau^2} \le \sigma_y$$

τ = Shear stress in bolt

$= \dfrac{8(2T_{peak} - T_F)10^3}{D\pi n d_b^2}$

σ_{pre} = Specified bolt pre-stress,

$= \dfrac{4F_{bolts}}{\pi n d_b^2}$

T_{peak} = Peak torque, (see (A)(b))

D = Bolt pitch diameter(PCD) (mm)

d_b = Bolt shear diameter (mm)

(C) Torque transmission based on ream fitted bolts only, is to fulfil the following requirements:
- the bolts are to have a light press fit
- the bolt shear stress due to two times the peak torque, T_{peak}(see (A)(b)) minus the friction torque, T_F(see (A)(a)) is not to exceed 0.58 σy
- the bolt shear stress due to the vibratory torque, T_V(see (A)(a)) for continuous operation is not to exceed σ_y/8.

This means that the diameter of the n fitted bolts is to fulfil the following criteria:

$$d_b \ge 66\sqrt{\frac{2T_{peak} - T_F}{nD\sigma_y}} \quad \text{and} \quad d_b \ge 143\sqrt{\frac{T_V}{nD\sigma_y}}$$

D = Bolt pitch diameter(PCD) (mm)

Ream fitted bolts may be replaced by expansion devices provided that the bolt holes in the flanges align properly.

Guidance note:
Ream fitted bolts with a light press fit means that the bolts when having a temperature equal to the flange, cannot be mounted by hand. A light pressing force or cooling should be necessary.

(2) Shrink fit connections
The friction capacity is to be fulfil the following at a temperature of 35℃.

Required torque capacity(kNm) in the full speed range

$T_{C1} = 2.0 \cdot T_0 + 1.8 \cdot (K_{Aice} - 1) \cdot T_0$

The minimum value for T_{C1} is $2.8 \cdot T_0$

K_{Aice} and T_0 = see (1)(A)(a)

Tangential force(kN) : $F_T = 2 \cdot T_{C1}/D_S$

(D_S is shrinkage diameter (m), mid-length if tapered.)

Axial force (kN) : $F_A = p \cdot \pi \cdot D_S \cdot L \cdot \theta \cdot 10^3 \pm Th_{ice}$

Here,

+ = for propellers with pulling action including thrusters and pods with dual direction of rotation.

\- = for propellers with dual direction of rotation.

p = surface pressure (MPa)

L = effective length (m) of taper in contact in axial direction disregarding (i.e. not subtracting) oil grooves and any part of the hub having a relief groove

θ = half taper, e.g. taper = 1/30, θ = 1/60

Th_{ice} = the highest axial force in the applicable ice rules.

With friction force (kN) $F_{FR} = p \cdot \mu \cdot \pi \cdot D_s \cdot L \cdot 10^3$ the necessary surface pressure p_{35T} (MPa) at 35℃ for safe torque transmission can be determined by :

$$p = \frac{\sqrt{F_T 2 \cdot \left(1 - \frac{\theta^2}{\mu^2}\right) + Th_{ice}^2} \pm Th_{ice} \cdot \frac{\theta}{\mu}}{\mu \cdot \pi \cdot D_S \cdot L \cdot 10^3 \cdot \left(1 - \frac{\theta^2}{\mu^2}\right)}$$

μ = coefficient of friction, (see **Table 3.22.11**)

Table 3.22.11 Static coefficients of friction, μ

Application	Hub material (shaft material = steel)		
	Steel	Cast iron or nodular cast iron	Bronze
Oil injection	0.14	0.12	0.13
Dry fit on taper	0.15	-	0.15
Glycerine injection	0.18	0.16	0.17
Heated in oil	0.13	0.10	-
Dry heated/cooled(part not degreased or protected vs. oil penetration; nor high shrinkage pressure applied)	0.15	0.12	-
Dry heated/cooled(part degreased or protected vs. oil penetration; or high shrinkage pressure applied)	0.20	0.16	-
Special friction coating	To be specially approved		

(3) Keyed connections

(A) For key connections transmitting torque only, there is to be a minimum interference fit (friction torque) that corresponds to the applicable vibratory torque for continuous operation with a safety factor of 2.0. This means a friction torque:

$$T_F \geq 2.0\, T_V = 2(K_{Aice} - 1)\, T_0$$

When calculating shrink fit pressures between cylindrical members with one or two keyways, the real pressure is less than the calculated due to relief caused by the keyways. This influence may be approximated by a reduction factor of 0.8.
With these assumptions and solid shaft with steel hub the necessary amount of shrinkage Δd (mm) is:

$\Delta d = T_F / (128 dL\mu(1-(d/D)^2))$

T_F , T_V, K_{Aice}, T_0 = see (1)(A)(a)

Δd = shrinkage amount (mm) estimated as minimum amount due to specified tolerances or pull-up distance minus $0.8(R_{z-shaft}+R_{z-hub}) \approx 5(R_{a-shaft}+R_{a-hub})$ (mm).

d = shaft diameter (mm)

D = outer diameter of hub (mm)

L = hub length (mm)

μ = coefficient of friction (0.15 may be used)

R_a = "arithmetical mean" surface roughness (mm) as defined in ISO4287/1 for shaft and hub, respectively.

R_z = "ten point height" surface roughness (mm) as defined in ISO4287/1 for shaft and hub, respectively.

For tapered connections the minimum friction torque is to be provided by means of either a specified push up force or a specified pull up length. Te latter is to be consistent with Δd above. However, if test pull-up is carried out, the subtraction of the surface roughness term may be omitted.

(B) The key shear stress and the surface pressures in the shaft and hub keyways, respectively are calculated on the basis of the applied repetitive peak torque T_{peak} (see (1)(A)(a)) minus the actual friction torque T_F according to (A). Furthermore, the uneven distribution of the load along a key with a length beyond $L_{eff}/d = 0.5$ is considered empirically. If $L_{eff}/d < 0.5$ then $L_{eff}/d = 0.5$ is to be used in the formulae below.

Shear stress in key: $\tau = (T_{peak} - T_F/S)2000(1+0.25(L_{eff}/d - 0.5))/(dL_{eff}bi)$

Side pressure of key (for contact with shaft and hub):

$$\sigma = (T_{peak} - T_F/S)2000(1+0.25(L_{eff}/d-0.5))/(dL_{eff}h_{eff}i)$$

L_{eff} = effective bearing length of the key (mm)

b = width of key (mm)

i = number of keys, if 2 keys use i = 1.5

h_{eff} = effective height of key contact with shaft and hub, respectively i.e. key chamfer and keyway edge rounding considered.

S = 2

Permissible shear stress in key: $0.3f_d$ times the yield strength of the key material.

Permissible side pressures: $1f_sf_d$ times the respective yield strengths.

f_d = torque direction factor.

For unidirectional torque : f_d = 1

For dual directional torque with 10^3 to 10^4 reversals : f_d = 2/3

For 10^6 or more reversals : f_d = 1/3

f_s = support factor.

For the key : f_s = 1

For the shaft : f_s = 1.2

For the hub : f_s = 1.5

1005. Propulsion shaft line reinforcement

1. Determination of factors for ice reinforcement of shaft line.

P = rated power (kW)

n_p = propeller speed (rpm) at a rated power

T_O = torque (kNm) in the actual component

T_{ICE} = ice torque (kNm) according to **1003.**

u = gear ratio (if no reduction gear, or for components on the propeller side of a reduction gear use u = 1)

I = equivalent mass moment of inertia in kgm^2 based on torque of all parts on engine side of component under consideration.

Masses rotating with engine speed to be transformed according to :

$I_{equiv} = I_{actual} u^2$

In propulsion system with hydraulic coupling, torque converter or electromagnetic slip coupling, the masses in front of the coupling are not to be taken into consideration

I_t = equivalent mass moment of inertia of propulsion system in kgm^2(Masses in front of hydraulic or electromagnetic slip coupling are not to be taken into consideration.)

f = $560/(\sigma_b + 160)$ material factor

2. Application factor for diesel and/or turbine machinery in general:

$$K_{Aice} = 1 + \frac{T_{ice}\, I}{u\, T_O\, I_T}$$

3. Application factor for electric motor machinery or diesel machinery with hydrodynamic torque converter:

1) Diesel engine with torque converter or hydrodynamic coupling:

$$K_{Aice} = \frac{T_{TCmax}}{T_0} + \frac{T_{ice}\, I}{u\, T_0\, I_t}$$

$T_{TC\max}$ = maximum possible transmittable torque through converter/coupling.

2) Electro motor drive:

$$K_{Aice} = \frac{T_{\max}}{T_O} + \frac{T_{ice}\, I}{u\, T_O I_T}$$

$T_{\max}$ = motor peak torque (steady state condition).

Alternatively to the above criteria, the ice impact load may be documented by simulation of the transient dynamic response in the time domain. For branched system, such simulation is in general recommended.

4. Shaft connections are to be in accordance with following .

(1) Flange connections : see **1004. 8** (1).

(2) Shrink fit connections : to be in accordance with following.

The friction capacity is to be fulfil the following.

Required torque capacity(kNm) in the full speed range $T_{C1} = 1.8 \cdot T_0 + 1.6 \cdot (K_{Aice} - 1) \cdot T_0$
The minimum value for T_{C1} is $2.5 \cdot T_0$

K_{Aice} and T_0 = see **1004. 8** (1)(A)(a)
Tangential force(kN) : $F_T = 2 \cdot T_{C1}/D_S$
(D_S is shrinkage diameter (m), mid-length if tapered.)
Axial force (kN) : $F_A = p \cdot \pi \cdot D_S \cdot L \cdot \theta \cdot 10^3 \pm Th_{ice}$
(in gear boxes, replace Th_{ice} with $K_{Aice}F_{Agear}$)

Here,

+ = for axial forces pulling off the cones such as propellers with pulling action including thrusters and pods with dual direction of rotation and controllable pitch propeller.

- = for axial forces pushing up the cones such as for propellers with pushing actions.

p = surface pressure (MPa)

L = effective length (m) of taper in contact in axial direction disregarding (i.e. not subtracting) oil grooves and any part of the hub having a relief groove

θ = half taper, e.g. taper = 1/30, θ = 1/60

Th_{ice} = the highest axial force in the applicable ice rules.

With friction force (kN) $F_{FR} = p \cdot \mu \cdot \pi \cdot D_s \cdot L \cdot 10^3$ the necessary surface pressure p (MPa) can be determined by :

$$p = \frac{\sqrt{F_T 2 \cdot \left(1 - \frac{\theta^2}{\mu^2}\right) + Th_{ice}^2} \pm Th_{ice} \cdot \frac{\theta}{\mu}}{\mu \cdot \pi \cdot D_S \cdot L \cdot 10^3 \cdot \left(1 - \frac{\theta^2}{\mu^2}\right)}$$

μ = coefficient of friction, (see **1004. 8** (2) **Table 3.22.12**)

(3) Keyed connections : see **1004. 8** (3).

5. The diameter of the propeller shaft in way of aft bearing and at least a length 2.5 times the required diameter forward of propeller flange or hub, is not to be less than:

$$d_p = 1.16\left(\frac{0.9\sigma_n c_r t^2}{[0.9 - (R_R/R)]\sigma_y}\right)^{\frac{1}{3}} \quad \text{(mm)}$$

$c_r t^2$ = actual value of blade section considered at the termination of the blade root fillet (rounded upwards to nearest 1/20 of R).

σ_y refers to the shaft material.

σ_n refers to the blade material, see **1004. 4.**

c_r and t as given in **1004. 4.**

The propeller shaft diameter may be evenly tapered to 1.15 times the required intermediate shaft diameter between the aft bearing and the second aft bearing. Forward of this bearing the propeller shaft diameter may be reduced to 1.05 times the required diameter of the intermediate shaft (using material factor valid for propeller shaft).

The propeller shaft flange thickness (propeller fitting) is to be at least 0.3 times the actual shaft diameter. The fillet radius is to be at least 0.125 times the actual shaft diameter.

6. The diameter of the intermediate shaft is not to be less than:

$$d_m = Fk\left(\frac{P f K_{Aice}}{n_p u}\right)^{\frac{1}{3}} \quad \text{(mm)}$$

F = F as given in **Pt 5, Ch 3, Sec 2**.

k = K1 as given in **Pt 5, Ch 3, Sec 2**.

7. Thrust bearing

(1) Support and construction of the thrust bearing are to be designed to avoid excessive axial shaft movements caused by heavy axial forces when the propeller hits ice.

(2) The thrust bearing is to have static strength designed for not less than the nominal thrust plus the static ice force as defined in **1004. 4**. The ice force is assumed to act in the axial direction. Both forward and astern directions are to be considered.

(3) The basic static load ratings of roller bearings are not to be less than 2 times the load according to (2).

(4) For calculation of the bearing pressures in the ice conditions the following thrust force applies:

$$T_{HI} = 1.1\,T_H + 0.25\,F_{LE} \pm 0.75\,F_{LE} \text{(kN)}$$

F_{LE} = according to **1004. 7.**

T_H = mean «bollard thrust» of the propeller or 1.25 times the mean thrust at maximum continuous ahead speed, in kN.

(5) Calculated lifetime (B_{10}) of roller bearings is to be min 40,000 h, by applying the load T_{HI}.

8. Reduction gear

(1) The reduction gear is to meet the requirements in **Pt 5, Annex 5-4**, utilizing the application factor K_{Aice} in accordance with **1005.** instead of K_A.

(2) Axial ice load according to **7**, when applicable, is to be considered with respect to bearing arrangement and stiffness of the gear housing.

9. Clutches

If the factor K_{Aice} > 1.4, the following torque capacities of clutches are to be increased by the ratio: K_{Aice}/ 1.4.

- static friction torque : at least 1.8T_0 and preferably not above 2.5T_0 (When above 2.5T_0, the doc umentation such as simulation calculation of the engaging process is to be submitted.)
- dynamic friction torque : at least 1.3T_0.

10. Torsional elastic coupling

The coupling is to be designed so that :

(1) $T_{Kmaxl} > T_0 K_{Aice}$

(2) $T_{KN} \geq 0.5\,T_0(K_{Aice}+1)$

(3) As long as the natural frequency of the "propeller versus engine"-mode is much lower than the propeller blade passing frequency(ratio < 50%): $T_{KV} \geq 0.5\,T_0(K_{Aice}-1)$
Otherwise : $T_{KV} > T_0(K_{Aice}-1)$

K_{Aice} = application factor due to ice shock, see **2** and **3**.

T_{KV} = permissible vibratory torque for continuous operation (see **Fig 3.22.12**)

T_{Kmaxl} = permissible maximum torque for repetitive loads as transient vibration, typically during clutching in etc., (see **Fig 3.22.13**)

T_{KN} = permissible mean torque with the corresponding highest nominal shear stress in the elastomer and the bonding stress

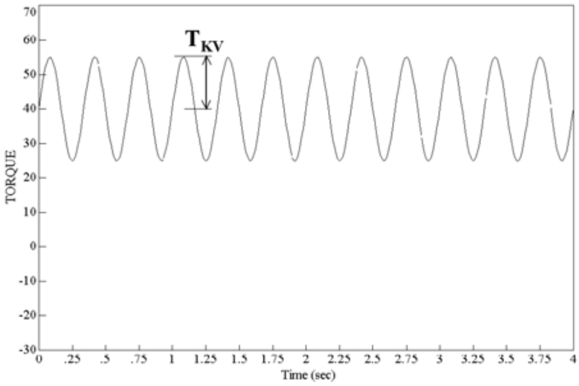


Fig 3.22.12 T_{KV}

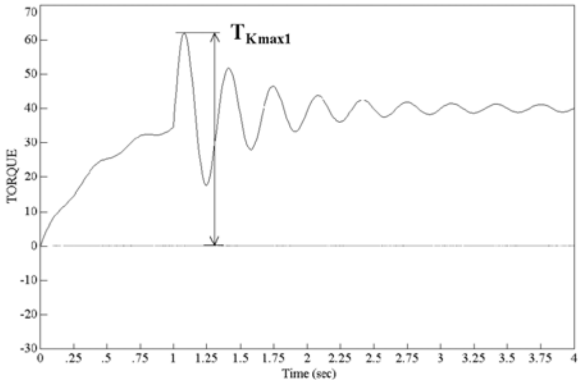


Fig 3.22.13 T_{Kmaxl}

Alternatively to the above criteria, the ice impact loads on the elastic coupling may be documented by simulation of the transient dynamic response in the time domain. For branched systems, such simulation is in general recommended.

Section 11 Thrusters

1101. General

1. Special cold climate environmental conditions are to be taken into consideration in the thruster design.

2. Means of heating and circulation of lubrication hydraulic oil are to be provided.

1102. Propulation thrusters

1. Thrusters, which are used for propulsion purpose, are to comply with the relevant requirements in **Sec 10**.

Guidance Note :
Any thruster intended to be used for propulation in ice, not only the main propulsion thrusters, is defined as propulsion thrusters in this context.

2. Steering gear for azimuth thrusters is to be designed to withstand all relevant ice loads. Both ice loads on propeller nozzle(**704.**) and on propeller blade(**1004.**) are to be considered.

1103. Other thruster

1. For shafting the following applies:

(1) Maximum peak torque, which may occur due to ice in the propeller, is to be taken into consideration.

(2) The load F in **3** is to be considered for the propeller shaft.
Maximum permissible equivalent stress is 80 % of the yield stress or 0.2 % proof stress of materials.

2. For reduction gears the application factor (K_A) is to be taken as minimum 1.2.

3. The propeller blade is to be designed to withstand a peak load, without exceeding 80% of blade material yield or 0.2 % proof stress of:

$$F = \frac{T}{0.85\,R\sin\alpha_{0.85}} \quad \text{(kN)}$$

T = maximum peak torque of prime mover (kNm)
$\alpha_{0.85}$ = pitch angle at radius 0.85 R
R = propeller radius (m)
The load F is assumed to apply at 0.85 R, perpendicular to the blade plane.

Section 12 Stability and Watertight Integrity

1201. Application

1. Vessels with class notation Icebreaker or PL are to comply with the requirements of relevant international conventions as well as the requirements of this subsection.

2. Definitions and general requirements related to damage stability approval for passenger ships are to be applied as far as applicable.

Guidance note;

The requirements contained in this section are based on the **IMO MSC/Cir.1056** "Guidelines for Ships Operating in Arctic ice covered waters" as applicable for POLOR classes 1 to 3.

1202. Definitions

1. Symbols
P_{zb} = vertical beaching force, see **402**.

2. Terms
Beaching lever = beaching moment divided by the vessel's displacement.

3. More definitions are in accordance with relevant international conventions.

1203. Documentation

1. Documentation for approval
- preliminary damage stability calculations
- final damage stability calculations
  (not required in case of approved limit curves, or if approved lightweight data are not less favourable than estimated lightweight data).

2. Documentation for information
- internal watertight integrity plan.

3. Other plans and documents deemed necessary by the Society

1204. Requirements for intact stability

1. The initial metacentric height GM is not to be less than 0.5 m.

2. Account shall be taken of the effect of icing in the stability calculations.

Guidance Note:

The realistic figures for thickness and density of the accumulated ice load may vary with different areas. In the lack of detailed information the following ice loads should be accounted for;

- 30 kg per square metre on exposed weather deck and gangways
- 7.5 kg per square metre for projected lateral area of each side of the vessel above the water plane
- the weight distribution of ice discontinuous structures such as railing, rigging, posts and equipment shall be included by increasing the total area for the projected lateral plane of the vessel's sides by 5 %. The static moment of this area shall be increased by 10 %.

3. Suitable calculations should be carried out and/or tests conducted to demonstrate the following:

(1) the ship, when operated in ice within approved limitations, during a disturbance causing roll, pitch, heave or heel due to turning or any other cause, should maintain sufficient positive stability, and

(2) when riding up in ice and remaining momentarily poised at the lowest stem extremity, should maintain sufficient positive stability.

4. Sufficient positive stability in **Par 3.** (1) and (2) means that the ship is in a positive state of equilibrium with a positive metacentric height of at least 150 mm, and a line 150 mm below the edge of the freeboard deck as defined in the applicable LL-Convention, is not submerged.

5. For performing stability calculations on ships that ride up onto the ice, the ship should be assumed to remain momentarily poised at the lowest stem or extremity as follows:

- for regular stem profile, at the point at which the stem contour is tangent to the keel line
- for a stem fitted with a structurally defined skeg, at the point at which the stem contour meets the top of the skeg
- for a stem profile where the skeg is defined by shape alone, at the point at which the stem contour tangent intersects the tangent of the skeg, or
- for a stem profile of novel design, the position should be specially considered
- the same considerations shall be made for ships designed for breaking ice at the stern.

1205. Requirements for damage stability

1. The damage assumptions in **1205. 2.** to **6.** and the criteria in **1205. 7.** and **8.** are to be the basis of damage stability calculations.

2. The dimensions of an ice damage penetration should be taken as :

- longitudinal extent 0.045 of deepest ice waterline length if centered forward of the point of maximum beam on the waterline, and 0.015 of waterline length otherwise,
- depth 760 mm measured normal to the shell over the full extent of the damage, and
- vertical extent the lesser of 0.2 of deepest ice draft, or of longitudinal extent.

3. The centre of the ice damage may be located at any point between the keel and 1.2 times the deepest draft. The vertical extent of damage may be assumed to be confined between the keel and 1.2 times the deepest ice draft.

4. If damage of lesser extent than that specified above results in a more severe condition, such lesser extent is to be assumed.

5. For pipes, ducts or tunnels situated within the assumed extent of damage, see **1207.**

6. The following permeability factors are to be assumed:

- store rooms : 0.60
- machinery spaces : 0.85
- tanks and other spaces : 0.95
- partially filled ballast tanks : consistent with minimum tank content.

7. Damage criteria at the final stage of flooding:

- the final equilibrium waterline after damage is to be below the edge of any non-watertight opening
- the final equilibrium heel angle after damage is not to exceed 15°. This may be increased to 17° if the deck edge is not submerged
- residual stability criteria at final stage
  · GZ after damage has at least 20° positive range beyond equilibrium
  · maximum GZ of at least 0.10 m within 20° beyond the maximum equilibrium position.

8. Damage criteria at the intermediate stages of flooding:

- the waterline after damage is to be below the edge of any non-weathertight opening
- the heel angle after damage is not to exceed 25°. This may be increased to 30° if the deck edge is not submerged
- residual stability criteria at intermediate stages
  · GZ after damage has at least 10° positive range beyond equilibrium
  · maximum GZ of at least 0.05 m within 10° beyond the maximum equilibrium position.

9. A maximum allowable VCG curve with respect to damage stability is to be included in the stability manual. Otherwise the damage stability approval shall be limited to the presented loading conditions.

1206. Requirements for beaching stability

1. The vessel's stability is to be assessed when beaching on a large ice feature, assuming maximum allowable VCG. The assumptions in **1206. 2.** and **3.** and criteria in **1206. 4.** and **5.** are to be the basis of such assessment.

2. Centric beaching assumption:

The vertical beaching force P_{ZB} in **402.** is to be assumed at the F.P., 1.0 m below the waterline, at the longitudinal centre line of the vessel.

3. Eccentric beaching assumption:

The vertical beaching force P_{ZB} in **402.** is to be assumed at the F.P., 1.0 m below the waterline, 0.125 B off the longitudinal centre line of the vessel.

4. Centric beaching criteria:

- the GM is to be positive
- the aft deck edge is not to be submerged.

However, for vessels built with an ice knife positioned in such a way that the aft deck edge can not be submerged, the latter criterion does not need to be considered.

5. Eccentric beaching criteria:

- the GM is to be positive
- the beaching lever, calculated as 0.125 $B \times P_{ZB}$ /displacement is not to exceed 0.5 times the maximum GZ.

1207. Requirements to watertight integrity

1. As far as practicable, tunnels, ducts or pipes which may cause progressive flooding in case of damage, are to be avoided in the damage penetration zone. If this is not possible, arrangements are to be made to prevent progressive flooding to volumes assumed intact. Alternatively, these volumes are to be assumed flooded in the damage stability calculations.

2. The scantlings of tunnels, ducts, pipes, doors, staircases, bulkheads and decks, forming watertight boundaries, are to be adequate to withstand pressure heights corresponding to the deepest equilibrium waterline in damaged condition. ⚓

Annex 3-1 Guidance for Survey and Composition of Loading Manuals

1. Composition of loading manual

The loading manual is to be composed to the followings;

(1) General
Explanation of guidance for loading which is related to the ship's strength and in aiding of ship's master for its performance and condition.

(2) Standard loading condition
Explanation for the ship's standard loading condition

(3) Strength calculation for other conditions than standard loading condition. (See **5**)
However, the ships relating category 2 of **Ch 3, Table 3.3.3** are not necessary.

2. Contents is to be included in 'General'

(1) General explanatory notes for the arrangements, scantlings, structure and characteristics

(2) Precaution for loading
For the standard loading conditions the results of analysis of structural strength including transverse strength and local strength and operational precautions based on the results of analysis of the strength are to be specified. For loading different from the standard loading conditions, such items of precautions that no excessive stress as viewed from hull strength might be caused are to be specified. And further, precautions relative to weight shifting involving the transfer of ballast water and cargo for making the standard loading conditions or any other arbitrary loading conditions are to be specified. Although specific contents may differ on each ship, precautions must be generally taken on the following points in preparing the Loading Manual;

(A) The minimum bow draught required for the structural strength of the strengthened bottom forward
(B) Limitation to loading height of cargo holds
(C) Acceptability of alternate loading, two-port loading, etc.
(D) Limitation to liquid levels in tanks
(E) Limitation to loading with respect to local strength and transverse strength (e.g. limitations to the maximum design cargo weight on deck or hatch cover)
(F) Limitation to loading with respect to longitudinal hull strength
(G) Precautions for ballasting / deballasting and drydocking

(3) Allowable values for longitudinal still water bending moment and still water shearing force, and allowable stresses
Allowable values of longitudinal still water bending moment and still water shearing force calculated in accordance with the requirements of **4.** are to be prescribed. And, definition of positive (+) and negative (-) symbols of shearing force and longitudinal bending moment are to be prescribed in **5.2.**

(4) For bulk carriers, ore carriers and combination carriers of 150 m in length and above in L_f, the followings are included in addition to the above (1) to (3);

(A) For bulk carriers, envelop results or envelop data and allowable values to shearing force and still water bending moment under the cargo hold flooding.
(B) Where the cargos are fully loaded, empty cargo holds. if the ship is not permitted to remaining empty hold, this is to be noted in loading manual.
(C) Maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of draught at mid-hold position.
(D) Maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions. The calculating methods for allowable mass including the mass in (C) above are to be in accordance with **Annex 7-4 "Guidance for calculating the maximum allowable and minimum required mass of cargo and double bottom contents for bulk carriers"**
(E) Allowable loading weight of tank top and characteristic for the cargoes other than bulk cargoes
(F) Allowable loading weight of cargo hatch covers and deck. If cargo is not approved to load on the cargo hatch covers and deck, this is to be noted in loading manual.
(G) Ratio of maximum ballast exchanging and loading plans of ballast. And it is also to be prescribed that these are to be agreed with terminal including the ratio of ballasting exchange.

3. Standard loading condition

(1) In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the calculations of still water bending moment and shear force.
Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions.
Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.
(A) Cargo ships, container ships, roll on roll off ships, refrigerated cargo ships, bulk carriers, ore carriers, etc.
(a) Light load condition
(b) Ballast conditions (at arrival and departure)
(c) Homogeneous loading conditions of cargo (at arrival and departure)
(d) All non-homogeneous loading conditions as given in the specifications (at arrival and departure)
(e) Specially approved loading conditions for short voyage or in smooth water, where necessary
(f) Temporary severe loading conditions during cargo loading or unloading, where necessary
(g) Conditions for entering dry dock while afloat
(h) If applicable, Guidance for the ballasting exchange while the ship is at sea.
(i) All loading conditions specified Rule **Pt 7, Ch 3, Sec 2** for bulk carriers with notation BC-A, BC-B or BC-C, as applicable.
(B) Oil tankers
(a) Light load condition
(b) Ballast conditions (at arrival and departure)
(c) Homogeneous loading conditions (at arrival and departure)
(d) All non-homogeneous loading conditions as given in the specifications (at arrival and departure)
(e) Conditions which largely differ from the standard ballast condition due to tank cleaning or other work while the ship is at sea
(f) Temporary severe loading conditions during cargo loading or where necessary, unloading
(g) Conditions for entering dry dock while afloat
(h) If applicable, Guidance for the ballast exchanging while the ship is at sea.
(C) Chemical tankers
(a) The same conditions as specified in (B) for oil tankers
(b) The loading conditions specified in the Operation Manual
(c) Loading conditions for cargo items included in the approved list of cargoes, which are with high density, or require heating or isolated stowage.
(d) If applicable, Guidance for the ballast exchanging while the ship is at sea.
(D) Ships carrying liquefied gas as in bulk
(a) Light load condition
(b) Ballast conditions (at arrival and departure)
(c) Homogeneous loading conditions (at arrival and departure)
(d) Loading conditions involving empty or partially loaded tanks
(e) Loading conditions where two or more kinds of cargoes with largely different specific gravity are loaded in different tanks
(f) Loading in smooth water where an increased vapour pressure is approved
(g) Temporary severe loading conditions during cargo loading or unloading, where necessary.
(h) Conditions for entering dry dock while afloat
(i) If applicable, Guidance for the ballast exchanging while the ship is at sea.
(E) Combination carriers
(a) The same conditions as specified respectively in (A) and (B) above for cargo ships and oil tankers
(b) If applicable, Guidance for the ballast exchanging while the ship is at sea.
(F) For bulk carriers, ore carriers and combination carriers of 150 m length and above in L_f, the following loading conditions are to be included in addition to the above (A) and (E)

loading conditions. However, the following (d) and (e) loading conditions may be followed by the specification agreed between owner and builder, and also if some of the following loading conditions are not included in the Loading Manual a note to this effect is to be given in the Loading Manual.

(a) Alternate light and heavy cargo loading conditions at maximum draught, where applicable.
(b) Homogeneous light and heavy cargo loading conditions at maximum draught.
(c) Ballast conditions, For vessels having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty. Partial filling of fore peak tank is not acceptable in design ballast conditions, unless effective means are provided to prevent accidental overfilling.
(d) Short voyage conditions where the vessel is to be loaded to maximum draught but with limited amount of bunkers.
(e) Multiple port loading/unloading conditions.
(f) Deck cargo condition, where applicable.
(g) Guidance for typical loading/unloading sequences where the vessel is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, alternate conditions where applicable and relevant part loaded conditions is to be included. When this guidance is composed, precaution must be taken on loading rate, ballast and deballasting rates and applicable strength limitations, and the followings in this guidance are to be included.
   (i) The typical loading sequences as relevant should include the following loading conditions
      ① Loading conditions in above (a), (b), (d), (e) and (f)
      ② Block loading
   (ii) The loading/unloading sequences may be port specific or typical.
   (iii) The sequence is to be built up step by step from commencement of cargo loading to reaching full deadweight capacity. Each time the loading equipment changes position to a new hold defines a step. In addition to longitudinal strength, the local strength of each hold is to be considered.
   (iv) For each load condition above mentioned in (i), the summary for all steps is to include the followings,
      ① How much cargo is filled in each hold during the different steps.
      ② How much ballast is discharged from each ballast tank during the different steps.
      ③ The maximum still water bending moment and shear at the end of each step.
      ④ The ship's trim and bow, stern and mean draught at the end of each step.
      ⑤ The ship's air-draught when necessary.
   (v) The form of guidance for loading/unloading sequences is referred to **Table 4.**

(G) Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tank at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

(a) design stress limits are satisfied for all filling levels between empty and full, and
(b) for bulk carriers, Rule **Pt 7, Ch 3, Sec 10**, as applicable, is complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and any intermediate condition, the tanks intended to be partially filled are assumed to be:

(a) empty
(b) full
(c) partially filled at intended level

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of those tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of those one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full.

The trim conditions mentioned above are:

(a) trim by stern of 3% of the ship's length, or

(b) trim by bow of 1.5% of the ship's length, or

(c) any trim that cannot maintain propeller immersion(I/D) not less than 25%, where;

I : the distance from propeller centerline to the waterline

D : propeller diameter (see **Fig 1**)

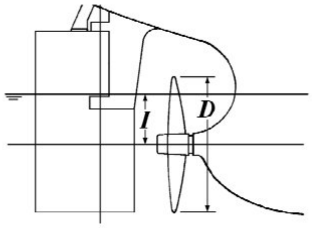


Fig 1 Immersion of propeller

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

(H) Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirements of (G), applies to the peak tanks only.

(I) Sequential ballast water exchange

Requirements of (G) and (H) are not applicable to ballast water exchange using the sequential method.

(2) Graphical illustration of standard loading conditions

(A) To enable the ship master to readily grasp the relationships between loading conditions and hull strength under the standard loading conditions and to utilize them as guidance for planning the loading, the results of calculation of longitudinal still water bending moment (M_S) and still water shearing force (F_S) at each condition are to be subjected to graphical illustration together with the respective allowable values. In this case, the directions of positive and negative are also to be specified for M_S and F_S.

(B) The above mentioned results of calculation are to be shown on a single page or on two spread pages as far as possible on each condition, together with arrangement plan of compartments (tanks and cargo holds), cargo stowage table and the results of trim and stability calculations. Descriptive examples of these are shown **5.3.** Restrictions imposed for operation of the ship in the standard loading conditions if any, are to be specified.

(3) Additional notation

(A) In addition to the requirements in 3 (1) (F) (g), the additional special feature notation **BLU-1** shall be assigned to ships which for bulk carriers with notation **BC-A** or **BC-B** and Ore carriers satisfied with the average loading rate in accordance with **Table 1** and the following requirements. If average loading rate is specified to be higher than those given in **Table 1**, loading rates are specified in the loading manual and submitted for the approval of the Society.

(a) The de-ballast capacity of the vessel shall meet the requirements for the average loading rates as specified in **Table 1**. If average loading rate is specified to be higher than those given in **Table 1**, the de-ballast capacity of the vessel shall meet the requirements for the higher loading rates. The average loading rate is defined as rate achieved from start to completion of total cargo loading divided by time elapsed.

(b) The vessel shall be designed such that minimum 50% of maximum permissible cargo intake per cargo hold can be loaded in one pour.

(c) Inner bottom strength shall be according to the requirements in **Pt 11, Ch 12, Sec 1** for CSR bulk carriers or **Pt 7, Ch 2, 202. 6** for ore carriers or **Pt 7, Ch 3, 304. 3** for bulk carriers.

(d) Each ballast tank shall be fitted with a separate stripping system to enhance de-ballasting and stripping during the loading/unloading sequences.

(e) Check of local strength for single and adjacent hold loading pattern shall be integrated into the software of the on-board loading computer.

(f) The vessel shall be fitted a remote sounding for water ballast and fuel oil storage tanks and draught reading system with an on-line interface into the software of the onboard loading computer.

(g) Special consideration shall be given if loading with two or more loaders simultaneous is specified.

Table 1 Average loading rate

Deadweight (DWT) (ton)	Average loading rate (ton/h)
30,000 < DWT ≤ 50,000	5,000
50,000 < DWT ≤ 80,000	8,000
80,000 < DWT	12,000

(B) In addition to the requirements in 3 (1) (F) (g), the additional special feature notation **BLU-2** shall be assigned to ships which for bulk carriers with notation **BC-A** or **BC-B** and Ore carriers satisfied with the average loading rate in accordance with **Table 2** and the following requirements. If average loading rate is specified to be higher than those given in **Table 2**, loading rates are specified in the loading manual and submitted for the approval of the Society.

(a) The de-ballast capacity of the vessel shall meet the requirements for the average loading rates as specified in **Table 2**. If average loading rate is specified to be higher than those given in **Table 2**, the de-ballast capacity of the vessel shall meet the requirements for the higher loading rates. The average loading rate is defined as rate achieved from start to completion of total cargo loading divided by time elapsed.

(b) The vessel shall be designed such that minimum 100 % of maximum permissible cargo intake per cargo hold can be loaded in one pour.

(c) The requirements in (A). (c) to (g) are to be satisfied.

Table 2 Average loading rate

Deadweight (DWT) (ton)	Average loading rate (ton/h)
30,000 < DWT ≤ 50,000	6,000
50,000 < DWT ≤ 80,000	9,000
80,000 < DWT ≤ 200,000	13,500
200,000 < DWT ≤ 250,000	14,000
250,000 < DWT	16,000

4. Allowable values for longitudinal strength

The allowable values for longitudinal still water bending moment and still water shearing force which are specified in the Loading Manual are to be determined with the consideration given to the design condition of the ship. Those values, however, are not to exceed the values specified in the following, at positions of transverse section of the hull where deemed necessary by the Surveyor.

(1) Allowable still water longitudinal bending moment (M_S)

For the ships specified in **Ch 3, 104. 1** (1) of the Rules, the values obtained from the following (A) or (B), whichever is smaller, is to be taken as the allowable value for each positive and negative moment at a transverse section of the ship under consideration. However, these values are to be also complied with **Ch 3, Sec 4.**

(A) Value determined by longitudinal bending moment

$$M_S(+) = 175fZ \times 10^{-3} - M_W(+) \quad \text{(kN-m)}$$

$$M_S(-) = 175fZ \times 10^{-3} - M_W(-) \quad \text{(kN-m)}$$

f = for the ships using the value f_B or f_D specified in **Ch 3, 124.** of the Rules, those values is to be used. For the ships not using those values, the value $1/K$ is to be used.

Z = section modulus of transverse section of the ship with respect to the ship's bottom or strength deck at the position under consideration (cm^3)

$M_W(+)$, $M_W(-)$ is to be in accordance with **Ch 3, Table 3.3.1** of the Rules.

(B) Value determined by torsional bending moment
In case where torsional moment is generated in the hull due to uneven cargo stowage, the warping stress value used in applying **Pt 7, Ch 4, 202.** of the Guidance is to be deducted from the value in [ ] in the following formula.

$$M_S(+) = \left[\frac{175}{K} - \sqrt{(0.75\sigma_V(+))^2 + \sigma_H^2 + \sigma_W^2}\right]\frac{Z_V}{1000} \quad \text{(kN-m)}$$

$$M_S(-) = -\left[\frac{175}{K} - \sqrt{(0.75\sigma_V(-))^2 + \sigma_H^2 + \sigma_W^2}\right]\frac{Z_V}{1000} \quad \text{(kN-m)}$$

$\sigma_V(+)$, $\sigma_V(-)$ is to be obtained from the following formula.

$$\sigma_V(+) = \frac{M_W(+)}{Z_V} \times 10^3$$

$$\sigma_V(-) = \frac{M_W(-)}{Z_V} \times 10^3$$

$M_W(+)$, $M_W(-)$ = as specified in **Ch 3, Table 3.3.1** of the Rules.

σ_H, σ_w, Z_V = as specified in **Pt 7, Ch 4, Sec 2** of the Guidance.

(2) For the ships under **Ch 3, 104. 1** (2) and (3) of the Rules and for the ships which are not under (1) and (3), longitudinal still water bending moment at the positions of transverse section of the ship under consideration for each positive and negative moment is to be determined from the preceeding (1) (A) and to satisfy the requirements **Ch 3, Sec 4** of the Rules.

(3) The allowable value for shearing force (F_S)

(A) The allowable value for shearing force is to be obtained from the following formula.

$$F_S(+) = \frac{110}{K} \times \frac{t_S I}{0.5Q} \times 10^{-2} - F_W(+) \quad \text{(kN)}$$

$$F_S(-) = -\frac{110}{K} \times \frac{t_S I}{0.5Q} \times 10^{-2} - F_W(-) \quad \text{(kN)}$$

t_S = thickness of side shell plating at positions under consideration. However, for the ships having longitudinal bulkheads, thickness of the part of longitudinal bulkheads are to be included (mm)

I, Q, $F_W(+)$ and $F_W(-)$ = as specified in **Ch 3, 301.** of the Rules.

(B) When the shearing force of the thickness of side shell plating is directly calculated, the value of preceeding (A) or the value to be obtained from following formula is to be taken, whichever is smaller.

$$F(+) = F\frac{\tau_P}{\tau} - F_W(+) \quad \text{(kN)}$$

$$F(-) = -F\frac{\tau_P}{\tau} - F_W(-) \quad \text{(kN)}$$

F = the shearing force acting on transverse section of the ship used in the direct strength calculation which is in accordance with **Ch 3, 301.** of the Guidance.

$F_W(+)$, $F_W(-)$ = As specified in **Ch 3, 301.** of the Rules

τ_P = allowable shearing force as specified in **Ch 3, 301.** of the Guidance. (N/mm^2)

τ = shearing force acting on transverse section of the ship determined by the direct strength calculation, where the greatest value among those which occur in side shell plating, bilge hopper tanks and top side tanks is to be taken (N/mm^2).

(C) The allowable value for shearing force in still water bending moment determined by the preceeding (A) and (B) is to be also complied with **Ch 3, Sec 4** of the Rules.

(4) Allowable values for still water bending moment and shearing force in harbour water free from the effects of waves may be obtained by taking half the values of the wave induced longitudinal bending moment and shearing force as specified in (1) and (2) respectively.

5. Composition of loading manual

5.1 Method of longitudinal strength for loading conditions different from the standard loading condition

(1) Confirmation items for longitudinal strength
Calculating and checking method of longitudinal strength for loading conditions different from the standard loading condition is to be in accordance with **Fig 2** and the following items are to be included for each point of output.
(A) Still water bending moment (M_S)
(B) Still water shearing force (F_S)
(C) Still water shearing force for alternate loading condition (F_C) (shearing force modified by alternate loading to F_S). However, for the ships designed without consideration of load distribution by double bottom structure, confirmation of still water shearing force for alternate loading condition may be dispensed

(2) Point of output for checking longitudinal strength
(A) At least six points of output of longitudinal still water bending moment are to be properly arranged in the range (including the midship 0.5 L).
(B) The points of output of still water shearing force are to be arranged at a position of fore and aft bulkheads of cargo loaded compartments and/or similar spaces. However, where the distance between transverse bulkheads is small such as cofferdam, checking of strength at either one of the bulkheads may be omitted. Also, where the shearing force is considered to be apparently small, checking of strength may be omitted.

(3) Grouping of loads in calculation
(A) Loads in those tanks symmetrically arranged on both sides of the ship may be summarized in same group in calculation.
(B) In case where two or more hatch openings are provided for one cargo hold, calculations to be made for each such hatch opening. However, where separation according to type of cargo is unnecessary, calculation may be made by hold.

(4) Procedure for checking longitudinal strength
(A) In order to facilitate checking of allowable cargo loading, the relation between loading and longitudinal strength, and the procedure of checking longitudinal strength are to be explained by using flow chart or any other proper means. Descriptive examples are shown in **5.4.**
(B) The following allowable values corresponding to values calculated in (1) above are to be clearly specified so that the shipmaster can judge the adequacy of cargo loading without making mistakes.
(a) Allowable value for longitudinal still water bending moment (allowable value of M_S)
(b) Allowable value for still water shearing force (allowable value of F_S)
(C) Terms and symbols used for describing the calculated values and allowable values are to be

same as used in (1) and (4) (B).

(5) Method of Calculation

(A) Calculations of longitudinal still water bending moment (M_S) and still water shearing force (F_S)
Longitudinal still water bending moment and still water shearing force are to be determined basing upon direct strength calculation.

(B) Calculation of still water shearing force in alternate loading (F_C)
Corrective calculations in case where the adjoining holds are alternately loaded are to be made according to the method as given in **5.6.**

(C) Calculation of these are to be attached to Loading Manual.

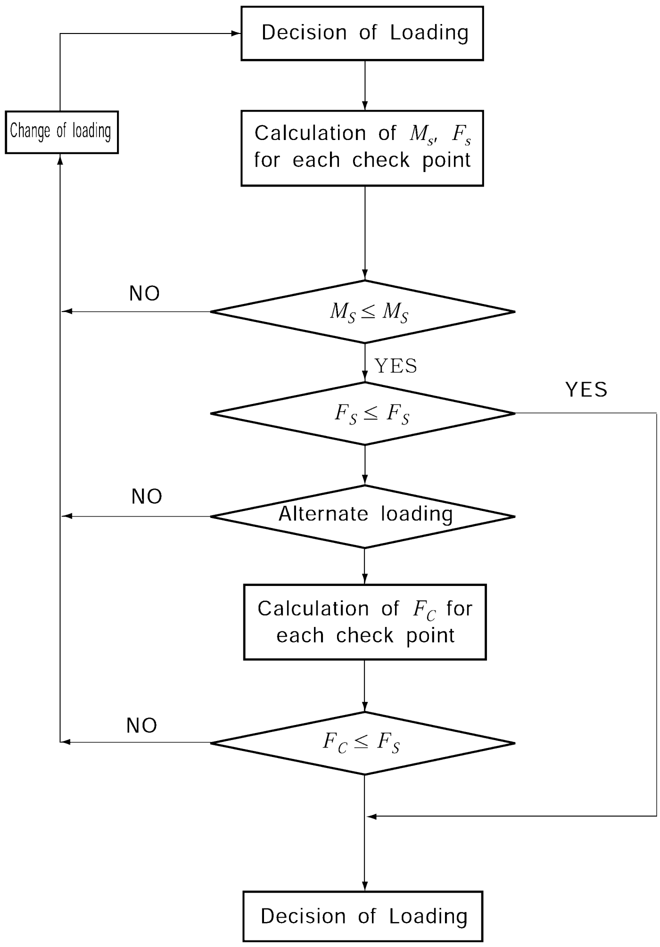


Fig 2 Flow chart of confirmation of longitudinal strength

5.2 Descriptive example for the allowable value for longitudinal bending moment and still water shearing force.

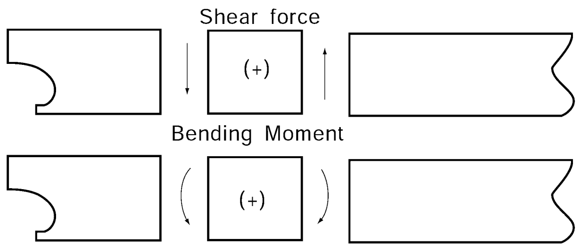
For the permissible value of still water bending moments and shearing forces are to be as follows at sea and in harbor.

At sea

Check Point	Permissible value of still water Bending Moments		Permissible value of still water Shearing forces	
	(+)	(−)	(+)	(−)

In harbor

Check Point	Permissible value of still water Bending Moments		Permissible value of still water Shearing forces	
	(+)	(−)	(+)	(−)

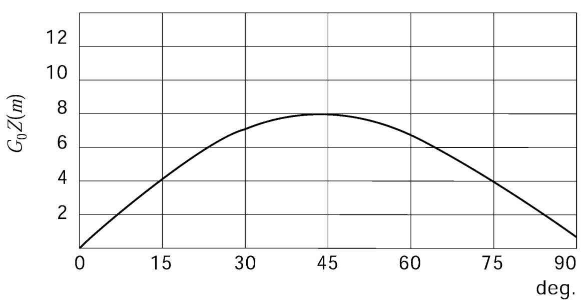


5.3 Descriptive example for standard loading conditions

CONDITION NO.Ⅱ NORMAL BALLAST CONDITION DEPARTURE

DISPLACEMENT		T	138362
DRAFT AT C.F.		m	10.52
DRAFT	FORE	m	8.87
	AFT	m	12.47
	MEAN	m	10.67
TRIM		m	3.60
ꝏG		m	-8.65
ꝏB		m	-5.50
ꝏF		m	-2.29
MTC		t-m	2629.8
KM		m	25.70
KG		m	12.36
GM		m	13.34
GG_0		m	0.44
G_0M		m	12.90
PROPELLER IMMERSION(I/D)		%	75.41
DETAIL OF DEADWEIGHT			
CARGO OIL		t	0
BALLAST WATER		t	99445
FULL OIL		t	3760
DIESEL OIL		t	
FRESH WATER		t	500
CONSTANT		t	322
OTHERS PROVISIONS		t	
DEADWEGHT TOTAL		t	104027
LONGITUDINAL STRENGTH			
MAX. BENDING MOMENT(AT FR 95)		kN-m	1,740,740
MIN. BENDING MOMENT (AT FR 79)		kN-m	-3,553,630
MAX. SHEAR FORCE(AT FR 88)		kN	138,330
MIN. SHEAR FORCE (AT FR 58)		kN	-78,570
STABILITY			
G_0Z MAX.		m	7.84
ANGLE OF G_0Z(MAX.)		deg.	40.00

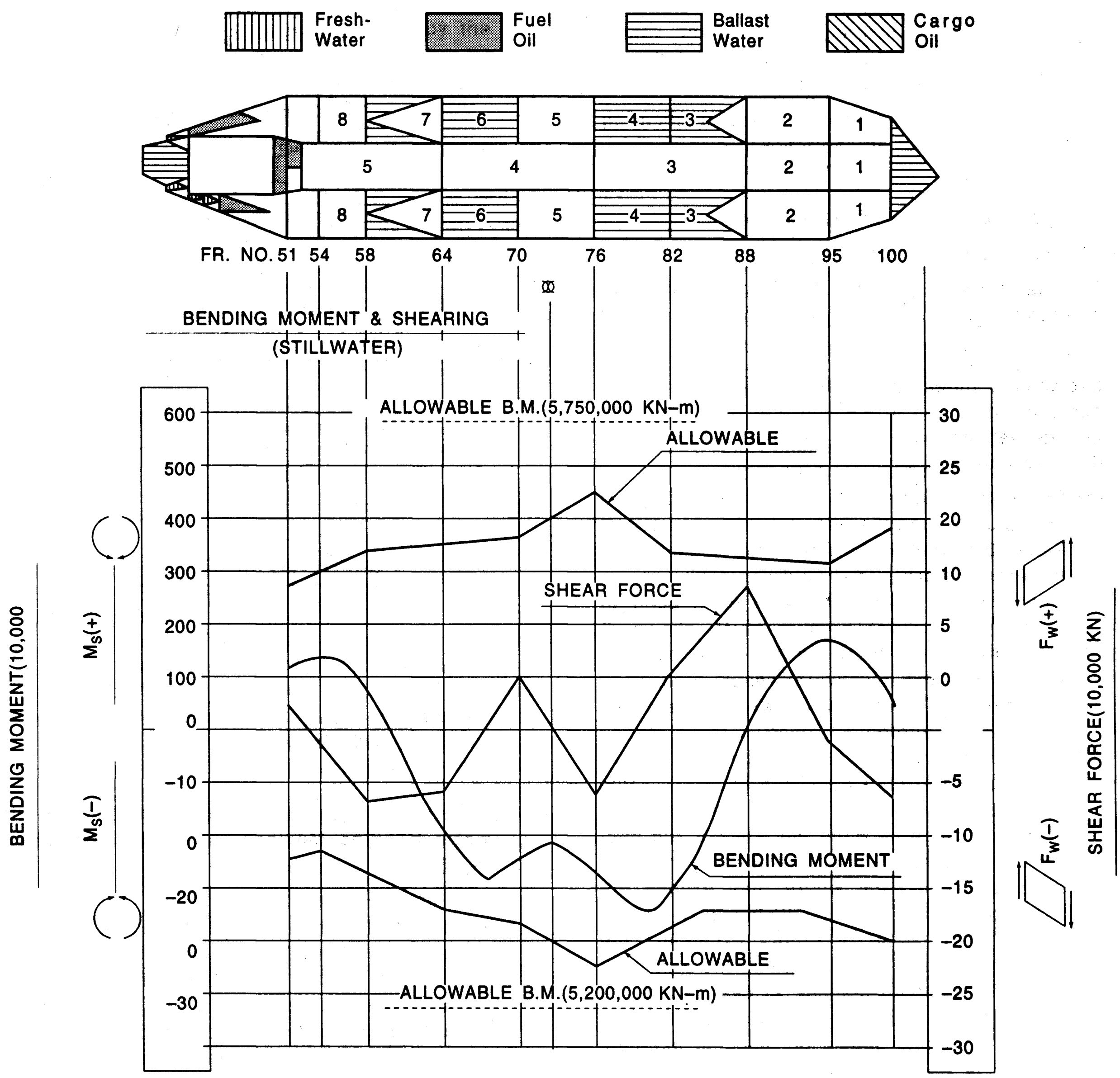
STATICAL STABILITY CURVE



WEIGHT CONDITIONS

TANK	CARGO OIL (BALLAST WATER)												
	NO1 CT	NO2 CT	NO3 CT	NO4 CT	NO5 CT	NO1 WT	NO2 WT	NO3 WT	NO5 WT	NO6 WT	NO7 WT	NO8 WT	SLOP T
WEIGHT (t)	0	0	0	0	0	0	0	20000	0	27284	14000	0	0
VOL/CAP (%)	0	0	0	0	0	0	0	74	0	98	53	0	0

TANK	BALLAST WATER				FRESH WATER				FUEL OIL				
	FPT	NO4 WT	APT		FWT	DRWT	TSWT (F)	TSWT (A)	FOT (P)	FOT (S)	FOST (P)	FOST (S)	
WEIGHT (t)	9919	27288	954		200	170	60	70	995	994	1091	680	
VOL/CAP (%)	98	98	98		50	54	53	50	33	33	98	98	



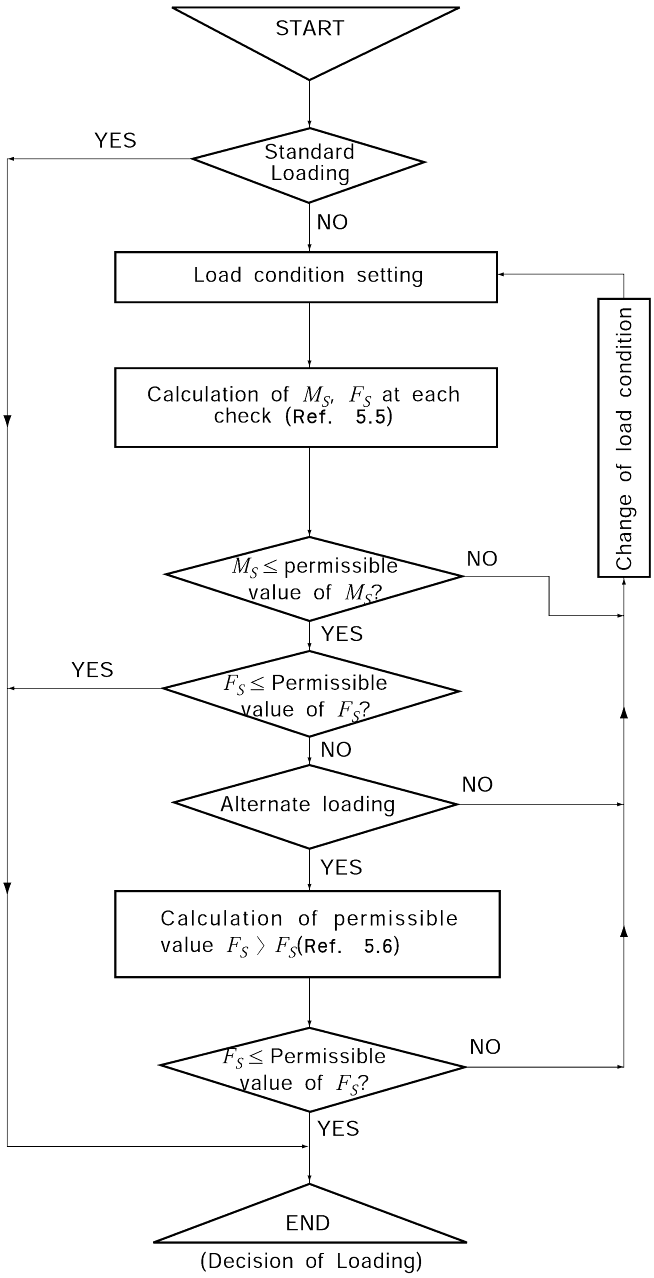


Fig 3

5.4 Descriptive example on the procedure of calculation of longitudinal still water bending moment and still water shearing force

Adjustments in loading and judging procedure

In case where loading different from the standard loading conditions is made, the longitudinal still water bending moment (M_S) and still water shearing force(F_S, F_C) are to be obtained by the procedures stated below and the loading is to be adjusted in such a manner that the values as obtained above do not exceed the respective allowable values. Since the allowable value are set in such a manner that the stresses acting on the hull due to longitudinal bending moment and shearing force predictable while the ship is sailing in the ocean do not exceed the allowable limits to the structural strength of the specific part of the hull under consideration, the strength of the ship during at sea can be ensured so far as the values of M_S, F_S and F_C at each point of output do not exceed the corresponding allowable values.

The longitudinal bending moment and shearing force to be checked are as follows

Still water bending moment (M_S)

Still water shearing force (F_S)

Still water shearing force acting on longitudinal bulkhead (F_C)

Explanatory notes on details of calculation procedures will be given in **5.5** and **5.6,** but calculation and its verification are to be made according to the following flow Chart in **Fig 3.**

(1) Calculate values of M_S and F_S at each point of output through the use of the form as shown **Table 3** in **5.5** by giving the quantities of loading for each cargo hold and tank.

(2) Check if the values of M_S at each point of exceed the allowable value of M_S shown in **Fig 3.** If they are verified to be in the range between the positive and negative allowable proceed to the next step. In case where exceed the allowable values, alternate loading is to be made.

(3) Check if the values of F_S at each point of output obtained in (1) exceed the allowable value of F_S as shown in **Fig 3.** If they are verified to be in the range between the positive and negative allowable values, the loading may be acceptable. In case where they exceed the allowable values, proceed to the next step.

(4) Check if the point of output exceeding the allowable value of F_S falls within the area subjected to alternate loading. In case where the alternate loading is found to be irrelevant, alternation in loading should be made. If alternate loading is found to be irrelevant, proceed to the next step.

(5) On points of output exceeding the allowable value of F_S, F_C is to be calculated in accordance with **Table 5.**

5.5 Method of calculation of longitudinal still water bending moment and still water shearing force

(1) General explanation

In applying this method of calculation of longitudinal strength, the longitudinal still water bending moment and still water shearing force at various locations of the hull under the actual loading condition of the ship can be obtained.

The method of calculation and symbols for longitudinal strength are as follows

ΣW = Integral value of deadweight from the fore end of L to each point of output (shearing force due to dead-weight) (1,000 tons)

SS = Integral value of (buoyancy-light weight) from the fore end of L to each point of output (shearing force due to (buoyancy-light weight)×(1,000 tons)

ΣM_t = Double integral value of deadweight from the fore end of L to each point of output (bending moment due to deadweight)× (1,000 tons-m)

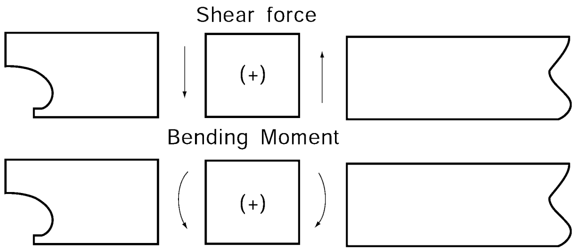
SB = Double integral value of buoyancy and the ship's weight from the fore end of L to each point of output (bending moment due to buoyancy and the ship's light weight) (1,000 tons-m)

The longitudinal still water shearing force(F_S) and still water bending moment (M_S) at each point of output can be calculated by the following formula

$$F_S = (SS - \Sigma W) \times 9800 \quad \text{(kN)}$$

$$M_S = (\Sigma M - SB) \times 9800 \quad \text{(kN-m)}$$

where the sign convention of F_S and M_S is the same of each allowable value, as shown in the following figures



In this method of calculation of longitudinal strength, the shearing forces (SS) and the bending moments (SB) due to buoyancy and the ship's light weight are calculated for every metre of draught and the longitudinal strength data, a list of shearing forces and bending moments for respective set-up draughts are prepared. In **Table 4,** an example of numerical table for one set for the specific draught is given for an example.
Accordingly, by calculating only the shearing force and bending moment due to dead weight, the longitudinal still water shearing force (F_S) and still water bending moment (M_S) for each point of output can easily be obtained on board the ship.

(2) Procedure for calculation of Longitudinal strength
The calculation of longitudinal strength may be proceeded by filling up the spaces given in **Table 3.** The procedure is given as follows

(A) After draught (DA) and trim
The after draught and trim, in the conditions for which the calculation of longitudinal strength is to be made, are to be filled up in the blank spaces. In this case, the trim by the bow is to be noted with negative sign (-).

(B) Base draught (DB) and difference of draught (ΔD)
A draught, closes to but is less than the after draught is to be selected from among the base draughts given in the longitudinal strength data and is to be filled up in the space for the base draught, and the difference between the after draught and the selected base draught is to be entered in the space for the difference (ΔD).

(C) Column for Weight
One-thousandth of the deadweight (ton) in the respective compartments is to be entered in this column.

(D) Column for Wi
This column is for indicating the dead-weight in the respective compartments exerted on points of longitudinal strength output, which is obtained by multiplying the deadweight by the ratio (ratio of compartment to be included in each point of output).

(E) Column for Mi
This column is for indicating the moment around the midship which is created by the deadweight in the respective compartments, and here the value of $W_i \times G$ is to be entered.

(F) ΣWi, ΣMi
The accumulations of Wi and Mi. included between the fore end and each point of output are to be filled up here.

(G) SS and SB
SS and SB indicate the shearing force and the bending moment due to buoyancy and the ship's light weight respectively and they are to be calculated according to the following procedures

(a) Correction factors (CD and CT) in accordance with base value, difference of draught and trim
The base value (column ①) and the respective correction factors (CD and CT) at each point of output is to be transferred from the longitudinal strength data for the draught adopted as the base draught to the corresponding space.

(b) Correction for difference of draught (ΔD) (column ②)
This is to correct the difference between the base draught and the actual draught. The correction is to be made by multiplying the correction factor (CD) by the difference of draught (ΔD).

Table 3 Calculation sheet for still water bending moments(M_S) shearing force (F_S)

○ CONDITION

AFT DRAFT (DA) : (m)
BASE DRAFT (DB) : (m)
DIFFERENCE(△D)=DA-DB : (m)
TRIM : (m)

i	D.W.ITEM	WEIGHT 1/1,000	RATIO	LOAD (W_i)	G	MOMENT
1	FORE PEAK TANK		1.000		140.08	
	FR. 99	ΣW_i = ( ) $i=1$			ΣM_i = ( ) $i=1$	
2	No. 1C.O.T. (C)		1.000		121.30	
3	No. 1C.O.T. (P/S)		1.000		120.20	
	FR. 94	ΣW_i = ( ) $i=1\sim3$			ΣM_i = ( ) $i=1\sim3$	
4	No. 2C.O.T. (C)		0.500		94.80	
5	No. 2C.O.T. (P/S)		1.000		94.63	
	FR. 88	ΣW_i = ( ) $i=1\sim5$			ΣM_i = ( ) $i=1\sim5$	
6	No. 2C.O.T. (C)		0.500		64.80	
7	No. 3C.O.T. (P/S)		1.000		64.80	
	FR. 82	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim7$	
8	No. 3W.B.T. (C)		0.500		34.80	
9	No. 4C.O.T. (P/S)		1.000		34.80	
	FR. 76	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim9$	
10	No. 3W.B.T. (C)		0.500		4.80	
11	No. 5C.O.T. (P/S)		1.000		4.80	
	FR. 70	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim11$	
12	No. 4C.O.T. (C)		0.500		-25.20	
13	No. 6C.O.T. (P/S)		1.000		-25.19	
	FR. 64	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim13$	
14	No. 4C.O.T. (C)		0.500		-55.20	
15	No. 7C.O.T. (P/S)		1.000		-55.07	
	FR. 58	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim15$	
16	No. 5C.O.T. (C)		0.674		-80.17	
17	No. 8C.O.T. (P/S)		1.000		-79.93	
	FR. 54	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim17$	
18	No. 5C.O.T. (C)		0.326		-95.08	
19	SLOP TANK (P/S)		1.000		-94.74	
	FR. 52	ΣW_i = ( ) $i=1\sim7$			ΣM_i = ( ) $i=1\sim19$	

	ITEM	SHEARING FORCE (F_S)			BENDING MOMENT (M_S)		
FR.99	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-132.8) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		110,000~-99,080	ALLOWABLE BENDING MOMENT		2,790,000~-2,183,600
FR.94	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-109.8) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		129,000~-113,370	ALLOWABLE BENDING MOMENT		4,340,000~-3,321,300
FR.88	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-79.8) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		128,000~-112,030	ALLOWABLE BENDING MOMENT		6,040,000~-4,449,800
FR.82	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-49.8) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		122,000~-112,720	ALLOWABLE BENDING MOMENT		6,590,000~-4,459,000
FR.76	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-19.8) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		113,000~-112,900	ALLOWABLE BENDING MOMENT		6,520,000~-4,159,000
FR.70	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-10.2) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		113,500~-113,690	ALLOWABLE BENDING MOMENT		6,520,000~-4,459,000
FR.64	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-40.2) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		102,000~-113,180	ALLOWABLE BENDING MOMENT		6,520,000~-4,159,000
FR.58	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-70.2) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		93,000~-112,030	ALLOWABLE BENDING MOMENT		6,030,000~-4,422,200
FR.54	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-90.2) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		100,400~-111,370	ALLOWABLE BENDING MOMENT		1,100,000~-3,358,000
FR.52	BASE VALUE		①			①	
	DRAFT CORRECTION	CD ( ) × △ D	②		CD ( ) × △ D	②	
	TRIM CORRECTION	CT ( ) × TRIM	③		CT ( ) × TRIM	③	
	BUOYANCY & L.W.	①+②+③	SS		①+②+③	SB	
	DEADWEIGHT	Σ Wi	ΣW		ΣW × (-100.0) + ΣMi ( )	ΣW	
	CALCULATED VALUE	(SS-ΣW) × 9,800			(ΣM - SB) × 9,800		
	ALLOWABLE VALUE	ALLOWABLE SHEARING FORCE		102,000~-112,370	ALLOWABLE BENDING MOMENT		3,830,000~-3,321,300

(c) Correction for trim (column ③)
In case where the ship has any trim, the correction for trim is to be made by multiplying the correction factor (CT) by the value of trim (m).
(d) Summation
The base value 0, corrected value for the difference of draught ② and the corrected value for trim ③ are to be summed up and the sums are to be filled up in the spaces for SS and SB.

Table 4 Longitudinal strength data (for buoyancy & light ship weight)
***** Each value shows(actual value/1,000) *****
Base draft 12.000 meter

CALCULATION POSITION	SHEAR FORCE (UNIT MT) BASE VALUE (S.F.)	DRAFT CORRECTION (CD)	TRIM CORRECTION (CT)	BENDING MOMENT (UNIT MT-M) BASE VALUE (B.M.)	DRAFT CORRECTION (CD)	TRIM CORRECTION (CT)
FRAME (99)	2.876	0.401	-0.398	18.730	2.903	-3.078
FRAME (94)	11.902	1.4031	-1.298	181.011	23.039	-22.151
FRAME (88)	26.933	2.932	-2.545	760.620	87.944	-80.102
FRAME (82)	42.272	4.471	-3.647	1798.719	198.979	-173.183
FRAME (76)	57.510	6.009	-4.594	3295.504	356.179	-297.098
FRAME (70)	72.780	7.548	-5.389	5249.910	559.546	-447.489
FRAME (64)	88.048	9.087	-6.029	7662.468	809.082	-619.135
FRAME (58)	102.735	10.638	-6.515	10528.060	1104.844	-807.690
FRAME (54)	110.924	11.599	-6.740	12667.050	1327.222	-940.344
FRAME (52)	114.087	12.026	-6.818	13770.015	1443.008	-1006.792

(H) ΣW and ΣM
ΣW and ΣM indicate the shearing force and bending moment due to deadweight respectively which are obtained by the following procedure
(a) Column for ΣW
ΣW is the accumulation(ΣWi) of dead-weight at each point of output which is to be transferred in this column.
(b) Column for ΣM
ΣM is the bending moment at each point of output converted from the bending moment (ΣMi) around the midship due to deadweight at each point of output, and the values obtained from the following formula is to be entered.

$$\Sigma W \times \ (corrected\ lever) + \Sigma Mi$$

(I) Still water shearing force
Still water shearing force(F_S) indicated the actual still water shearing force under loading condition at each point of output and is obtained from by the following formula.

$$F_S = (SS \cdot \ \Sigma W) \times 9800 \quad \text{(kN)}$$

(J) Longitudinal still water bending moment (M_S)
Longitudinal still water bending moment indicates the actual longitudinal still water bending moment under loading condition at each point of output, and is obtained from the following formula

$$M_S = (\Sigma M - SB) \times 9800 \quad \text{(kN-m)}$$

5.6 Method of calculation of shearing force in alternate loading

In case where the adjoining holds are loaded alternately, the shearing force is to be corrected in accordance with the calculation form shown in **Table 5.**

(1) Method of calculation (See **Fig 3**)

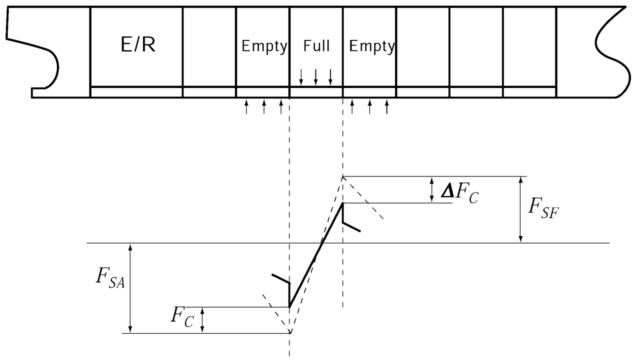


Fig 3 Correction of still water shearing force in alternate loading condition

Table 5 Example of calculation sheets for shearing force (F_C) when alternately loaded.

			FR. 37	FR. 70		FR. 102		FR. 125		FR. 158		FR. 181		FR. 205
①	F_S (kN)													
	Holds		No. 6 Cargo Hold		No. 5 Cargo Hold		No. 4 Cargo Hold		No. 3 Cargo Hold		No. 2 Cargo Hold		No. 1 Cargo Hold	
②	$F_{SF}-F_{SA}$ (kN)													
	Top Side Tank		No. 4 Top Side Tank				No. 3 Top Side Tank				No. 2 Top Side Tank		No. 1 Top Side Tank	
③	Weight of TST (kN)													
④	C (Load ratio)		0.5		0.5		0.5		0.5		1.0		1.0	
⑤	F_T (③×④)													
⑥	$F_{SF}-F_{SA}-F_T$ (②-⑤)													
⑦	C (coefficient)		0.305		0.264		0.264		0.250		0.264		0.302	
⑧	ΔF_C (⑥×⑦)													
⑨	F_{CA} and F_{CF}		F_{CA} ①+⑧	F_{CF} ①-⑧	F_{CA} ①+⑧	F_{CF} ①-⑧	F_{CA} ①+⑧	F_{CF} ①-⑧	F_{CA} ①+⑧	F_{CF} ①-⑧	F_{CA} ①+⑧	F_{CF} ①-⑧	F_{CA} ①+⑧	F_{CF} ①-⑧
⑩	Permissible shearing forces (kN)	+	30,200	25,500		26,300		27,600		27,600		25,200		29,300
		-	-28,100	-25,200		-25,200		-27,600		-28,700		-28,500		-30,400

(A) Still water shearing force (F_S) (column ①) (kN)
Still water shearing force obtained in **5.5** is to be transferred to column ①.

(B) Load between transverse bulkheads
($F_{SF}-F_{SA}$) (column ②) (kN)
For each hold, still water shearing force (F_S) at aft end bulkhead of hold is given as F_{SA}, and shearing force (F_S) at fore end bulkhead of hold is given as F_{SF}, and the difference, $F_{SF}-F_{SA}$ is entered in column ②.

(C) Ballast weight of topside tank (column ③) (kN)
Where topside tank is loaded with ballast etc., the weight of the load (tons) is multiplied

by **9.8** and the corresponding value (kN) is entered in column ③.

(D) Ballast weight of topside tank between bulkheads (F_T) (column ⑤) (kN)
This column represents, for each hold, ballast (F_T) of topside tank supported by transverse bulkheads at fore and aft ends of the holds, and a value derived by multiplying the ballast weight of top side tank by the load ratio C in column ④ is recorded.

(E) Load acting on double bottoms($F_{SA}-F_{SF}-F_T$) (column ⑥) (kN)
This column represents, for each hold, the load which acts on the double bottoms of the holds, and (value of column ② − value of column ⑤) is recorded.

(F) Shearing force modifier (ΔF_c) (column ⑧) (kN)
This column represents, for each hold, the shearing force modifier which modifies the shearing force at fore and aft ends bulkhead of the hold, and the value obtained by multiplying the load in column ⑥ by a coefficient C (column ⑦) in accordance with **Ch 3, Table 3.3.6** of the Guidance is recorded.

(G) Shearing force at fore and aft of transverse bulkhead (F_{CA} and F_{CF}) (column ⑨) (kN)
This column represents shearing force at fore side of aft end bulkhead of hold (F_{CA}) or shearing force at aft side of fore end bulkhead of hold (F_{CF}) is given in the following (a) and (b).

(a) The shearing force at the fore side of aft end bulkhead of hold is to be givens F_{CA} as follows.

$$F_{CA}=F_{SA}+\Delta F_c$$

where

F_{SA}= shearing force at aft end bulkhead of hold under consideration, whose value is recorded in column ①.

ΔF_c = shearing force modifier at the hold under consideration whose value is recorded in column ⑧.

(b) the shearing force at the aft side of fore end bulkhead of hold is to be given as F_{CF} as follows.

$$F_{CF}=F_{SF}+\Delta F_c$$

where

F_{SF} = shearing force at fore end bulkhead of hold under consideration, whose value is recorded in column ①.

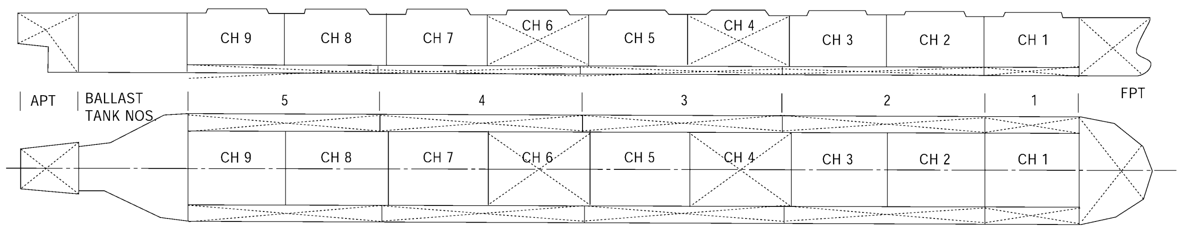
ΔF_c = as given in the preceding (a).

(H) Allowable value of shearing force (kN)
The allowable values of shearing force are indicated in the column ⑩, and thus the value of shearing force in alternate loading condition (value of column ⑨) is to be in the range between these two allowable values.

Table 6 Form of the guidance for cargo loading/unloading

Vessel Name		Condition at commencement of loading/discharging	Light Ballast Arrival with 10% Bunker	Maximum loading/discharging rate	–
Class No.		Condition at end of loading/discharging	Homogeneous Full Load Departure with 100% Bunker	Maximum ballasting/deballasting rate	–
Port (specific or typical)		Total mass of cargo to be loaded/discharged(t)		Average loading/discharging rate	–
Dock water density (t/m^3)		Number of loaders/dischargers		Average ballasting/deballasting rate	–

Step	Cargo Operations(ton)					Ballast Operation(ton) (+ : charged, - : discharged)												Values at the end of each step						
	No.5	No.4	No.3	No.2	No.1	APT	No.5 WBT		No.4 WBT		No.3 WBT		No.2 WBT		No.1 WBT		FPT	T_{aft} (m)	T_{fwd} (m)	T_{mean} (m)	Trim (m)	S.F (%)	B.M (%)	Remarks
							Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper								
0																								sea limits
1																								harbour limits
2																								harbour limits
3																								harbour limits
4																								harbour limits
5																								harbour limits
Draft Survey	Total Cargo onboard(t) :			Remaining Cargo to be loaded(t) :		Total amount of bunkers onboard(t) :																		
6																								harbour limits
7																								harbour limits
8																								harbour limits
9																								sea limits



Hold/Ballast content at end of loading/discharging(ton)													
Total Cargo	No.5	No.4	No.3	No.2	No.1	APT	No.5 WBT	No.4 WBT	No.3 WBT	No.2 WBT	No.1 WBT	FPT	Total Ballast

*1 Maximum occurring values among all conditions above(ton)						
	No.5	No.4	No.3	No.2	No.1	Net Load Double Bottom = M_n - $T \times B \times l_c \times \rho(t)$ where, M_n = Mass in hold + Mass in Double Bottom (t), B = Breadth moulded(m) l_c = Length of hold from bulkhead to bulkhead(m), T = Draft(m)
Net Load						
*2 Net Load in 2 Holds						

Notes
*1 : This table is not required to existing ships. *2 : Net load in two adjacent holds. The latest date for implementation is 1st. July 1999 Total amount of bunkers onboard at the final stage : 1970 ton

Annex 3-2 Guidance for the Direct Strength Assessment

I. General

1. Application

(1) This Guidance deals with procedure of direct structural analysis that is composed of structural modeling, stress calculating, yielding check and buckling check for the primary supporting members of hull.
(2) This Guidance consists of global structural analysis and hold structural analysis according to size of structural model.

2. Classification note

Upon the request of the applicant (i.e., the Owner or the Builder), the class notation **SeaTrust(DSA1)** or **SeaTrust(DSA2)** shall be assigned to ships which have been built to comply with the following requirements.

(1) The ships, which are contracted for construction on or after 1 April 2006 and are to be complied with Rule **Pt 11** or **Pt 12,** are to meet all the requirements of the corresponding parts.
(2) The container ships, bulk carriers and double hull tankers should meet all requirements in **Ⅲ. Hold Analysis** and **SeaTrust(DSA1)** is assigned to those ships. Where, however, it is deemed to be necessary by the Society, the requirements in **Ⅱ. Direct Global Structural Analysis** should be applied additionally, and **SeaTrust(DSA2)** is assigned in this case.
(3) When allowing the classification notation **SeaTrust(DSA1)** or **SeaTrust(DSA2)** for other types of ships not specified in (1) or (2) above, the relevant requirements of this Guidance may be applied as appropriate.

II. Direct Global Structural Analysis

1.General

(1) Application
(A) This Guidance provides overall procedures to be used in the global structural analysis with direct transfer of loads from hydrodynamic and stochastic analysis for the purpose of structural safety assurance. This guidance is only applicable to ships intended for unrestricted service and specified in **Ch 3** of the Rules.
(B) The design of the structure is to be in accordance with **Ch 3** of the Rules regardless of the structural analysis according to this guidance, and the results of the direct global structural analyses cannot be used to reduce the basic scantlings based on the Rules.
(C) It is recommended to use a return period of at least 20 years in North atlantic for design loads, which is equivalent to 10^{-8} probability level.
(D) The seakeeping and hydrodynamic load analysis is to be carried out using computer program recognized by the Society based on linear 2D Strip method or linear 3D panel method. The non-linear effects should be considered if these effects are regarded to be important after initial evaluation of the hull shape.
(E) The structural analysis is to be carried out using computer program which can consider the effects of bending deformation, shear deformation, axial deformation and torsional deformation.
(2) Documentation
The followings should be presented to the Society for approval of the direct global structural analysis in accordance with this Guidance.
- basic input(drawings, loading manual, etc)
- structural model
- hydrodynamic model
- mass model
- assumptions and theory used in analysis
- results of the seakeeping and hydrodynamic analysis

- results of the structural analysis

(3) The flow chart of the direct global structural analysis is shown in **Fig 1**

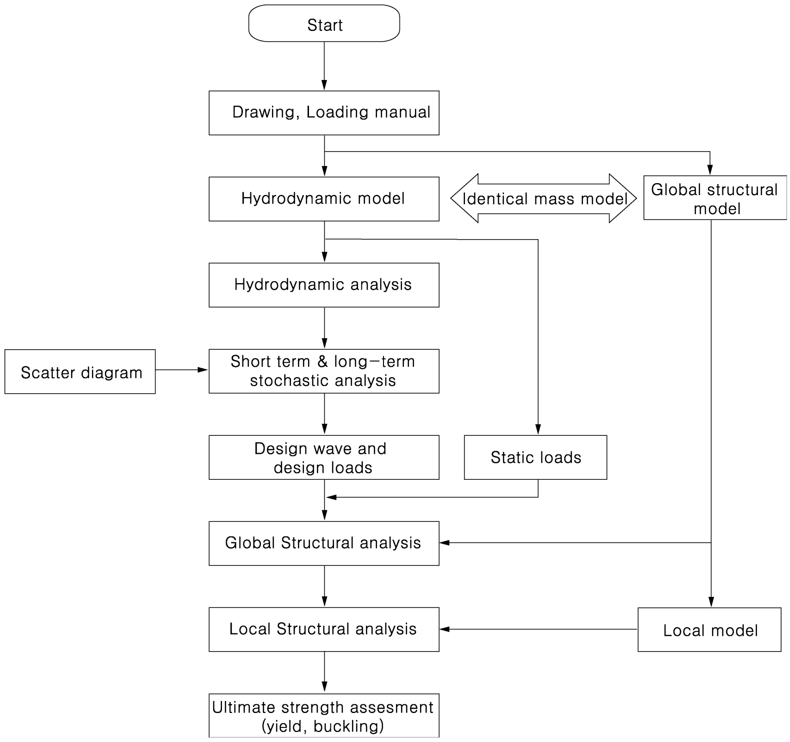


Fig 1 Flow chart of the direct global structural analysis

2. Hydrodynamic model

(1) The hydrodynamic model applied in seakeeping and hydrodynamic load analysis is to represent the geometry and hydrodynamic characteristics of wetted surface exactly as far as possible.

(2) 2D strip model

At least 25 ~ 30 strips should be applied, including at least 10 ~ 14 offsets points on half side. A good representation in areas with large transitions in shape(bow and fore part, bilge) should be ensured using higher density of strips and offsets points. Even areas with constant shape should be divided into several segments to consider the gradient of the hydrodynamic pressure distribution.

(3) 3D Panel model

The element size should be sufficiently small to avoid numerical errors. At least 30 ~ 40 stations, including 15 ~ 20 panels at each station should be applied. This means 500 ~ 800 elements on half side. A good representation in areas with large transitions in shape(bow and fore part, bilge) should be ensured using higher density of panels. Areas with constant shape should be divided into several panels to consider of hydrodynamic pressure distribution.

(4) Hydrodynamic model should be made to coincide with structural model in geometry, displacement and center of buoyancy.

3. Structural model

(1) Modeling of structure

(A) The model of structure to be analysed is to include its surrounding members which are considered to have a material influence on the behaviors of the members.

(B) A proper selection of shell elements, beam elements and truss elements is to be made to represent the global stiffness of the hull precisely.

(C) The scantlings is to be modelled with corrosion addition.

(D) In general, one shell element may be used to model the structures between girders or floors in the global structural analysis. However, if the structural analysis is carried out to get deformation response and nominal stresses of the structural members in the midship hold area, the modelling is to be done in accordance with **III. Hold Analysis.** For the critical areas where the element size is not small enough to get a proper structural response, finer mesh divisions should be used. The finer mesh models may be solved separately in the condition of same boundary conditions as the global structural model.

(E) The proper size of meshes should be selected to consider the stress distribution predicted in the model and to avoid abnormally large aspect ratios of meshes.

(F) If a shell element is stiffened by several stiffeners, two equivalent stiffeners each of which has the half of the total stiffness, may be modelled along the both sides of the element.

(G) The effective cross-section area of a stiffener is to decided according to following **Table 1** which depends on the end connection.

Table 1 Line element effective cross-section area

End connection	Effective cross-section area
sniped both ends	30 % cross-section area of stiffener
sniped one end, connected other end	70 % cross-section area of stiffener
connected both ends	100 % cross-section area of stiffener
Primary member face bars	100 % cross-section area

(H) Model check

In order to confirm the proper modelling of the hull structure, the model is to be checked according to the following methods, or equivalent ones recognized by the Society.

(a) The tolerance between the section modulus obtained from F.E model and that of the midship drawings, is to be less than ±1 %.

(b) The axial bending stresses should be the same value as those obtained from the beam theory as far as possible. The axial bending stresses are M/Z in the beam theory, where M is the sum of the still water bending moment and the wave bending moment and Z is the section modulus of the section of interest.

(2) Boundary conditions

The boundary conditions for the global structure model should reflect simple supporting. This is obtained through the example shown **Table 2** and **Fig 2.** The fixation points should be located far away from the areas of interest.

Table 2 Boundary condition

Location	Displacement		
	δx	δy	δz
Point A	1	1	1
Point B	0	1	1
Point C	0	1	0
(Notes) 1 : constrained 0 : Free			

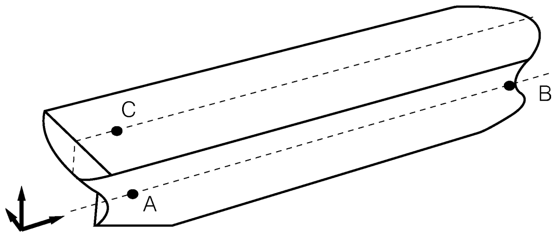


Fig A3.2.2 Boundary condition

4. Mass model

(1) The total weight of the ship structures is the sum of all the individual members. The weight of each member is the product of structure volume by structure density, and the structure density may be increased properly to consider omitted minor structures. The additional weight should be distributed properly over ship length because the weight differences occur all over the ship.
(2) The cargo weight model should have the same longitudinal, vertical and transverse mass distribution in accordance with the loading manual. However, the total weight can be modelled as a point mass at the gravity center of weight.
(3) If there is a slight differences between the mass model used in hydrodynamic analysis and that used in structural analysis, severe unbalance forces may be resulted in. Therefore the amount, the gravity center and the distribution of the total weight used in both of the analysis are to be identical, as far as possible.
(4) The hydrodynamic model and the structure model should be in proper balance and give a good representation of the still water vertical bending moment distribution in the ship loading manual. The displacement, longitudinal gravity center (LCG) and the still water vertical bending moment (SWBM) should be checked to meet following tolerances compared with those from loading manual.

- Displacement : 1 %
- LCG : 0.1 % of length
- SWBM : 3 %

5. Load analysis

(1) Loading condition
The loading conditions are to include both of the ballast condition and the full load condition which are most demanded and also include both of the maximum still water sagging and the hogging condition.
(2) Hydrostatic loads
Hydrostatic loads may be calculated based on hydrodynamic model and weight or structural model and weight. The buoyancy and the weight should be in proper balance. Especially for the ship with significant trim, the unbalance forces should be minimized as far as possible.
(3) Hydrodynamic loads
(A) In general, zero forward speed is recommended for the purpose of hydrodynamic analysis.
(B) Wave heading angles
The hydrodynamic load analysis should consider all heading angles from 0° to 360°, with the heading angle spacing less than 30°.
(C) Wave length
The hydrodynamic load analysis should consider a sufficient number of wave lengths more than 20 including the longest length about 4times of the ship length and the shortest length about 5times of the smallest panels. The range and density of wave lengths should be selected to ensure a good representation of all relevant response transfer functions, including peak values.
(D) Seakeeping and hydrodynamic load analysis
The seakeeping and hydrodynamic load analysis is to be carried out using the program recognized by the Society based on the calculation conditions described in (A), (B) and (C)

above. The results of the analysis should include the transfer functions of motions in 6 degrees of freedom (for 2D strip, surge motion omitted), sectional forces and moments, acceleration and pressure at the places of interest(for 2D strip, the axial forces due to pressures omitted).

(E) Short-term analysis
The short-term analysis is to be carried out based on the transfer functions obtained from the analysis described in (D) above and the wave spectrum which represents the total energy of irregular seaway. The Bretschneider or two parameter Pierson-Moskowitz spectrum is recommended for the North Atlantic, described by the following expression :

$$S(\omega) = \frac{H_s^2}{4\pi}\left(\frac{2\pi}{T_z}\right)^4 \omega^{-5} \exp\left(-\frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4 \omega^{-4}\right)$$

where,

H_s : Significant wave height (m)

ω : Angular wave frequency (rad/s)

T_z : Average Zero up-crossing wave period (s)

$$T_z = 2\pi\left(\frac{m_0}{m_2}\right)^{\frac{1}{2}}$$

The spectral moments of order n of the response process for a given heading may be described as

$$m_n = \int_\omega \sum_{\theta_0 - 90^\circ}^{\theta_0 + 90^\circ} f_s(\theta)\omega^n\, S(\omega | H_s, T_z, \theta) d\omega$$

using a spreading function usually defined as $f_s(\theta) = k\cos^2(\theta)$

where k is selected such that :

$$\sum_{\theta_0 - 90^\circ}^{\theta_0 + 90^\circ} f_s(\theta) = 1$$

where,

θ_0 : Main wave heading

θ : Relative spreading around the main wave heading

(F) Long-term analysis
The long-term Sanalysis is to be carried out based on the results of short-term analysis described in above (E) and the wave data of the North Atlantic. The scatter diagram shown in **Table 3**(IACS Rec. No. 34), represents the wave data of the North Atlantic which covers the areas designated as 8, 9, 15 and 16 in **Fig 3.**

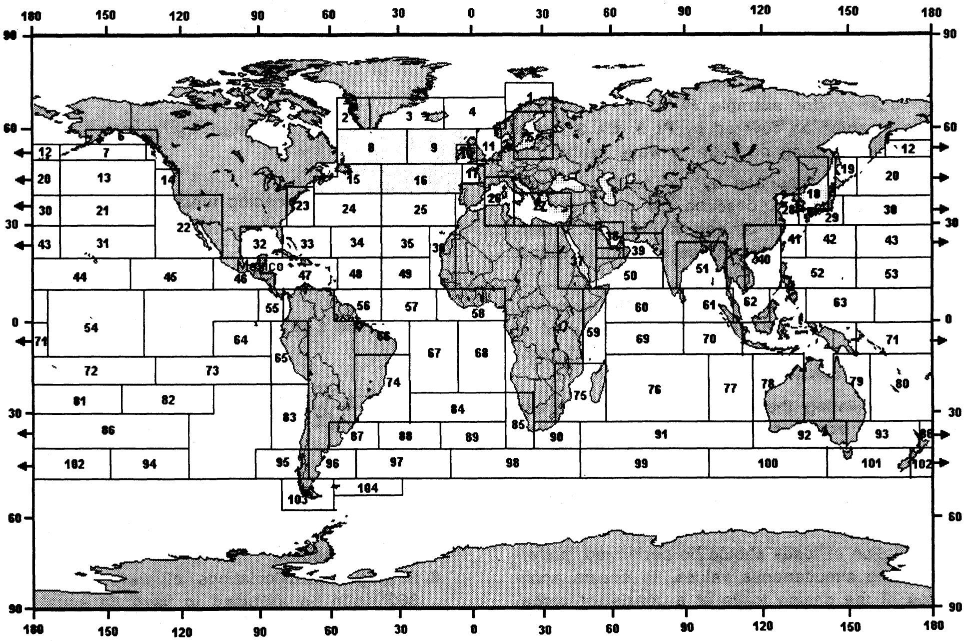


Fig 3 Definition of the extent of the North Atlantic

Table 3 Probability of sea-states in the North Atlantic described as occurrence per 100000 observations. Derived from BMT's Global Wave Statistics

T_Z / H_S	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	SUM
0.5	0.0	0.0	1.3	133.7	865.6	1186.0	634.2	186.3	36.9	5.6	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3050
1.5	0.0	0.0	0.0	29.3	986.0	4976.0	7738.0	5569.7	2375.7	703.5	160.7	30.5	5.1	0.8	0.1	0.0	0.0	0.0	22575
2.5	0.0	0.0	0.0	2.2	197.5	2158.8	6230.0	7449.5	4860.4	2066.0	644.5	160.2	33.7	6.3	1.1	0.2	0.0	0.0	23810
3.5	0.0	0.0	0.0	0.2	34.9	695.5	3226.5	5675.0	5099.1	2838.0	1114.1	337.7	84.3	18.2	3.5	0.6	0.1	0.0	19128
4.5	0.0	0.0	0.0	0.0	6.0	196.1	1354.3	3288.5	3857.5	2685.5	1275.2	455.1	130.9	31.9	6.9	1.3	0.2	0.0	13289
5.5	0.0	0.0	0.0	0.0	1.0	51.0	498.4	1602.9	2372.7	2008.3	1126.0	463.6	150.9	41.0	9.7	2.1	0.4	0.1	8328
6.5	0.0	0.0	0.0	0.0	0.2	12.6	167.0	690.3	1257.9	1268.6	825.9	386.8	140.8	42.2	10.9	2.5	0.5	0.1	4806
7.5	0.0	0.0	0.0	0.0	0.0	3.0	52.1	270.1	594.4	703.2	524.9	276.7	111.7	36.7	10.2	2.5	0.6	0.1	2586
8.5	0.0	0.0	0.0	0.0	0.0	0.7	15.4	97.9	255.9	350.6	296.9	174.6	77.6	27.7	8.4	2.2	0.5	0.1	1309
9.5	0.0	0.0	0.0	0.0	0.0	0.2	4.3	33.2	101.9	159.9	152.2	99.2	48.3	18.7	6.1	1.7	0.4	0.1	626
10.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	10.7	37.9	67.5	71.7	51.5	27.3	11.4	4.0	1.2	0.3	0.1	285
11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.3	13.3	26.6	31.4	24.7	14.2	6.4	2.4	0.7	0.2	0.1	124
12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	4.4	9.9	12.8	11.0	6.8	3.3	1.3	0.4	0.1	0.0	51
13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.4	3.5	5.0	4.6	3.1	1.6	0.7	0.2	0.1	0.0	21
14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.2	1.8	1.8	1.3	0.7	0.3	0.1	0.0	0.0	8
15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.7	0.5	0.3	0.1	0.1	0.0	0.0	3
16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	1
SUM	0	0	1	165	2091	9280	19922	24879	20870	12898	6245	2479	837	247	66	16	3	1	100000

* The H_S and T_Z are class midpoints.

6. Design waves

(1) The design wave is defined as the regular wave that gives the same response level as the long-term value. The heading angle and the wave length of the design wave are chosen as the values where the relevant transfer function has its maximum and the design wave amplitude is chosen as the long-term value divided by the maximum value of the transfer function. If the wave steepness is too high (wave height/wave length>1/7) it is necessary to choose a slightly longer wave length.

(2) Dominant Load Parameter (DLP), the basis of design wave determination, should be chosen to assure that structural members, where extreme wave loads may act on or severe stresses may occur, are safe. Following DLPs should be considered necessarily .

- Vertical bending moment at midship
- Horizontal bending moment at midship
- Torsional moment at $L/4$, $L/2$ and $3L/4$
- Vertical acceleration at FP
- Roll

It is necessary to chose other DLPs where the structural safety should be assured due to its weak structure like a large opening.

7. Loads transfer

(1) The design waves are to be determined according to each DLP, and the dynamic loads including inertia forces and the hydrodynamic pressures should be transfer to the structural model properly. It should be confirmed that the sectional loads acting on the structural model are the same values as the loads calculated in the hydrodynamic load analysis.

(2) Hydrodynamic pressure transfer
The hydrodynamic pressure calculated in the hydrodynamic load analysis may be transferred in type of force or pressure. The unbalance forces resulted from the difference between hydrodynamic model and the structural model should be minimized as far as possible.

(3) Inertia force transfer

(A) Weight of structure itself
The acceleration at the center of a element is calculated by the combination of motions in 6 degree-of-freedom. The inertia forces are obtained from the product of the acceleration by the mass of the element and are to be distributed on the relevant nodes properly.

(B) Solid cargo
The acceleration of a solid cargo like a container should be calculated at the center of its real position and the inertia forces induced by the cargo should be distributed on the actual supporting nodes, which depend on the direction of the acceleration.

(C) Liquid cargo
The acceleration of a liquid cargo may be calculated at its center of gravity and the internal pressures induced by the acceleration should be distributed on the boundary of the tank in the type of pressure. The reference location of pressure head is top of the tank boundary for the vertical acceleration and mid of the free surface for the axial and the lateral acceleration.

(4) Unbalance force
The unbalance forces may be resulted from a variety of sources such as the differences between the structural model and the hydrodynamic model, the non-consistent mass model, viscous damping forces due to roll motion and etc. These forces, which act on the fixation points of structural model should be documented and presented including the total amount, the sources and the procedures used to resolve.

8. Structural analysis and acceptance criteria

(1) Structural analysis

(A) The structural analysis is to be carried out with the Finite Element Method.

(B) An approved analysis program having adequate accuracy should be used. If deemed necessary, documents related to systems used in the analysis and documents for confirming the accuracy may be required to be submitted to the Society.

(2) Acceptance criteria
The results of global structural analysis is to be assessed for the failure mode of yielding ac-

cording to the allowable stress shown in **Table 4**.

Table 4 Allowable stress

Structural members	Allowable stress		
	σ_e (N/mm^2)	σ (N/mm^2)	τ (N/mm^2)
Side shell, Double bottom	$0.9\sigma_Y/K$	-	-
Double bottom girder	$0.9\sigma_Y/K$	$177/K$	$83/K$
Longitudinal bulkhead	$0.9\sigma_Y/K$	-	$83/K$
Floor	$0.9\sigma_Y/K$	-	$108/K$
Upper deck	$0.9\sigma_Y/K$	$177/K$	-
Transverse bulkhead, Web frame	$177/K$	-	$83/K$
Fine mesh structural analysis			
Mean stress	σ_Y/K	-	-
Stress concentrate region	$< 1.2\sigma_Y$	-	-

(Notes)

1. σ_Y : yield stress
2. The equivalent stress σ_e is to be as follows.

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

σ_x : Normal stress in x-direction of element coordinate system
σ_y : Normal stress in y-direction of element coordinate system
τ : Sheer stress on the face in x-y-direction of element coordinate system

3. σ : σ_x or σ_y

Table A 3.2.5 Material factor

Steel grades	K
A, B, D and E	1.0
$AH32$, $DH32$ and $EH32$	0.78
$AH36$, $DH36$ and $EH36$	0.72
$AH40$, $DH40$ and $EH40$	0.68

III. Guidance for the Hold Analysis

1. General

(1) Application

(A) When determining the scantlings of each structural member by using a direct strength calculation, the scope and the procedure of the direct strength calculation may be defined in consultation with the Society.

(B) Even when the scantlings of each structural members are decided by the hold analysis, the requirements in **Ch 3** of the Rules are to be complied with.

(C) When the thickness of steel plate is decided by the direct strength calculations, the thickness is not to be less than minimum thickness specified in the Rules

(D) Analysis method and analysis program is able to consider the effect of bending deformation, shear deformation, axial deformation and torsional deformation.

(E) Analysis method and analysis program is able to express the movements of 2-D or 3-D structural models under the reasonable boundary conditions.

(F) Where hold analysis is executed, data specifying the conditions of calculations and data summarizing their results are to be submitted to the Society.

(G) When carrying out the hold analysis for other types of ships not specified in this guidance, the relevant requirements of this guidance may be applied as appropriate.

(2) Procedure of hold analysis

A general flow chart of the hold analysis is show in **Fig 4**

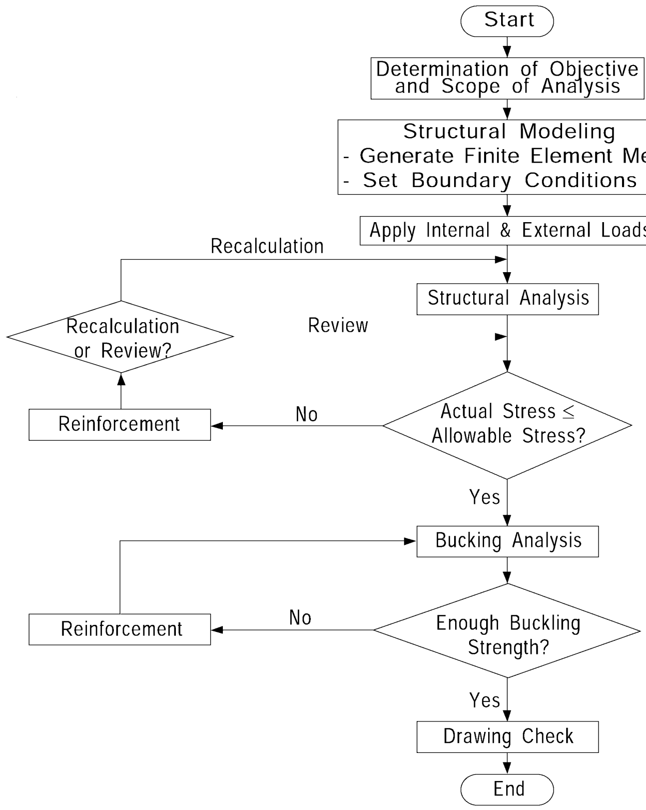


Fig 4 Procedure for hold analysis

(3) Modeling of structure

(A) The model of structure to be analysed is to include its surrounding members considered to have material influences on the behaviors of the members of which the scantlings are to be determined by direct strength calculations.

(B) The modeling is to be such that any proper elements chosen from among plate bending elements, beam elements, bar elements, etc. can reproduce the behaviors of the structure with the highest possible fidelity.
(C) The scantlings including corrosion allowances which are shown on the plans may be used for modelling.
(D) When the degree of division of a member into model elements is insufficient for the determination of scantlings by direct strength calculation, the member concerned is to be subject to the calculation by remeshing with fine meshes to enable further study on the basis of the results of the analysis.
(E) The structural models of bulk carriers, double hull tankers and container ships are to comply with the requirements in **3, 4** and **5** respectively.
(F) The F.E model should be represented using a right handed cartesian co-ordinate system as shown in **Table 6.**

Table 6 Co-ordinate system

	Direction	Remark
x	Longitudinal	Positive forward
y	Transverse	Positive to port
z	Vertical	Positive upwards from the baseline

(G) Side shell, longitudinal bulkheads and other similar members subjected to large shearing force are preferably to be modelled into two or three dimensional structure by using shell elements.
(H) In meshing, proper sizes of meshes are to be selected in accordance with the stress distribution in the model which can be predicted and abnormally large aspect ratios of meshes are to be avoided.
(I) Girders and similar members having stress gradients along their depth are to be so meshed as to enable their discrimination.
(J) In principle, access openings and lightening holes, etc., are to be represented. Where openings are not represented in the structural model, both the mean shear stress and the element shear stress are to be increased in direct proportion to the modelled web shear area divided by the actual web area. But in areas of interest of shear stress, especially in double bottom girders and in floor plates adjacent to the hopper knuckle, etc., representing the opening using a fine mesh is to be required.
(K) When modelling into beam element, the plate of a width equal to 0.1 of span of the member on its each side may, as a rule, be included, provided that the plate to be included is effectively reinforced by other members or is recognized by the Society to have a sufficient thickness, and, in addition, this width equal to 0.1 of the span does not exceed half of the distance to the neighbouring member.
(L) Non-continuous stiffeners are to be represented by line elements with the cross sectional area according to the end connection as shown in **Table 1.**

(4) Model check
(A) In order to confirm the proper modelling of the hull structure, the model is to be verified according to the following methods, or to be in accordance with the discretion of the Society.
(B) The difference between the section modulus calculated from F.E model and the midship drawing, is to be in ±1 % allowance.
(C) The hull girder bending stresses resulting from the finite element analysis are to be in good agreement with those calculated according to the beam theory. The hull girder bending stresses by the beam theory are calculated as M/Z, where M is the sum of still water bending moment and wave bending moment and Z is the section modulus at the considered position.

(5) Boundary conditions
Reasonable boundary conditions are to be applied to describe the behaviour of actual structure. The boundary conditions of bulk carriers, double hull tankers and container ships are to comply with the requirements in **3, 4** and **5** respectively.

(6) Design loads
(A) The loads due to longitudinal bending moment of hull girder at the forward and aft end boundaries of the structure model may, as a rule, not be taken into consideration. When these loads are taken into consideration, however, the allowable stress to be applied to the results of calculations is to be determined at the directions of the Society.
(B) The design loads to be taken into consideration are, as a rule, to be the loads due to cargo and water ballast loaded on board, hydrostatic pressure and wave loads.
(C) The load due to the inertia force of cargo is to be considered in addition to those specified in (B) above, when the Society considers it is necessary.
(D) The cargo holds, where dynamic impact loads such as sloshing loads are predicted, are to be specially considered and proper data in this connection are to be submitted.
(E) The design loads of bulk carriers, double hull tankers and container ships are to comply with the requirements in **3, 4** and **5** respectively.
(7) Loads due to cargo and water ballast
(A) Loads due to Ore Cargo, Grain Cargo, etc.
(a) The density, loading height and surface of the cargo are to be determined by giving reference to the preliminary loading manual, etc.
(b) The density, loading height and repose angle of cargo used in the calculations are to be clearly indicated. If considered necessary, the angle of internal friction of the cargo and the angle of friction between the cargo and wall surface are to be indicated.
(B) Loads due to liquid cargo, water ballast, etc.
(a) The upper end of water head for a tank is to be the mid-point of the distance between the top of tank and the top of overflow pipe.
(b) For the water head of large deep tanks, proper additional water head corresponding to the dynamical influence is to be considered in addition to the water head specified in (a) above.
(c) For the liquid cargo and water ballast to be loaded in harbours or similar quiet waters, the water head corresponding to the actual loading height may be used as the water head.
(d) Except where considered necessary, the loads due to fuel oil, fresh water and similar consumables may not be taken into consideration.
(e) The densities and water heads of cargoes are to be specified.
(8) Hydrostatic pressure
(A) The water head at the scantling draught(m), corresponding to respective loading conditions is to be considered as hydrostatic pressure at the ships bottom and sides.
(B) Load for hydraulic pressure test
(a) The upper end of water head of a tank being subjected to hydraulic pressure test is to be a point at a height of 2.4 m above the top of tank.
(b) The water pressure at the bottom and sides under the condition of hydraulic pressure test is to be the hydrostatic pressure corresponding to a draught equal to 1/3 of the scantling draught.
(9) Wave loads
(A) Wave induced loads
(a) As the wave induced loads corresponding to the wave crest and trough, the water heads(m) corresponding to the variations H_0, H_1 and H_2 from the hydrostatic pressure at the still water draught, according to the following formulae are to be taken into consideration. (See **Fig 5**)

$$H_0 = 0.5 \times H_W \quad (\text{m}), \qquad H_1 = 0.9 \times H_W \quad (\text{m}), \qquad H_2 = 0.25 \times H_W \quad (\text{m})$$

where,

$H_W = 0.61L^{1/2}$ -------------------- $L \leq$ 150 m

$= 1.41L^{1/3}$ --------------------- 150 m $< L \leq$ 250 m

$= 2.23L^{1/4}$ --------------------- 250 m $< L \leq$ 300 m

$= 9.28$ --------------------- 300 m $< L$

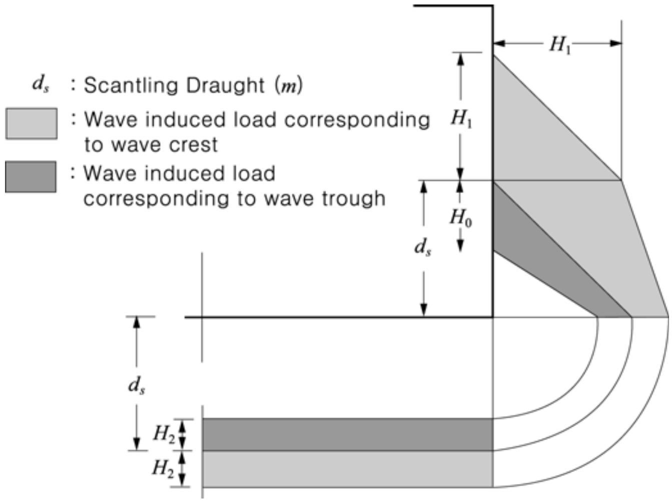


Fig 5 Wave induced load

(b) The wave induced loads in harbours and similar quiet waters may be taken as equal to 1/2 of the values of H_0, H_1 and H_2 specified in (a) above.

(c) The wave induced loads may be assumed to be equally distributed throughout the ship's length.

(10) Allowable stress

When the loads and boundary conditions specified in from (5) to (9), preceding are to be applied to the structural model according to the (3) above, the scantlings of members are to be determined so that the values of stress in each of them may not exceed the values given below.

(A) Allowable stress for mild steel members

For bulk carriers, double hull tankers and container ships, values specified in **3, 4** and **5** respectively, are to be applied. Where nothing particular is provided for, the values are to be left to the Society's directions.

(B) Allowable stress for high tensile steel members

Values according to (1) above divided by the coefficient K in **Table 7** are to be used.

Table 7 Material factor K

Steel grades	K
A, B, D and *E*	1.0
AH 32, *DH* 32 and *EH* 32	0.78
AH 36, *DH* 36 and *EH* 36	0.72
AH 40, DH 40 and *EH 40*	0.68

2. Buckling strength calculation

(1) Application

(A) The buckling strength of each structural member of the hull is to be examined on the basis of the results of direct strength calculations carried out in accordance with **1** preceding.

(B) This guidance can be applied only where the corrosion protection is considered very carefully on the panel of which the buckling strength to be examined. In case where the panel is not appropriately protected against corrosion, the analytical procedure is to be within the discretion of the Society.

(C) The buckling strength can be examined by other analytical procedure instead of the guidance when deemed appropriate by the Society.

(2) Working stress

(A) Stress Components

For the panels which are to be reviewed for the buckling stress, in-plane stresses are to have been determined in element coordinate system as listed below (See **Fig 6**)

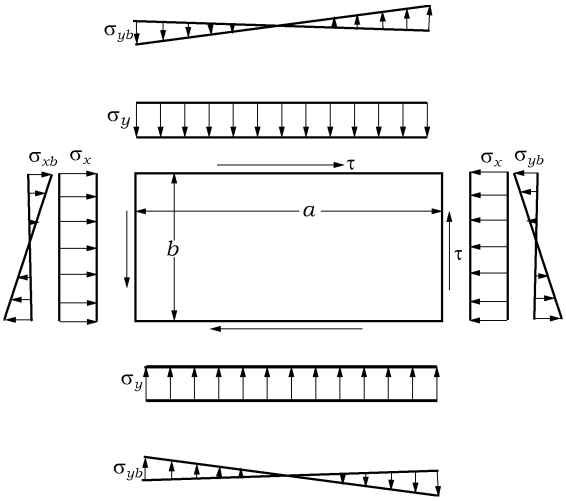


Fig 6 Working stress of panel

σ_x = compressive stress in x-direction (N/mm^2)
σ_{xb}= in-plane bending stress in x-direction (N/mm^2)
σ_y = compressive stress in y-direction (N/mm^2)
σ_{yb} = in-plane bending stress in y-direction (N/mm^2)
τ = shearing stress (N/mm^2)

Here, the stresses σ_x, σ_y are to be taken as positive when they are compressive stresses, while they are set to zero when they are tensile ones.

(B) Consideration for longitudinal bending stress of hull
As the loads due to longitudinal bending moment in still water at the end boundaries of the structure model are not taken into account in determining the working stresses specified in (A) above, the stress due to this longitudinal bending moment of hull girder is to be added for double bottom girders particularly.

(C) Grouping by features of stress distribution
Grouping according to **Table 8** is to be made depending upon the features of distribution of working stresses in the members and panels. In case where the grouping seems difficult, examination is to be done based on each group.

Table 8 Group

Group	Features	Example of members to be considered	λ
A	Relatively small shearing stress and in-plane bending stress in comparison with compressive stress or bi-axial compressive stresses with same order	Decks, bottom and inner bottom shell related to longitudinal strength and longitudinal bulk-head plating forming bi-axial stress field. Transverse bulkhead plating and deep girder, etc., forming bi-axial stress field.	1.2
B	Relatively small in-plane bending stress and large uni-axial compressive stress with shearing stress	Side shell and sloped bulkhead of side tank.,etc, forming uni-axial and shearing stress field; Bulkhead plating under high shearing stress; Girder and floor, etc., forming mono-axial and shearing stress field	1.2
C	Relatively small compressive stress and large in-plane bending stress with shearing stress	Girder and floor,.etc, forming bending and shearing stress field	1.2

(D) Modification of working stresses

(a) The in-plane stresses determined in (A) are to be modified according to **Table 9** for each group. In this case, it is to be performed exchange of coordinate according to necessity.

(b) The stresses modified according to (a) above are to be assumed as the working stresses used for the calculation of buckling strength.

(3) Buckling strength calculation

(A) Procedure of buckling strength calculation (See **Table 10**)

(a) Representative equivalent stress

The representative equivalent stress σ_{eq} is to be calculated as given in **Table 11** from the working stresses of the panel.

(b) Equivalent elastic buckling stress

(i) In this case, it is to be noted that the aspect ratio of Group A is not to be less than 1.0, According to the elastic buckling formula, buckling stresses σ_{xcr}, σ_{ycr}, τ_{cr} may be obtained.

(ii) The equivalent elastic buckling stress is to be calculated from the buckling stresses σ_{xcr}, σ_{ycr}, τ_{cr}.

(c) Equivalent plastic buckling stress

(i) When the equivalent elastic buckling stress σ_{cr} is greater than half of the yield stress σ_y the equivalent plastic buckling stress σ'_{cr} is to be calculated.

(ii) The yield stress σ_y is to be accordance with the following value. (N/mm^2)

$$\sigma_y = \frac{235}{K} \quad (\text{N/mm}^2)$$

Table 9 Modification of In-plane stresses for each group

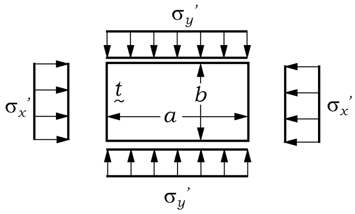
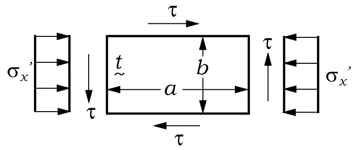
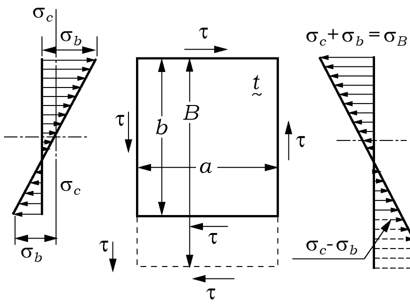
Group	Stress condition	Modified in-plane stress
A	Where $\sigma_x \geq \sigma_{xb}$ and $\sigma_y \geq \sigma_{yb}$ to be assumed as : $\sigma_x{}' = \sigma_x + \frac{1}{2}\sigma_{xb}$ $\sigma_y{}' = \sigma_y + \frac{1}{2}\sigma_{xb}$	
B	Where $\sigma_x \geq \sigma_{xb}$ to be assumed as: $\sigma_x{}' = \sigma_x + \frac{1}{2}\sigma_{xb}$.	
C	Where $\sigma_x < \sigma_{xb}$ to be assumed as: $\sigma_c = \sigma_x$ $\sigma_b = \sigma_{xb}$ $\sigma_B = \sigma_c + \sigma_b$	Assumed panel with B : $B = \left(1 + \frac{\sigma_c}{\sigma_b}\right)b = \frac{\sigma_B}{\sigma_b}b$ 

Table 10 Buckling strength calculation

	Group A	Group B	Group C
Working stress	$\sigma'_x,\ \sigma'_y$	$\sigma_x{}',\ \tau$	$\sigma_B,\ \tau$
σ_{eq}	$\sqrt{\sigma'^2_x - \sigma'_x\,\sigma'_y + \sigma'^2_y}$	$\sqrt{\sigma'^2_x + 3\tau^2}$	$\sqrt{\left(\frac{3}{4}\sigma_B\right)^2 + 3\tau^2}$
Aspect ratio β	$a/b(\geq 1.0)$ (See **Table 9**)	a/b (See **Table 9**)	a/B (See **Table 9**)
Buckling stress	$\sigma_{xcr} = K_x\sigma_e$ $\sigma_{ycr} = K_y\sigma_e$	$\sigma_{xcr} = K_x\sigma_e$ $\tau_{cr} = K_s\sigma_e$	$\sigma_{Bcr} = K_B\sigma_e$ $\tau_{cr} = K_s\sigma_e$
Euler's stress of plate σ_e	$\frac{E\pi^2}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$		$\frac{E\pi^2}{12(1-\nu^2)}\left(\frac{t}{B}\right)^2$
Formula for elastic bucking stress	See **Table 11**		
σ_{cr}	$\sqrt{\sigma^2_{xcr} - \sigma_{xcr}\,\sigma_{ycr} + \sigma^2_{ycr}}$	$\sqrt{\sigma^2_{xcr} + 3\tau^2_{cr}}$	$\sqrt{\left(\frac{3}{4}\sigma_{Bcr}\right)^2 + 3\tau^2_{cr}}$
σ'_{cr}	Where $\sigma_{cr} > \frac{1}{2}\sigma_y$ $\sigma'_{cr} = \sigma_y\left(1 - \frac{\sigma_y}{4\sigma_{cr}}\right)$ σ_y : Yield stress of material		

Table 11 Interaction formula for elastic buckling

Group A	Group B	Group C
$\frac{K_x}{K_{x0}}+\frac{K_y}{K_{y0}}=1$ $\frac{K_y}{K_x}=\frac{\sigma'_y}{\sigma'_x}$ $K_{x0}=\gamma_x\frac{\beta^2}{m^2}\left(\frac{m^2}{\beta^2}+1\right)^2$ $K_{y0}=\gamma_y\left(\frac{m^2}{\beta^2}+1\right)^2$ m : As specified in **Table 13** or **Fig 7** in accordance with ratio of β and (σ'_y/σ'_x) Positive integer equal to the number of half waves of buckling mode which give the min value of bucking stress γ_x, γ_y : reduction factor due to opening, See **Table 12.**	$\frac{K_x}{K_{x0}}+\left(\frac{K_s}{K_{s0}}\right)^\alpha=1$ $\frac{K_s}{K_x}=\frac{\tau}{\sigma_x'}$ $K_{x0}=\gamma_x\frac{\beta^2}{m^2}\left(\frac{m^2}{\beta^2}+1\right)^2$ $K_{s0}=\begin{cases}\gamma_s\left(4+\frac{5.34}{\beta^2}\right)\cdots\cdots\ \beta<1\\ \gamma_s\left(5.34+\frac{4}{\beta^2}\right)\cdots\cdots\ \beta\geq 1\end{cases}$ $m=\begin{cases}1\cdots\cdots\ \beta<\sqrt{2}\\ 2\cdots\cdots\ \sqrt{2}<\beta\leq\sqrt{6}\\ 3\cdots\cdots\ \sqrt{6}<\beta\leq\sqrt{12}\\ 4\cdots\cdots\ \sqrt{12}<\beta\leq\sqrt{20}\\ \beta\cdots\cdots\ \sqrt{20}<\beta\end{cases}$ $\alpha=\begin{cases}2\cdots\cdots\ \beta\geq 1/2\\ 0.7(1/\beta+1)\text{ or 4.9 whichever}\\ \text{is smaller}\cdots\cdots\ \beta<1/2\end{cases}$ γ_x, γ_s : reduction factor due to op-ening	$\left(\frac{K_B}{K_{B0}}\right)^2+\left(\frac{K_s}{K_{s0}}\right)^2=1$ $\frac{K_s}{K_x}=\frac{\tau}{\sigma'_x}$ $K_{B0}=\begin{cases}15.87+\frac{1.87}{\beta^2}+8.6\beta^2\cdots\ \beta\leq 2/3\\ 23.9\cdots\cdots\ \beta>2/3\end{cases}$ $K_{s0}=\begin{cases}\gamma_s\left(4+\frac{5.34}{\beta^2}\right)\cdots\cdots\ \beta<1\\ \gamma_s\left(5.34+\frac{4}{\beta^2}\right)\cdots\cdots\ \beta\geq 1\end{cases}$ γ_s : reduction factor due to opening See **Table 12.**

Table 12 Reduction factor due to option

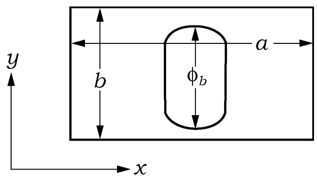
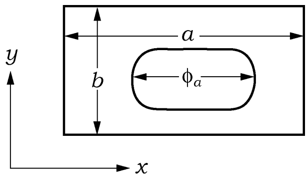
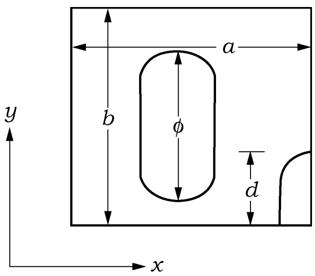
γ_x	$\gamma_s = \dfrac{1}{\{1+\phi_b/(2b)\}^2}$ ϕ_b : Length of opening due to y-direction of element coordinate system. However, surrounding of opening are properly reinforced γ_x is taken as 1.0.	
γ_y	$\gamma_y = \dfrac{1}{\{1+\phi_a/(2a)\}^2}$ ϕ_a : Length of opening due to x-direction of element coordinate system. However, surrounding of opening are properly reinforced γ_y is taken as 1.0.	
γ_s	$\gamma_s = \delta \cdot \gamma_{xy}$ γ_{xy} : As obtained from the following formula $\gamma_{xy} = \dfrac{1}{\{1+\phi/(2S)\}^2}$ S : Plate breadth in the direction of the major axis of opening. However, surrounding of opening are properly reinforced γ_{xy} is taken as 1.0. ϕ : Length of opening of major axis δ : As obtained from the following formula $\delta = \dfrac{1}{4(d/a)-1}$ d : Length of slot without reinforcement where $d/a \leq 0.5$, δ is taken as 1.0	

Table 13 Value of m

β		Ratio of stresses	m
$1 \sim \sqrt{2}$		-	1
$\sqrt{2} \sim \infty$		$\sigma'_y > \dfrac{\beta^4-4}{\beta^2(5+2\beta^2)}\sigma'_x$	1
$\sqrt{2} \sim \sqrt{6}$		$\dfrac{\beta^4-4}{\beta^2(5+2\beta^2)}\sigma'_x \geq \sigma'_y$	2
$\beta \geqq \sqrt{6}$	$\sqrt{m(m+1)} \sim \infty$	$\dfrac{\beta^4-(m-1)^2m^2}{\beta^2\{(m-1)^2+m^2+2\beta^2\}}\sigma'_x \geq \sigma'_y > \dfrac{\beta^4-(m+1)^2m^2}{\beta^2\{(m+1)^2+m^2+2\beta^2\}}\sigma'_x$	m
	$\sqrt{m(m+1)} \sim \sqrt{(m+1)(m+2)}$	$\dfrac{\beta^4-(m+1)^2m^2}{\beta^2\{(m+1)^2+m^2+2\beta^2\}}\sigma'_x \geq \sigma'_y$	$m+1$

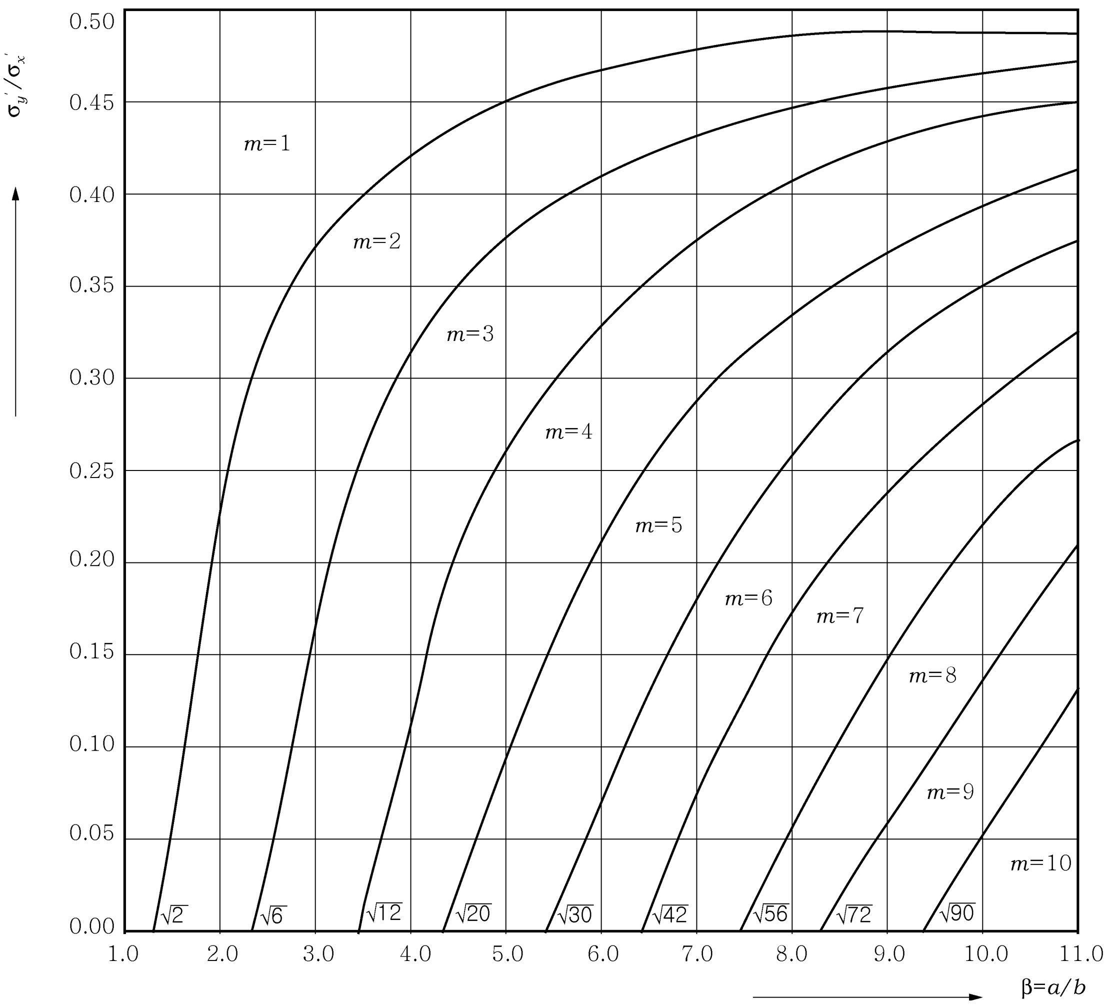


Fig 7 The number of half waves of buckling mode which gives the min. value of buckling stress

(B) Judgement of buckling strength

The results derived from (A) above are to satisfy the following conditions (a) or (b), where λ is the buckling criterion given in **Table 8.**

(a) Where the equivalent elastic buckling stress σ_{cr} is greater than half of the yield stress σ_y

$$\sigma'_{cr} \geq \lambda\,\sigma_{eq}$$

(b) Where the equivalent elastic buckling stress σ_{cr} is smaller than half of the yield stress σ_y

$$\sigma_{cr} \geq \lambda\sigma_{eq}$$

3. Bulk Carrier

(1) General

(A) When determining the scantlings of structural members of cargo hold of a bulk carrier by direct strength calculations, necessary materials and date on the calculation procedure are previously to be submitted to the Society for approval. The procedure is to comply with the following (2) to (5).

(B) Except for those specifically provided for in this part, **Par 1.** is to be applied.

(2) Structural models

(A) Model extent

The range of structure to be analyzed is, one side of the three(1/2+1+1/2) adjacent cargo tanks in the parallel body part, including whole length or half length of each cargo oil tank and transverse bulkhead between these two tanks. However, If there is asymmetry of the ship structure or cargo or ballast loading condition about the ship's centerline. Cargo hold length(l_h) is described in **Pt 7, Ch 3, 301.2** of the Guidance.(See **Fig 8**)

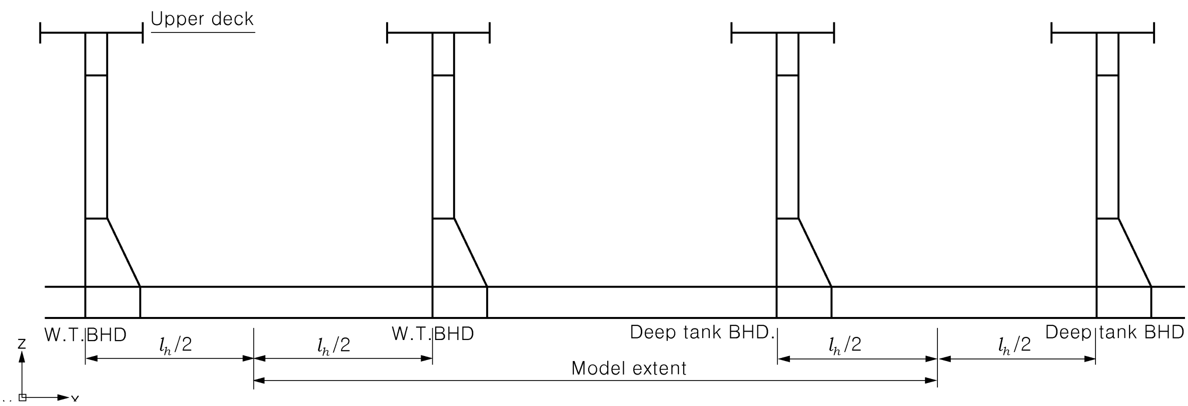


Fig 8 Hold model extent

(B) Structural modeling

(a) The structural modeling with shell elements mesh is : longitudinally, one element between every frame, transversely one element between longitudinal spacing and vertically three or more elements over the depth of double bottom girders and floors. Typical arrangements representing bulk carrier are shown in **Fig 9** to **11**

(b) For the calculation by remeshing with fine meshes, an example of meshing, as a standard, is shown in **Fig 12.** The depth of transverse web is to be meshed into 3 sub depths.

(c) The primary members including side shell, inner bottom, upper deck and corrugated bulkheads, etc. subjected to large shearing shell elements. Shedder plates in corrugated bulkhead are also to be modelled by using shell elements.

(d) Girders and similar members having stress gradients along their depth are to be so meshed as to enable their discrimination.

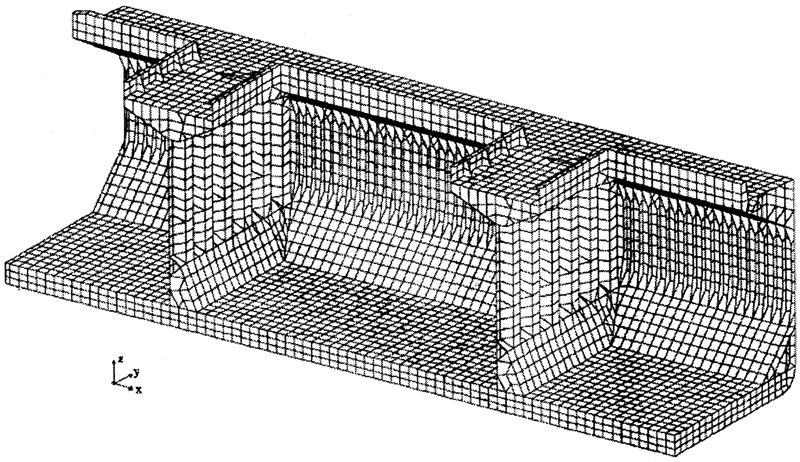


Fig 9 Example of hold model

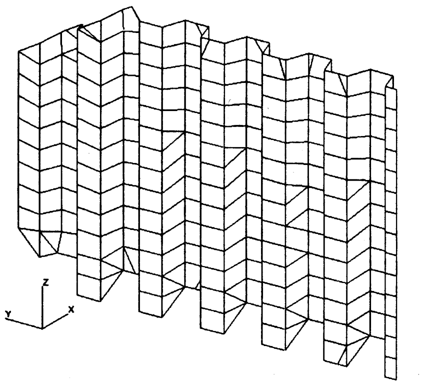


Fig 10 Example of corrugated bulkhead

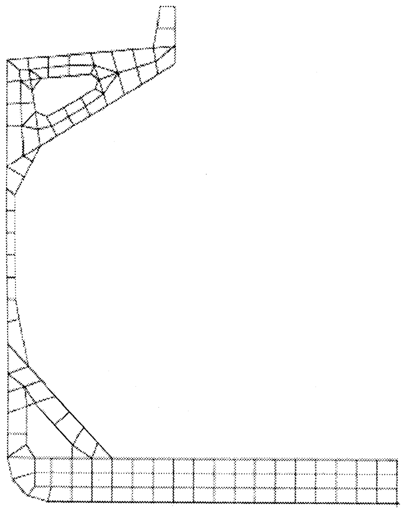


Fig 11 Example of typical web frame

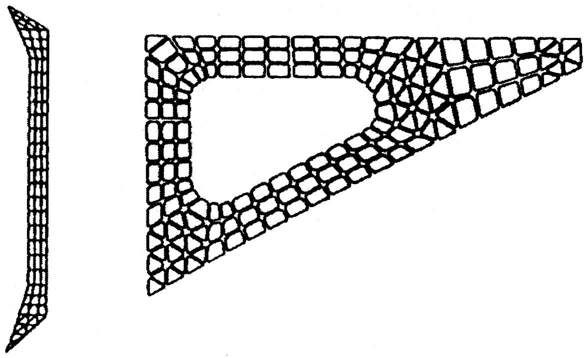


Fig 12 Example of fine-mesh

(3) boundary condition

The following descriptions of boundary conditions are to be applied for half breadth model. For a full breadth model, no constraints are required for the centerline plane. However, a node on the centerline at the keel at the both ends of the model are to be constrained in the transverse direction. The example of boundary conditions are shown in **Table 14** and **Fig 13.**

(A) End planes (①) : Symmetric condition
(B) Centerline plane (②) : Symmetric condition
(C) Vertical counter forces distributed to the side shell nodes at the oil tight BHDs to eliminate reaction at the vertical constraints.(③)

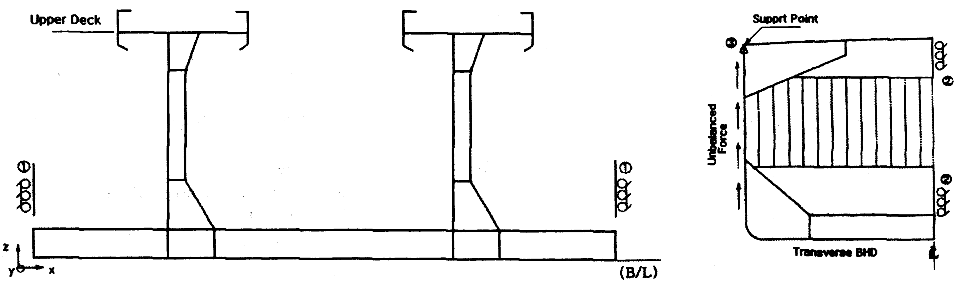


Fig 13 Boundary condition

Table 14 Restraint on degrees of freedom

Position \ Coord.	Displacement			Rotation		
	U_x	U_y	U_z	θ_x	θ_y	θ_z
① Both end of model	1	0	0	0	1	1
② Centerline	0	1	0	1	0	1
③ Top of Transverse BHD	0	0	1	0	0	0
Remarks 1 : Restrainted 0 : Free						

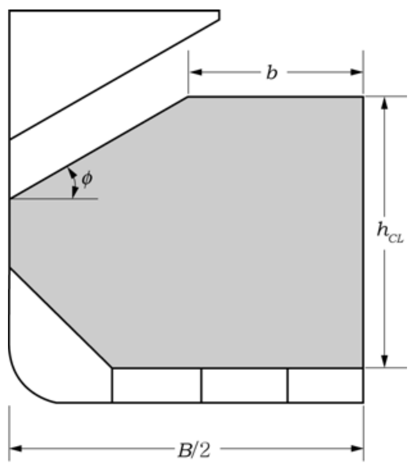


Fig 14 Assumed cargo surface

(4) Load
(A) General
In principle, the cargo and ballast loads, still water loads and wave loads etc. are applied to the F.E model.
(B) Loading conditions
The loading conditions to be taken into consideration are, as a rule, to be the full load condition and the ballast condition. When special loading conditions, such as alternate loading, multi-port loading or loading of cargo of specially high density are predicted, such conditions are to be contained in the calculations. **Table 16** gives an example.
(C) Internal loads
(a) Loads due to ore cargo grain cargo, etc.
(i) The height and surface of the cargo are to be determined in accordance with below as a standard.(See **Fig 14**)

- The shape of cargo surface is assumed to be horizontal longitudinally and transversely in the part near the ship's centreline and sloped down straight to the ship's sides with the angle of repose ϕ.
- The width of the horizontal part b is assumed to be equal to 1/4 of the breadth of the hold.
- The loading height h_{CL} is determined in accordance with the mass, angle of repose and density of the cargo to be loaded. The shape of cargo surface may be assumed to be unchanged for the whole breadth above.
- When the density and angle of repose of the cargo are not specified, they are to be taken as 3.0 (t/m^3) and 30° respectively.

(ii) The loads on the vertical walls of the hold are, in principle, to be determined by the following formula. The cargo load is not to be applied to the side platings.

$9.81\gamma hk^2$ (N/m^2)

where:

γ = density of cargo (kg/m^3)

h = vertical height from the panel in question to the surface of cargo right above the panel (m)

k = values given in **Table 15.**

β = angle between slant plating of bilge hopper and inner bottom plating.(see **Fig 15**)

Table 15 Coefficient k

angle β (degree)	k
$\beta \leq 40°$	1.0
$40° < \beta < 80°$	$1.4 - 0.01\beta$
$\beta \geq 80°$	0.6

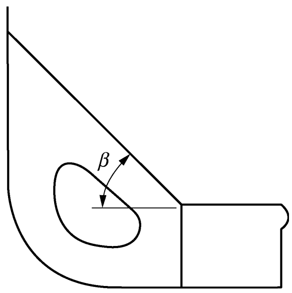


Fig 15 Angle β

Table 16 Load case

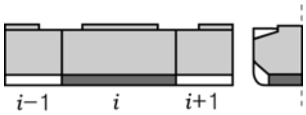
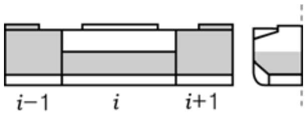
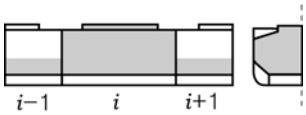
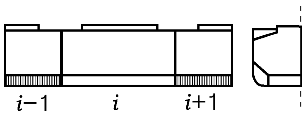
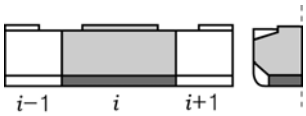
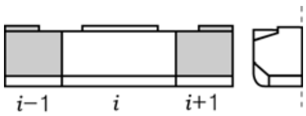
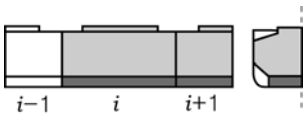
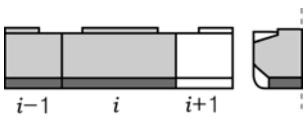
No	Description	Draft	Load pattern	Masses		
1	Full loaded	T		Cargo Mass	$i-1$	M_{Full}
					i	M_{Full}
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	M_{DBFO}
					$i+1$	empty
2	Slack load 1	T		Cargo Mass	$i-1$	M_{Full}
					i	$0.5M_H$
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
3	Slack load 2	T		Cargo Mass	$i-1$	$0.5M_H$
					i	M_{Full}
					$i+1$	$0.5M_H$
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
4	Normal ballast	T_{BDmax}		Cargo Mass	$i-1$	empty
					i	empty
					$i+1$	empty
				DB Mass	$i-1$	M_{DBBW}
					i	empty
					$i+1$	M_{DBBW}
5	Multi port 1	0.67 T		Cargo Mass	$i-1$	empty
					i	M_{Full}
					$i+1$	empty
				DB Mass	$i-1$	empty
					i	M_{DBFO}
					$i+1$	empty
6	Multi port 2	0.83 T		Cargo Mass	$i-1$	M_{Full}
					i	empty
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
7	Multi port 3a Block loading	0.67 T		Cargo Mass	$i-1$	empty
					i	M_{Full}
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	M_{DBFO}
					$i+1$	M_{DBFO}
8	Multi port 3b Block loading	0.67 T		Cargo Mass	$i-1$	M_{Full}
					i	M_{Full}
					$i+1$	empty
				DB Mass	$i-1$	M_{DBFO}
					i	M_{DBFO}
					$i+1$	empty

Table 16 Load case (continued)

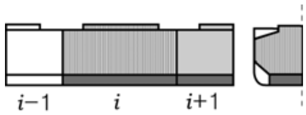
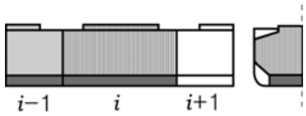
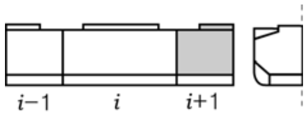
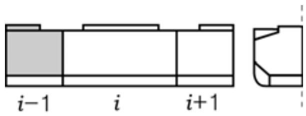
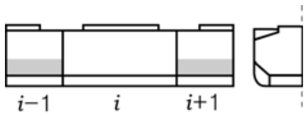
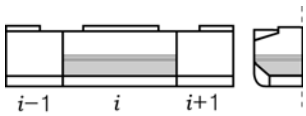
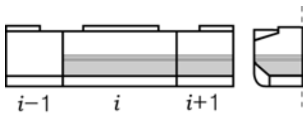
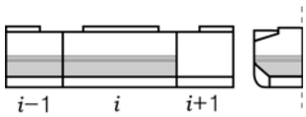
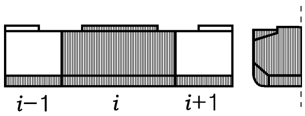
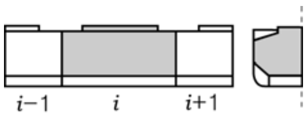
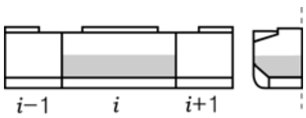
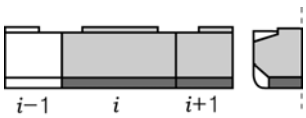
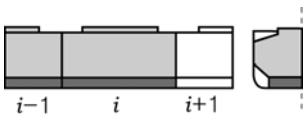
No	Description	Draft	Load pattern	Masses		
9	Multi port 3c Block loading	0.67 T		Cargo Mass	$i-1$	empty
					i	M_{BW}
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	M_{DBFO}
					$i+1$	M_{DBFO}
10	Multi port 3d Block loading	0.67 T		Cargo Mass	$i-1$	M_{Full}
					i	M_{BW}
					$i+1$	empty
				DB Mass	$i-1$	M_{DBFO}
					i	M_{DBFO}
					$i+1$	empty
11	Multi port 4a Block loading	0.75 T		Cargo Mass	$i-1$	empty
					i	empty
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
12	Multi port 4b Block loading	0.75 T		Cargo Mass	$i-1$	M_{Full}
					i	empty
					$i+1$	empty
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
13	Alter. 1	T		Cargo Mass	$i-1$	M_{HD}
					i	empty
					$i+1$	M_{HD}
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
14	Alter. 2	T		Cargo Mass	$i-1$	empty
					i	$M_{HD}+0.1M_H$
					$i+1$	empty
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
15	Alter. 3a Block loading (according to a design loading condition)	T		Cargo Mass	$i-1$	empty
					i	$M_{Blk}+0.1M_H$
					$i+1$	$M_{Blk}+0.1M_H$
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
16	Alter. 3b Block loading (according to a design loading condition)	T		Cargo Mass	$i-1$	$M_{Blk}+0.1M_H$
					i	$M_{Blk}+0.1M_H$
					$i+1$	empty
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty

Table 16 Load case (continued)

No	Description	Draft	Load pattern	Masses		
17	Heavy ballast	T_{BDmin}		Cargo Mass	$i-1$	empty
					i	M_{BW}
					$i+1$	empty
				DB Mass	$i-1$	M_{DBBW}
					i	M_{DBBW}
					$i+1$	M_{DBBW}
18	Harbour 1a	0.67 T		Cargo Mass	$i-1$	empty
					i	M_{Full}
					$i+1$	empty
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
19	Harbour 1b	0.67 T		Cargo Mass	$i-1$	empty
					i	M_{HD}
					$i+1$	empty
				DB Mass	$i-1$	empty
					i	empty
					$i+1$	empty
20	Harbour 2a Block loading	0.67 T		Cargo Mass	$i-1$	empty
					i	M_{Full}
					$i+1$	M_{Full}
				DB Mass	$i-1$	empty
					i	M_{DBFO}
					$i+1$	M_{DBFO}
21	Harbour 2b Block loading	0.67 T		Cargo Mass	$i-1$	M_{Full}
					i	M_{Full}
					$i+1$	empty
				DB Mass	$i-1$	M_{DBFO}
					i	M_{DBFO}
					$i+1$	empty

T : scantling draught, T_{BDmin} : heavy ballast draught, T_{BDmax} : deepest ballast draught

M_{Full} : the cargo mass in the cargo hold corresponding to cargo with virtual density(homogeneous mass/volume of the hold including its hatchway, minimum 1.0 ton/m^3) filled to the top of the hatch coaming (ton). M_{Full} is in no case to be less than M_H.

M_H : the cargo mass in the cargo hold corresponding to a homogeneously loaded condition at designed maximum load draught (ton)

M_{HD} : the maximum cargo mass allowed to be carried in a cargo hold according to design alternately cargo loaded condition (ton)

M_{Blk} : the cargo mass in the cargo hold corresponding to a condition with high density cargo in two adjacent holds, if applicable (ton)

M_{BW} : the water mass in ballast hold (ton)

M_{DBFO} : the fuel mass in double bottom fuel oil tank (ton)

M_{DBBW} : the water mass in double bottom ballast tank (ton)

i : number of the cargo hold to be investigated

$i-1, i+1$: number of the cargo hold aft of the cargo hold to be investigated and forward of the cargo hold to be investigated

(b) Loads due to liquid cargo, water ballast, etc.
In a cargo hold commonly used as a water ballast tank, the water head at a certain position is to be taken equal to the greater of the value obtained from the following formula and the value of h in the same formula.

$$0.85(h+\Delta h) \quad \text{(m)}$$

where:

h = height from the position in question to the top of hatch coaming (m)

Δh = a value obtained from the following formula

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25\left(\frac{2}{3}B - 10\right)$$

l_t = length of tank (m), it is to be taken as 10 m, where it is less than 10 (m).

B = breadth of ship (m), it is to be taken as 15 m, where B is less than 15 (m).

(D) External load

(a) Still water load

Still water load is to apply as specified in **1.** (8).

(b) Wave induced load

Wave induced load is to apply as specified in **1.** (9).

(5) Allowable stress for element types

(A) Allowable stress for element types

The permissible values of normal stress σ and equivalent stress σ_e of each member are to be as given in **Table 17.** The allowable stresses in the fine meshes according to the **Table 18.**

Table 17 Allowable stress (N/mm^2)

Structural members considered		σ_l	σ_t, σ_v	σ_e
Longitudinal strength members	Bottom shell plating; inner bottom plating; sloping plate of bilge hopper tanks or topside tanks	$110/K$	$145/K$	$145/K$
	Girder		—	$175/K$
Transverse strength members	Sloping plate of stools, transverse bulkhead plating		$145/K$	$175/K$
	Floor		—	$175/K$

Notes:

1. The equivalent stress σ_e is to be as follows.

$$\sigma_e = \sqrt{\sigma_l^2 - \sigma_l \sigma_t + \sigma_t^2 + 3\tau^2} \quad \text{: (for longitudinal strength members)}$$

$$\sigma_e = \sqrt{\sigma_v^2 - \sigma_v \sigma_t + \sigma_t^2 + 3\tau^2} \quad \text{: (for transverse strength members)}$$

σ_l = normal stress in lengthwise direction

σ_t = normal stress in breadthwise direction

σ_v = normal stress in depthwise direction

τ = shearing stress

2. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
3. The point of detecting stress is to the centre of the element.
4. K : material factor given in **Table 7.**

(B) Allowable Stress in the case where hull girder section modulus has a fair allowances.

The allowable values of normal stress (N/mm^2) in lengthwise direction in the bottom shell and inner bottom plating may be as determined from the following formula.

- For structural model by using shell elements : $\frac{145}{K} - 35 f_B$

(C) Allowable stress for loading / unloading conditions in the harbour
The allowable stress for loading / unloading conditions in the harbour may be 110 % of the values given in **Table 17** and **Table 18.**.

(6) Buckling strength
Buckling strength assessment to be carried out in accordance with **2.**

(7) Fatigue strength
Fatigue strength assessment may be carried out in accordance with **Annex 3-3 "Guidance for the Fatigue Strength Assessment of Ship Structures".**

Table 18 Allowable stress (N/mm²) (For results of the calculations by remeshing with fine meshes)

Structural members considered		σ_a	τ	σ_e
Transverse rings	Parallel part	—	—	$175/K$
	Corners	$195/K$	—	$195/K$
Side frames	Middle of parallel part	$175/K$	—	$175/K$
	Upper and lower ends of parallel part	$215/K$	$70/K$	$195/K$

Note:
1. σ_a = normal stress of face plate
2. The equivalent stress σ_e is to be as follows.

$$\sigma_e = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau^2}$$

(The element coordinate system is to be x-y rectangular coordinate system)
σ_x = normal stress in x-direction of element coordinate system
σ_y = normal stress in y-direction of element coordinate system
τ = shearing stress on the x face in the y-direction of element coordinate system
3. The point of detecting stress is to be the centre of the element.
4. K : material factor given in **Table 7.**

4. Double Hull Oil Tanker

(1) General
(A) In case where scantlings of structural members of cargo oil tank in double hull tanker are determined by the hold analysis, necessary documents and data on the calculation method are to be submitted to the Society for obtaining approval beforehand.
(B) Except for those specifically provided for in this part, **Par 1.** is to be applied.

(2) Structural modeling
(A) The range of analysis
The range of structure to be analyzed is, one side of the three adjacent cargo oil tanks in the parallel body part, including whole length or half length of each cargo oil tank and transverse bulkhead between these two tanks. However, this range is to be extended if necessary so that every condition can be reproduced considering the arrangement of ballast tanks in double hull structures, loading patterns of cargo oil and ballast, and longitudinal and transverse symmetries of the bulkheads and girders attached thereto.
(B) Structural modelling
The structural modelling with shell element mesh is : longitudinally two or more elements between every web frame, transversely one element between longitudinal spacing and vertically three or more elements over the depth of double bottom girders an floors. Typical arrangements representing double hull tanker are shown in **Fig 16** to **Fig 17.**

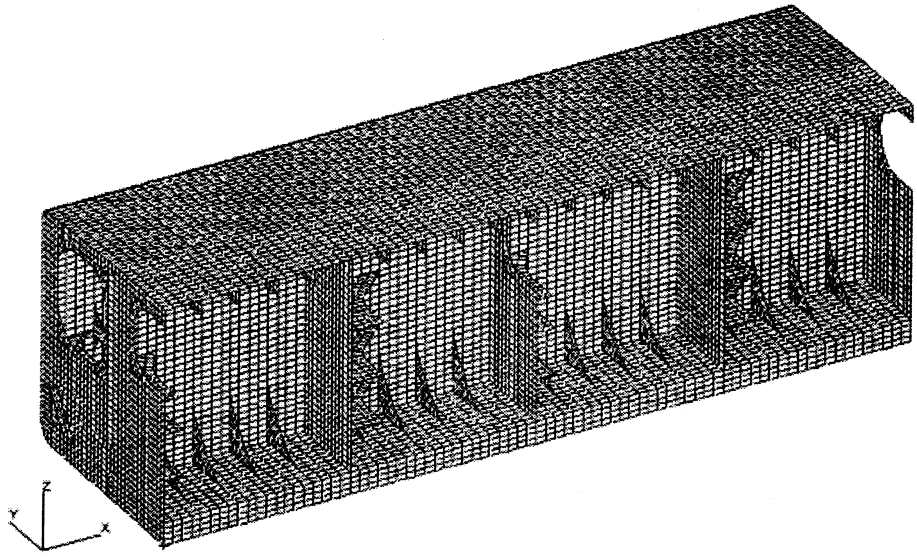


Fig 16 Example model for cargo oil tank structures

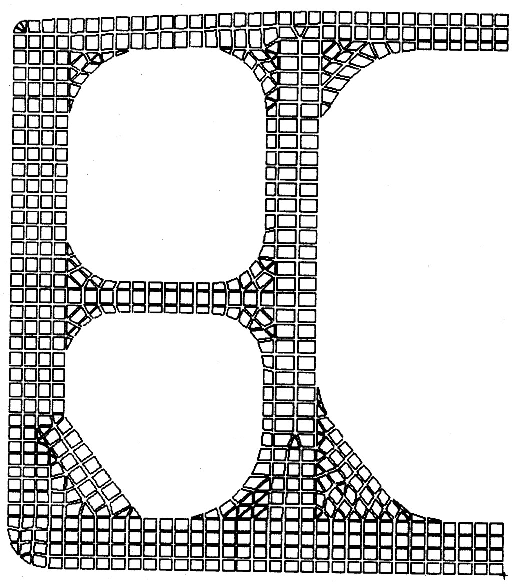


Fig 17 Example of model for side transverse structure

(3) Boundary conditions

The boundary conditions described in this section are to be applied to the F.E model for symmetric load case, as shown in **Fig 18** and **Table 19.**

- End planes (①) : Symmetric condition
- Centerline plane (②) : Symmetric condition
- Vertical counter forces distributed to the side shell nodes at the oil tight BHDs to eliminate reactions at the vertical constraints.(③)

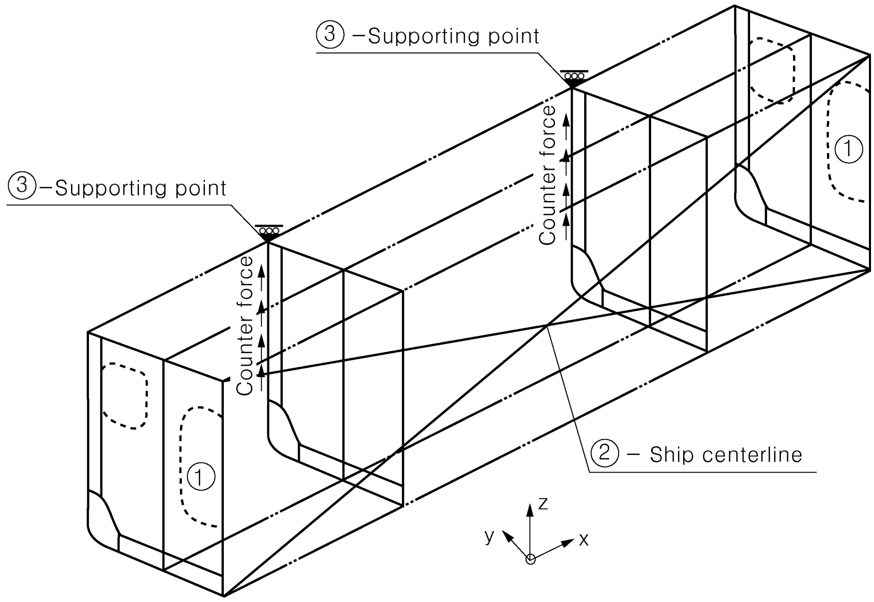


Fig 18 Boundary condition

Table 19 Boundary conditions

Position \ Coord.	Displacement			Rotation		
	U_x	U_y	U_z	θ_x	θ_y	θ_z
① Both ends of model	1	0	0	0	1	1
② Centerline	0	1	0	1	0	1
③ Top of side shell at the oil tight bulkheads	0	0	1	0	0	0
Remark ; 1 : Fixed 0 : Free						

(4) Applied load

Load to be applied to structural models are to be a combination of internal loads and external loads specified below. In case where, however, another combination of loads is clearly severer than that specified, the latter may be omitted.

(A) Internal loads

(a) Hydrostatic test condition

The water head is to be the vertical distance (m) from each point to a point 2.4 m above the deck at side (m). Examples relating to ship types are shown in **Table 20** to **24.**

(b) Navigating condition

The loading conditions for consideration are, in principle, to be the full load condition and ballast condition. In case where special loading condition such as two-ports loading is predicted, such a special case is to be included. Examples relating to ship's types are shown in **Table 20** to **24.**

(i) Water head h' at each position in cargo oil tanks is to be obtained from the following formula:

$$h' = \rho(h + \Delta h) \quad \text{(m)}$$

where :

ρ = maximum designed specific gravity of cargo as given in the loading manual.

h = vertical distance measured from the position under consideration to the top of hatch (m). But, for lower cargo oil tanks in tankers having mid-decks, vertical distance measured from the position under consideration on the level of mid-deck (m).

Δh = Additional water head given by the following formula; For L-type, U-type of tanks, h is to be determined as deemed appropriate by the Society (m)

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10)$$

l_t = tank length (m). however, where it is less than 10 (m), it is to be taken as 10.

b_t = tank breadth (m). however, where it is less than 10 (m), it is to be taken as 10.

(ii) Water head h' at each position in ballast tanks is to be obtained from the following formula:

$$h' = \rho h \quad \text{(m)}$$

where :

ρ = sea water gravity (=1.025)

h = vertical distance measured from the position under consideration to the mid-point of distance between the top of tanks and the top of overflow pipes (m).

(iii) Requirements prescribed in (b) also apply to cargo oil tanks which possibly utilized as ballast tanks at sea.

(iv) For water head h' in ships in harbour or similar quiet waters, Δh may not be considered.

(B) External loads

(a) Hydrostatic test condition

The water pressure at the bottom and sides under the condition of hydraulic pressure test is to be the hydrostatic pressure corresponding to a draught equal to 1/3 of the designed maximum load draught. (9)

(b) Navigating condition

(i) The water heads (m) of outer bottom and side shell are to apply as specified in **1.** (9).

(ii) In case where cargo oil tanks are empty under the navigation condition and the wave induced load assumes wave crests, deck loads are to be taken into account. Deck loads in this case are to be of values given by the following formula referred to as deck girders(see **Ch 10, Table 3.10.1** of the Rules).

$$h = a(bf - y) \quad \text{(kN/m}^2\text{)}$$

where :

α = 2.25 (In case of longitudinal deck girders outside the line of hatchway opening of the strength deck for midship part) or 3.45 (In case of the other deck girders)

b = 1.0

f = as given in the following table

Ship Length	f
$L <$ 150 m	$\frac{L}{10}e^{-\frac{L}{300}} + \left(\frac{L}{150}\right)^2 - 1.0$
150 m $\leq L <$ 300 m	$\frac{L}{10}e^{-\frac{L}{300}}$
300 m $\leq L$	11.03

y = vertical distance from the load line to weather deck at side (m).

(C) Loading condition

Table 20 to **24** gives the standard load cases which are to be considered in the assessment.

(5) Allowable stress

Allowable stress for the modelling by using shell elements are shown in **Table 25.**

(6) Deflection of transverses

In case where the results of the hold analysis show that relative deformations on transverses and vertical web supporting longitudinals, longitudinal beams or bulkhead stiffeners or between bulkheads are large, the added stress due to their effects is to be considered by detail analysis.

(7) Buckling Strength

Buckling strength assessment to be carried out in accordance with **Par. 2.**

(8) Fatigue strength

Fatigue strength assessment may be carried out in accordance with **Annex 3-3 "Guidance for the Fatigue Strength Assessment of Ship Structures".**

Table 20 Load case of two or three rows of longitudinal bulkhead

Load Case	Case	External load		Internal load	
		Static	Wave induced load	Caro oil tank	Ballast tank
Hydrostatic test condition	T-1	$1/3\ d_s$ 1)	-	D+2.4 m	-
Full loading conditions	F-1	d_s 1)	W_C 2)	4)	-
	F-2	d_s 1)	W_T 3)	4)	-
	F-3	d_s 1)	W_C 2)	4)	-
	F-4	$0.4D$	-	4)	-
Ballast condition	B-1	Ballast draft 6)	-	-	5)
	B-2	Ballast draft 6)	-	4)	5)

Remark

1) d_s : scantling draught

2) W_C : wave induced load for wave crest

3) W_T : wave induced load for wave trough

4) Water head of cargo oil tank is described in (4)(A)(b)(i).

5) Water head of cargo oil tank is described in (4)(A)(b)(ii).

6) Ballast draft in loading manual is to be applied.

Table 21 Load case of four rows of longitudinal bulkhead

Load case	Case	External load		Internal load	
		Static	Wave induced load	Cargo oil tank	Ballast tank
Hydrostatic test condition	T-1	$1/3\ d_s$ [1]	-	$D+2.4$ m	-
	T-2	$1/3\ d_s$ [1]	-	$D+2.4$ m	-
Full load and special loading condition	F-1	d_s [1]	W_C [2]	[4]	-
	F-2	d_s [1]	W_T [3]	[4]	-
	F-3	d_s [1]	W_C [2]	[4]	-
	F-4	d_s [1]	W_T [3]	[4]	-
	F-5	d_s [1]	W_C [2]	[4]	-
	F-6	d_s [1]	W_T [3]	[4]	-
	F-7	$0.4D$	-	[4]	-
	F-8	$0.4D$	-	[4]	-
	F-9	d_s [1]	W_C [2]	[4]	-
	F-10	d_s [1]	W_C [2]	[4]	-
	F-11	d_s [1]	W_C [2]	[4]	-
Ballast condition	B-1	Ballast draft[6]	-	-	[5]
	B-2	Ballast draft[6]	-	[5]	[5]
	B-3	Ballast draft[6]	-	[5]	[5]

Remark

1) d_s : scantling Draught

2) W_C : wave induced load for wave crest

3) W_T : wave induced load for wave trough

4) Water head of cargo oil tank is described in (4)(A)(b)(i).

5) Water head of cargo oil tank is described in (4)(A)(b)(ii).

6) Ballast draft in loading manual is to be applied.

Table 22 Case of two rows of longitudinal bulkhead

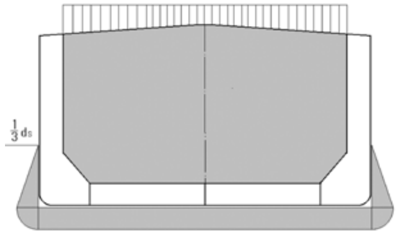
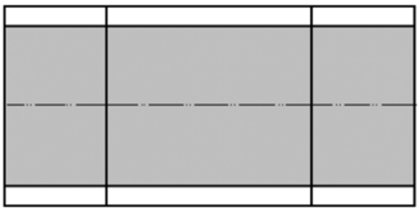
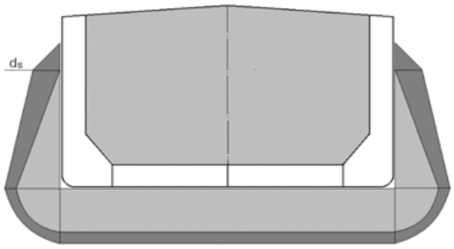
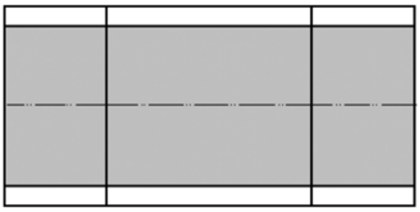
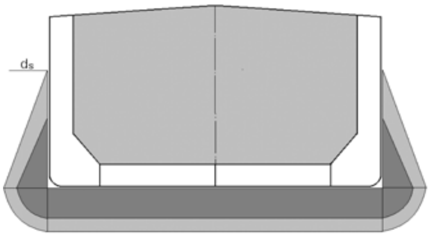
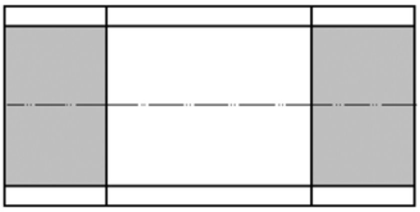
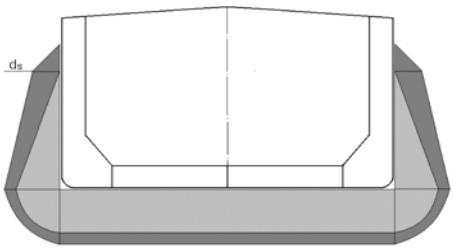
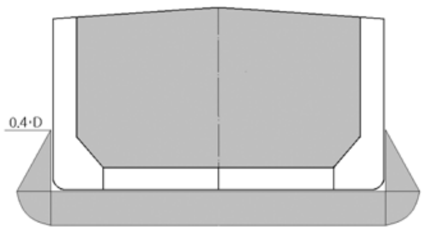
Load case		Loading pattern	Center tank
Hydrostatic test condition	T-1		
Full load and special loading condition	F-1		
	F-2		
	F-3		
	F-4		

Table 22 Case of two rows of longitudinal bulkhead (continued)

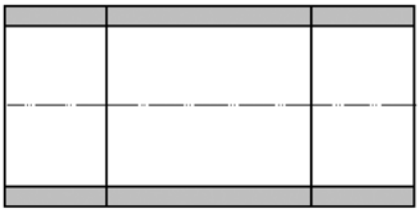
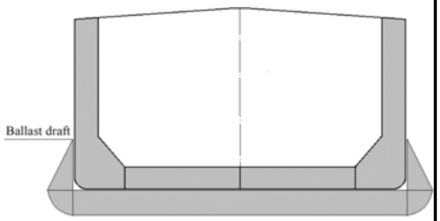
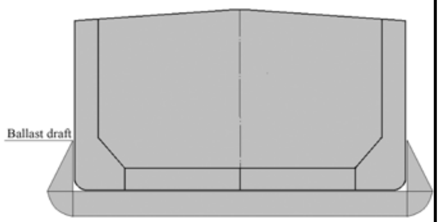
Load case		Loading patter	Center tank
Ballast condition	B-1		
	B-2		

Table 23 Case of three rows of longitudinal bulkhead

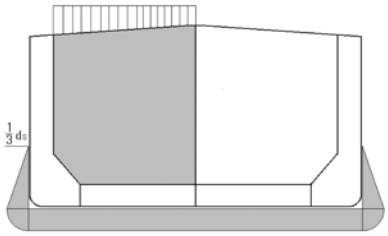
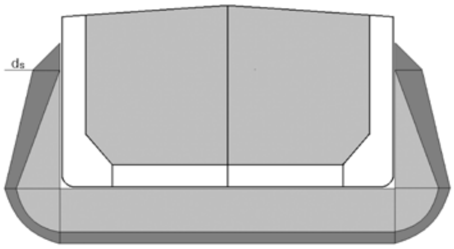
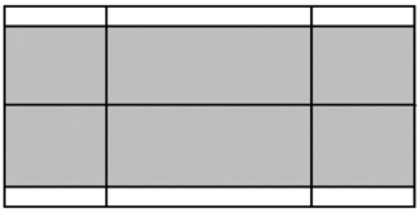
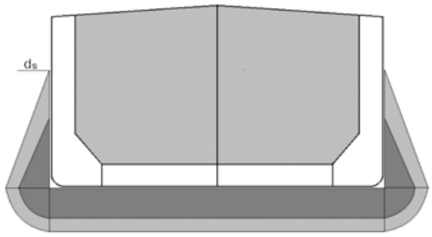
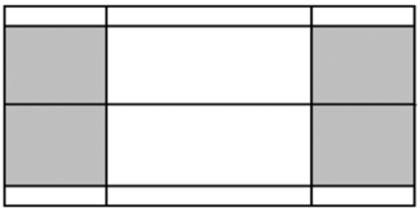
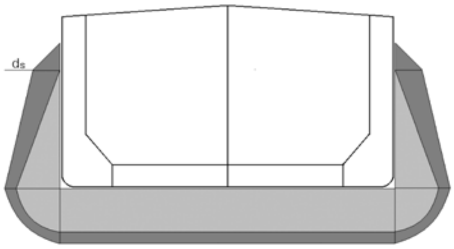
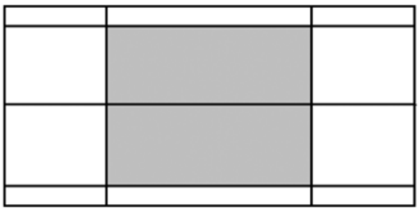
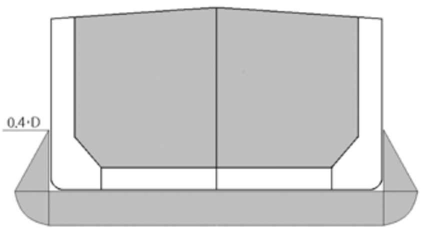
Load case		Loading pattern	Center tank
Hydrostatic test condition	T-1		
Full load and special loading conditions	F-1		
	F-2		
	F-3		
	F-4		

Table 23 Case of three rows of longitudinal bulkhead (continued)

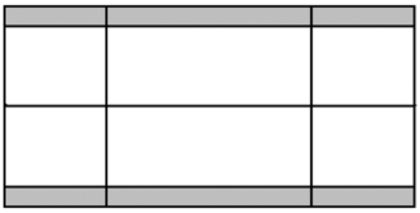
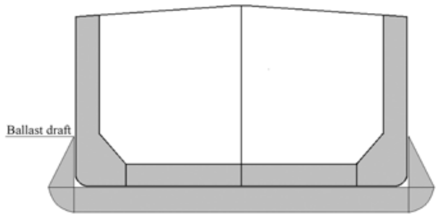
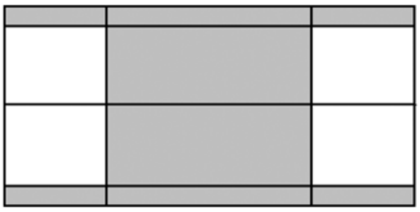
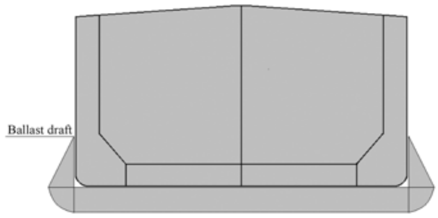
Load case		Loading pattern	Center tank
Ballast conditions	B-1		
	B-2		

Table 24 Case of four rows of longitudinal bulkhead

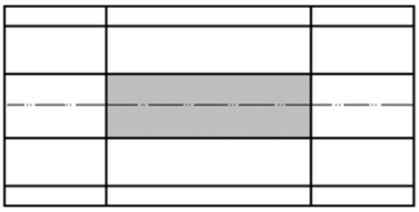
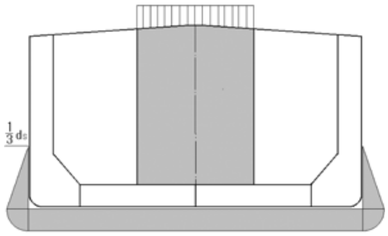
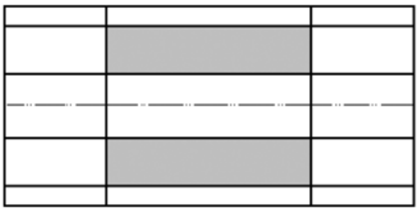
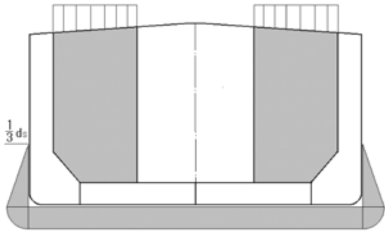
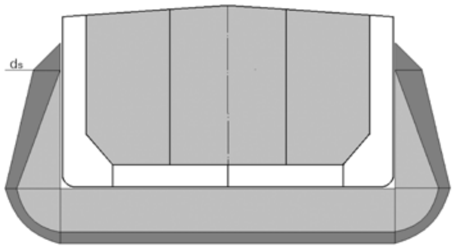
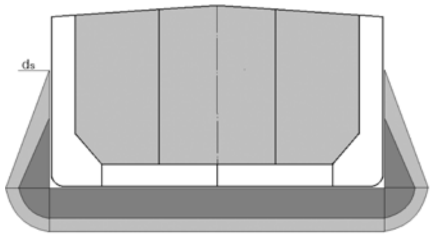
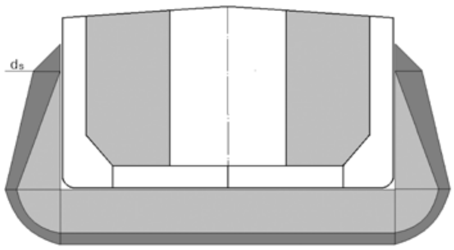
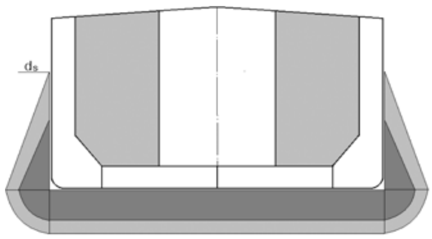
Load case		Loading pattern	Center tank
Hydrostatic test condition	T-1		
	T-2		
Full load and special loading conditions	F-1		
	F-2		
	F-3		
	F-4		

Table 24 Case of four rows of longitudinal bulkhead (continued)

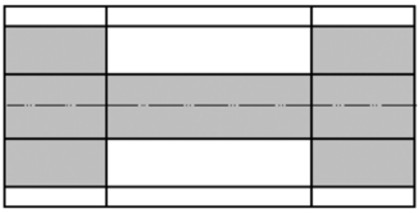
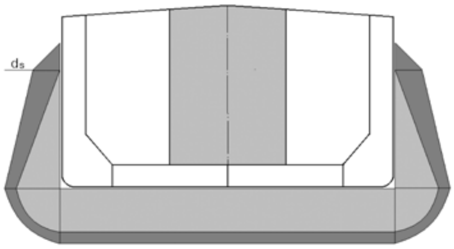
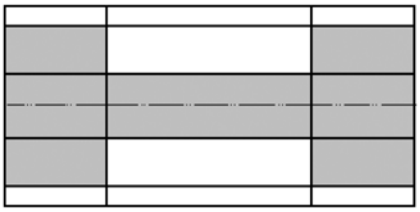
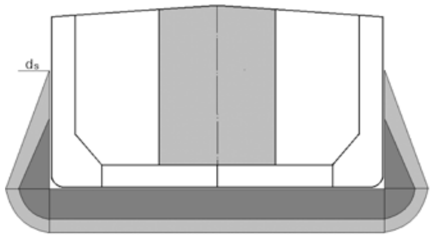
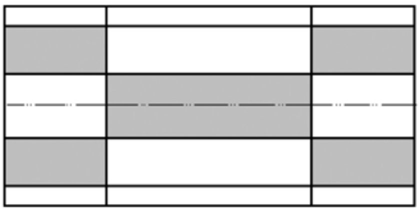
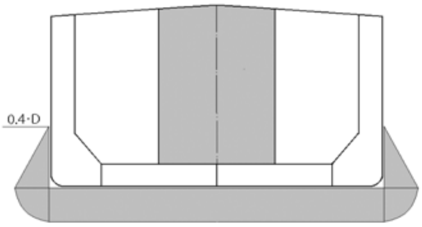
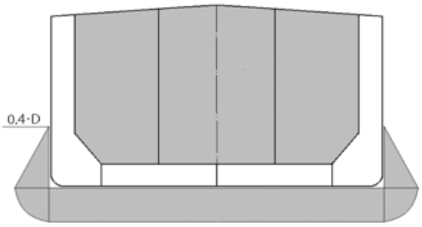
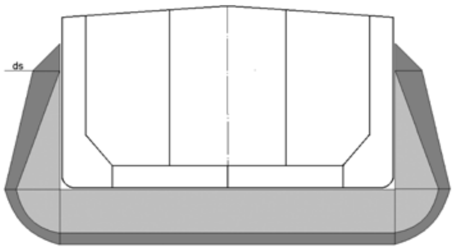
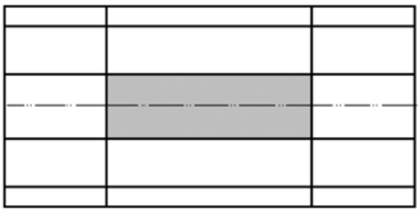
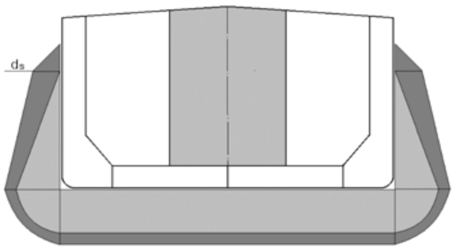
Load case		Loading pattern	Center tank
Full load and special loading conditions	F-5		
	F-6		
	F-7		
	F-8		
	F-9		
	F-10		

Table 24 Case of four rows of longitudinal bulkhead (continued)

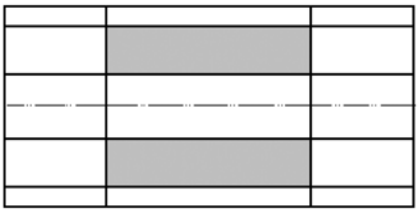
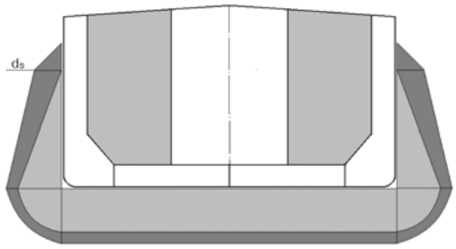
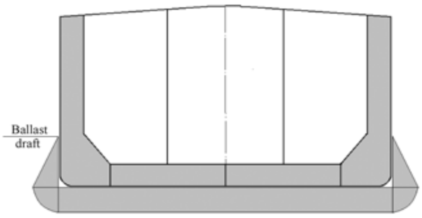
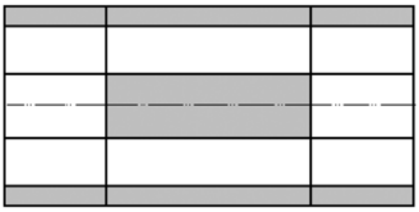
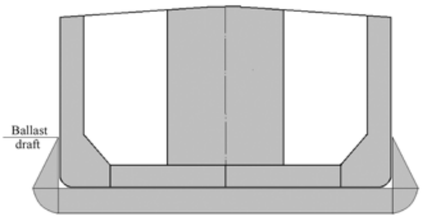
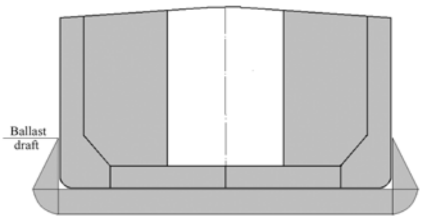
Load case		Loading pattern	Center tank
Full load and special loading conditions	F-22		
Ballast conditions	B-1		
	B-2		
	B-3		

Table 25 Allowable stress for plate structure

	Structural members considered		σ_l	σ_t, σ_v	σ_e
primary members in double hull structure	Longitudinal strength members	Shell plating, Longitudinal bulkhead	$135/K-35f$ max. $125/K$	$145/K$	$145/K$
		Girder, stringers		–	$175/K$
	Floor, transverse			–	$175/K$

1. σ_e is as follows

horizontal longitudinal strength member :

$$\sigma_e = \sqrt{\sigma_l^2 - \sigma_l \sigma_t + \sigma_t^2 + 3\tau^2}$$

vertical longitudinal strength member :

$$\sigma_e = \sqrt{\sigma_l^2 - \sigma_l \sigma_v + \sigma_v^2 + 3\tau^2}$$

transverse strength member :

$$\sigma_e = \sqrt{\sigma_v^2 - \sigma_v \sigma_t + \sigma_t^2 + 3\tau^2}$$

σ_l : normal stress in lengthwise direction
σ_t : normal stress in breadthwise direction
σ_v : normal stress in depthwise direction
τ : shearing stress

2. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
3. The point of detecting stress is to be the center of the element.
4. f is to be 0 at the position of the horizontal neutral axis of the cross sectional area of hull, f_D on upper deck, and f_B on bottom shell plating, and to be determined by linear interpolation according to height from the neutral axis.

Structural members considered			σ_a	$\sigma_e(F)$
Primary members outside double hull structure	Face plate	Parallel part	$175/K$	–
		Corners	$195/K$	–
	Web plate	Parallel part	–	$175/K$
		Corners	–	$195/K$

1. σ_a : normal stress of face plate
2. σ_e is as follows

$$\sigma_e = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau^2}$$

σ_x : normal stress in x-direction of element coordinate system
σ_y : normal stress in y-direction of element coordinate system
τ : shearing stress on the x face in $y$direction of element coordinate system

3. The point of detecting stress is to be the center of the element.

5. Container ship

(1) General

(A) In case where scantlings of structural members of cargo hold in container ship are determined by the hold analysis, necessary documents and data on the calculation method are to be submitted to the Society for obtaining approval beforehand.

(B) Except for those specifically provided for in this part, **Par 1.** is to be applied.

(2) Structural modeling

(A) Model extent

The extent of finite element model is to include four 40 ft container bays (2-holds length) located at amidship. The model is to represent the full depth of the ship and the half breadth. However if there is asymmetry about the ship's centerline for the primary structure and cargo loading, then full breadth model need to be represented. (see **Fig 19**)

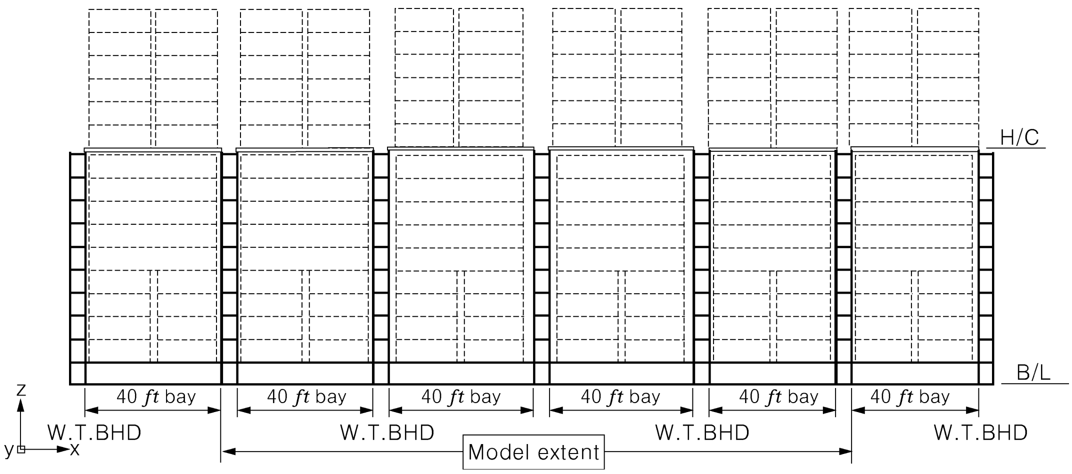


Fig 19 Model extent

(B) Structural modelling

The structural modelling with shell element mesh is : longitudinally two or more elements between every web frame, transversely one element between longitudinal spacing and vertically three or more elements over the depth of double bottom girders and floors. Typical arrangements representing container ship are shown in **Fig 20** to **23.**

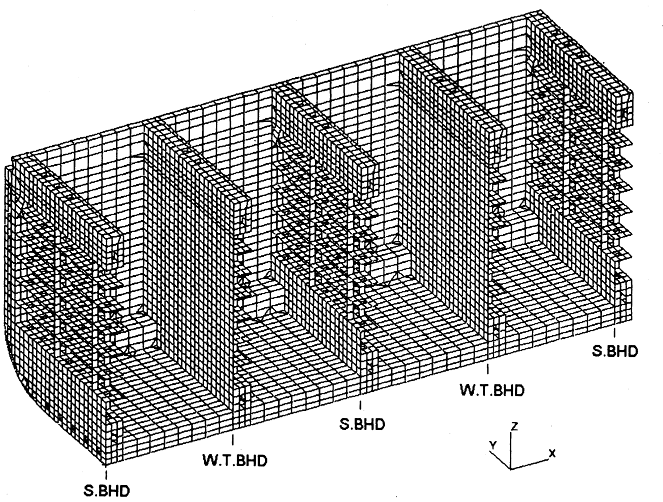


Fig 20 Hold model

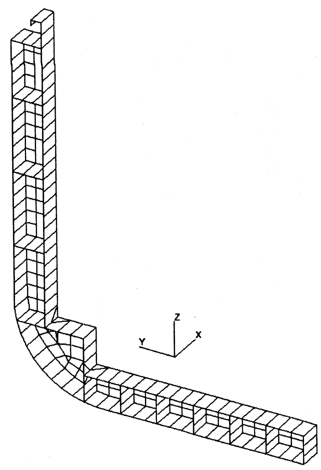


Fig 21 Web frame model

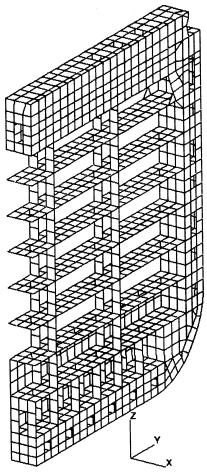


Fig 22 Support BHD model

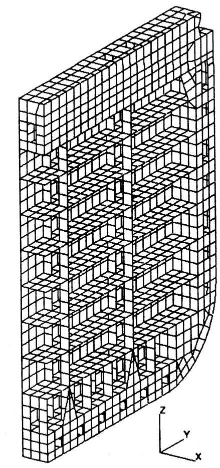


Fig 23 W.T.BHD. model

(3) Boundary condition
The boundary conditions described in this section are to be applied to the analysis model for symmetric load case, as shown in **Fig 24** and **Table 26**

- End planes (①) : symmetric condition
- Centerline plane (②) : symmetric condition
- Vertical counter forces distributed to the side shell nodes at the oil tight BHDs to eliminate reactions at the vertical constraints.(③)

Table 26 Boundary conditions (Symmetric)

Position \ Coord.	Displacement			Rotation		
	U_x	U_y	U_z	θ_x	θ_y	θ_z
① Both ends of the model	1	0	0	0	1	1
② Centerline plane	0	1	0	1	0	1
③ Top of side shell at the oil tight bulkheads P	0	0	1	0	0	0
(Notes) 1 : Fixed 0 : Free						

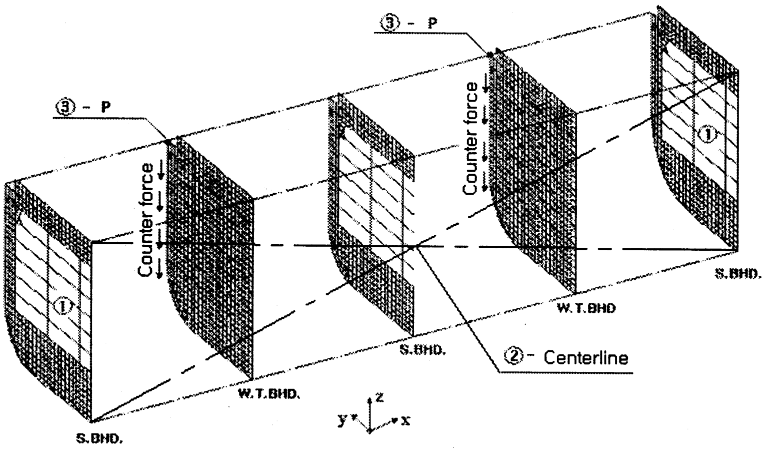


Fig 24 Boundary conditions (Symmetric)

The boundary conditions described in this section are to be applied to the analysis model for asymmetric load case, as shown in **Fig 25** and **Table 27.**

- Both ends of the model (①) : symmetric condition
- Connection line of bottom shell and watertight bulkhead to be restrained in horizontal displacement (②)
- Connection line of side shell and watertight bulkhead to be restrained in vertical displacement(③)

Table 27 Boundary conditions (Asymmetric)

Position \ Coord.	Displacement			Rotation		
	U_x	U_y	U_z	θ_x	θ_y	θ_z
① Both ends of the model	1	0	0	0	1	1
② Line L	0	1	0	0	0	0
③ Line S	0	0	1	0	0	0
(Notes) 1 : Fixed 0 : Free						

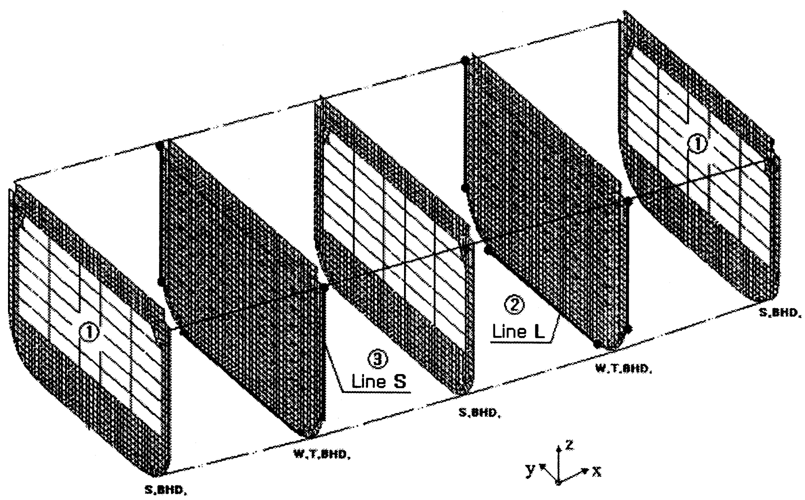


Fig 25 Boundary conditions (Asymmetric)

(4) Load

(A) Applied load

The following load components are be considered : container load, hydrostatic pressure, wave loads and ballast loads etc..

(a) Container load

(i) Container loads according to design load are to be applied as point loads to the hull structure grid points nearest to the base of the container stacks. On hatch cover container stack load should be considered properly in account for actual force transfer to hull structure through girder system of hatch cover and support arrangement on hatch coaming.

(ii) According to the load case, acceleration components due to ship motion are to be considered. The formulas of acceleration factors are to be applied in accordance with the method deemed appropriate by the Society.

(b) Still water load

Still water load is to apply as specified in **1.** (8)

(c) Wave induced load

Wave induced load is to apply s specified in **1.** (9)

(d) Ballast load

Ballast load is to apply as specified in **1.** (7)

(B) Loading conditions

Table 28 and **Table 29** gives the standard load cases which are to be considered in the assessment.

(a) One bay empty condition (F-1)

(i) One 40 ft bay to be empty of containers. The remaining bays and hatch covers over to be filled with 20 ft containers.

(ii) The external pressure is to be taken scantling draft and wave induced loads corresponding to the wave crest.

(b) One bay empty condition (F-2)

(i) One 40 ft bay to be empty of containers. The remaining bays to be filled with 40 ft containers and hatch covers over to be filled with 20 ft containers.

(ii) The external pressure is to be taken scantling draft and wave induced loads corresponding to the wave crest.

(c) One bay empty condition (F-3)

(i) One 40 ft bay and hatch covers over to be empty of containers. The remaining bays to be filled with 40 ft containers and hatch covers over to be filled with 20 ft containers.

(ii) The external pressure is to be taken scantling draft and wave induced loads corresponding to the wave crest.

(d) Homogeneous loading condition (F-4)

(i) All container bays in hold and hatch covers over to be filled with 20 ft containers.

(ii) The external pressure is to be taken scantling draft and wave induced loads corresponding to the wave trough.

(e) Heeled condition (H-1)

(i) All container bays in hold and hatch covers over to be filled with 20 ft containers. External sea pressure in the heeling condition are to be taken at the moment of freeboard deck immersion and no wave induced load to be applied.

(ii) Transverse loads caused by ship acceleration are to be calculated by the method deemed appropriate by the Society.

(f) Heeled condition (H-2)

(i) All container bays in hold to be filled with 40 ft containers and hatch covers over to be filled with 20 ft containers. External sea pressure in the heeling condition are to be taken at the moment of freeboard deck immersion and no wave induced load to be applied.

(ii) Transverse loads caused by ship acceleration are to be calculated by the method deemed appropriate by the Society.

(g) Surge loading condition (S-1)

(i) All container bays in hold to be filled with 40 ft containers and hatch covers over to be filled with 20 ft containers. The external pressure is to be taken scantling draft and wave induced loads corresponding to the wave crest.

(ii) The container loads to be considered longitudinal acceleration factor due to ship motion. The longitudinal force acting on containers within hold is to be calculated at the center of each container and is to be suitably distributed to the bulkhead primary members in way of the cell guides. The longitudinal force action on containers on hatch covers is to be calculated at the midheight of the stack. The following assumptions are to be made:
- · Wind load may be neglected
- · The moment about the stack base caused by the longitudinal force may be ignored
- · Container load of hatch cover over to be applied properly on the hatch coming.

(h) Flooded condition (A-1)

(i) This loading case is to ensure that the structural integrity of the transverse watertight bulkhead and stringers when the container hold is flooded as a result of collision or other accidental occurrence.

(ii) The external pressure may be taken at a draught equal to the scantling draught and internal pressure in damaged hold may be taken at a draught equal to 90 % of freeboard deck level.

Table 28 Load cases

Load case description	Case	External load		Container load			
		Still water load	Wave induced load	Cargo hold		Hatch cover over	
One bay empty condition	F-1	d_s[1]	W_C[2]	empty bay	-	empty bay above	20 ft
				other bays	20 ft	other covers	20 ft
	F-2	d_s[1]	W_C[2]	empty bay	-	empty bay	20 ft
				other bays	40 ft	other bays	20 ft
	F-3	d_s[1]	W_C[2]	empty bay	-	empty bay	-
				other bays	40 ft	other bays	20 ft
Homogeneous loading condition	F-4	d_s[1]	W_T[3]	all bays	20 ft	all covers	20 ft
Heeled condition	H-1	[4]	-	all bays	40 ft	all covers	20 ft
	H-2	[4]	-	all bays	20 ft	all covers	20 ft
Surge loading condition	S-1	d_s[1]	W_C[2]	all bays	40 ft	all covers	20 ft
Flooded condition	A-1	d_s[1]	-	flooded hold	-	all covers	20 ft
				non-flooded hold	20 ft		

Notes :
1) d_s : scantling draught
2) W_C : wave induced load for wave crest
3) W_T : wave induced load for wave trough
4) Draft at the moment of freeboard deck immersion

Table 29 Load case

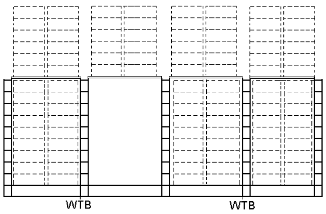
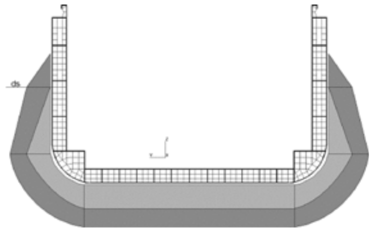
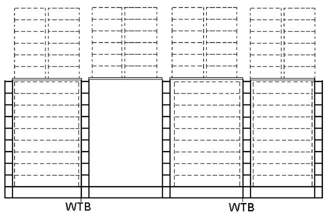
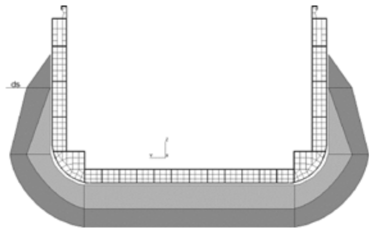
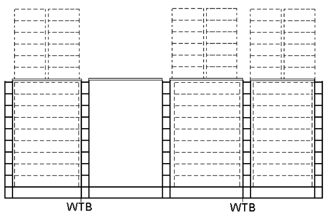
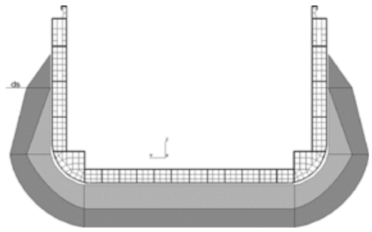
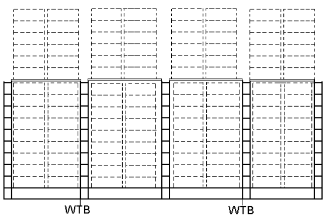
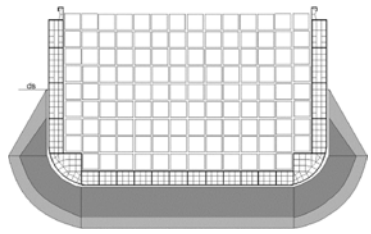
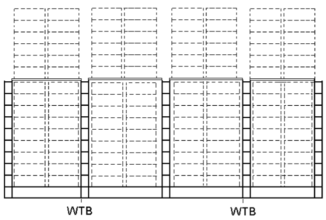
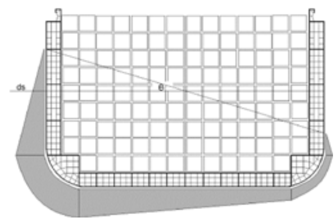
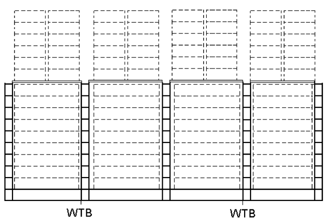
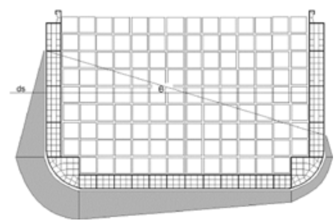
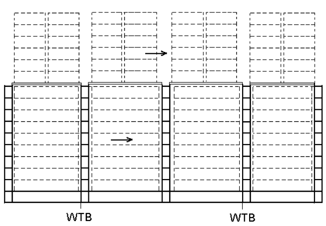
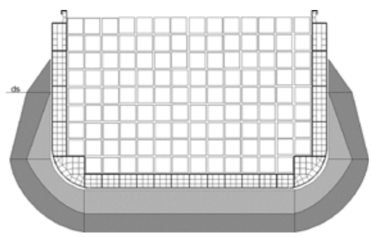
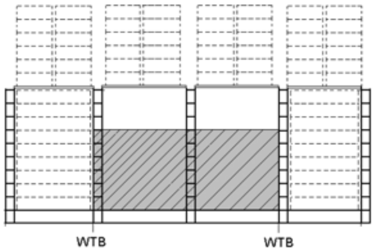
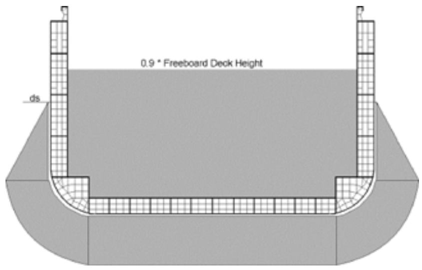
Load case		Loading pattern	Center tank
One bay empty condition	F-1		
	F-2		
	F-3		
Homogeneous loading condition	F-4		
Heeld condition	H-1		
	H-2		
Surge loading condition	S-1		

Table 29 Load case (continued)

Load case		Loading pattern	Center tank
Flooded condition	A-1		

(5) Allowable stress
Allowable stress for the modelling by using shell elements are shown in **Table 30.** But, The stresses resulting from Load case A-1 are given in **Table 31.**
(6) Buckling strength calculation
Buckling strength assessment to be carried out in accordance with **2.** However, For LCA-1, buckling safety factor to be applied 1.0.

Table 30 Allowable stress

Structural member considered \ Stress	σ_l	σ_t , σ_v	σ_e	τ
Bottom shell, Inner bottom	$110/K$	$145/K$	$145/K$	-
Longitudinal bulkhead, Side shell	-	$145/K$	-	$83/K$
Girder	-	-	$175/K$	$83/K$
Stringer	$110/K$	-	$175/K$	$83/K$
Water tight bulkhead	-	$145/K$	$175/K$	-
Transverse web frame, floor	-	-	$175/K$	-

(Notes)
1. The equivalent stress σ_e is to be as follows.

$$\sigma_e = \sqrt{\sigma_l^2 - \sigma_l \cdot \sigma_t + \sigma_t^2 + 3\tau^2}$$ (for longitudinal strength members)

$$\sigma_e = \sqrt{\sigma_v^2 - \sigma_v \cdot \sigma_t + \sigma_t^2 + 3\tau^2}$$ (for transverse strength members)

σ_l : normal stress in lengthwise direction
σ_t : normal stress in breadthwise direction
σ_v : normal stress in depthwise direction
τ : shear stress
2. Opening in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
3. The point detection stress is to the center of the element.

Table 31 Allowable stress (A-1)

Structural members considered	Steel grades	σ_v	τ
Trans. water tight bulkhead, side transverse web frame, stringer and girder	*A*, *B*, *D* and *E*	235	136
	AH 32, *DH* 32 and *EH* 32	315	182
	AH 36, *DH* 36 and *EH* 36	355	205

Annex 3-3 Guidance for the Fatigue Strength Assessment of Ship Structures

1. General

(1) This Annex is the Guidance which assesses the fatigue strength of a ship structure. This guidance provides a guideline for a simplified fatigue analysis method and a direct fatigue analysis method (See **Fig 1**)

(2) The ships, which are contracted for construction on or after 1 April 2006 and are to be complied with Rule **Pt 11** or **Pt 12,** are to meet all the requirements of the corresponding parts. For other ships deemed necessary by the Society in consideration of the ship's kind, size and configuration, the requirements in this Annex are to be applied.

(3) For ships which were checked based on the above fatigue analysis method, following class notation are assigned.

(A) The method of simplified fatigue analysis

(a) The method using stress concentration factor of Annex 3-3 2 (3) : **SeaTrust(FSA1)**

(b) The method using FEM of Annex 3-3 2 (2) : **SeaTrust(FSA2)**

(B) The method of direct fatigue analysis : **SeaTrust(FSA3)**

(4) In case of special purpose ships, new type of ships or ships requiring more precise fatigue strength assessment, the direct fatigue analysis method is to be applied to assess the fatigue strength. A spectral fatigue analysis method or a transfer function method may apply to the direct fatigue analysis.

(5) Other equivalent methods may be applied to assess the fatigue strength when deemed appropriate by the Society.

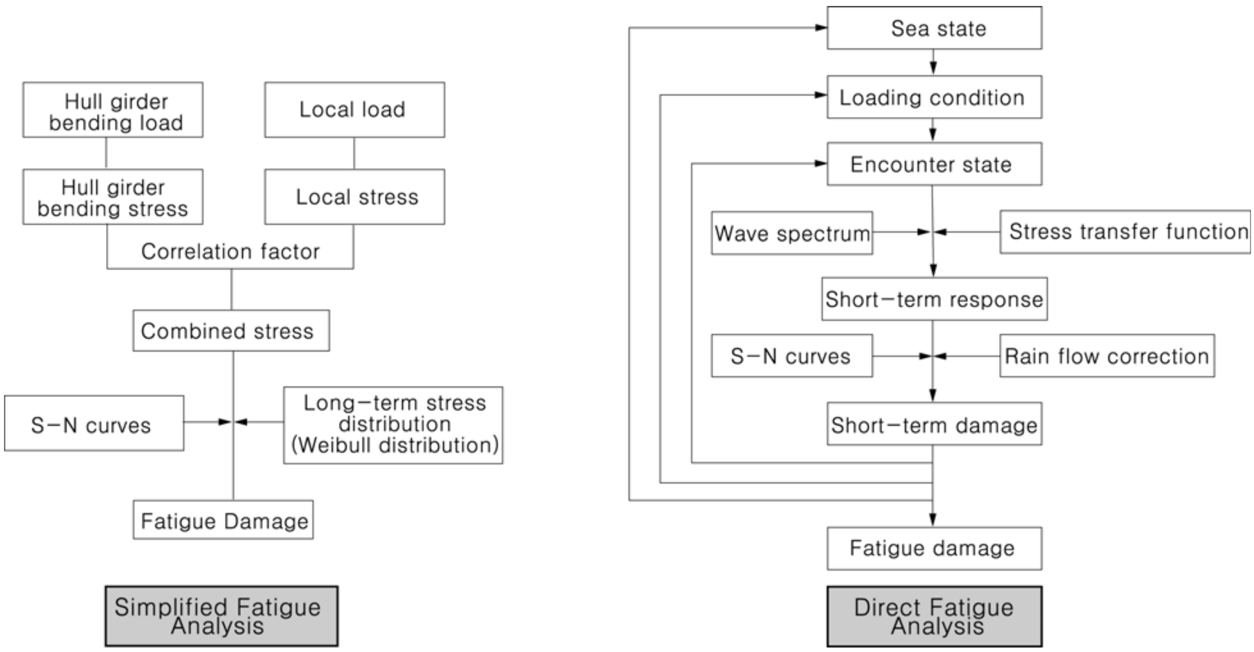


Fig 1 Fatigue analysis method

2. Stress analysis

In the fatigue analysis, three kinds of stresses; i. e. the nominal stress, the hot spot stress and notch stress can be used. The hot spot stress approach is to be employed in this Guidance.

(1) Definition of stress

(A) Nominal stress

The Nominal stress is global stress calculated in a sectional area, disregarding the local stress-raising effects of the structural discontinuities, weld bead shape, etc.

(B) Hot spot stress

(a) The hot spot stress includes all stress-raising effects by a structural discontinuity. It does not include the stress peak effect caused by the local notch and the weld bead shape. The hot spot stress in plate structure is divided into the membrane stress and the bending stress. It is linearly distributed in thicknesswise. In general, hot spot stress is greater than the nominal stress, but hot spot stress is equal to nominal stress at the position far enough from the discontinuity of structures.

(b) For the calculation of the hot spot stress, the three dimensional finite element analysis is to be performed. Then, it can be determined by extrapolating maximum principal stresses outside the region affected by the weld geometry. The stress range near welding toe is to be used consistently depending on the effect by type and size of the finite element.

(C) Notch stress

Hot spot region is the location where occurs a fatigue crack as the welding toe. The total stress at the location is defined as the notch stress.

(D) Edge stress

Edge stress on plate members includes the nominal stress of the plates and stress-raising effects on the edge of plates. It is calculated by using the finite element method.

(2) Finite element analysis

The finite element model of the structure is to consist of shell elements. At the hot spot region, the 4-noded quadrilateral shell elements of the size $t \times t$ are used, where t is the plate thickness. The weld bead is not included in the finite element model. In order to determine the surface stress distribution of the shell element, fictitious beams without stiffness are put on the connection line of shell element. In the structural analysis, FE models are to be based on as built scantlings and the beam element stresses are calculated taking account of shear flexibility.

(A) Calculation of hot spot stress

The hot spot stress is to be calculated by means of the surface stress distribution from the FE analysis. The hot spot stress approach at weld toe in accordance with the connection types is shown in **Fig 2.** In order to eliminate the notch effect and to consider the weld leg length, the hot spot stress at the weld toe is obtained by a linear extrapolation of the stresses determined at the locations $0.5t$ and $1.5t$ from the weld toe.

$$\sigma_{hot} = \frac{3\sigma(0.5t) - \sigma(1.5t)}{2}$$

$\sigma(x)$: Using the Lagrange interpolation method, the stress at a location x from the weld toe is to be generally calculated as follows

$$\sigma(x) = c_1(x)\sigma_1 + c_2(x)\sigma_2 + c_3(x)\sigma_3 + c_4(x)\sigma_4$$

$$c_1(x) = \frac{(x-x_2)(x-x_3)(x-x_4)}{(x_1-x_2)(x_1-x_3)(x_1-x_4)}$$

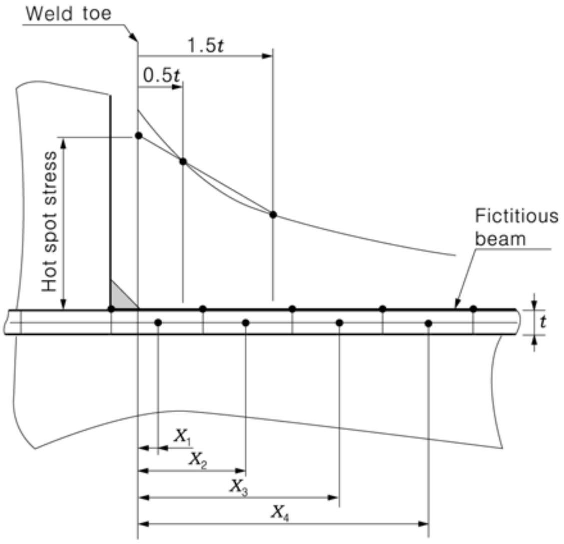
$$c_2(x) = \frac{(x-x_1)(x-x_3)(x-x_4)}{(x_2-x_1)(x_2-x_3)(x_2-x_4)}$$

$$c_3(x) = \frac{(x-x_1)(x-x_2)(x-x_4)}{(x_3-x_1)(x_3-x_2)(x_3-x_4)}$$

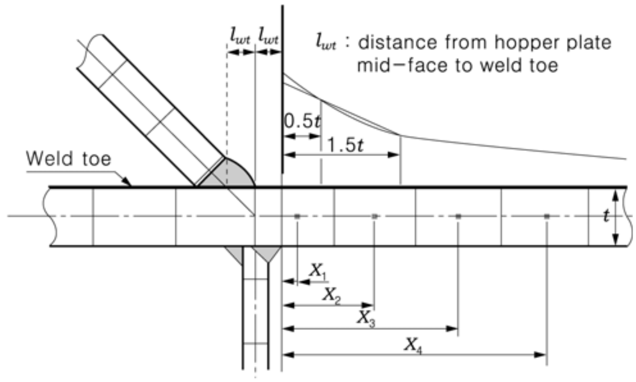
$$c_4(x) = \frac{(x-x_1)(x-x_2)(x-x_3)}{(x_4-x_1)(x_4-x_2)(x_4-x_3)}$$

(B) Calculation of edge stress

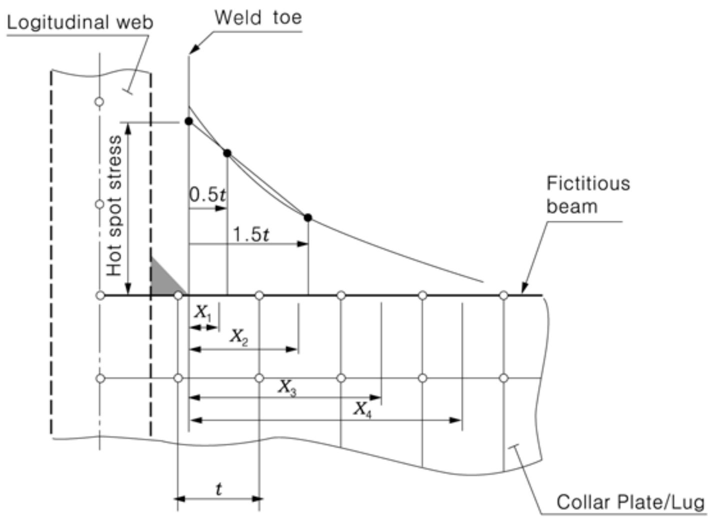
The FE model of the plate structure is to consist of 4-noded quadrilateral shell elements of size $t \times t$ in the vicinity of the edge, where t is the plate thickness. In order to calculate the edge stress, fictitious beams without stiffness are put on the edge of the plate. In the structural analysis, the edge stresses are obtained from these beam element stresses.



(a) Connection of longitudinal and transverse stiffener (or BKT)



(b) Bilge Knuckle Part



(c) Connection of longitudinal and collar plate (or lug)

Fig 2 Determination of hot spot stress

(3) Stress concentration factor

(A) The stress concentration factor is defined as the ratio of the hot spot stress σ_{hot} to the nominal stress σ_{nom}. In the weld connection of the longitudinal and transverse (or trans. BHD) stiffeners, the hot spot stress may be calculated using the stress concentration factors $K_{s,l}$, $K_{s,a}$ in **Table 1** as follow:

$$\sigma_{hot,l} = K_{s,l}\,\sigma_{nom,l}$$

$$\sigma_{hot,g} = K_{s,a}\,\sigma_{nom,g}$$

where,

$K_{s,l}$ = the stress concentration factor by lateral load

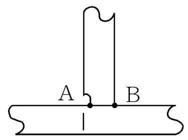
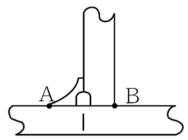
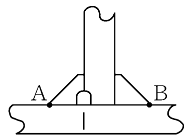
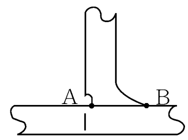
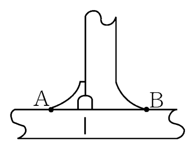
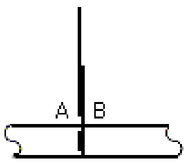
$K_{s,a}$ = the stress concentration factor by axial load

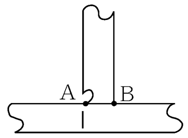
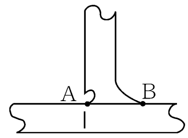
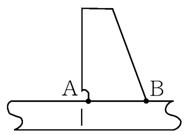
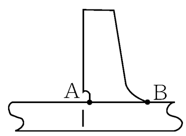
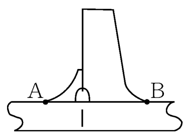
$\sigma_{nom,l}$ = nominal stress as specified in **Par 4** (2) (A) (b)

$\sigma_{nom,g}$ = nominal stress as specified in **Par 4** (2) (A) (a) (iii)

(B) For end structures of longitudinals, the stress concentration factor due to relative deflection is considered to be the same value as the stress concentration factor due to lateral load.

Table 1 Stress concentration factors $K_{s,l}$ and $K_{s,a}$

No	Model		$K_{s,l}$		$K_{s,a}$	
			Point A	Point B	Point A	Point B
LF-1		Single hull	1.71	0.87	1.37	1.27
		Double hull	1.54	1.11	1.35	1.29
LF-2		Single hull	0.75	1.42	1.31	1.48
		Double hull	0.74	1.47	1.31	1.48
LF-3		Single hull	1.03	0.98	1.51	1.52
		Double hull	0.98	1.04	1.51	1.52
LF-4		Single hull	1.75	0.69	1.40	1.42
		Double hull	1.65	0.79	1.40	1.42
LF-5		Single hull	0.78	0.81	1.40	1.34
		Double hull	0.74	0.85	1.40	1.34
LF-0			1.20	1.20	1.20	1.20

No	Model		$K_{s,l}$		$K_{s,a}$	
			Point A	Point B	Point A	Point B
Mod. LF-1		Single hull	1.72	0.90	1.34	1.28
		Double hull	1.53	1.15	1.36	1.30
Mod. LF-4		Single hull	1.75	0.69	1.45	1.36
		Double hull	1.63	0.79	1.44	1.38
LB-1		Single hull	1.72	0.23	1.49	1.45
LB-2		Single hull	1.70	0.09	1.49	1.22
LB-3		Single hull	0.56	0.31	1.12	1.08

3. Fatigue life assessment

(1) Hot spot stress approach

It is not easy to calculate the nominal stresses nor to select the corresponding S-N curves for complex ship structure. Therefore, for the fatigue strength assessment of a ship structure, the hot spot stress by geometrical discontinuity of the structure is to be calculated using the finite element method or the stress concentration factors. The S-N curve which is not including the stress concentration effect is to be applied the hot spot stress approach. In this case, only the structural geometry effects are accounted for, while local notch effects like the weld geometry are considered to be implicitly included in the S-N curve.

(2) Design S-N curve

(A) In order to assess the fatigue strength of ship structure, S-N curves as shown in **Fig 3** are to be used where D curve is to be used for welded structures, C curve for the edge of plate and B curve for the grounded edge of plate.

(B) The design S-N curves are defined as the mean(the curves of (A) above) minus two standard deviations and thus correspond to survival probability of 97.6 %. The slopes of these curves are changed beyond $N=10^7$ cycles considering Haibach effect. (see **Fig 3**)

$$\log N = \log c - m log \sigma \quad \text{for } N \le 10^7$$
$$\log N = \log c' - m' \log \sigma \quad \text{for } N > 10^7$$

where,

$\log c$ and $\log c'$ = the life intercepts of the S-N curve (See **Table 2**)

m and m' = the negative inverse slopes of the S-N curve (See **Table 2**)

Table 2 Value of $\log c, \log c'$ and m, m'

curves	$N \le 10^7$		$N > 10^7$	
	$\log c$	m	$\log c'$	m'
B	15.006	4.0	17.006	5.0
C	13.626	3.5	16.466	5.0
D	12.182	3.0	15.625	5.0

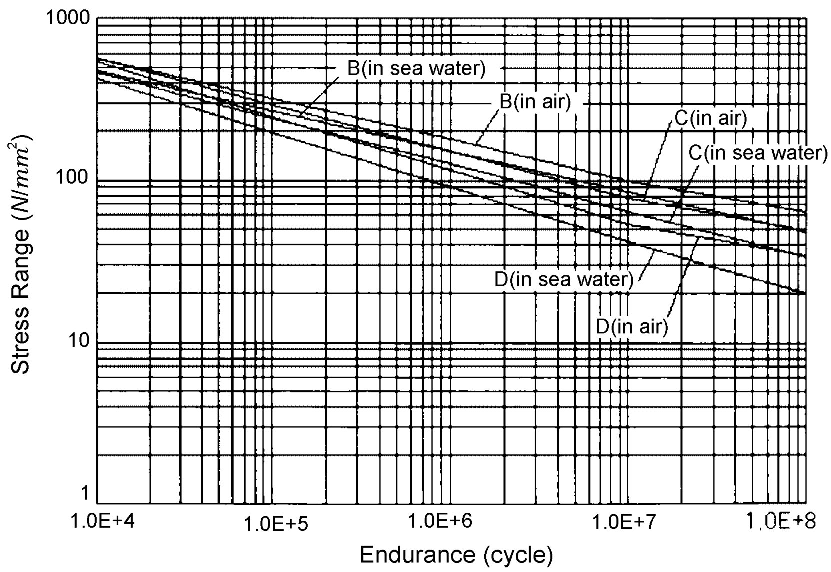


Fig 3 Design S-N curve[*1]

[*1] "Basic Design" S-N Curves for Non-nodal Joint" given in "Offshore Installation; Guidance on Design, Construction and Certification, Sec. 21, 4th ed. London January, U.K Department of Energy"

(C) Corrosion effect

For unprotected joints exposed to sea water, the design S-N curve is to be modified with half life time of S-N curve in air. However, no slope change is incorporated in the S-N curve at 10^7 cycles:

$$\log N = \log c_1 - m \log \sigma$$

where,

$\log c_1 = \log c - \log 2$, the values of $\log c$ and m are to be as given in **Table 2.** However, in case that the hull structure members in ballast tanks are protected against the corrosion by effective means, the design S-N curve in air is to be applied for the first half of the design life and the free-corrosion S-N curve for the remainder of the design life. In calculation, the stresses are determined with as-built scantlings.

(D) Mean stress effect

(a) Since most fatigue tests are conducted under pulsating tension loading, the effect of mean tensile stresses, which tend to reduce the fatigue life, is accounted for in the S-N curves. The beneficial effect of compressive stresses is to be considered when these S-N curves are used for the fatigue strength assessment.

(b) The correction of stress range with the consideration of mean stress effect is to follow **Annex C 1.4.5.11.** of Rule **Pt 12**.

(3) Calculation of fatigue life

According to the Miner-Palmgren linear cumulative damage rule, the fatigue damage ratio D is calculated. The fatigue life is given by L/D (years) where L is design life (years).

4. Simplified fatigue analysis

For the fatigue strength assessment of longitudinals, the simplified fatigue analysis is to be applied and the hull girder bending load and the local load are taken into account in this analysis. The former accounts for the vertical wave bending moment and the horizontal wave bending moment, and the latter for the wave load. In this guidance, the loads are determined at the probability level of exceedance 10^{-4}.

(1) Fatigue design load

(A) Hull girder bending load

(a) Vertical wave induced bending moment

The vertical wave induced bending moments are obtained from the following formulae.

$$M_w(+) = 0.19 f C_1 C_2 L^2 B C_b \quad \text{(kN-m)}$$

$$M_w(-) = -0.11 f C_1 C_2 L^2 B (C_b + 0.7) \quad \text{(kN-m)}$$

where,

f = factor to transform the load from 10^{-8} to 10^{-4} probability level, and to be calculated as follows.

$$f = 0.5^{1/\xi}$$

ξ = Weibull shape parameter as specified in **Par 4** (2) (B) (b).

C_b = the block coefficient. However, it is to be taken as 0.6, where it is less than 0.6.

C_1 = wave coefficient as specified in **Ch 3, 201. Table 3.3.1** of the Rules

C_2 = distribution factor as presented respectively in **Ch 3, 201. Tables 3.3.1** of the Rules.

(b) Horizontal wave induced bending moment

The horizontal wave bending moment is obtained from the following formula:

$M_H = 0.18 f C_1 C_H L^2 d (C_b + 0.7)$ (kN-m)

where,
f = factor as specified in (a)
C_1 and C_b = as specified in (a)
C_H = as specified in **Pt 7, Ch 4, 202.** of the Guidance

(B) Local wave load
(a) Local wave pressure
The wave pressure on the ship's side is to be taken as follows:

(i) For the load point on and above the waterline:

$$p_T = p_T^f K_1 \left(1 - \frac{h}{a_w}\right) \quad (\text{kN/m}^2)$$

(ii) For the load point below the waterline:

$$p_T = p_T^f K_1 \left(1 - \frac{K_2 h}{d}\right) \quad (\text{kN/m}^2)$$

where,
$p_T^f = 0.095L + 34.0$ (kN/m^2)
K_1 = Coefficient as specified in the following formulae

for 0.4L amidships = 1.0
afterward of AP = 1.5
forward of FP = $\dfrac{5.5(0.85 - C_b)}{1 - C_b^2} + 2.0$
For intermediate longitudinal positions, K_1 is to be obtained by interpolation.

K_2 = Coefficient as specified in the following formulae
for 0.4L amidships = 0.5
at the ends of ship = 1.0
For intermediate longitudinal positions, K_2 is to be obtained by interpolation.

a_w = as specified in (b)
h = vertical distance from the waterline to the load point
C_b = block coefficient. Where, however, when C_b exceeds 0.85, C_b is to be taken as 0.85.

(b) Local wave pressure range
The local wave pressure range P_d is to be calculated as follows. (See **Fig 4**)

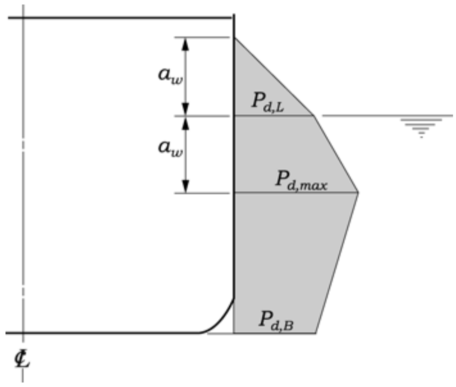


Fig 4 Local wave pressure range p_d

(i) For the load point on and above the waterline:

$$p_d = p_T^f K_1 \left(1 - \frac{h}{a_w}\right) \quad (\text{kN/m}^2)$$

(ii) For the load point between the waterline and $p_{d,\max}$:

$$p_d = 10h + p_T^f K_1 \left(1 - \frac{K_2 h}{d}\right) \quad (\text{kN/m}^2)$$

(iii) For the load point on and below $p_{d,\max}$:

$$p_d = 2 p_T^f K_1 \left(1 - \frac{K_2 h}{d}\right) \quad (\text{kN/m}^2)$$

a_w : the vertical distance from the waterline to the point of the maximum pressure range, $p_{d,\max}$, given as:

$$a_w = \frac{1}{\dfrac{1}{2d} + \dfrac{10}{p_T^f}}$$

(C) Internal pressure loads due to ship motion

(a) Dynamic internal pressure loads

The dynamic internal pressure, p_i in kN/m^2, from liquid cargo or ballast water is not to be less than that obtained from the following formulas, which is the greater:

$$p_i = 2f\rho_c a_v h_s \quad (\text{kN/m}^2)$$
$$p_i = 2f\rho_c a_t |y_s| \quad (\text{kN/m}^2)$$

f = as specified in (A) (a) above

ρ_c = density of liquid cargo and density of sea water, 1.025

h_s = vertical distance from point considered to surface inside tank (m)

y_s = horizontal distance from center of free surface of liquid in tank to point considered (m)

a_v or a_t = accelerations in vertical or horizontal direction as specified in (b) (vi)

(b) Accelerations due to ship motion

(i) Acceleration due to heave motion

The acceleration due to heave motion of a ship is given by the following formula.

$$a_z = \frac{V^{1.2}}{2\sqrt{L}} + \frac{361}{L} + 0.49 \quad (\text{m/sec}^2)$$

V : ship design speed (knots)

(ii) Accelerations due to sway motion

The acceleration due to sway motion of a ship is given by the following formula.

$$a_y = \frac{178}{L} + 0.36 \quad (\text{m/sec}^2)$$

(iii) Accelerations due to pitch motion

The acceleration due to pitch motion is given by the following formula.

$$a_\theta = \theta \times \left(\frac{2\pi}{T_\theta}\right)^2 \times l_\theta \quad (\text{m/sec}^2)$$

θ = maximum pitch angle (single amplitude) given by the following formula

$$\theta = \frac{19.62}{L} + 0.022 \quad (\text{rad})$$

T_θ = period of pitch given by the following formula

$$T_\theta = 1.86\sqrt{\frac{L}{g}} \quad (\text{sec})$$

l_θ = distance from axis of rotation for pitching to center of tank/mass (m), and the axis of rotation may be taken as the smaller of $(D/4 + d/2)$ and $D/2$ above the base line at 0.45L from A.P.

(iv) Accelerations due to roll motion

The acceleration due to roll motion is given by the following formula.

$$a_\phi = \phi \times \left(\frac{2\pi}{T_\phi}\right)^2 \times l_\phi \quad (\text{m/sec}^2)$$

ϕ = maximum roll angle (single amplitude) given by the following formula

$$\phi = kC_s f_0 \sqrt{0.131 - 0.005\,T_\phi} \quad (\text{rad})$$

k = 1.0 for ships without bilge keel
= 0.8 for ships with bilge keel (including ships with anti-rolling tank)
C_s = 0.82 for bulk carriers and tankers
= 0.96 in generals
f_0 = values obtained from the following formula.

$$f_0 = 0.86 + 2.72C_b - (B/d) \times (0.11 + 0.34C_b)$$

Where C_b is under 0.45, C_b is to be taken as 0.45, and where C_b is 0.7 and over, C_b is to be taken as 0.7. And where B/d is under 2.4, B/d is to be taken as 2.4, and where B/d is 3.5 and over, B/d is to be taken as 3.5.

T_ϕ = period of roll given by the following formula.

$$T_\phi = \frac{4C_f B}{\sqrt{GM_T}} \quad \text{(sec)}$$

Where T_ϕ is under 6.0, T_ϕ is to be taken as 6.0, and where T_ϕ is 20.0 and over, T_ϕ is to be taken as 20.0.

C_f = values obtained from the following formula.

$$C_f = 0.373 - 0.023(B/d) - 0.043(L/100)$$

Where B/d is under 2.4, B/d is to be taken as 2.4, and where B/d is 3.5 and over, B/d is to be taken as 3.5.

GM_T = metacentric height (m). Where, however, the values of the GM_T have not been calculated for relevant loading condition, the following approximate values may be used:

$0.07B$ in general
$0.12B$ for single skin tankers, bulk carriers and fully loaded double hull tankers
$0.25B$ for bulk carriers in the ballast condition
$0.33B$ for double hull tankers in the ballast condition

l_ϕ = distance from axis of rotation for rolling to center of tank/mass (m), and the axis of rotation may be taken as the smaller of $(D/4 + d/2)$ and $D/2$ above the base line at 0.45L from A.P.

(v) Accelerations due to yawing
The acceleration due to yawing is given by the following formula.

$$a_{\psi} = \left(\frac{6.95}{L} - 0.017\right) l_{\psi} \quad (\text{m/sec}^2)$$

l_{ψ} = distance from axis of rotation for yawing to center of tank/mass (m), and the axis of rotation may be taken as stipulated in (iii).

(vi) Combined accelerations

① Combined vertical acceleration

$$a_v = \sqrt{a_z^2 + a_{\phi z}^2 + a_{\theta z}^2} \quad (\text{m/sec}^2)$$

a_z = as specified in (i)

$a_{\phi z}$ = vertical component of roll acceleration given by the following formula

$$a_{\phi z} = \phi \left(\frac{2\pi}{T_{\phi}}\right)^2 l_{\phi y} \quad (\text{m/sec}^2)$$

ϕ and T_{ϕ} = as specified in (iv)

$l_{\phi y}$ = transverse distance from axis of rotation for rolling to center of tank/mass (m), and the axis of rotation may be taken as stipulated in (iii).

$a_{\theta z}$ = vertical component of pitch acceleration given by the following formula

$$a_{\theta z} = \theta \left(\frac{2\pi}{T_{\theta}}\right)^2 l_{\theta x} \quad (\text{m/sec}^2)$$

θ and T_{θ} = as specified in (iii)

$l_{\theta x}$ = longitudinal distance from axis of rotation for pitching to center of tank/mass (m), and the axis of rotation may be taken as stipulated in (iii).

② Combined horizontal acceleration

$$a_t = \sqrt{a_y^2 + a_{\phi y}^2 + a_{\psi y}^2} \quad (\text{m/sec}^2)$$

a_y = as specified in (ii)

$a_{\phi y}$ = horizontal component of roll acceleration given by the following formula

$$a_{\phi y} = \phi \left(\frac{2\pi}{T_{\phi}}\right)^2 l_{\phi z} \quad (\text{m/sec}^2)$$

ϕ and T_{ϕ} = as specified in (iv)

$l_{\phi z}$ = vertical distance from axis of rotation for rolling to center of tank/mass (m), and the axis of rotation may be taken as stipulated in (iii).

$a_{\psi y}$ = horizontal component of yaw acceleration given by the following formula

$$a_{\psi y} = \left(\frac{6.95}{L} - 0.017\right) l_{\psi x} \quad \text{(m/sec}^2\text{)}$$

$l_{\psi x}$ = longitudinal distance from axis of rotation for yawing to center of tank/mass (m), and the axis of rotation may be taken as stipulated in (iii).

(2) Stress calculation

(A) Nominal stress

(a) Nominal stress due to axial load

(i) The wave induced vertical hull girder bending stress range for the structural member is to be calculated as follows:

① For the structural member above the neutral axis:

$$\sigma_{nom,V} = \frac{M_w(+) - M_w(-)}{Z_D} \frac{z - z_{NA}}{D - z_{NA}} \times 10^3 \quad \text{(N/mm}^2\text{)}$$

② For the structural member below the neutral axis:

$$\sigma_{nom,V} = \frac{M_w(+) - M_w(-)}{Z_B} \frac{z_{NA} - z}{z_{NA}} \times 10^3 \quad \text{(N/mm}^2\text{)}$$

where,

Z_D = the section moduli at the strength deck about the horizontal neutral axis (cm^3)

Z_B = the section moduli at the bottom about the horizontal neutral axis (cm^3)

z = the vertical distances from the bottom to the structural member under consideration (m)

z_{NA} = the vertical distances from the bottom to the horizontal neutral axis (m)

(ii) The wave induced horizontal hull girder bending stress range for the structural member is calculated as follows:

$$\sigma_{nom,H} = \frac{2\,M_H}{Z_H} \frac{y}{B/2} \times 10^3 \quad \text{(N/mm}^2\text{)}$$

where,

Z_H = the section modulus at the ship's side about the ship's centerline (cm^3)

y = the horizontal distance from the ship's centerline to the structural member under consideration (m)

(iii) Hull girder wave bending stress range

The hull girder wave bending stress range is not to be less than that obtained from the following formula, whichever is the greater:

$$\sigma_{nom,g} = 0.5\,\sigma_{nom,V} + \sigma_{nom,H} \quad \text{(N/mm}^2\text{)}$$

$$\sigma_{nom,g} = \sigma_{nom,V} \quad (\text{N/mm}^2)$$

(b) Nominal stress due to lateral load
Nominal stress on the flange of a longitudinal, at the connection with a transverse web, can be analyzed by using a uniformly loaded beam with both ends fixed in consideration of the effective breadth of the shell plating. In addition, nominal stress is to account for the increased stress due to the asymmetrical section of the longitudinal. Then, the nominal stress on the flange of the longitudinal is defined as

$$\sigma_{nom,l} = \sqrt{\sigma_e^{\ 2} + \sigma_i^{\ 2} + 2\rho_c \sigma_e \sigma_i}$$

ρ_c = the correlation factor between the wave load and internal load, being taken as $\rho_c = -0.6$

σ_e = nominal stress due to external sea pressure load is determined according to the following formula.

$$\sigma_e = (1 + C_t)\frac{p_d S l^2}{12 Z_f} \times 10^3 \quad (\text{N/mm}^2)$$

σ_i = nominal stress due to liquid cargo or ballast water is determined according to the following formula.

$$\sigma_i = (1 + C_t)\frac{p_i S l^2}{12 Z_f} \times 10^3 \quad (\text{N/mm}^2)$$

p_d = wave pressure (N/mm^2) as specified in **Par 4** (1) (B) (b).

p_i = internal pressure load (kN/m^2) due to liquid cargo or ballast water as specified in **Par 4** (1) (C) (a).

S = spacing of longitudinal (m)

l = spacing of transverse web (m)

Z_f = section modulus of longitudinal (cm^3)

C_t = the stress increasing factor due to the asymmetrical section of a longitudinal is to be calculated as follows:

$$C_t = 1.68(0.38 + A_f/A_w)(e^2 + 0.28e)$$

$$e = \frac{b}{b_f}$$

A_f = flange area (cm^2)

A_w = web area (cm^2)

b = distance from the flange center to the web center (cm) (See **Fig 5**)

b_f = breadth of the flange (cm) (See **Fig 5**)

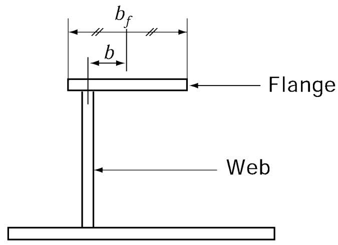


Fig 5 b **and** b_f

(c) Nominal stress due to relative deflection

(i) At the connection of a longitudinal to a transverse bulkhead, the additional bending stress, due to the relative deflection between the transverse bulkhead and the adjacent transverse web, is to be considered and defined as

$$\sigma_{nom,r} = \frac{6EI\delta}{Z_f l^2} \times 10^{-5} \quad (\text{N/mm}^2)$$

where,

δ = relative deflection between transverse bulkhead and transverse web (m)

I = moment of inertia of longitudinal (cm^4)

E = elastic modulus, 2.06×10^5 (N/mm^2) for steel.

Z_f = section modulus of longitudinal (cm^3)

l = spacing of transverse web (m)

The relative deflection between the transverse bulkhead and the transverse web can be determined by the three dimensional hold analysis. However, when the relative deflection is not known, the nominal stress due to the relative deflection is assumed to be 50% of the nominal stress due to the lateral load as follows:

$$\sigma_{nom,r} = 0.5\sigma_{nom,l}$$

Where the longitudinal is fitted with soft toe brackets on both sides of the transverse bulkhead, the additional bending stress due to the relative deflection may not be considered in the fatigue analysis.

(ii) In case of double side skin construction, nominal stress due to relative deflection may be calculated according to the Rule **Pt 12 Annex C 1.4.4.11.**

(B) Combined stress range

(a) The combined stress used to calculate the fatigue life of a ship structure is the hot spot stress, which is to be determined from multiplying the nominal stress in (A) above by stress concentration or FE analysis. The combined stress is to be complied with the following formulae as the combination of the stress component due to the local load, the hull girder bending load and the relative deflection.

$$\sigma_0 = f_E \times \max\begin{cases}\sigma_{hot,l} + \sigma_{hot,r} + 0.6\sigma_{hot,g} \\ 0.6(\sigma_{hot,l} + \sigma_{hot,r}) + \sigma_{hot,g}\end{cases}$$

where,

f_E : Reduction factor on derived combined stress range accounting for the long-term sailing routes of a ship, the following values may be used:

f_E = 1.0 for shuttle tankers and vessels that frequently operate in the North Atlantic or in other harsh environments

Elsewhere : f_E = 0.8

σ_0 = combined stress range is to be determined at the probability level of 10^{-4} (N/mm^2)

(b) The long-term distribution of the stress range may be represented by the two parameter Weibull distribution. The Weibull shape parameter depends on ship type, location of structural member, sea environment, etc. In this guidance, however, the Weibull shape parameter ξ for a longitudinal may be taken as

$$\xi = 1.1 - 0.35\frac{L-100}{300}$$

(c) The Weibull shape parameter of the combined stress range is assumed to be the same value as the local stress range.

(3) Calculation of fatigue damage ratio

(A) According to the Miner-Palmgren linear cumulative damage rule, the fatigue damage ratio D is calculated using numerical integration as follows:

$$D = \Sigma\frac{n_i}{N_i}$$

where,

n_i = number of stress cycles in stress block i for long-term distribution of the combined stress range

N_i = number of cycles to failure at the i-th constant stress range.

If the long-term distribution of the stress range follows a Weibull one, the damage ratio D_{air} is given by the following formula:

$$D_{air} = \frac{N_t}{c'}\frac{\sigma_0^{m'}}{(\ln N_0)^{m'/\xi}}\gamma(1+\frac{m'}{\xi},t_7) + \frac{N_t}{c}\frac{\sigma_0^{m}}{(\ln N_0)^{m/\xi}}\Gamma(1+\frac{m}{\xi}) - \frac{N_t}{c}\frac{\sigma_0^{m}}{(\ln N_0)^{m/\xi}}\gamma(1+\frac{m}{\xi},t_7)$$

where,

ξ = Weibull shape parameter

Γ = complete Gamma function given by the following formula

$$\Gamma(z) = \int_0^\infty t^{z-1}e^{-t}dt$$

γ = incomplete Gamma function given by the following formula.

$$\gamma(z,x) = \int_0^x t^{z-1}e^{-t}dt$$

c, c' and m, m' = as specified in **Table 2**

t_7 = as specified in the following formula

$$t_7 = \left(\frac{\sigma_7}{\sigma_0}\right)^{\xi} \ln N_0$$

σ_7 = stress range of the design S-N curve at $N = 10^7$ cycles

N_t = the total number of stress cycles for a design life of ships and considering voyage days of 85% for the design life of Y(years), the total number of stress cycles is given by the following formula.

$$N_t = \frac{2.68 \times 10^7}{4 \log L} \times Y$$

(B) For unprotected joints exposed to sea water, the damage ratio D_{cor} is given by

$$D_{cor} = \frac{N_t}{c_1} \frac{\sigma_0^m}{(\ln N_0)^{m/\xi}} \Gamma(1 + \frac{m}{\xi})$$

However, for the structural members protected by effective means in ballast tanks, the damage ratio D is to be calculated as follows:

$$D = 0.5 D_{air} + 0.5 D_{cor}$$

(C) In case of considering the full loaded condition and the ballast condition as the load condition, the relevant draft is to be applied in the calculation of the local wave pressure range and the fatigue damage ratio at each condition (D_{Full} and $D_{Ballast}$) is to be calculated. Therefore, the formula for calculating the total fatigue damage can be expressed as follow:

$$D = p_{lF} D_{Full} + p_{lB} D_{Ballast}$$

p_{lF} and p_{lB} = probability at the full loaded condition and the ballast condition, where, however, the values are not given, 0.6 and 0.4 may be used respectively

(4) Locations of member subjected to fatigue strength assessment
Structural members for which the fatigue strength assessment is to be required in accordance with the simplified fatigue analysis are longitudinals and locations of the members are given in **Table 3.**

Table 3 Locations to be assessed for fatigue analysis

	Locations
1	Intersection of bottom or inner bottom longitudinals and floor or transverse bulkhead
2	Intersection of side shell or inner skin bulkhead longitudinals and transverse or transverse bulkhead
3	Intersection of deck longitudinals and transverse or transverse bulkhead

5. Spectral fatigue analysis

(1) General

For assessment of the spectral fatigue analysis, the Short-term closed-form method is to be applied in this Guidance. The part fatigue damage from each cell in the wave scatter diagram can be calculated using the closed-form expressions by incorporating a S-N curve and the Miner-Palmgren rule. The fatigue damage for a life time of a ship is a sum of all the part fatigue damage considering.

(2) Short-term response

(A) Since the wave is assumed to be stationary in a short-term sea state, its statistical properties are specified by the wave spectrum. The wave spectrum for the different sea states can be given by the following Pierson-Moskowitz wave spectrum.

$$S_\eta(\omega|H_s,T_z) = \frac{H_s^2}{4\pi}\left(\frac{2\pi}{T_z}\right)^4\omega^{-5}\exp\left[-\frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4\omega^{-4}\right]$$

where,

ω = wave frequency (rad/sec)

H_s = significant wave height

T_z = wave period

(B) Using the stress transfer function $H(\omega|\theta)$, the response spectrum of the ship can be calculated as follows.

$$S(\omega|H_s,T_z,\theta) = |H(\omega|\theta)|^2 S_\eta(\omega|H_s,T_z)$$

where

θ = wave heading angle

$H(\omega|\theta)$ = stress response to a regular wave with unit amplitude for different frequencies and wave heading angles

(C) The area under the response spectrum and the second moment of the response spectrum can be calculated as follows.

$$m_0 = \int_0^\infty \sum_{\theta-90}^{\theta+90}\left(\frac{2}{\pi}\right)\cos^2\theta\, S(\omega|H_s,T_z,\theta)\,d_\omega$$

$$m_2 = \int_0^\infty \sum_{\theta-90}^{\theta+90}\left(\frac{2}{\pi}\right)\cos^2\theta\,\omega^2 S(\omega|H_s,T_z,\theta)\,d_\omega$$

(3) Short-term fatigue damage

(A) Referring to the cell (i,j) in the wave scatter diagram associated with a significant wave height H_{si} and a zero up-crossing wave period T_{zj}, if the stress range distribution is represented by a probability density function g_{ij}, the number of stress cycles within s and $s+ds$ is obtained from the following formulae.

$$n_{ij} = T\, f_{ij}\, p_{ij}\, g_{ij}\, ds$$

T = design life of a ship

p_{ij} = probability of occurrence of H_{si} and T_{zj}

f_{ij} = Zero up-crossing frequency of stress response in the sea state.

$$f_{ij} = \frac{1}{2\pi}\sqrt{\frac{m_{2ij}}{m_{0ij}}}$$

m_{0ij}, m_{2ij} = area under the response spectrum and the second moment of the response spectrum as specified in (2) (C) above

g_{ij} = probability density function as specified in (B)

(B) The part fatigue damage D_{ij} for a sea state (i,j) can be calculated from,

$$D_{ij} = \frac{n_T}{c}\, r_{ij}\, p_{ij} \int_0^\infty s^m\, g_{ij}\, ds$$

n_T = total stress cycles for a life time of a ship given by the following formula

$$n_T = fT$$

c, m = life intercepts and negative inverse slopes of the S-N curve as specified in **Table 2**, respectively

p_{ij} = as specified in (A) above

r_{ij} = ratio of the response zero up-crossing frequency in a given sea state to the average crossing frequency given by the following formula

$$r_{ij} = \frac{f_{ij}}{f}$$

f = average frequency given by the following formula

$$f = \sum_i \sum_j p_{ij} f_{ij}$$

g_{ij} = probability density function of the stress range for a sea state (i,j) expressed as follows

$$g_{ij} = \frac{s}{4m_{0ij}} \exp\left(-\frac{s^2}{8m_{0ij}}\right)$$

m_{0ij}, m_{2ij} = as specified in (A) above

where a bi-linear S-N curve is used to consider Haibach effect, the short-term fatigue damage ratio may be calculated from,

$$D_{ij} = 2^{\frac{3m}{2}} \frac{n_T}{c}\, \Gamma\left(\frac{m}{2}+1\right) \lambda_{ij}\, \mu_{ij}\, r_{ij}\, p_{ij}\, m_{0ij}^{\frac{m}{2}}$$

where,

μ_{ij} = as specified in the following formula

$$\mu_{ij} = 1 - \frac{\gamma\left(\frac{m}{2}+1,\, t_{ij}\right) - t_{ij}^{\frac{m-m'}{2}}\,\gamma\left(\frac{m'}{2}+1,\, t_{ij}\right)}{\Gamma\left(\frac{m}{2}+1\right)}$$

$m, m', c, n_T, r_{ij}, p_{ij}, m_{0ij}$ = as specified in (B)

$$t_{ij} = \frac{s_7^2}{8\,m_{0ij}}$$

s_7 = the stress range of the design S-N curve at $N = 10^7$ cycles

Γ and γ = complete Gamma function and incomplete Gamma function, respectively

λ_{ij} = Rain flow correction factor in a given sea state

$$\lambda_{ij} = a + (1-a)(1-\epsilon_{ij})^b$$

$$a = 0.926 - 0.033\,m$$
$$b = 1.587\,m - 2.323$$
$$\epsilon_{ij} = \sqrt{1 - \frac{m_{2ij}^2}{m_{0ij}\,m_{4ij}}}$$

(4) Long-term cumulative fatigue damage

(A) Taking account of all heading directions and loading conditions, the long-term cumulative fatigue damage ratio in air is calculated as follows.

$$D_{air} = 2^{\frac{3m}{2}}\,\frac{n_T}{c}\,\Gamma\left(\frac{m}{2}+1\right)\sum_i\sum_j\sum_k\sum_l \lambda_{ijkl}\,\mu_{ijkl}\,r_{ijkl}\,p_{ijkl}\,m_{0ijkl}^{\frac{m}{2}}$$

p_{ijkl} = combined probability given by the following formula

$$p_{ijkl} = p_{ij}\,p_k\,p_l$$

p_k, p_l = probability for the heading angle and the loading condition, respectively

(B) For unprotected joints exposed to sea water, the damage ratio D_{cor} is given by

$$D_{cor} = 2^{\frac{3m}{2}}\,\frac{n_T}{c_1}\,\Gamma\left(\frac{m}{2}+1\right)\sum_i\sum_j\sum_k\sum_l \lambda_{ijkl}\,\gamma_{ijkl}\,p_{ijkl}\,m_{0ijkl}^{\frac{m}{2}}$$

However, for the structural members protected by effective means in ballast tanks, the damage ratio D is to be calculated as follows:

$$D = 0.5\,D_{air} + 0.5\,D_{cor}$$

(5) Structural members to be assessed for fatigue strength

(A) General

(a) Structural members subject to fatigue strength assessments are selected considering the structural system of the ship, and the importance, functions, etc of the members.

(b) Structural members in which fatigue cracks are likely to initiate because of stress concentration due to structural discontinuities, and structural members at locations where watertightness problems are likely to occur due to cracks in the compartments, are selected for the fatigue assessment on priority.

(B) Structural members subject to the fatigue strength assessment according to ship type

(a) Structural members being of possible assessment for the fatigue strength according to ship type

(i) Tankers : as specified in **Table 4, Fig 6** and **Fig 7**

(ii) Bulk carriers : as specified in **Table 5** and **Fig 8**

(iii) Container carriers : as specified in **Table 6**

(b) Locations with high stresses are selected from the locations mentioned in (a) above and the fatigue strength is assessed.

Table 4 Structural members of tankers for fatigue strength assessment

Symbol	Members	Locations
a	Inner bottom plating, slant plating	Intersection of double bottom floor and bilge hopper slant plating
b	Side longitudinal bulkhead plating, slant plating	Intersection of side longitudinal bulkhead and bilge hopper slant plating
c	Inner bottom plating, longitudinal bulkhead	Intersection of double bottom floor and transverse on longitudinal bulkhead
d	Side longitudinal bulkhead plating, Longitudinal bulkhead plating	Intersection of deck transverse and side longitudinal bulkhead
		Intersection of deck transverse and longitudinal bulkhead
e	Side longitudinal bulkhead plating	Intersection of cross tie and side longitudinal bulkhead
f	Side longitudinal bulkhead plating, Longitudinal bulkhead plating	Intersection of horizontal girder and side longitudinal bulkhead
		Intersection of horizontal girder and longitudinal bulkhead
g	Side longitudinal bulkhead plating, Longitudinal bulkhead plating	Intersection of swash bulkhead and side longitudinal bulkhead
		Intersection of swash bulkhead and longitudinal bulkhead

Table 5 Structural members of bulk carriers for the fatigue strength assessment

Members	Locations
Inner bottom plating	Intersection of sloping plate of lower stool, girder, floor plate and inner bottom plating
	Intersection of sloping plate of bilge hopper tanks, girder, floor plate and inner bottom plating
Sloping plate of bilge hopper tanks	Intersection of lower end of hold frame and sloping plate of bilge hopper tank
	Intersection of inner bottom plating and sloping plate of bilge hopper tanks
Transverse bulkhead	Intersection of sloping plate of lower stool and transverse bulkhead
	Intersection of sloping plate of upper stool and upper part of transverse bulkhead
	Intersection of slant plating of topside tanks and upper part of transverse bulkhead
Sloping plate of topside tanks	Intersection of upper end of hold frame and sloping plate of topside tanks
	Intersection of end of hatch coaming and sloping plate of topside tanks
Sloping plate of lower stool	Intersection of inner bottom plate and sloping plate of lower stool

Table 6 Structural members of container carriers for the fatigue strength assessment

Members	Locations
Hatch	Typical hatch coaming and corner in the midship
	After hatch coaming and corner in the after cargo hold (in front of engine room forward bulkhead)
	Hatch coaming and corner within the forward part of the cargo area

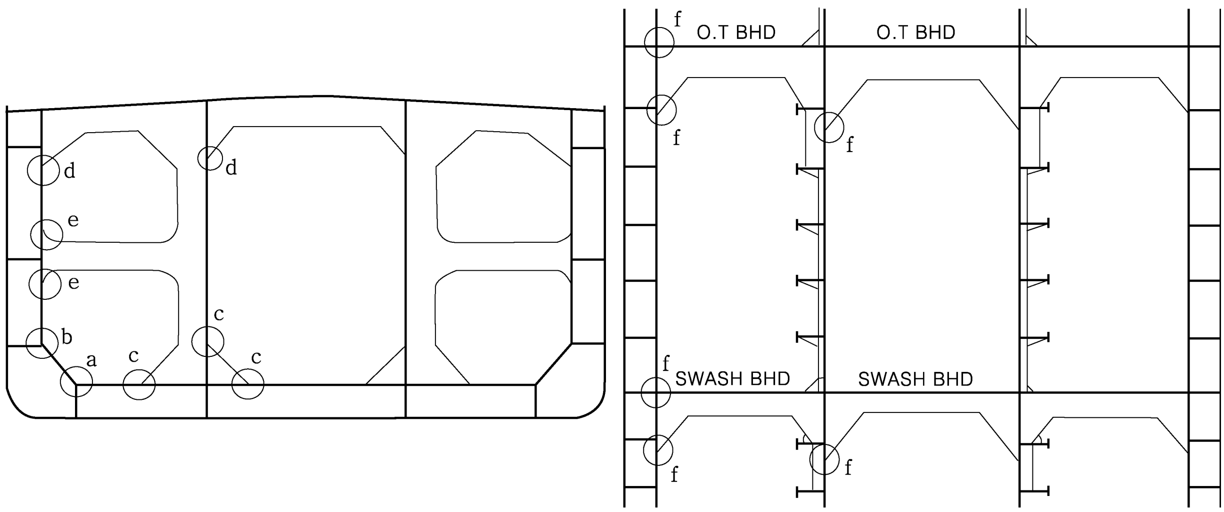


Fig 6 Locations for the fatigue strength assessment(Tankers)

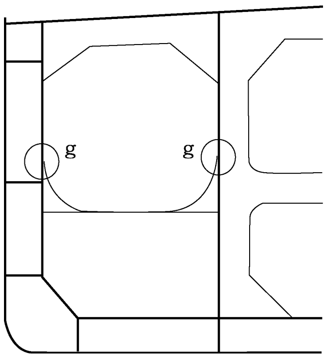


Fig 7 Locations for the fatigue strength assessment(Tankers)

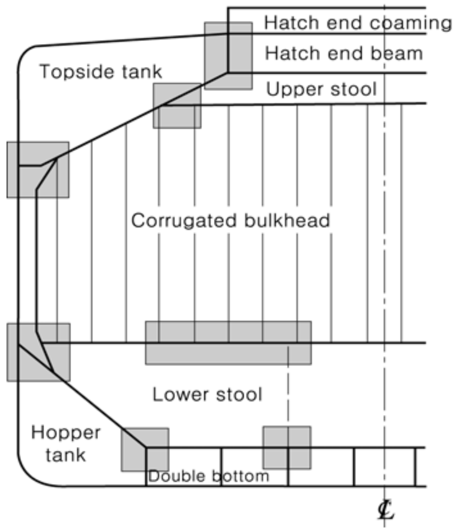


Fig 8 Locations for the fatigue strength assessment(Bulk carriers)

6. Transfer function method

(1) General

In order to perform the spectral fatigue assessment, structural analyses for all wave loads calculated for all heading directions and frequencies have to be carried out to obtain stress transfer functions. However, in the transfer function method, a discrete unit load approach is used. The loads acting on the hull are divided into several load components. The transfer functions for the each load component are determined using a seakeeping software for each wave condition and the influence coefficients for structure are computed by finite element analysis for each unit load. The non-linear effect of the wave induced load at the waterline region can also be considered in the transfer function method.

(2) Stress transfer function

The stress transfer function may be obtained by multiplying the load transfer function by the stress influence coefficient which means the stress value due to the unit load. The combined stress transfer function is to be obtained by a linear summation of each stress transfer function as follows:

$$H(\omega,\theta) = 2\left[\sum_{i=1}^{3} A_i F_i(\omega,\theta) + \alpha \sum_{i=1}^{n_{st}} \sum_{ji=1}^{6} B_{ij} P_{ij}(\omega,\theta) + \sum_{i=1}^{n_{st}} \sum_{ji=1}^{2} C_{ij} W_{ij}(\omega,\theta)\right]$$

(A) Hull girder load

A_i = stress influence coefficient due to unit hull girder load

A_1 = stress influence coefficient due to unit vertical bending moment

A_2 = stress influence coefficient due to unit horizontal bending moment

A_3 = stress influence coefficient due to unit torsional moment

$F_i(\omega,\theta)$ = transfer function of hull girder load

$F_1(\omega,\theta)$ = transfer function of vertical bending moment

$F_2(\omega,\theta)$ = transfer function of horizontal bending moment

$F_3(\omega,\theta)$ = transfer function of torsional moment

(B) Wave pressure

$P_{ij}(\omega,\theta)$: transfer function for pressure coefficient of 5th order power function, P_j, at the i-th station of a ship is given by the following formula.

$$P(b) \cong \sum_{j=1}^{6} P_j \, bj^{j-1}$$

$P(b)$ = external pressure distribution with the girth-wise coordinate

b = girth-wise coordinate, $b = 0$ at keel

P_j = coefficient of the power function is to be determined by the regression analysis for the calculated hydrodynamic pressures at the i-th station of a ship

B_{ij} = stress influence coefficient due to the j-th unit pressure distribution at the i-th station of a ship and the j-th unit pressure distribution is as follows:

$j = 1$ for uniform pressure (1)
$j = 2$ for linear distributed pressure(b)
$j = 3$ for quadratic distributed pressure(b^2)
$j = 4$ for cubic distributed pressure(b^3)
$j = 5$ for forth order distributed pressure(b^4)
$j = 6$ for fifth order distributed pressure(b^5)

(C) Cargo load

C_{ij} = stress influence coefficient due to unit inertia force at the i-th station of a ship

C_{i1} = stress influence coefficient due to unit vertical inertia force at the i-th station of a ship

C_{i2} = stress influence coefficient due to unit horizontal inertia force at the i-th station of a ship

$W_{ij}(\omega,\theta)$ = transfer function due to the inertia force of cargo weight at the i-th station of a ship

$W_{i1}(\omega,\theta)$ = transfer function due to vertical inertia force at the i-th station of a ship

$W_{i2}(\omega,\theta)$ = transfer function due to horizontal inertia force at the i-th station of a ship

(D) In order to consider the non-linear effect of the stress range in the waterline region, the reduction factor, α, is to be used as follows:

$\alpha = 0.5\left(1 - \frac{h}{a_w}\right)$: above the waterline

$\alpha = 0.5$: at the waterline

$\alpha = 1.0$: below a_w

h and a_w = as specified in **Par 4** (1) (B) (a)

For intermediate location between the waterline and a_w, α is to be obtained by interpolation

(3) Using stress transfer function obtained from (2) above, the short-term response spectrum is to be calculated according to **Par 5** (2). The short-term fatigue damage ratio and the long-term cumulative fatigue damage ratio are to be obtained according to **Par 5** (3) and (4), respectively. ⚓

Annex 3-4 Guidance for the Hull Construction Monitoring Procedure

1. General

(1) Introduction

(A) The general quality of a vessel is enhanced by superior structural design, improved construction procedures and effective through life monitoring. In structural terms, the performance of structural elements or connections between members is dependent on the adoption of adequate quality control measures relating to both the quality of detail design and the construction. The detail design, the methods of manufacture and the degree of quality control significantly affect the fatigue performance of a structure. This is particularly evident at locations within the structure identified as 'critical'.

(B) Misalignment, inappropriate edge preparation, excessive gap, weld sequence and weld quality alters the fatigue properties of these joints. Setting appropriate controls on the key factors affecting fatigue performance at the design stage and utilising enhanced monitoring procedures at critical locations ensures that a high degree of workmanship is achieved and avoids unnecessary remedial action in the later stages of the build process.

(C) The links to Direct Strength Assessment (DSA) and Direct Fatigue Assessment (DFA) within the Hull Construction Monitoring (HCM) procedure ensure that a seamless transition of quality monitoring is achieved throughout the life of the vessel.

(D) The SeaTrust HCM procedure forms an element of an integrated approach to the design, construction and monitoring of the critical areas of ship structures. The application of the HCM procedure enhances not only the confidence of the Owner and this Society in the hul1 construction but also quality control procedures employed by the Shipyard at the structurally critical locations.

(2) Objective

(A) The main objective of the SeaTrust HCM procedure is to ensure that the locations within the ship structure, that have been identified as critical, are built to both an acceptable quality standard and approved construction procedures.

(B) The HCM procedure is applied in addition to the requirements for vessels built under special survey, and is based on the application of enhanced controls on alignment, fit-up, edge preparation and workmanship to the critical areas of the relevant hul1 structures to attain the required structural performance.

(C) A secondary objective is that during the service life of the vessel, the Hull Construction Monitoring Plan(HCMP) is used to focus the attention of any future classification survey to the critical locations.

(3) Outline of the procedure

(A) The pre-construction meeting includes advice to the Builder's representatives and owners site manager on the specific application of the Hull Construction Monitoring procedure.

(B) At the plan development and approval stage, the application of the HCM procedure identifies the areas and locations within the ship structure that may experience high levels of stress or fatigue damage assessed on the basis of DSA and DFA results and procedures. The critical areas are those areas of the ship structure that have been shown by structural analysis and service experience to have a higher probability of failure than the surrounding ship structure. The critical locations are specific points identified within the critical areas that are prone to fatigue, and where detail design improvement may have to be undertaken. Particular emphasis is placed on those primary structural locations specified as having enhanced fatigue life specifications within the DFA procedures.

(C) In order to promote a satisfactory level of strength and fatigue performance, detailed construction tolerances are agreed between this Society and the Shipbuilder for each ship considered for the HCM notation in accordance with the Hull Construction Monitoring Standards. The HCMP is prepared by the builder as a catalogue of the critical locations together with the required construction tolerances and an outline of the quality control and quality assurance procedures to be applied. The completed HCMP is sent to this Society for review and subsequent approval.

(D) The Shipyard quality personnel are responsible for the inspection and recording of results during the construction of the ship in accordance with approved yard procedures and the requirements of this society. This site Surveyor provide third party inspection to confirm that the alignment, fit-up, workmanship and construction tolerances conform to the agreed standard specified in the HCMP. Where the approved construction tolerances are exceeded, the Shipbuilder undertakes corrective action to the satisfaction of the requirements of the HCMP.

(E) On satisfactory completion of the HCM requirements, this Society assigns the "**SeaTrust (HCM)**" notation. Upon completion of the ship, the site Surveyor sends a copy of the approved HCMP to head office.

(F) During the lifetime of the vessel, the HCMP is maintained on board and is used to focus periodical surveys on the critical locations in order to monitor the structural integrity and performance.

(G) The Construction Monitoring Procedure has been subdivided into three phases to be applied sequentially as shown in **Table 1** and **Fig 1.**

Table 1 Hull construction monitoring phases

Phase I	Plan approval	Analysis to determine the critical locations
Phase II	Survey during Construction	Survey to ensure satisfactory construction standards
Phase III	Lifetime application of HCMP	Monitor the structural integrity using the HCMP

(4) Scope of application

(A) In cases where the DSA and/or DFA procedures have been applied on a voluntary basis, the Construction Monitoring Procedure shall be applied.

(B) This procedure is applied to areas of the structure that have been identified as being critical locations through the application of the SeaTrust procedures for Direct Structural Assessment (DSA) and Direct Fatigue Assessment (DFA).

(C) The procedure is adopted in association with requirements of this Society for vessels constructed under Special Survey.

(D) Any subsequent modifications or repairs to the ship's structure are, where applicable, to be in accordance with this procedure.

(5) Classification notation

(A) Upon satisfactory application of this procedure, the vessels may be eligible to be assigned the Hull Construction Monitoring notation "**SeaTrust (HCM)**".

2. Hull Construction Monitoring Standard

(1) Hull Construction Monitoring Standard

(A) The Hull Construction Monitoring Standard (HCMS) sets down the Construction Monitoring tolerances to be achieved at the critical locations in order that the requirements for the HCM notation are met. The HCMS covers such aspects of construction such as:

. Alignment
. Fit-up
. Remedial Measures

(B) When identifying the critical locations, particular consideration should be given to critical locations identified by DSA or DFA that constitute a unit joint and critical joints assembled in areas where environmental controls are difficult to apply such as in the erection area or building dock.

(C) In all cases, the construction standards and tolerances not indicated in this standard are to be at least equivalent to the approved yard, national or international ship construction standards in use.

(D) The quality standards for the alignment, fit-up and repair of critical structural components during new construction are shown in **Table 2** to **Table 5.**

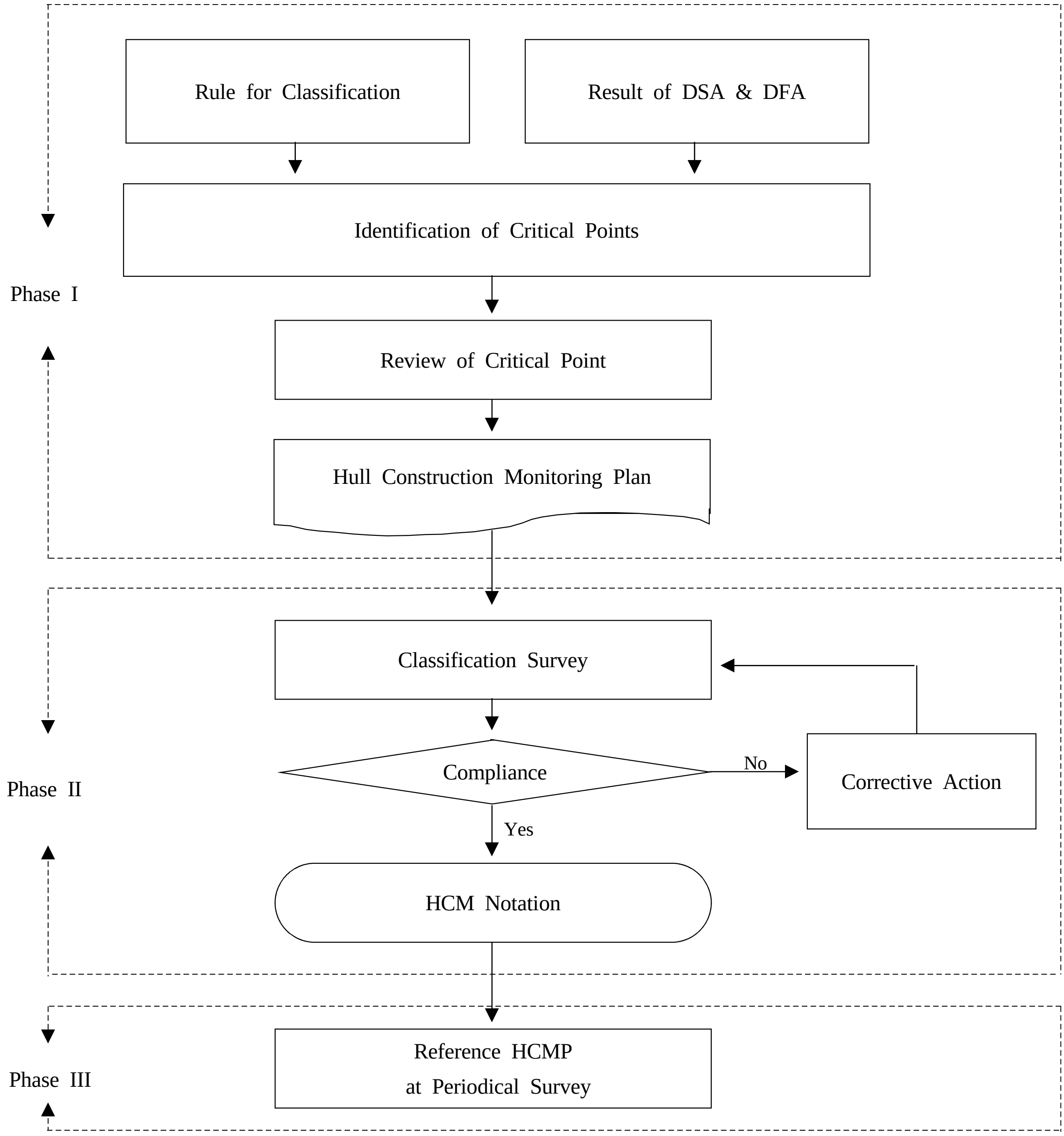


Fig 1 Hull construction monitoring procedure

(2) Scope of the Hull Construction Monitoring Standard

(A) The HCMS does not replace the shipbuilding construction standard employed by the shipyard and accepted by this society. It is a supplementary standard supported by a survey procedure to promote a higher level of structural performance throughout the life of the ship.

(B) The construction and manufacture of the structural details in way of the identified critical areas shall be carried out in accordance with the following:

. Rules and Regulations for the Classification of Ships.

. The approved construction tolerances contained within the Hull Construction Monitoring Plan.

. The associated non-destructive examination (NDE) requirements, if necessary, at the discretion of the attending Surveyor.

(3) Structural Alignment Considerations

(A) The consistent application of remedial measures to correct poor fit-up and alignment is one of the key indicators that a problem may exist in the construction procedures.

(B) Any inaccuracy in the welding of blocks into erection units will have an amplified effect at the erection stage. If adequate dimensional control has not been exercised it will be necessary to cut away edges to align the units being erected. This has the effect of causing further misalignments in adjacent units that will also require modification.

(C) The most critical types of welded structural connection are angled cruciform joints such as the sloping hopper plate connection with the inner bottom plating and the outer longitudinal girder of double hull tankers. At these locations, adequate dimensional control is a prerequisite to ensure good alignment.

(D) The application and maintenance of a suitable alignment method such as 100 mm offset lines is recommended to aid accurate fit up and alignment. For critical structural members it is recommended that any reference marks are indicated in a permanent manner, on both sides of the plate and the actual misalignment checked using jigs/templates, if necessary.

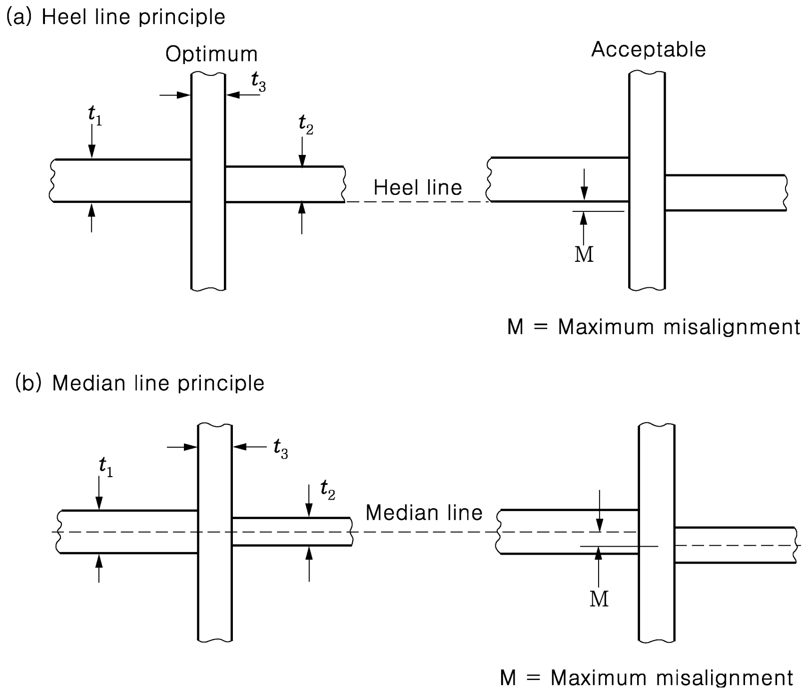


Fig 2 Recommended alignment of primary members

(E) In general, there are two types of alignment method in use ; the median line principle and the heel or moulded principle. These principles are outlined in **Fig 2.** While both alignment methods are generally acceptable, in cases where a more onerous trading pattern is specified or enhanced service life expectations are required, consideration should be given to the application of a suitable alignment method appropriate to the design criteria in order to achieve a preferable level of alignment. In addition to alignment considerations it may also be preferable to apply a more stringent tolerance beyond those detailed in this procedure. In order to eliminate difficulties associated with alignment, a prudent consideration by the shipyard would be to ensure, where practicable, that the thickness of all structural members is reasonably compatible within regions where critical locations are likely to be identified.

(F) In addition to the basic design criteria, certain joints may be identified as requiring an enhanced level of alignment through the application of service experience. The joints identified may depend upon the ship type and the structural configuration but in general the following joints may require additional consideration:
. Lower hopper knuckle on bulk carriers and oil tankers.
. Lower stool connection to floors in way of longitudinal girders in bulk carriers.
. Lower cofferdam bulkhead cruciform joint on membrane type gas carriers.

. Upper hopper knuckle on membrane type gas carriers.
. Aft end cargo area transition zone on membrane type gas carriers.
. Fore end cargo area transition zone on membrane type gas carriers.

(G) When verifying the alignment of structural members, it should be noted that it is often impractical to directly measure the median line alignment and a heel line approach is used in lieu of direct measurement of alignment at median lines. Where the heel line approach is used, the maximum median line tolerances maybe converted into heel line values using the equations given in **Fig 3.**

(H) In cases where two or more critical locations are connected by a secondary stiffening arrangement i.e. double bottom/inner bottom longitudinals, it may be considered prudent to ensure that the alignment is maintained.

(4) Construction considerations

(A) At the sub-assembly stage, a high degree of accuracy may be obtained using methods such as 'backmarking' prior to fit-up.

(B) It is generally found that a consistently higher degree of accuracy is achieved within the assembly shop where the conditions are controlled since blocks and pre-erection units are generally of a smaller size. This makes it easier to meet the specified construction tolerances during fit-up and alignment.

(C) If the critical connections are part of much larger erection joints in the building dock or berth it is much harder to control the alignment and fit-up of the interface and weld quality due to the size of the units and other external factors.

During all stages of construction, but particularly when fabrication and erection takes place external to the construction hall, measures are to be taken to screen and pre-warm, as necessary, the general and local weld areas. Surfaces are to be dry and rapid cooling of welded joints is to be prevented.

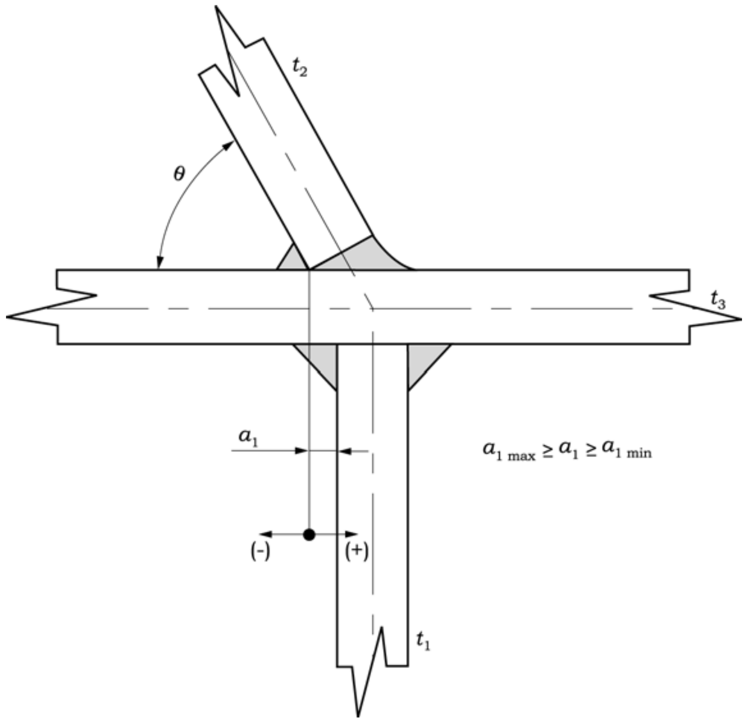
(5) Quality control and quality assurance

(A) The construction standards are to be received general approval as part of the certification procedures and their application is included with the quality plan submitted to this Society for approval.

(B) The construction standards and tolerances to be applied to the critical areas are to be agreed between this Society and the shipbuilder.

(C) In all cases the applied tolerances and standards are not to be less than those specified in the IACS "Shipbuilding and Repair Quality Standard".

(D) Any deviation from the approved structural configuration and/or approved procedures is to be submitted to this Society for consideration.



$$a_{1max} = \frac{1}{2}\left(\frac{t_2}{\sin\theta} + \frac{t_3}{\tan\theta} - t_1\right) + M \qquad M = \frac{t_{min}}{3}(\max\ 5mm)$$

$$a_{1min} = \frac{1}{2}\left(\frac{t_2}{\sin\theta} + \frac{t_3}{\tan\theta} - t_1\right) - M \qquad t_{min} = \min[t_1, t_2, t_3]$$

a_{1max} = max heel line tolerance measured in the direction of the acute angle
a_{1min} = max heel line tolerance measured in the direction of the abuse angle
θ = angle of sloping plate to the horizontal
t_1 = thickness of girder or transverse member
t_2 = thickness of sloping plate
t_3 = thickness of table member

Comparison of equivalent tolerances

t_1	t_2	t_3	θ	a_{1max}	a_{1min}	Med. Line
12	22	20	60	16.5	8.5	4
12	26	20	60	18.8	10.8	4
14	22	20	45	23.2	13.9	4.7
14	26	20	45	26.0	16.7	4.7

Fig 3 Equivalent heel line tolerances

3. Phase 1 – Plan Development and Approval

(1) Objectives

(A) The first objective of this stage is to identify the critical locations as defined in l.2.3 of this document.

(B) The second objective is to compile the HCMP prior to submission to this Society for approval.

(2) Identification of the critical locations

(A) Experience with ships in service has enabled this Society to provide information to assist the Shipbuilder in determining the critical locations that may be vulnerable to fatigue. Particular emphasis is placed on are as where high stress magnitudes may be anticipated and for which correct alignment is important.

(B) The critical locations are to be clearly identified and labelled on the appropriate structural drawings contained within the HCMP and submitted to this Society for approval.

(3) Hull construction monitoring plan

(A) The hull construction monitoring plan (HCMP) is a document compiled by the shipyard to provide a record of the enhanced quality standards and procedures employed by the Shipbuilder to ensure that an increased level of construction quality control is employed at those areas of the structure that have been identified as critical to the vessel.

(B) The HCMP is submitted to Head Office of this Society for formal approval as soon as possible prior to steel cutting. The HCMP is reviewed by both this society's site Surveyor and Plan Approval Surveyor in order that the findings of practical construction, structural analysis and fatigue analysis are uniquely reflected in the plan. Once approval is given, this society's site Surveyors maintain efficient contact between all interested parties to ensure that the requirements of the HCMP are fully understood and are complied with.

(C) The HCMP is supplemental to and does not replace the Quality Plan provided by the Shipbuilder.

(D) On receipt of the approved HCMP, the Shipbuilder, in association with this Society's Surveyor, ensures that all of the requirements contained within the HCMP are met in addition to any shipbuilding standards used.

(E) A typical HCMP is to contain the following information:

. Appropriate structural plans with the critical locations clearly marked.
. Details of appropriate construction tolerances including any 'design offset' at the critical locations are to be included on the appropriate structural plans for approval.
. Summary table of all critical locations indicating tolerances applied.
. Alignment verification methods used, i.e. Offset marking.
. Outline of quality controls in place during block construction, pre-erection and erection.
. Outline of Q.A procedures used.
. Methods for recording and reporting of inspection results.
. Details of standard remedial measures to be employed where required.
. Non destructive testing plan

(F) A copy of the approved HCMP is maintained on board either in electronic or hard copy format through-out the life of the vessel. The HCMP is to be used to focus survey on those areas of the structure identified during the design process as being critical to the operational effectiveness of the vessel.

4. Phase 2 - Construction Monitoring

(1) Fabrication and pre-erection

(A) The attending Surveyor and the Shipbuilder's quality control personnel agree a satisfactory inspection routine that embodies both the Shipbuilders Quality Control and the Construction Monitoring requirements. The Owner's Representatives shall be notified of the agreed inspection routine.

(B) Measures are, in general, to be taken to screen and pre-warm, as necessary, the general and local weld areas. Surfaces are to be dry and rapid cooling of welded joints is to be prevented. For any given welding method, the welding procedures are to be approved by this society. In addition, the Shipbuilder ensures that all welding operators employed on that process are qualified as approved by this society.

(C) The fabrication plans and other appropriate specifications, procedures and work instructions necessary for each phase of the fabrication process are to be made available at the appropriate inspection locations. The Shipbuilder maintains the inspection status of the critical structural components at appropriate stages in the fabrication process. This may include the direct marking of individual components. The marking method used is to be discussed and agreed with the attending Surveyor.

(D) Prior to the welding of critical joints, the Shipbuilder liaises with the attending Surveyor with respect to arranging appropriate 'fit-up' inspection, if necessary. Records of inspection and measurements are to be easily referenced against the relevant structural components and be accessible to this society.

(E) The workmanship employed throughout the stages of material preparation and assembly of pre-fabricated units is to conform to the relevant standards defined in the HCMP. Faulty workmanship or non-compliance with the specified tolerances noted by the Surveyor is to be rectified to the Surveyors satisfaction before progressing to the next stage of production.

(2) Assembly of units

(A) The assembly welding sequences, in general, are to be agreed prior to construction and to the satisfaction of the attending Surveyor. At each stage of assembly, particular attention is to be paid to ensure that the fit-up, alignment and welding of units is in accordance with the approved plans and to the approved HCM tolerances.

(B) Where a critical connection is also an erection joint, the attending Surveyor is to liaise with the Shipyard to provide adequate inspection to ensure that the required construction tolerances are achieved. During unit erection it is common for plates to be released and material cropped to allow acceptable fit-up and alignment. This process often results in damage to the surrounding plating detrimental to the strength of the structure. It is recommended that where such practices have been employed, full penetration welding is specified for the re-welding of the structure. Where insert plates have been used, it is recommended that these plates are left loose until such time that acceptable fit-up and alignment has been achieved.

(3) Inspection of welds

(A) Regular examination of the NDE records, in conjunction with the Shipbuilder, verifies that the quality of welding operations is satisfactory. Any departure from acceptable standards is to be investigated, including additional tests as considered desirable.

(B) Finished welds are to undergo a visual inspection by the attending Surveyor. The Shipbuilder shall ensure that all welds presented for visual inspection are clean, having all rust and weld slag removed and be free of coatings that may impair the inspection. The inspection is to verify that all welds are sound, free from cracks, undercut, notches, substantially free from lack of fusion, incomplete penetration, slag inclusion and porosity. The surface of all finished welds shall be inspected to ensure that they are reasonably smooth, substantially free of overlap and undercut. Fillet welds are to be inspected to ensure that they are continuous around scallops, brackets, stiffeners, etc. thus avoiding craters and incipient cracks at points of stress concentration.

(C) Weld sizes shall be inspected to ensure they are consistent over their entire length and are of the correct dimensions. Finished weld profile characteristics can have a marked effect upon joint fatigue. The approved dimensional requirements are to be verified using a suitable gauge and shall meet the criteria specified in the HCM Standard.

(D) In addition to visual inspection, the critical locations are to be subjected to the NDE requirements. Welds may be examined using approved methods such as Ultrasonic, Magnetic Particle, Radiographic, Eddy Current, Dye Penetrant or other acceptable methods appropriate to the configuration of the weld.

(E) The Shipyard production personnel involved in the fabrication joints to undergo NDE are not to be informed of the exact locations of the NDE prior to welding. Similarly, the proposed location of NDE is not to be marked or indicated on the plates prior to welding.

(F) The quality of a finished weld often varies with the method used due to factors such as heat input and the process itself. When specifying an NDE procedure, full consideration is to be given to the weld process employed to ensure that the method of NDE is suitable for the type of weld under consideration.

(G) Where defects are observed, additional NDE is to be carried out to determine the full extent. Unacceptable weld defects detected by NDE inspection are to be repaired or completely removed and re-welded as appropriate using approved procedures and consumables.

(H) Prior to any repair or re-welding at critical locations, the joint is to be inspected by the attending Surveyor to ensure that the alignment and gap comply with the specified tolerances.

(I) In critical areas where repairs and rewelds have been undertaken, the Surveyor is to ensure that excessive welding leading to distortion, stress concentration has not taken place. Re-inspection using the appropriate method of NDE shall be carried out until no further defects are discovered.

(J) The Surveyor may request additional or random NDE inspections where it is considered necessary.

(K) Only where absolutely necessary should methods for fatigue strength improvement be considered at the fabrication stage and then only as remedial measures. In these cases, strict quality control procedures are to be applied.

(4) Departure from the approved arrangements

(A) Modifications or alterations to the design or construction of a particular structural arrangement or detail in way of an identified critical area are to be approved by this society.

(B) In this case, the Shipbuilder is to re-submit to this society, the appropriate plans indicating all of the required changes. Reassessment of the structure may be a requirement along with the submission of a revised HCMP. Any reassessment carried out by this Society with regard to post-approval modifications or alterations may be chargeable to the Shipbuilder.

5. Construction Monitoring Compliance

(1) Compliance

(A) The attending Surveyor shall ensure that during the various stages of the construction process, all structure in way of fatigue critical locations has been examined in accordance with the inspection plan.

(B) The attending Surveyor is to ensure that, where applicable, all of the requirements of the HCMP have been met in addition to any rules and standards applied.

(C) On satisfactory completion of all inspections, the Surveyor shall confirm that the structure complies with the approved HCM tolerances and assign the appropriate notation "SeaTrust (HCM)".

(2) Non-Compliance

(A) Throughout the various stages of construction, the attending Surveyor shall inform the Shipbuilder immediately, upon completion of an inspection, of any defined critical joint or location that does not comply with the approved HCMP.

(B) Where the Shipbuilder is to utilize remedial measures or corrective action not stated in the HCMP, an agreement should be reached on an approved remedial plan to ensure that compliance is reached through discussions between this Society and the Shipbuilder. The proposal shall contain details of any modifications to the structural arrangement, scantlings, welding processes to be employed and NDE to be performed.

(C) Through discussions between this Society and the Shipbuilder an agreement shall be reached on an approved remedial plan. Repairs, re-work and inspection shall be carried out in accordance with the approved remedial plan until compliance is granted.

6. Phase 3 - Lifetime Application

(1) Through life monitoring

(A) The Surveyor attending future classification surveys shall identify, from the HCMP, those structural locations that will require special consideration and extended examination during survey.

(B) The nature of the critical locations requires that the Surveyor pay particular attention to defects such as corrosion, local damage, evidence of cracking, and local coating breakdown.

(C) All repairs undertaken at the critical locations identified in the HCMP are to be undertaken in accordance with these procedures.

(2) Structural alterations

(A) In cases where a vessel has undergone significant structural alteration, any locations subsequently identified as being critical to the structural integrity are to be constructed to the tolerances specified in the original HCMP. A revised HCMP is to be produced as early as practicable in the design process in accordance with these procedures and submitted for approval.

(B) Joints not previously identified but subsequently found to be critical are to be examined in detail to ensure that no construction irregularities such as severe misalignment and weld imperfections exist.

Table 2 Principle alignment

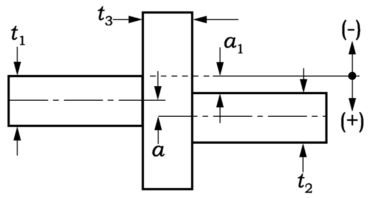
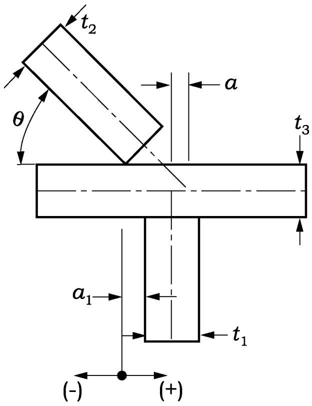
Detail	Heel	Median
	$a_{1max} \geq a_1 \geq a_{1min}$ where, $a_{1max} = \frac{1}{2}(t_1 - t_2) + M$ $a_{1min} = \frac{1}{2}(t_1 - t_2) - M$	$a \leq M$
	Median line tolerances may be converted to an equivalent heel line tolerance using the equations given below. $a_{1max} \geq a_1 \geq a_{1min}$ where, $a_{1max} = \frac{1}{2}\left(\frac{t_2}{\sin\theta} + \frac{t_3}{\tan\theta} - t_1\right) + M$ $a_{1min} = \frac{1}{2}\left(\frac{t_2}{\sin\theta} + \frac{t_3}{\tan\theta} - t_1\right) - M$	
$M = \frac{t_{min}}{3}$ (max 5 mm) where, t_{min} = min (t_1, t_2, t_3)		

Table 3 Fit-up of tee fillet welds

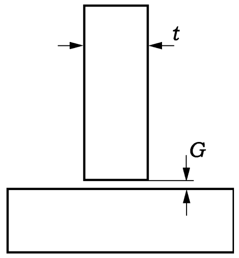
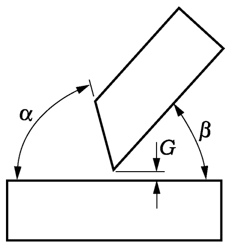
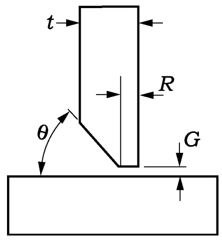
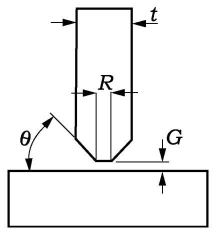
Detail	HCM Standard	Remark
	$G \le 2$ mm	
	α = 45°- 60° β = 70°- 90° $G \le 2$ mm	
	$G \le 2$ mm $R \le 3$ mm θ = 50°	
	$t > 19$ mm $G \le 3$ mm $R \le 3$ mm θ = 50°	

Table 4 Misalignment repair

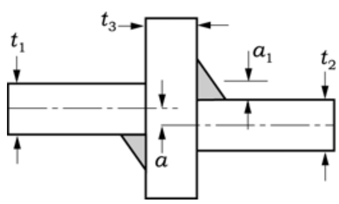
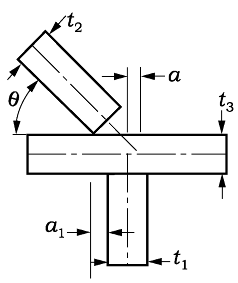
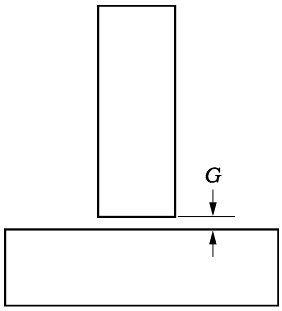
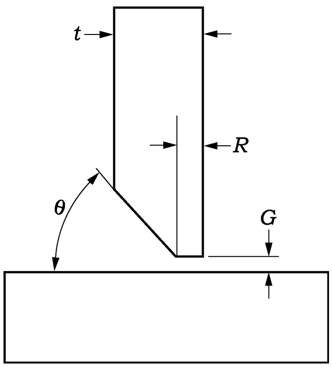
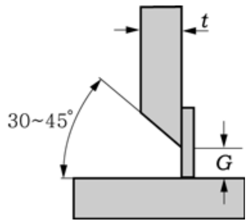
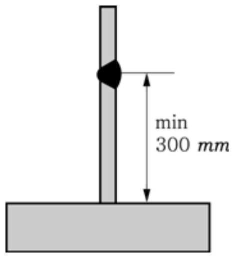
Detail	Heel	Median
	$a_{1max} + 0.5M \ge a_1 \ge a_{1max}$ or $a_{1min} > a_1 \ge a_{1min} - 0.5M$ Increase weld leg by 15 %	$t_{min}/3 < a \le t_{min}/2$ Increase weld leg by 15 %
	$a_1 \ge a_{1max} + 0.5M$ or $a_1 \ge a_{1min} - 0.5M$ Release and refit over a minimum $50a$ where $M = \frac{t_{min}}{3}$ (max 5 mm) $t_{min} = \min(t_1, t_2, t_3)$	$a > t_{min}/2$ Release and refit over a minimum $50a$

Table 5 Fillet weld fit-up repair

<table>
<tr><th>Detail</th><th>Repair Standard</th><th>Note</th></tr>
<tr>
<td rowspan="3">


</td>
<td>$2\text{ mm} < G \le 5\text{ mm}$:
length of weld to Rule leg by $+(G-2)$</td>
<td rowspan="3">For cruciform joints :

1) $3\text{ mm} < G \le 6\text{ mm}$
The weld should be full penetration and subject to additional ultrasonic NDE using both 45° and 70° probes, to the satisfaction of the surveyor.

2) $G > 6\text{ mm}$
The joint is to be adjusted until compliance is reached or an insert plate is to be fitted to the satisfaction of the surveyor.</td>
</tr>
<tr>
<td>$5\text{ mm} < G \le 16\text{ mm}$:
champer to 30°- 45°, build up with welding on one side, with or without backing bar, remove backing strip if used, back gouge and seal with weld.

</td>
</tr>
<tr>
<td>$G \le 16\text{ mm}$ or
$G > 1.5t$
Insert plate of min width 300 mm to be used

</td>
</tr>
</table>

ANNEX 3-5 Load cases for propeller and the shape of the propeller ice torque excitation for the ships strengthened for navigation in ice and polar class ships

Table 1. Load cases for open propeller

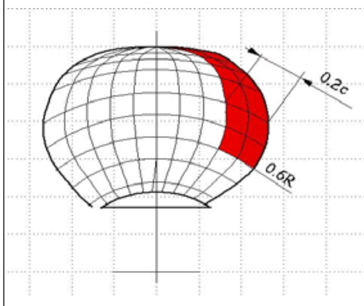
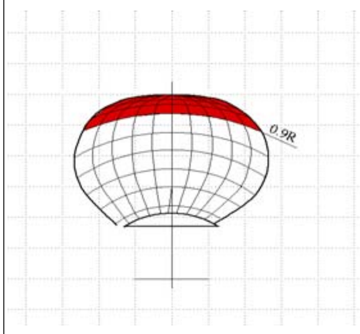
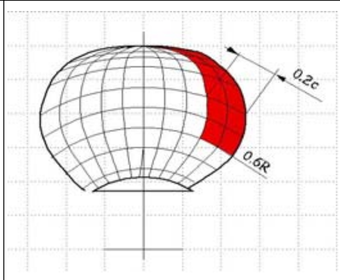
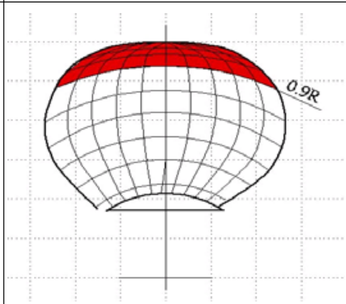
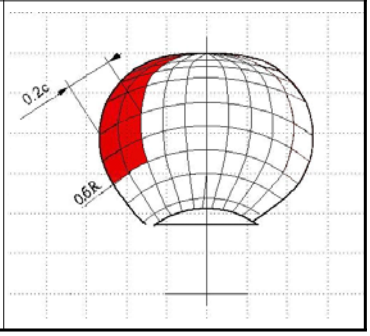
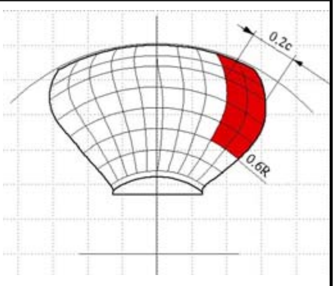
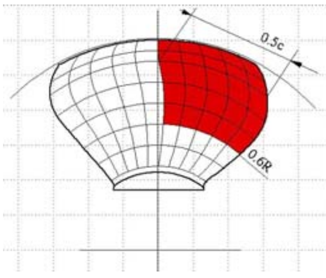
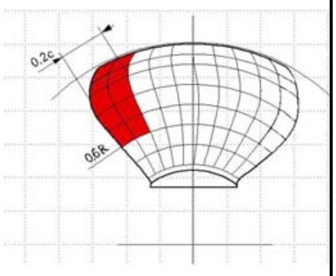
Load case	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade(suction side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade(suction side) on the propeller tip area outside of 0.9 R radius	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 4	50% of F_f	Uniform pressure applied on the propeller face (pressure side) on the propeller tip area outside of 0.9 R radius	
Load case 5	60% of F_f or F_b which is greater	Uniform pressure applied on the propeller face (pressure side) to an area from 0.6 R to the tip and from the trailing edge to 0.2 times the chord length	

Table 2. Load cases for ducted propeller

Load case	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied o the back of the blade(suction side) to an area from 0.6 R to the tip and from the leading edge to 0.2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6 R to the tip and from the leading edge to 0.5 times the chord length	
Load case 5	60% of F_f or F_b which is greater	Uniform pressure applied on the propeller face (pressure side) to an area from 0.6 R to the tip and from the trailing edge to 0.2 times the chord length	

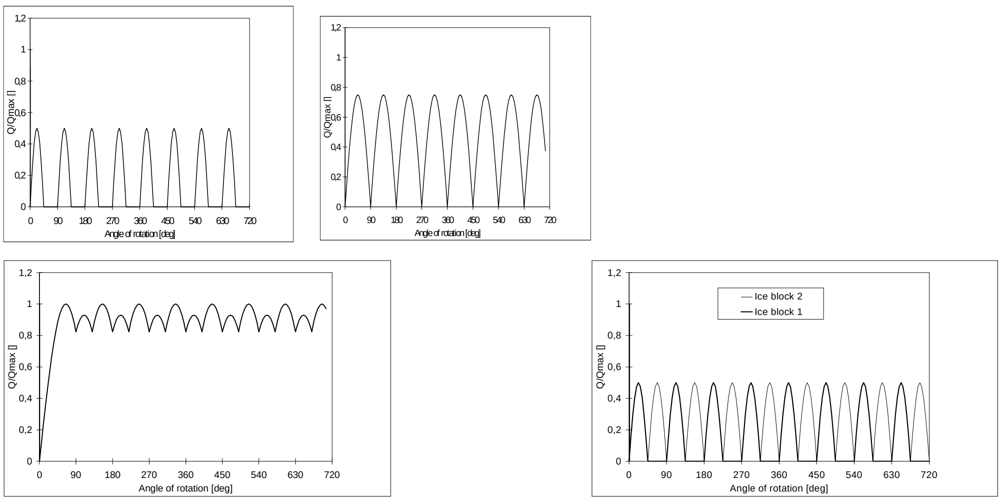


Fig 1 The shape of the propeller ice torque excitation for 45, 90, 135 degrees single blade impact sequences and 45 degrees double blade impact sequence(two ice pieces) on a four-blade propeller

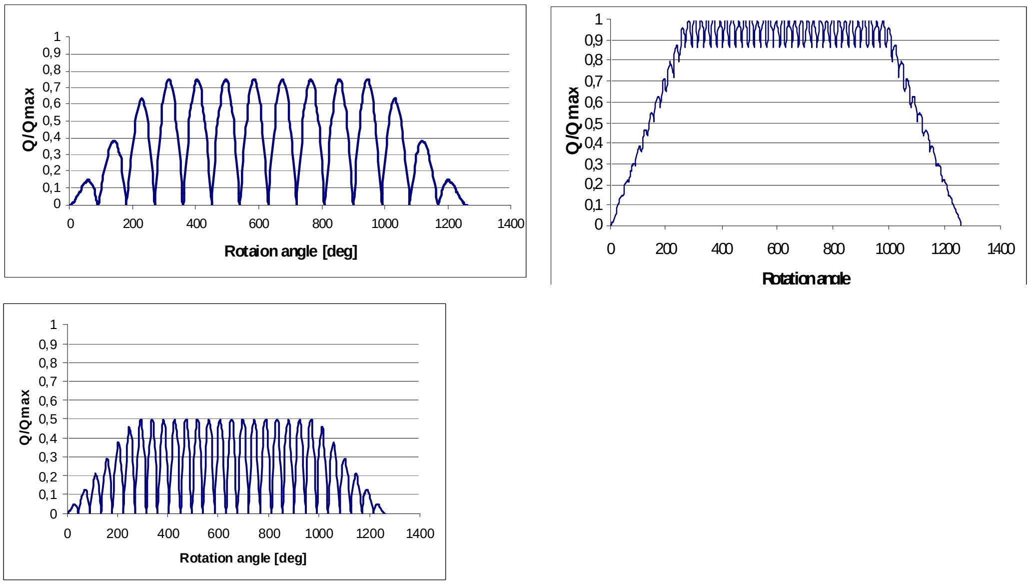


Fig 2 The shape of the propeller ice torque excitation for 90, and 135 degree single-blade impact sequences and 45 degree double-blade impact sequence. (Figures apply for propellers with 4 blades.)

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 3 HULL STRUCTURES

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2011

Rules for the Classification of Steel Ships

Part 4 Hull Equipment

Rules

2011

Guidance Relating to the Rules for the Classification of Steel ships

Part 4 Hull Equipment

Guidance

2011

Rules for the Classification of Steel Ships

Part 4

Hull Equipment

RA-04-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 4 "HULL EQUIPMENT"

1. Unless expressly specified otherwise, the requirements in these Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date : 10 May 2010 (based on the application date for classification survey)

Chapter 3 BOW DOORS, SIDE AND STERN DOORS

Section 2 Side and Stern Doors
- 206. 2 has been amended.

Effective Date : 1 July 2011

Chapter 8 EQUIPMENT NUMBER AND EQUIPMENT

Section 2 Equipment Number
- 203. 3 has been newly added.

Section 3 Anchors
- 309. 1 has been amended.

Section 5 Steel Wire Ropes
- All have been amended.

CONTENTS

CHAPTER 1 RUDDERS

Section 1 General

101. Application

1. The requirements in this Chapter apply to single plate rudders and double plate rudders of stream line section and ordinary shape, being divided into the following types ;

(1) Type *A* : Rudders with upper and bottom pintles. (See **Fig 4.1.1** Type *A*)
(2) Type *B* : Rudders with the neck bearing and the bottom pintle. (See **Fig 4.1.1** Type *B*)
(3) Type *C* : Rudders having no bearing below the neck bearing. (See **Fig 4.1.1** Type *C*)
(4) Type *D* : Mariner type rudders with neck bearing and pintle, of which lower end is fixed. (See **Fig 4.1.1** Type *D*)
(5) Type *E* : Mariner type rudders with two pintles, of which lower ends are fixed. (See **Fig 4.1.1** Type *E*)

2. The construction of rudders with three or more pintles and of those with special shape or sectional form are to be in accordance with the discretion of the Society.

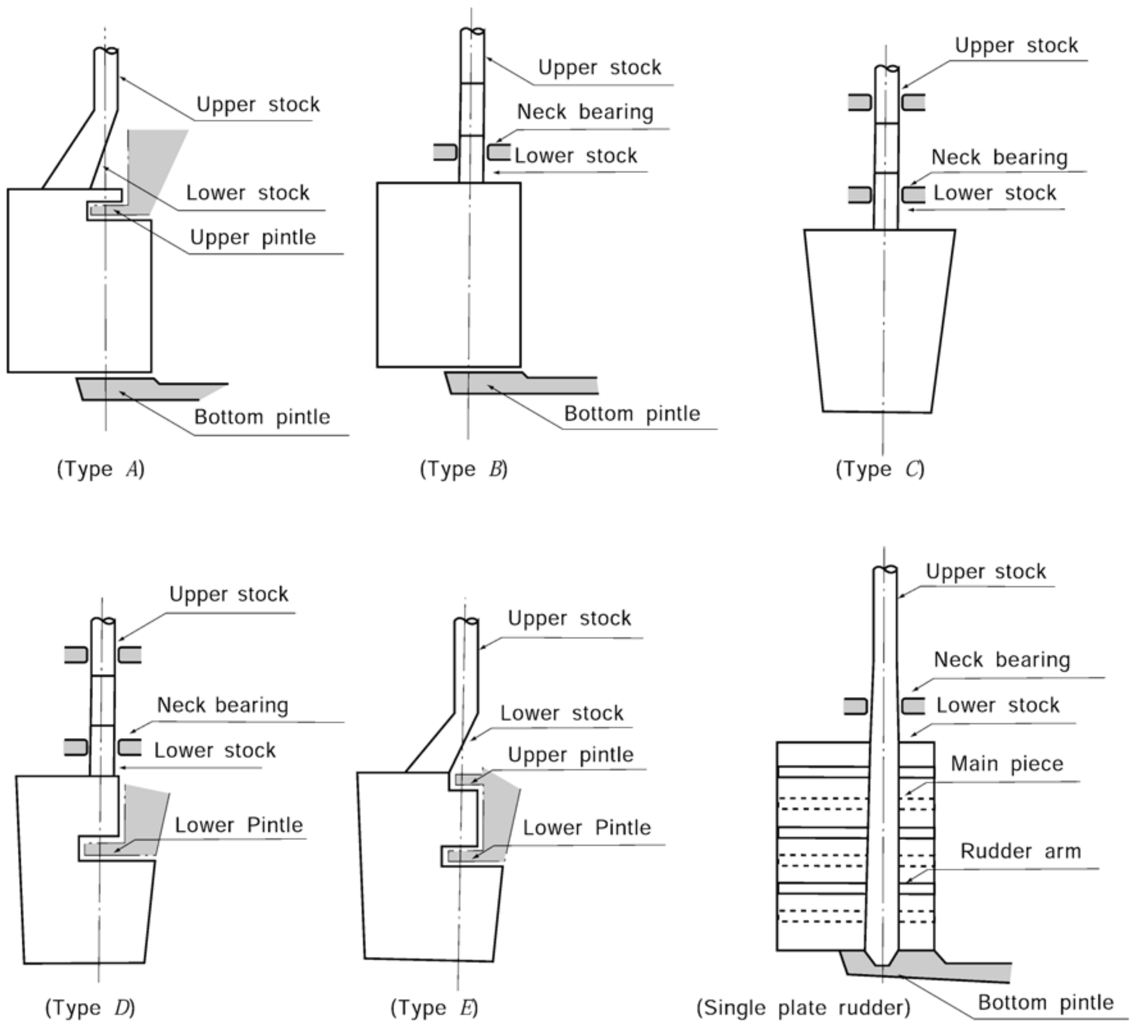


Fig 4.1.1 Types of rudders

3. The construction of rudders designed to move more than 35 *degrees* on one side is to be in accordance with the discretion of the Society.

102. Materials

1. Rudders stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forging or carbon steel casting conforming to the requirements in **Pt 2, Ch 1** of the Rules. For rudder stocks, pintles, coupling bolts and keys, the minimum yield stress is not to be less than 200 (N/mm^2). The requirements in this Chapter are based on a material's yield stress of 235 (N/mm^2). If material is used having a yield stress differing from 235 (N/mm^2) the material factor K is to be determined by **Table 4.1.1.**

Table 4.1.1 Material factor K (for steel forging and carbon steel casting)

σ_y (N/mm^2)	K
$\sigma_y > 235$	$K=\left(\frac{235}{\sigma_y}\right)^{0.75}$
$\sigma_y \le 235$	$K=\left(\frac{235}{\sigma_y}\right)^{1.0}$
σ_y = yield stress(N/mm^2) of material used, and is not to be taken greater than 0.7 σ_T or 450(N/mm^2), whichever is smaller value. σ_T = minimum tensile strength of material used (N/mm^2).	

2. When the rudder stock diameter is reduced because of the application of steels with yield stresses exceeding 235 (N/mm^2), special consideration is to be given to deformation of the rudder stock to avoid excessive edge pressures at edge of bearings.

3. Welded members of rudders such as rudder plates, rudder frames, rudder main pieces, and edge bars are to be made of rolled steels for hull conforming to the requirements in **Pt 2, Ch 1** of the Rules. The required scantlings may be reduced when high tensile steels are applied. When reducing the scantling, the material factor K is to be as **Table 4.1.2.**

Table 4.1.2 Material factor K (for rolled steel)

Material	K
A, B, D or E	1.0
AH 32, DH 32 or EH 32	0.78
AH 36, DH 36 or EH 36	0.72

103. Increase in diameter of rudder stocks for special cases

1. The diameters of rudder stocks for ships exclusively engaged in towing services are not to be less than 1.1 times those required in this Chapter.

2. In ships which may be frequently steered at a large helm angle when sailing at their maximum speed, such as fishing vessels, the diameters of rudder stocks and pintles, as well as the section modulus of main pieces, are not to be less than 1.1 *times* those required in this Chapter.

3. In ships which might require quick steering, the diameters of rudder stocks are to be properly increased beyond the requirements in this Chapter.

4. The rudders for ships classified for ice strengthening are to be in accordance with the requirements of **Pt 3, Ch 20, 216.** in addition to the requirements of this Chapter.

104. Sleeves and bushes

Bearings located from the bottom of rudder to well above the load line are to be provided with sleeves and bushes.

Section 2 Rudder Force

201. Rudder force

The rudder force F_R upon which the rudder scantlings are to be based is to be obtained from the following formula, for each of going ahead or astern. However, when the rudder is arranged behind the propeller that produces an especially great thrust, the rudder force is to be appropriately increased.

$$F_R = 132 K_1 K_2 K_3 A V^2 \quad \text{(N)}$$

where :

A = area of rudder plate (m^2).

V = speed of ship(Kt) as defined in **Pt 3, Ch 1** of the Rules. When the speed is less than 10 *knots*, V is to be replaced by $V_{\min}$ obtained from the following formula ;

$$V_{\min} = \frac{V+20}{3} \quad \text{(Kt)}$$

For the astern condition, the astern speed V_a is to be obtained from the following formula. However, when the maximum astern speed is designed to exceed V_a the design maximum astern speed is to be used.

$$V_a = 0.5 V \quad \text{(Kt)}$$

K_1 = factor depending on the aspect ratio Λ of the rudder area, obtained from the following formula.

$$K_1 = \frac{\Lambda + 2}{3}$$

Λ = as obtained from the following formula. However, Λ is not required to be greater than 2.

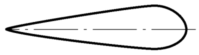
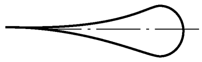
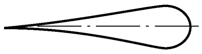
$$\Lambda = \frac{h^2}{A_t}$$

h = mean height of rudder (m), which is determined according to the coordinate system in **Fig 4.1.2.**

A_t = sum of rudder plate area A (m^2) and area of rudder post or rudder horn, if any, within the mean height of rudder h.

K_2 = factor depending on the rudder profile (See **Table 4.1.3**).

Table 4.1.3 Factor K_2

Profile type	K_2	
	Ahead condition	Astern condition
NACA-00 Göttingen profiles 	1.1	0.80
Hollow profiles 	1.35	0.90
Flat side profiles 	1.1	0.90

K_3 = factor depending on the location of rudder (See **Table 4.1.4**).

Table 4.1.4 Factor K_3

Location of rudder	K_3
for rudders outside the propeller jet	0.8
for rudders behind a fixed propeller nozzle	1.15
otherwise	1.0

Section 3 Rudder Torque

301. Rudder torque of Type B and Type C rudders (Rudder without cut-outs)

The rudder torque T_R of Type B and C rudders is to be obtained for ahead and astern conditions, respectively, according to the following formula.

$$T_R = F_R \times r \quad \text{(N-m)}$$

where :

F_R = as specified in **201.**

r = distance from the centre of rudder force on the rudder to the centreline of the rudder stock, determined by the following formula.

$$r = b(\alpha - e) \quad \text{(m)}$$

For the ahead condition, however, r is not to be less than $r_{\min}$ obtained from the following formula.

$$r_{\min} = 0.1b \quad \text{(m)}$$

b = mean breadth(m) of rudder determined by the coordinate system in **Fig 4.1.2.**

α = to be as **Table 4.1.5.**

Table 4.1.5 Factor α

Course of rudder	α
Ahead condition	0.33
Astern condition	0.66

e = balance factor of the rudder obtained from the following formula.

$$e = \frac{A_f}{A}$$

A_f = portion of the rudder plate area situated ahead of the centreline of the rudder stock (m^2).

A = as specified in **201.**

302. Rudder torque of Type *A*, *D* and *E* rudders (Rudder with stepped contours)

The rudder torque T_R of Type A, D and E rudders is to be obtained for the ahead and astern conditions, respectively, according to the following formula :

$$T_R = T_{R1} + T_{R2} \quad \text{(N-m)}$$

For the ahead condition, however, T_R is not to be less than $T_{R\min}$ obtained from the following formula :

$$T_{R\min} = 0.1\, F_R \frac{A_1 b_1 + A_2 b_2}{A} \quad \text{(N-m)}$$

where :

T_{R1} and T_{R2} = rudder torque(N-m) of portion of A_1 and A_2, respectively, obtained from the following formulae, respectively.

$$T_{R1} = F_{R1} \times r_1 \quad \text{(N-m)}$$
$$T_{R2} = F_{R2} \times r_2 \quad \text{(N-m)}$$

A_1 and A_2 = areas of respective rectangulars (m^2) determined by dividing the rudder area into two parts so that $A = A_1 + A_2$ (A_1 and A_2 include A_{1f} and A_{2f} respectively), as specified in **Fig 4.1.3.**

b_1 and b_2 = mean breadth (m) of portions A_1 and A_2, determined by applying **Fig 4.1.2** correspondingly.

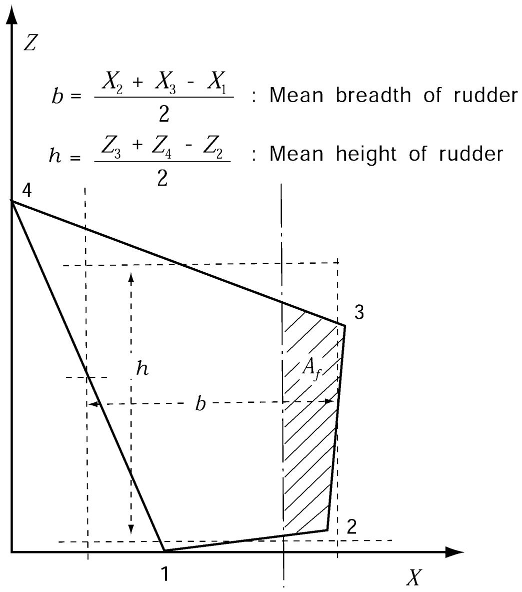


Fig 4.1.2 Coordinate system o rudders

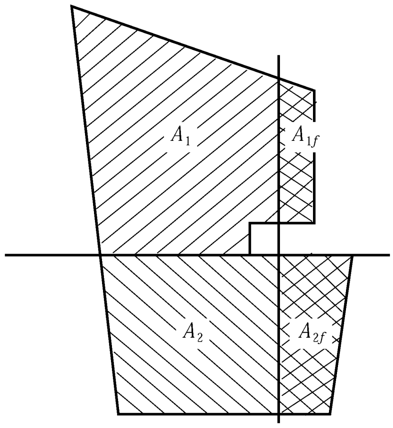


Fig 4.1.3 Division of rudder area

F_R and A = as specified in **201.**

F_{R1} and F_{R2} = the rudder force of portions A_1 and A_2, obtained from the following formulae, respectively.

$$F_{R1} = F_R \frac{A_1}{A} \quad \text{(N)}$$

$$F_{R2} = F_R \frac{A_2}{A} \quad \text{(N)}$$

r_1 and r_2 = the distances from each centre of rudder force of portions A_1 and A_2 to the centre-line of the rudder stock, determined by the following formulae, respectively.

$$r_1 = b_1(\alpha - e_1) \quad \text{(m)}$$
$$r_2 = b_2(\alpha - e_2) \quad \text{(m)}$$

e_1 and e_2 = the balance factors of portions A_1 and A_2, obtained from the following formulae, respectively.

$$e_1 = \frac{A_{1f}}{A_1}, \quad e_2 = \frac{A_{2f}}{A_2}$$

α = to be as **Table 4.1.6.**

Table 4.1.6 Factor α

Locations of rudder parts		α
For parts of a rudder not behind a fixed structure such as rudder horn	for ahead condition	0.33
	for astern condition	0.66
For parts of a rudder behind a fixed structure such as rudder horn	for ahead condition	0.25
	for astern condition	0.55

Section 4 Rudder Strength Calculation

401.Rudder strength calculation

1. The rudder strength is to be sufficient against the rudder force and rudder torque as given in **Sec 2** and **Sec 3.** When the scantling of each part of a rudder is determined, the following moments and forces are to be considered.

For rudder body : bending moment and shear force

For rudder stock : bending moment and torque

For pintle bearing and rudder stock bearing : supporting force

2. The bending moments, shear forces and supporting forces to be considered are to be determined by a direct calculation or an approximate simplified method as deemed appropriate by the Society.

Section 5 Rudder Stocks

501. Upper stocks

The upper stock diameter d_u required for the transmission of the rudder torque is to be determined so that the torsional stress not exceed 68/Kg(N/mm^2). In dimensioning, the upper stock diameter may be determined by the following formula:

$$d_u = 4.2\sqrt[3]{T_R K_S} \quad \text{(mm)}$$

T_R = as specified in **301.** and **302.**

K_S = material factor for rudder stock, as given in **102.**

502. Lower stocks

The diameter d_l of the lower stock subjected to combined forces of torque and bending moment is to be determined so that the equivalent stress in the rudder stock not exceed 118 K_s (N/mm^2). The equivalent stress σ_e is to be obtained from the following formula :

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{(N/mm}^2\text{)}$$

where :

σ_b and τ_t = the bending stress and torsional stress acting on the lower stock, determined as follows respectively :

$$\sigma_b = \frac{10.2M}{{d_l}^3} \times 10^3 \quad (\text{N/mm}^2)$$

$$\tau_t = \frac{5.1\,T_R}{{d_l}^3} \times 10^3 \quad (\text{N/mm}^2)$$

M = bending moment(N-m) at the section of the rudder stock considered.

T_R = as specified in **301.** and **302.**

When the horizontal section of the lower stock forms a circle, the lower stock diameter d_l may be determined by the following formula :

$$d_l = d_u \sqrt[6]{1 + \frac{4}{3}\left(\frac{M}{T_R}\right)^2} \quad (\text{mm})$$

where :

d_u = upper stock diameter(mm) as given in **501.**

Section 6 Rudder Plates, Rudder Frames and Rudder Main Pieces

601. Rudder plate

The rudder plate thickness t is not to be less than that obtained from the following formula :

$$t = 5.5S\beta\sqrt{\left(d + \frac{F_R \times 10^{-4}}{A}\right)K_{pl}} + 2.5 \quad (\text{mm})$$

where :

A and F_R = as specified in **201.**

K_{pl} = material factor for the rudder plate as given in **102.**

d = as specified in **Pt 3, Ch 1, 111.**

β = to be obtained from the following formula :

$$\beta = \sqrt{1.1 - 0.5\left(\frac{S}{a}\right)^2} \quad \text{max : } 1.0\left(\frac{a}{S} \geq 2.5\right)$$

S = spacing of horizontal or vertical rudder frames, whichever is smaller (m).

a = spacing of horizontal or vertical rudder frames, whichever is greater (m).

602. Rudder frames

1. The rudder body is to be stiffened by horizontal and vertical rudder frames enabling it to act as bending girder.

2. The standard spacing of horizontal rudder frames, S_f is to be obtained from the following formula :

$$S_f = 0.2\left(\frac{L}{100}\right) + 0.4 \quad (\text{m})$$

3. The standard distance from the vertical rudder frame forming the rudder main piece to the adjacent vertical rudder frame is to be 1.5 *times* the spacing of horizontal rudder frames.

4. The thickness of rudder frames is not to be less than 8 mm or 70 % of the thickness of the rudder plates as given in **601.** whichever is greater.

603. Rudder main pieces

1. Vertical rudder frames forming the rudder main piece are to be arranged forward and afterward of the centreline of rudder stock at a distance approximately equal to the thickness of the rudder where the main piece consists of two rudder frames, or at the centreline of the rudder stock where the main piece consists of one rudder frame.

2. The section modulus of the main piece is to be calculated in conjunction with the vertical rudder frames specified in **Par 1** and rudder plates attached thereto. The effective breadth of the rudder plates normally taken into calculation are to be as follows :

(1) Where the main piece consists of two rudder frames, the effective breadth is 0.2 *times* the length of the main piece.
(2) Where the main piece consists of one rudder frame, the effective breadth is 0.16 *times* the length of the main piece.

3. The section modulus and the web area of a horizontal section of the main piece are to be such that bending stress, shear stress and equivalent stress will not exceed the following stress values, respectively.

$$\sigma_b = \frac{110}{K_m} \quad (\mathrm{N/mm^2}), \qquad \tau = \frac{50}{K_m} \quad (\mathrm{N/mm^2}), \qquad \sigma_e = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{120}{K_m} \quad (\mathrm{N/mm^2})$$

In the cases of Type A, D, and E rudders, however, the section modulus and the web area of a horizontal section of the main piece in way of cut-outs are to be such that bending stress, shear stress and equivalent stress not exceed the following stress values, respectively.

$$\sigma_b = \frac{75}{K_m} \quad (\mathrm{N/mm^2}), \qquad \tau = \frac{50}{K_m} \quad (\mathrm{N/mm^2}), \qquad \sigma_e = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{100}{K_m} \quad (\mathrm{N/mm^2})$$

where :

K_m = material factor for the rudder main piece as given in **102.**

4. The upper part of the main piece is to be so constructed as to avoid structural discontinuity.

5. Maintenance openings and cut-outs of rudder plates in Type A, D, and E rudders are to be rounded off properly.

604. Rudder plates, rudder arms and rudder main pieces of single plate rudders

1. The rudder plate thickness t is not to be less than that obtained from the following formula :

$$t = 1.5SV\sqrt{K_{pl}} + 2.5 \quad (\mathrm{mm})$$

where :

S = spacing (m) of rudder arms, not to exceed 1 m.

V = speed of ship (Kt) as specified in **201.**

K_{pl} = material factor for rudder plate as given in **102.**

2. Rudder arms are to comply with the following requirements.

(1) The thickness of rudder arms is not to be less than that of rudder plates.

(2) The section modulus of rudder arms is not to be less than the value obtained from the following formula. This section modulus, however, may be reduced gradually toward the edge of the rudder plate.

$$Z = 0.5\, S C_1^2\, V^2 K_a \quad (\mathrm{cm}^3)$$

where :

C_1 = horizontal distance (m) from the aft edge of the rudder plate to the centre of the rudder stock.

K_a = material factor for the rudder arm as given in **102.**

S and V = as specified in **Par 1.**

3. The diameters of main pieces are not to be less than those of lower rudder stocks. In rudders having no bearing below the neck bearing, however, the main piece diameter may be reduced gradually within the lower 1/3 area of the rudder, and may be 75 % of the specified diameter at the bottom part.

605. Connections

Rudder plates and frames are to be effectively connected and free from defects, cautions being taken to the workmanship.

606. Paintings and drainings

The internal surface of rudder is to be coated with effective paint, and means for draining are to be provided at the bottom of rudder.

Section 7 Couplings between Rudder Stocks and Main Pieces

701. Horizontal flange couplings

1. Coupling bolts are to be reamer bolts and at least 6 reamer bolts are to be used in each coupling.

2. Couplings are to comply with the requirements in **Table 4.1.7.**

702. Vertical flange couplings

1. Coupling bolts are to be reamer bolts and at least 8 reamer bolts are to be used in each coupling.

2. Couplings are to comply with the requirements in **Table 4.1.7.**

703. Cone couplings

1. Cone couplings without hydraulic arrangements (oil injection and hydraulic nut, etc.) for mounting and dismounting the coupling are to comply with the following requirements.

(1) The couplings are to have a taper on diameters of 1 : 8 ~ 1 : 12 and be secured by the slugging nut. (*See* **Fig 4.1.4**)

(2) The taper length l of rudder stocks fitted into the rudder plate is generally not to be less than 1.5 *times* the rudder stock diameter d_0 at the top of the rudder.

(3) For the couplings between stock and rudder, a key is to be provided. And the scantling of the key is to be to the discretion of the Society.

(4) The dimensions of the slugging nut as specified in the preceding (1) are to be as follows (*See* **Fig 4.1.4**) :

$d_g \geq 0.65 d_0$ (mm)

$h_n \geq 0.6 d_g$ (mm)

$d_n \geq 1.2 d_e$ or $1.5 d_g$ (mm), whichever is greater.

where :

d_g = external thread diameter(mm).

h_n = length of nut(mm).

d_n = outer diameter of nut(mm).

(5) The nuts fixing the rudder stocks are to be provided with efficient locking devices such as lock nut, nut stopper, etc.

(6) Couplings of rudder stocks are to be properly protected from corrosion.

Table 4.1.7 The minimum requirements for rudder couplings to stock

Parameter	Requirement	
	Horizontal flange coupling	Vertical flange coupling
d_b	$0.62\sqrt{\dfrac{d^3 K_b}{n e_m K_s}}$	$\dfrac{0.81d}{\sqrt{n}} \times \sqrt{\dfrac{K_b}{K_s}}$
M	-	$0.00043d^3$
t_f	$d_b\sqrt{\dfrac{K_f}{K_b}}$ (not less than $0.9d_b$)(1)	d_b
w_f	$0.67d_b$	$0.67d_b$

n = total number of bolts.
d_b = bolt diameter (mm).
d = stock diameter (mm), the greater of the diameters d_u or d_l according to **501.** and **502.**
M = the first moment of area of the bolts about the centreline of the coupling flange (cm^3)
e_m = mean distance (mm) of the bolt axes from the centre of the bolt system.
K_s = material factor for the rudder stock as given in **102.**
K_b = material factor for the bolts as given in **102.**
K_f = material factor for the coupling flange as given in **102.**
t_f = the thickness (mm) of the coupling flanges.
w_f = the width (mm) of the material outside the bolt holes of the coupling flanges.

NOTE :
(1) In way horizontal flange couplings, t_f is to be calculated from d_b determined by a number of bolts not exceeding 8.

2. Cone couplings with hydraulic arrangements (oil injection and hydraulic nut, etc.) for mounting and dismounting the coupling are to comply with the following requirements.

(1) Couplings are to have a taper on diameters of 1 : 12 ~ 1 : 20. The push-up force and push-up length are to be at the discretion of the Society.

(2) The nuts fixing the rudder stocks are to be provided with efficient locking devices. However, a securing plate for securing nut against the rudder body is not to be provided.

(3) Couplings of rudder stocks are to be properly protected from corrosion.

(4) The dimensions of the securing nuts are to be as specified **Par 1,** (4).

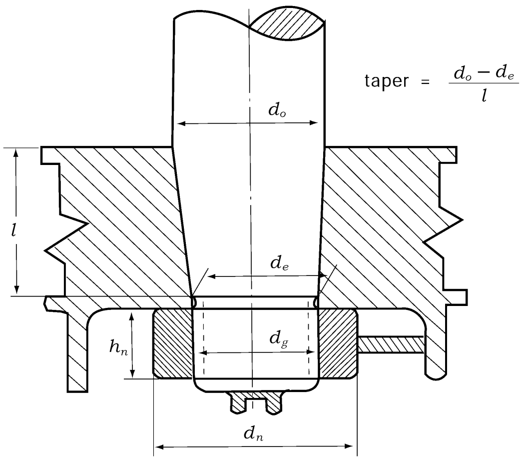


Fig 4.1.4 Cone coupling without hydraulic arrangements

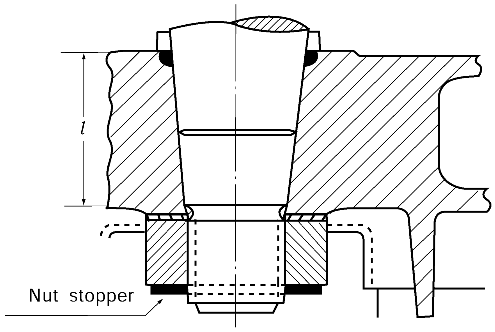


Fig 4.1.5 Cone coupling with hydraulic arrangements

Section 8 Pintles

801. Diameters of pintles

The diameters of pintles d_p are not to be less than the dimension obtained from the following formula.

$$d_p = 0.35\sqrt{BK_p} \quad \text{(mm)}$$

where :

B = reaction force in bearing (N)

K_p = material factor for pintles as given in **102.**

802. Construction of pintles

1. Pintles constructed as taper bolts are to have a taper on the diameter not exceeding the following values, and capable of being fitted to the gudgeons. The nuts fixing the pintles are to be provided with efficient locking devices.

(1) For keyed pintles to be assembled and locked with slugging nuts : 1 : 8 ~ 1 : 12

(2) For pintles mounted with hydraulic arrangements (oil injection and hydraulic nut, etc.) : 1 : 12 ~ 1 : 20

2. The minimum dimensions of the threads and the nuts of pintles are to be determined by applying the requirements in **703. 1** (4) correspondingly.

3. The length of the pintle housing in the gudgeon (*tapered length*) is not to be less than the maximum pintle diameter.

4. Pintles are to be properly protected from corrosion.

Section 9 Bearings of Rudder Stocks and Pintles

901. Minimum bearing surface

The bearing surface A_b (defined as the projected area : *Bearing length* × *outside diameter of sleeve)* is not to be less than the value obtained from the following formula.

$$A_b = \frac{B}{q_a} \quad (\mathrm{mm}^2)$$

where :

B = as specified in **801.**

q_a = allowable surface pressure(N/mm^2). The allowable surface pressure for the various bearing combination is to be taken from **Table 4.1.8.** When verified by tests, however, different values from those in this Table may be taken.

Table 4.1.8 Allowable surface pressure q_a

Bearing material	q_a (N/mm^2)
Lignum vitae	2.5
White metal (oil-lubricated)	4.5
Synthetic materials with hardness between 60 and 70, Shore D (1)	5.5
Steel (2), bronze and hotpressed bronze-graphite materials	7.0

NOTES :
(1) Indentation hardness test at the temperature of 23°C and humidity of 50 %, according to a recognized standard. Synthetic bearings are to be of approved type.
(2) Stainless and wear-resistant steel in an approved combination with a stock liner.

902. Length of bearings

The length / diameter ratio of the bearing surface is not to be greater than 1.2.

903. Bearing clearances

With metal bearings clearances are not to be less than d_{bs}/1000+1.0 (mm) on the diameter.

where :

d_{bs} = the internal diameter of bush (mm).

If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance in no way is to be taken less than 1.5 mm on bearing diameter.

904. Thickness of bush and sleeve

The thickness of any bush or sleeve t is not to be less than that obtained from the following formula.

$$t = 0.01\sqrt{B} \quad (\mathrm{mm})$$

where :

B = as specified in **801.**

However, t is not to be less than $t_{\min}$ as follows ;

$t_{\min}$ = 8 mm for metallic materials and synthetic materials

$t_{\min}$ = 22 mm for lignum vitae

Section 10 Rudder Accessories

1001. Rudder carriers

Suitable rudder carriers are to be provided for supporting the weight of rudder according to the form and the weight of the rudder, and care is to be taken to provide efficient lubrication at the support.

1002. Jumping stoppers

Suitable arrangements are to be provided to prevent the rudder from jumping due to wave shocks.

Section 11 Propeller Nozzles

1101. Application

1. The following requirements are applicable to propeller nozzles having an inner diameter of up to 5 m. Nozzles with larger diameters will be specially considered.

2. Special attention is to be given to the support of fixed nozzles at the hull structures.

1102. Design pressure

1. The design pressure for propeller nozzles is to be determined by the following formula:

$$P_d = cP_{do} \quad (\text{kN/m}^2)$$

$$P_{do} = \epsilon \frac{N}{A_p} \quad (\text{kN/m}^2)$$

N = maximum shaft power in (kW)

A_p = propeller disc area in (m^2)

$$A_P = D^2 \frac{\pi}{4}$$

D = propeller diameter in (m)

ϵ = factor according to the following formula:

$$\epsilon = 0.21 - 2 \times 10^{-4} \frac{N}{A_P}$$

$$\epsilon_{\min} = 0.1$$

c = 1.0 in zone 2 (propeller zone)

= 0.5 in zone 1 & 3

= 0.35 in zone 4

1103. Plate thickness

(1) The thickness of the nozzle shell plating is not to be less than:

$$t = 5a\sqrt{P_d} + 2.5 \quad (\text{mm})$$

$$t_{\min} = 7.5 \text{ mm}$$

a = spacing of ring stiffeners in (m)

(2) The web thickness of the internal stiffening rings shall not be less than the nozzles plating for zone 3.

1104. Section modulus

(1) The section modulus of the cross section shown in **Fig 4.1.6** around its neutral axis is not to be less than:

$$W = n \cdot d^2 \cdot b \cdot v_0^2 \quad (\mathrm{cm}^3)$$

d = inner diameter of nozzle in (m)

b = length of nozzle in (m)

n = 1.0 for rudder nozzles

= 0.7 for fixed nozzles.

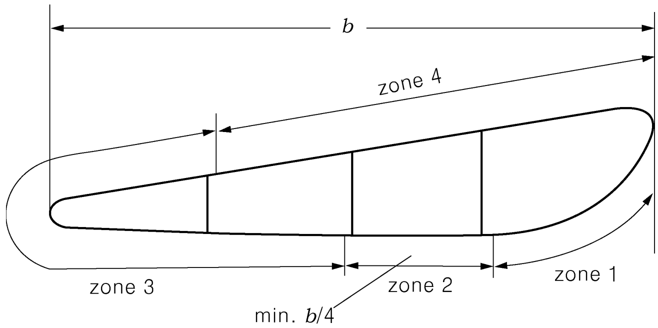


Fig 4.1.6

1105. Welding

The inner and outer nozzle shell plating is to be welded to the internal stiffening rings as far as practicable by double continuous welds. Plug welding is only permissible for the outer nozzle plating. ⚓

CHAPTER 2 HATCHWAYS AND OTHER DECK OPENINGS

Section 1 General

101. Application

1. The requirements apply to steel hatch covers and coaming in position Ⅰ and Ⅱ on weather decks. The requirements in **Ch 9** apply to steel hatch covers of small hatches fitted on the exposed fore deck.

2. Relaxation from the requirements in this Chapter will be specially considered where the ship has an unusually large freeboard.

3. The construction and means for securing the weathertightness of cargo and other hatchways in position I and II as defined **102.** shall be equivalent to the requirements of hatchways closed by weathertight covers of steel or other equivalent materials, unless the application of portable covers and secured weathertight by tarpaulins and battening devices is granted by the Administration.

102. Position of exposed deck openings

For the purpose of this Chapter, two positions of exposed deck openings are defined as follows:

Position I = Upon exposed freeboard and raised quarter decks, and upon exposed superstructure decks situated forward of a point located $0.25L_f$ from the for ward perpendicular.
Position II= Upon exposed superstructure decks situated abaft $0.25L_f$ from the forward perpendicular and upon exposed superstructure decks situated forward of a point located $0.25L_f$ from the forward perpendicular and located at least two standard heights of superstructure above the freeboard deck.

103. Material

The formulae for scantlings given in this Chapter are applicable to steel hatch covers and coaming. The use of materials other than steel is considered by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

104. Net scantlings

The gross scantlings are obtained by the net scantlings adding the corrosion additions. All scantlings referred to in this Chapter, except otherwise specified, are net, i.e. they do not include any margin for corrosion. When calculating the stresses σ and τ in **503.** and **504**, the net scantlings are to be used. The gross scantlings are obtained by the net scantlings adding the corrosion additions.

105. Corrosion additions

1. The corrosion addition for both sides to be considered for the plating and internal members of hatch covers, hatch coamings and coaming stays except stainless steel is equal to the value specified in **Table 4.2.1**.

For structural members made of stainless steel and aluminium alloys, the corrosion addition t_c is to be taken equal to 0 mm.

2. Renewal thickness

Structural drawings for hatch covers and hatch coamings complying with this Chapter are to indicate the renewal thickness ($t_{renewal}$) for each structural elements, given by the following formula in addition to the as built thickness ($t_{as-built}$). If the thickness for voluntary addition is included in the as built thickness, the value may be at the discretion of the Society.

$$t_{renewal} = t_{as-built} - t_c + 0.5 \quad \text{(mm)}$$

where,

t_c : Corrosion addition according to **Table 4.2.1**
In case that corrosion addition t_c is 1.0 mm, renewal thickness may be given by the following formula.

$$t_{renewal} = t_{as-built} - t_c \quad \text{(mm)}$$

Table 4.2.1 Corrosion additions t_c for steel hatch covers and hatch coamings

Corrosion addition t_c (mm)		
Member	Bulk carriers Ore carriers Combination carriers	Others except left column
Plating and stiffeners of single skin hatch cover	2.0	2.0 *
Top and bottom plating of double skin hatch cover	2.0	1.5 *
Internal structures of double skin hatch cover	1.5	1.0
Hatch coamings structures and coaming stays	1.5	1.5
* Corrosion addition t_c=1.0 mm for the hatch covers in may of cellular cargo holds intended for containers.		

106. Allowable stresses

The allowable stresses σ_a and τ_a, in N/mm^2, are to be obtained from **Table 4.2.2**.

Table 4.2.2 Allowable stresses (N/mm^2)

Members of:	σ_a (N/mm^2)	τ_a (N/mm^2)
Weathertight hatch cover	0.80 σ_y	0.46 σ_y
Pontoon hatch cover	0.68 σ_y	0.39 σ_y
Hatch coaming	0.95 σ_y	0.50 σ_y

σ_y : Yielding Stresses

107. External pressures on hatch covers

1. The wave pressure acting on hatch cover plate is as following **Table 4.2.3**. When the loads due to uniform cargoes or containers, etc. other than the weave loads are acting on hatch covers, the loads are to be considered additionally.

Table 4.2.3 Wave pressures on hatch covers

Ware Pressure P_W (kN/m²)			
Length for freeboard, L_f	Location	Position I	Position II
$L_f \geq 100$ m	$0.75 < x/L_f < 1$	$34.3+(14.8+a(L_f-100))(4\frac{x}{L_f}-3)$	
	$0 \leq x/L_f \leq 0.75$	34.3	25.5
$L_f < 100$ m	$0.75 < x/L_f < 1$	$12.2+\frac{L_f}{9}(5\frac{x}{L_f}-2)+3.6\frac{x}{L_f}$	
	$0 \leq x/L_f \leq 0.75$	$14.9+0.195L_f$	$11.3+0.142L_f$

Note :
a : coefficient taken equal to :
a = 0.0726 for Type B freeboard ships
a = 0.356 for Ships assigned reduced freeboard.
L_f : Length for freeboard defined in **Pt 3, Ch 1, Sec 1** (m). But need not be taken greater than 340 m.
x(m) : Distance from the end of stern to the center of hatch cover that should be considered.

Section 2 Arrangements

201. Height of hatchway coamings

1. The height of coamings above the upper surface of deck is to be at least 600 mm in Position I and 450 mm in Position II.

2. For hatchways closed by steel weathertight hatch covers fitted with gaskets and clamping devices, the height of coamings may be reduced from those prescribed in the preceding paragraph or omitted entirely subject to the satisfaction of the Society.

3. The height of hatchway coamings other than those provided in exposed portions of the freeboard or superstructure decks is to be to the satisfaction of the Society having regard to the position of hatchways or the degree of protection provided.

202. Hatch covers

1. Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight. However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2. The ordinary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

3. The spacing of primary supporting members parallel to the direction of ordinary stiffeners is to be not greater than 1/3 of the span of primary supporting members.

4. The breadth of the primary supporting member flange is to be not less than 40 % of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members. The flange outstand is not to exceed 15 times the gross flange thickness.

5. The ends of hatch covers are normally to be protected by efficiently secured galvanised steel strips.

6. Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes and stacks of containers on the cover. These retaining arrangements are to be located in way of the hatch coaming side brackets.

- Solid fittings are to be welded on the hatch cover where the corners of the containers are resting. These parts are intended to transmit the loads of the container stacks onto the hatch cover on which they are resting and also to prevent horizontal translation of the stacks by means of special intermediate parts arranged between the supports of the corners and the container corners.
- Longitudinal stiffeners are to stiffen the hatch cover plate in way of these supports and connect at least the nearest three transverse stiffeners.

7. The width of each bearing surface for hatch covers is to be at least 65 mm.

8. Steel hatchway covers of deep tanks are to be to the satisfaction of the Society.

9. In the case of sand carriers and dredgers, hatchway covers may be omitted at the discretion of the Society.

10. The arrangements for securing weathertightness are to be ensured that the tightness can be maintained in any sea conditions. For this purpose, tests for the tightness of covers are to be required to a water pressure of not less than 0.2 MPa at the initial survey and may also be required at periodical surveys and at annual surveys at the discretion of the Surveyor.

203. Hatch coamings

1. Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2. Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

3. Longitudinal coamings are to be extended at least to the lower edge of deck beams.

- Where they are not part of continuous deck girders, longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.
- Where longitudinal coamings are part of deck girders, their scantlings are to be as requirements of deck girder.

4. A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

Section 3 Width of attached plating

301. Ordinary stiffeners

The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

Where the attached plating extends on both sides of the stiffener : $b_r = S$

Where the attached plating extends on one side of the stiffener : $b_r = 0.5S$

S : Length, in mm, of the shorter side of the elementary plate panel.

302. Primary supporting members

The effective width of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through isolated beam or grillage model is to be obtained, in m, from the following formulae:

Where the plating extends on both sides of the primary supporting member : $b_p = b_{p1} + b_{p2}$

Where the plating extends on one side of the primary supporting member : $b_p = b_{p1}$

where :

$b_{p1} = \min(0.165 l_p, S_{p1})$ (m)

$b_{p2} = \min(0.165 l_p, S_{p2})$ (m)

l_p : Span, in m, of the considered primary supporting member

S_{p1}, S_{p2} : Half distance, in m, between the considered primary supporting member and the adjacent ones, S_{p1} for one side, S_{p2} for the other side.

When a isolated beam or a grillage analysis is used, the ordinary stiffeners are not to be included in the attached flange area of the primary members.

Section 4 Load Model

401. Lateral pressures and concentrated loads

1. General

The lateral pressures and concentrated loads to be considered as acting on hatch covers are indicated in **2.** to **6.** When two or more panels are connected by hinges, each individual panel is to be considered separately. In any case, the sea pressures defined in **2.** are to be considered for hatch covers located on exposed decks. Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in **3.** to **6.** are to be considered independently from the sea pressures.

2. Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

still water pressure : $P_s = 0$

wave pressure P_w is equal to the value specified in **Table 4.2.3.**

3. Internal pressures due to liquid cargo or ballast tanks

If applicable, the still water and wave lateral pressures are to be considered and to comply with the applicable provisions of the Society.

4. Pressures due to uniform cargoes

If applicable, the still water and wave lateral pressures are to be considered and to comply with the applicable provisions of the Society.

5. Pressures due to special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressure to be applied is considered by the Society on a case by case basis.

6. Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

402. Load point

1. Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located :

longitudinally, at the hatch cover mid-length

transversely, on the longitudinal plane of symmetry of the ship
vertically, at the top of the hatch coaming.

2. Lateral pressures other than the wave pressure

The lateral pressure is to be calculated :

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

Section 5 Strength Check

501. General

1. Application

The strength check is applicable to rectangular hatch covers subjected to a uniform pressure, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members. In the latter case, the stresses in the primary supporting members are to be determined by a grillage or a finite element analysis. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in **504. 4.**

2. Hatch covers supporting containers

The scantlings of hatch covers supporting container stacks are to comply with the applicable provisions of the Society.

3. Hatch covers subjected to concentrated loads

For hatch covers supporting concentrated loads, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in **503.** & **504.**

4. Covers of small hatchways

The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 0.6 m.

502. Plating

1. Net thickness

The net thickness of steel hatch cover top plating, in mm, is to be not less than the value obtained from the following formula :

$$t = 15.8 F_p S \sqrt{\frac{P_s + P_w}{0.95\sigma_y}} \quad \text{(mm)}$$

F_p : Factor for combined membrane and bending response, equal to :

F_p = 1.5 in general, for $\frac{\sigma}{\sigma_a} < 0.8$, for the attached plating of primary supporting members

$F_p = 1.9\frac{\sigma}{\sigma_a}$, for $\frac{\sigma}{\sigma_a} \geq 0.8$, for the attached plating of primary supporting members

S : Spacing of stiffeners. (m)

P_s : Still water pressure. (kN/m^2)

P_w : Wave pressure. (kN/m^2)

σ : Normal stress (N/mm^2) in the attached plating of primary supporting members, calculated according to **504. 3** or determined through a grillage analysis or a finite element analysis, as the case may be.

σ_a : Allowable stress (N/mm^2)

σ_y : The yield stress of material (N/mm^2)

2. Minimum net thickness

The net thickness, in mm, of hatch cover plating is to be not less than the greater of the following values :

$t = 0.01S$

$t = 6$

3. Critical buckling stress check

The compressive stress σ in the hatch cover plating, induced by the bending of primary supporting members, either parallel or perpendicular to the direction of ordinary stiffeners, calculated according to **504. 3** or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formula:

(1) The compressive stress, σ, in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, and the critical buckling stress, σ_{CP}, are to be evaluated as defined below :

$$\sigma \le 0.8\sigma_{CP}$$

$$\sigma_{CP} = \sigma_{E1} \quad \text{when } \sigma_{E1} \le \frac{\sigma_y}{2}$$

$$= \sigma_y\left[1 - \frac{\sigma_y}{4\sigma_{E1}}\right] \quad \text{when } \sigma_{E1} > \frac{\sigma_y}{2}$$

σ_y : Minimum upper yield stress or proof stress of the material (N/mm^2)

$$\sigma_{E1} = 3.6E\left(\frac{t}{1000S}\right)^2$$

E : Modulus of elasticity of the material to be assumed equal to for steel 2.06×10^5 (N/mm^2)

t : Net thickness of plate panel (mm)

S : Spacing of secondary stiffeners (m)

(2) The mean compressive stress, σ, in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, and the critical buckling stress, σ_{CP}, to be evaluated as defined below :

$$\sigma \le 0.8\sigma_{CP}$$

$$\sigma_{CP} = \sigma_{E2} \quad \text{when } \sigma_{E2} \le \frac{\sigma_y}{2}$$

$$= \sigma_y\left[1 - \frac{\sigma_y}{4\sigma_{E2}}\right] \quad \text{when } \sigma_{E2} > \frac{\sigma_y}{2}$$

σ_y : Minimum upper yield stress or proof stress of the material (N/mm^2)

$$\sigma_{E2} = 0.9mE\left(\frac{t}{1000S_s}\right)^2$$

$$m = C\left[1+\left(\frac{S_s}{l_s}\right)^2\right]^2 \frac{2.1}{\Psi+1.1}$$

E : Modulus of elasticity of the material to be assumed equal to for steel 2.06×10^5 (N/mm^2),

t : Net thickness of plate panel (mm)

S_s : Length of the shorter side of the plate panel (m)

l_s : Length of the longer side of the plate panel (m)

Ψ : Ratio between smallest and largest compressive stress

C : Coefficients obtained according to the kind of stiffeners at compressive side, which are given by the followings :

1.30 when plating is stiffened by primary supporting members

1.21 when plating is stiffened by secondary stiffeners of angle or T type

1.10 when plating is stiffened by secondary stiffeners of bulb type

1.05 when plating is stiffened by flat bar

(3) The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be at the Society's discretion.

503. Ordinary stiffeners

1. For flat bar ordinary stiffeners, the ratio h_W/t_W is to comply with the following formula :

$$\frac{h_W}{t_W} \le 15\sqrt{\frac{235}{\sigma_y}}$$

where:

h_W : Web height, in mm, of the ordinary stiffener.

t_W : Net thickness, in mm, of the ordinary stiffener.

2. Net section modulus and net shear sectional area

The net section modulus Z, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of an ordinary stiffener subject to lateral pressure are to be not less than the values obtained from the following formulae :

$$Z = \frac{(P_s+P_w)S l_s^2 10^3}{m\sigma_a} \quad (\text{cm}^3)$$

$$A_{sh} = \frac{5(P_s+P_w)S l_s}{\tau_a} \quad (\text{cm}^2)$$

where:

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to :

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at

both ends

l_s : Ordinary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all ordinary stiffener spans, the ordinary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10 % of the gross span, for each bracket.

3. Critical buckling stress check

(1) The compressive stress σ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, and the critical buckling stress σ_{CS}, to be evaluated as defined below :

$$\sigma \le 0.8\sigma_{CP}$$

$$\sigma_{CS} = \sigma_{ES} \quad \text{when} \quad \sigma_{ES} \le \frac{\sigma_y}{2}$$

$$= \sigma_y\left[1-\frac{\sigma_y}{4\sigma_{ES}}\right] \quad \text{when} \quad \sigma_{ES} > \frac{\sigma_y}{2}$$

where,

σ_y = minimum upper yield stress, in N/mm^2, of the material

σ_{ES} = ideal elastic buckling stress, in N/mm^2, of the secondary stiffener

= minimum between σ_{E3} and σ_{E4}

$$\sigma_{E3} = \frac{0.001\,EI_a}{Al^2}$$

E = modulus of elasticity, in N/mm^2

= 2.06×10^5 for steel

I_a = moment of inertia, in cm^4, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

A = cross-sectional area, in cm^2, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

l = span, in m, of the secondary stiffener

$$\sigma_{E4} = \frac{\pi^2 EI_w}{10^4 I_p l^2}\left(m^2+\frac{K}{m^2}\right)+0.385\,E\frac{I_t}{I_p}$$

$$K = \frac{Cl^4}{\pi^4 EI_w}\times 10^6$$

m = number of half waves, given by the following table :

	$0<K\le 4$	$4<K\le 36$	$36<K\le 144$	$(m-1)^2 m^2 < K \le m^2(m+1)^2$
m	1	2	3	m

I_w = sectorial moment of inertia, in cm^6, of the secondary stiffener about its connection with the plating

$= \dfrac{h_w^3\ t_w^3}{36} \times 10^{-6}$ for flat bar secondary stiffeners

$= \dfrac{t_f\ b_f^3\ h_w^2}{12} \times 10^{-6}$ for "Tee" secondary stiffeners

$= \dfrac{b_f^3\ h_w^2}{12(b_f + h_w)^2}\left[t_f\,(b_f^2 + 2b_f\,h_w + 4h_w^2) + 3t_w\,b_f\,h_w\right] \times 10^{-6}$ for angles and bulb secondary stiffener

I_p = polar moment of inertia, in cm^4, of the secondary stiffener about its connection with the plating

$= \dfrac{h_w^3\ t_w}{3} \times 10^{-4}$ for flat bar secondary stiffeners

$= \left(\dfrac{h_w^3\ t_w}{3} + h_w^2\ b_f\ t_f\right) \times 10^{-4}$ for flanged secondary stiffeners

I_t = St Venant's moment of inertia, in cm^4, of the secondary stiffener without top flange

$= \dfrac{h_w\ t_w^3}{3} \times 10^{-4}$ for flat bar secondary stiffeners

$= \dfrac{1}{3}\left[h_w\ t_w^3 + b_f\ t_f^3\left(1 - 0.63\dfrac{t_f}{b_f}\right)\right] \times 10^{-4}$ for flanged secondary stiffeners

h_w, t_w = height and net thickness, in mm, of the secondary stiffener, respectively

b_f, t_f = width and net thickness, in mm, of the secondary stiffener bottom flange, respectively

C = spring stiffness exerted by the hatch cover top plating

$$= \frac{k_p\ E\,t_p^3}{3S\left(1 + \dfrac{1.33k_p\ h_w\ t_p^3}{1000\,St_w^3}\right)} \times 10^{-3}$$

k_p = $1 - \eta_p$, to be taken not less than zero for flanged secondary stiffeners, k_p need not be taken less than 0.1

$\eta_p = \dfrac{\sigma}{\sigma_{E1}}$

σ = as defined in **502. 1**

σ_{E1} = as defined in **502. 3** (1)

t_p = net thickness, in mm, of the hatch cover plate panel

(2) For flat bar secondary stiffeners and buckling stiffeners, the ratio h / t_w is to be not greater than $15\ k^{0.5}$,

where:

h, t_w = height and net thickness of the stiffener, respectively

k = $235 / \sigma_y$

σ_y = minimum upper yield stress, in N/mm^2, of the material.

504. Primary supporting members

1. Application

The requirements in **3** to **5** apply to primary supporting members which may be analysed through isolated beam models. Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in **4**.

2. Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in **1**, the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \frac{S(P_s + P_w) l_m^2 10^3}{mZ} \quad (\text{N/mm}^2)$$

$$\tau = \frac{5S(P_s + P_w) l_m}{A_{sh}} \quad (\text{N/mm}^2)$$

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to :

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at both ends

l_m : Span of the primary supporting member, in m

S : Spacing of secondary stiffener, in m

A_{sh} : Net shear sectional area, in cm^2

Z : Net section modulus, in cm^3

3. Checking criteria

The normal stress σ and the shear stress τ, calculated according to 3. or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae :

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

4. Deflection limit

The net moment of inertia of a primary supporting member is to be such that the deflection does not exceed

$$\mu_{\max}$$

where:

μ : Coefficient taken equal to :

$0.0056\, l_{\max}$ for weathertight hatch covers

$0.0044\, l_{\max}$ for pontoon hatch covers

$l_{\max}$: Greatest span, in m, of primary supporting members.

5. Critical buckling stress check of the web panels of the primary supporting members.

(1) This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

(2) The shear stress τ in the web panels of the primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formulae :

$$\tau \le 0.8\tau_C$$

$$\tau_C = \tau_E \qquad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F\left[1 - \frac{\tau_F}{4\tau_E}\right] \qquad \text{when } \tau_E > \frac{\tau_F}{2}$$

where,

$\tau_F = \dfrac{\sigma_y}{\sqrt{3}}$

σ_y = minimum upper yield stress, in N/mm^2, of the material

$\tau_E = 0.9\, k_t\, E \left[\dfrac{t_{pr,n}}{1000\, d}\right]^2$

E = modules of elasticity, in N/mm^2

= 2.06 × 105 for steel

$t_{pr,n}$ = net thickness, in mm, of primary supporting member

$k_t = 5.35 + \dfrac{4.0}{(a/d)^2}$

a = greater dimension, in m, of web panel of primary supporting member

d = smaller dimension, in m, of web panel of primary supporting member.

(3) For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

(4) For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

6. Primary supporting members of variable cross-section

The net section modulus of primary supporting members with a variable cross-section is to be not less than the greater of the value obtained from the following formulae and the use of these formulae is limited to the determination of the strength of primary supporting members in which abrupt changes in the cross-section do not occur along their length. :

$$Z = Z_{CS} \quad (\text{cm}^3)$$

$$Z = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) Z_{CS} \quad (\text{cm}^3)$$

Z_{CS}: Net section modules calculated with considering the net thickness, in cm^3, for a constant cross-section, complying with the checking criteria in **504. 4.**

$\alpha = \dfrac{l_1}{l_0}$

$\psi = \dfrac{Z_1}{Z_0}$

l_1 : Length of the variable section part, in m (see **Fig 4.2.1**)

l_0 : Span measured, in m, between end supports (see **Fig 4.2.1**)

Z_1 : Net section modulus calculated with considering the net thickness at end, in cm^3 (see **Fig 4.2.1**)

Z_0 : Net section modulus calculated with considering the net thickness at mid-span, in cm^3 (see **Fig 4.2.1**)

Moreover, the net moment of inertia of primary supporting members with a variable cross-section calculated with considering it's net thickness is to be not less than the greater of the values obtained, in cm^4, from the following formulae :

$$I = I_{CS} \quad (cm^4)$$

$$I = (1 + 8\alpha^3 (\frac{1-\phi}{0.2 + 3\sqrt{\phi}})) I_{CS} \quad (cm^4)$$

I_{CS} : Net moment of inertia with a constant cross-section calculated with considering the net thickness, in cm^4, complying with **504. 5.**

$$\phi = \frac{I_1}{I_0}$$

I_1 : Net moment of inertia calculated with considering the net thickness at end with considering the net thickness, in cm^4 (see **Fig 4.2.1**)

I_0 : Net moment of inertia calculated with considering the net thickness at mid-span with considering the net thickness, in cm^4 (see **Fig 4.2.1**)

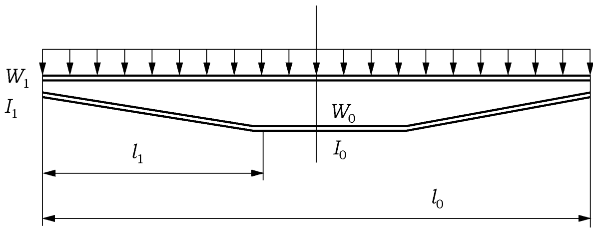


Fig 4.2.1 Variable cross-section stiffener

7. Buckling stiffeners on webs of primary supporting members

For buckling stiffeners on webs of primary supporting members, the ratio h_w / t_w is to comply with the following formulae :

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{\sigma_y}}$$

h_w : Web height of the stiffener (mm)

t_w : Net thickness of the stiffener (mm)

Section 6 Hatch Coamings

601. Stiffening

1. The ordinary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

2. Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances. Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

3. Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m. Where the height of the coaming exceeds 900 mm, additional strengthening may be required. However, reductions may be granted for transverse coamings in protected areas.

4. When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength. Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length. In some cases, the Society may require the continuity of coamings to be maintained above the deck.

5. Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

602. Load model

1. The lateral pressure P_c to be considered as acting on the hatch coamings are as follows.

(1) The pressure on the forward transverse hatch coaming of the foremost cargo hold is given by P_c = 290 (kN/m^2)
Where a forecastle deemed appropriate by the Society is fitted, however, this pressure may be reduced to 220 (kN/m^2).

(2) The pressure on the other coamings is given by P_c = 220 (kN/m^2)

(3) For cargo holds intended for the carriage of liquid cargoes, the liquid internal pressures applied on hatch coaming is also to be determined.

2. Where forward transverse hatch coaming of ships other than Bulk Carrier is protected by the adjacent forward cargo hold hatch or other structures effectively against the green sea forces the pressure may be suitably reduced in accordance with the discretion of the Society.

603. Scantlings

1. Plating

(1) The net thickness of the forward and side hatch coaming plate is not to be less than that obtained from the following formulae. The net thickness is not to be less than 9.5 mm.

$$t = 15.98S\sqrt{\frac{P_c}{0.95\sigma_y}}$$

S : The spacing of ordinary stiffener (m)

(2) For aft hatch coamings
- Where L is 100 m and under : $t = 4.5 + 0.05L$ (mm)
- Where L is greater than 100 m : $t = 9.5$ (mm)

2. Ordinary stiffeners

The net section modulus of the longitudinal or transverse ordinary stiffeners of hatch coamings is to be not less than the value obtained, in cm3, from the following formulae :

$$Z = 1.21 \frac{P_c S l^2 10^3}{m c_p \sigma_y}$$

l = span, in m

m = 16 in general

= 12 for the end span of stiffeners sniped at the coaming corners

c_p = Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness.

= 1,16 in the absence of more precise evaluation.

3. Coaming stays

The net section modulus, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in **Fig 4.2.2** and **Fig 4.2.3**) are to be not less than the values obtained from the following formulae :

$$Z = \frac{S_c P_c H_c^2 10^3}{2\sigma_a} \text{ (cm}^3\text{)}$$

$$t_w = \frac{S_c P_c H_c 10^3}{h \tau_a} \text{ (cm}^3\text{)}$$

where, H_c : Stay height, in m

S_c : Stay spacing, in m

h : Stay depth, in mm, at the connection with deck.

For calculating the section modules of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

For other designs of coaming stays, such as, for example, those shown in **Fig 4.2.4** and **Fig 4.2.5**, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae :

$\sigma \leq \sigma_a$

$\tau \leq \tau_a$

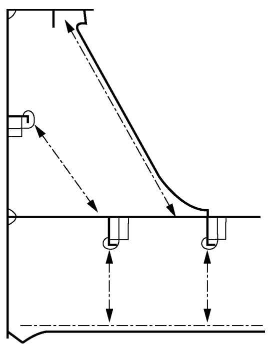


Fig 4.2.2 Coaming stay #1

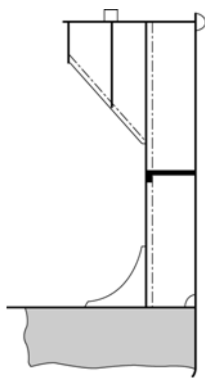


Fig 4.2.3 Coaming stay #2

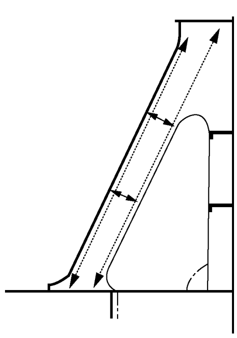


Fig 4.2.4 Coaming stay #3

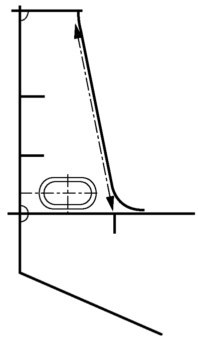


Fig 4.2.5 Coaming stay #4

4. Local details

(1) The design of local details is to comply with the requirements in this section for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below.
(2) Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.
(3) The normal stress σ and the shear stress τ, in N/mm^2, induced in the underdeck structures by the loads transmitted by stays are to comply with the following formulae :

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

(4) Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.
(5) Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld throat thickness is to be not less than 0.44 t_w, where t_w is the gross thickness of the stay web.
(6) Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

5. Coamings of small hatchways

The coaming plate thickness is to be not less than the lesser of the following values:

- the thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any,
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0.8 m or their greatest horizontal dimension exceeds 1.2 m, unless their shape ensures an adequate rigidity.

Section 7 Weathertightness, Closing Arrangement, Securing Devices and Stoppers

701. Weathertightness

1. Where the hatchway is exposed and closed with a single panel, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality. Weathertightness may also be ensured means of tarpaulins.

702. Gaskets

1. The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure through steel to steel contact. This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship's structure or by means of defined bearing pads.

2. The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements. Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

3. The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements. If necessary, suitable devices are to be fitted to limit such movements.

4. The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported. The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure. The gasket is to be effectively secured to the hatch cover.

5. Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

6. Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

7. In case of container ship with unusually large freeboard, gaskets may be omitted and clamping devices for steel hatchway covers may be suitably dispensed with at the discretion of the Society.

703. Closing arrangement, securing devices and stoppers

1. General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements. The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed. In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions. Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to **5.** to **7.** Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account. Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers. Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see **201**) are considered by the Society on a case by case basis. In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

2. Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers. Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices. At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels. The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

3. Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

4. Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible. Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers. Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

5. Area of securing devices

The gross cross area of each securing device is not to be less than the value obtained, in cm^2, from the following formula :

$$A = 1.4 S_S \left(\frac{235}{\sigma_y} \right)^{\alpha}$$

where,

S_S : Spacing, in m, of securing devices

α : Coefficient taken equal to: (0.75 for $\sigma_y > 235$ N/mm^2,
1.00 for $\sigma_y \leq 235$ N/mm^2)

In the above calculations, σ_y may not be taken greater than $0.7\sigma_t$.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified. In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

6. Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia of edge elements is to be not less than the value obtained, in cm^4, from the following formula :

$$I = 6 P_L S_S^4$$

where:

P_L : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

S_S : Spacing, in m, of securing devices

7. Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

8. Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure 175 kN/m^2. With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No.1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 when a forecastle is fitted.

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0.8 σ_y.

704. Tarpaulins

1. Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted. Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures. The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than :

- for waterproofing by tarring : 0.65 kg/m^2
- for waterproofing by chemical dressing : 0.60 kg/m^2
- for waterproofing by dressing with black oil : 0.55 kg/m^2

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

705. Cleats

1. Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

2. Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

706. Wedges, battens and locking bars

1. Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width. They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

2. Battens and locking bars

For all hatches steel bars or equivalent means shall be provided in order efficiently and independently to secure each section of hatch covers after tarpaulins are battened down. Hatch covers of more than 1.5 m in length shall be secured by at least two securing appliances. Acceptable equivalent means to steel bars shall consist of devices and materials which will provide strength equivalent to, and elasticity not greater than that of, steel. Steel wire rope cannot be regarded as satisfactory equivalent means.

Section 8 Additional Requirements

801. Portable beams

1. Carriers and sockets for portable beams are to be of substantial construction, having a minimum beaming surface of 75 mm, and are to be provided with means for efficient fitting and securing of the beams.

2. Coamings are to be stiffened in way of carriers and sockets by providing stiffeners from these fittings to the deck or equivalent strengthening.

3. Where sliding type of beams is used, the arrangement is to ensure that the beams remain properly in position where the hatchway is closed.

4. The depth of portable beams and the width of their face plates are to be suitable to ensure lateral stability of the beams. The depth of beams at their ends is not to be less than 0.4 times the depth at mid-span or 150 mm, whichever is greater.

5. The upper face plates of portable beams are to extend to the extreme ends of the beams. The web plates, for at least 180 mm at each ends, are to be increased in thickness to at least twice that at mid-span or to be reinforced with doubling plates.

6. Portable beams are to be provided with suitable gear for lifting on and off without getting upon them.

7. Portable beams are to be clearly marked to indicate the deck, hatchway and position to which they belong.

802. Steel pontoon cover

1. The depth of steel pontoon covers at supports is not to be less than one-third the depth at mid-span or 150 mm, whichever is greater.

2. The width of bearing surface for steel pontoon covers is not to be less than 75 mm.

3. Steel pontoon covers are to be clearly marked to indicate the deck, hatchway and position to which they belong.

803. Tarpaulins and securing arrangements for hatchway closed by portable covers

1. Battens are to be efficient for securing the tarpaulins and not to be less than 65 mm in width and 9 mm in thickness.

2. Wedges are to be fit the regulations of **706. 1.**

3. Cleats are to be set to fit the taper of the wedges. They are to be at least 65 mm wide and to be spaced not more than 600 mm from centre to centre. The cleats along each side are to be arranged not more than 150 mm apart from the hatch corners.

Section 9 Drainage

901. Arrangement

1. Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

2. Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

3. Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

4. If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

Section 10 Miscellaneous Openings

1001. Companionways

1. All openings in freeboard decks other than hatchways are to be protected by an enclosed superstructure, or by a deckhouse or companionway of equivalent strength.

2. In Position I the height above the deck of sills at the doorways in companionways is to be at least 600 mm. In Position II it is to be at least 380 mm.

1002. Protection of machinery space openings

Machinery space openings are to be efficiently enclosed by steel casings of ample strength. Machinery openings provided on freeboard deck are to be placed in superstructures or deckhouses as far as possible. Where the casings are not protected by other structures, the sills of access openings are not to be less than 600 mm in height above the deck in Position I and not to be less than 380 mm in Position II. The access openings are to be provided with permanent closures.

1003. Closures for access openings or openings

1. Annular spaces around funnels and all other openings in the machinery casings are to be provided with closing means capable of being operated from outside the machinery space in case of fire.

2. Access openings in the machinery spaces are to be provided with steel doors and to be located in enclosed positions as far as possible. Access openings above freeboard deck not within an enclosed superstructure are to be provided with doors capable of being closed and secured from both sides. Doors to exposed access openings on freeboard and sunken poop decks are to be of the outward opening type.

3. Exposed openings on tops of machinery casings are to be provided with covers capable of being readily closed and secured. ⚓

CHAPTER 3 BOW DOORS, SIDE AND STERN DOORS

Section 1 Bow Doors and Inner Doors

101. General

1. Application

(1) These requirements apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

(2) The requirements apply to all ro-ro passenger ships and ro-ro cargo ships engaged on international voyages and also to ro-ro passenger ships and ro-ro cargo ships engaged only in domestic (noninternational) voyages, except where specifically indicated otherwise herein.

(3) The requirements are not applicable to high speed, light displacement craft as defined in the IMO Code of Safety for High Speed Craft.

(4) The bow door and inner door of all existing ro-ro passenger ships constructed before or on 30 June 1996 are to be deemed appropriate by the Society.

2. Kinds of bow doors

The kinds of bow doors which are applied by this Chapter are generally two types as follows. However, other types of bow doors will be specially considered in association with the applicable requirements of these rules by the Society, except for following (1) and (2).

(1) Visor door
Visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

(2) Side-opening door
Side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated the side-opening bow doors are arranged in pairs.

3. Arrangement

Arrangements for the bow door and inner door are to comply with the following (1) to (5)

(1) Bow doors are to be situated above the freeboard deck except that where a watertight recess fitted for arrangement of ramps or other related mechanical devices is located forward of the collision bulkhead and above the deepest waterline, the bow doors may be situated above the recess.

(2) An inner door which is to be part of the collision bulkhead is to be fitted. The inner door does not need to be fitted directly above the bulkhead. Where the vehicle ramp is arranged as a part of collision bulkhead, and its position complies with requirements of **Pt 3, Ch 14, 201.**, the vehicle ramp may be regarded as an inner door. If this is not possible, a separate inner weather door is to be installed.

(3) Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in **Pt 3, Ch 14, 201.**

(4) Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

(5) The requirements for inner doors are based on the assumption that vehicle are effectively lashed and secured against movement in stowed position.

4. Definitions

The definitions which are used in this Chapter are as follows.

(1) Securing device

A device used to keep the door closed by preventing it from rotating about its hinges or its pivoted attachments to the ship.

(2) Supporting device
A device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed devices, that transmits loads from the door to the ship's structure.

(3) Locking device
A device that locks a securing device in the closed position.

(4) Ro-ro passenger ship
Passenger ship with ro-ro spaces or special category spaces.

(5) Ro-ro spaces
Ro-ro spaces are spaces not normally sub-divided in any way and normally extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion and/or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or, other receptacles) can be loaded and unloaded normally in a horizontal direction.

(6) Special category spaces
Special category spaces are those enclosed vehicle spaces above or below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

102. Strength criteria

1. Primary structure and securing and supporting devices

Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be determined to withstand the design loads defined in **103.**, using the following permissible stresses of **Table 4.3.1.**

Table 4.3.1 Permissible stress for primary members, securing and supporting devices

Stress	Permissible stress (N/mm^2)
Shear stress (τ)	$\tau = 80/K$
Bending stress (σ)	$\sigma = 120/K$
Equivalent stress $\left(\sigma_e = \sqrt{\sigma^2 + 3\tau^2}\right)$	$\sigma_e = 150/K$
K = material factor as specified in **Table 4.3.2**	

2. The buckling strength of primary members is to be verified as being adequate.

3. Stress of steel bearings in securing and supporting devices

For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8\sigma_y$.

σ_y = the yield stress of the bearing material

4. Tensile stress on threaded bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of bolts not carrying support forces is not to exceed $125/K$ (N/mm^2).

K = material factor as specified in **Table 4.3.2.**

103. Design loads

1. Bow doors

(1) External pressure

Design external pressure P_e, to be considered for the scantlings of primary members, securing and supporting devices of bow doors is to be taken as indicated by the following formula.

$$P_e = 2.75\lambda C_H(0.22 + 0.15\tan\alpha)(0.4V\sin\beta + 0.6\sqrt{L})^2 \quad (\text{kN/m}^2)$$

where :

V = contractual ship's speed, in knots

L = ship's length, in m, as specified in **Pt 3, Ch 1, 102.**, but need not be taken greater than 200 m.

λ = coefficient depending on the area where the ship is intended to be operated :

for sea going ships $\lambda = 1.0$

for ships operated in coastal waters $\lambda = 0.8$

for ships operated in sheltered waters $\lambda = 0.5$

C_H = coefficient that obtained from ship length as specified in **Table 4.3.3.**

α = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating measured in a vertical plane normal to the horizontal tangent to the shell plating (See **Fig 4.3.1**).

β = entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centerline and the tangent to the shell plating in a horizontal plane (See **Fig 4.3.1**).

Table 4.3.2 Material factor K

Material	K
A, B, D or E	1.0
AH 32, DH 32 or EH 32	0.78
AH 36, DH 36 or EH 36	0.72

Table 4.3.3 Coefficient C_H

L	C_H
$L < 80m$	$L/80$
$L \geq 80m$	1.0

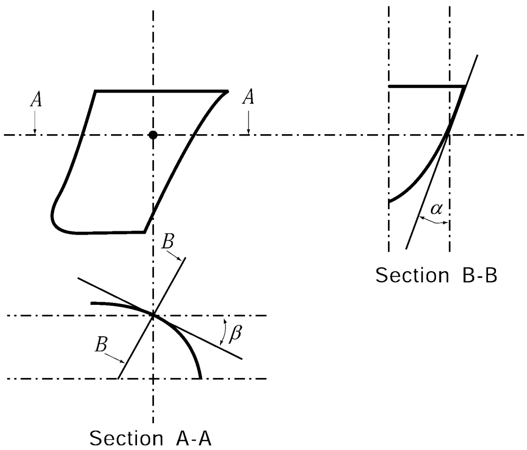


Fig 4.3.1 Entry and flare angle

(2) External forces

The design external forces considered in determining scantlings of securing and supporting devices of bow doors are not to be taken less than those given by the following formulae.

$F_x = P_{em} A_x$

$F_y = P_{em} A_y$

$F_z = P_{em} A_z$

F_x = the design external force (kN) in the longitudinal direction.

F_y = the design external force (kN) in the horizontal direction.

F_z = the design external force (kN) in the vertical direction.

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. (see **Fig 4.3.2**)

Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. (see **Fig 4.3.2**)

Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

A_z = area, in m^2, of the horizontal projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. (see **Fig 4.3.2**)

Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

h = height(m) of the door between the levels of the bottom of the door and the upper deck, or between the bottom of the door and the top of the door, whichever is lesser.

l = fore and aft length(m^2) of the door at a height $h/2$ above the bottom of the door.

P_{em}= external pressure, in kN/m^2, as given in **103.1** (1) with angles α_m and β_m defined as follows :

α_m = flare angle measured at a point on the bow door $l/2$ aft of the stem line on a plane $h/2$ above the bottom of the door (See **Fig 4.3.3**).

β_m = entry angle measured at a point on the bow door $l/2$ aft of the stem line on a plane $h/2$ above the bottom of the door (See **Fig 4.3.3**).

For doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the area and angles used for determination of the design values of external forces may require to be specially considered.

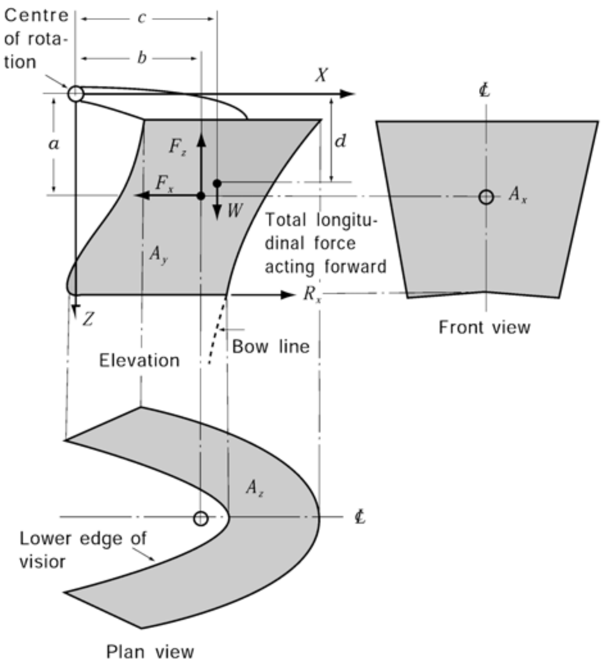


Fig 4.3.2 Visor type bow door

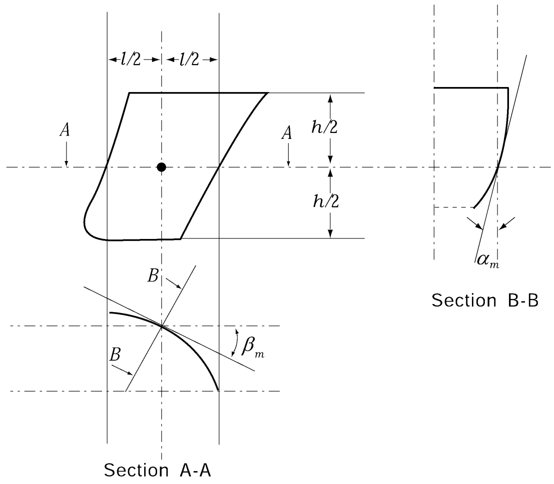


Fig 4.3.3 α_m **and** β_m

(3) For visor doors the closing moment M_y under external loads, in kN-m, is to be taken as the following formula.

$$M_y = F_x a + 10Wc - F_z b \quad \text{(kN-m)}$$

F_x and F_z = as specified in above (2).

W = mass of the visor door (ton)

a = vertical distance from visor pivot to the centroid of the transverse vertical projected area of the visor door (m)

b = horizontal distance from visor pivot to the centroid of the horizontal projected area of the visor door (m)

c = horizontal distance from the visor pivot to the center of gravity of the visor mass (m)

(4) Moreover, the lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1.5 kN/m^2 is to be taken into account.

2. Inner door

(1) External pressure

The design external pressure, in kN/m^2, considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of P_{e1} or P_{e2} as given by the following formulae.

$$P_{e1} = 0.45L \quad (\text{kN/m}^2), \qquad P_{e2} = 10h \quad (\text{kN/m}^2)$$

h = the distance from the load point to the top of the cargo space (m).

L = ship's length, as defined in **Pt 3, Ch 1, 102.** (m). But need not be taken greater than 200 m.

(2) Internal pressure
The design internal pressure, P_i, considered for the scantlings of securing devices of inner doors is not to be less than 25 kN/m^2.

104. Scantlings of bow doors

1. General

(1) The strength of bow doors is to be commensurate with that of the surrounding structure.
(2) Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

2. Primary structure

Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in **103. 1** (1) and permissible stresses given in **Table 4.3.1**. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

3. Secondary stiffeners

Secondary stiffeners are to be supported by primary members constituting the main stiffening of the door. The section modulus of secondary stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow doors stiffeners. In addition, stiffener webs are to have a net sectional area, A, not less than that obtained from the following formula.

$$A = \frac{QK}{10} \quad (\text{cm}^2)$$

Q = shear force (kN) in the stiffener calculated by using uniformly distributed external pressure P_e

P_e = as specified in **103. 1** (1)

K = material factor as specified in **Table 4.3.2**

4. Plating

The thickness of bow door plating is to be not less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

105. Scantlings of inner doors

1. General

(1) Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in **103. 2** (1) and permissible stresses given in **Table 4.3.1.** Normally, formulate for simple beam theory may be applied.
(2) Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

106. Securing and supporting of bow doors

1. General

(1) Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.
(2) The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.
(3) Where packing is required, the packing material is to be of a comparatively soft type, and the

supporting forces are to be carried by the steel structure only. Other types of packing may be considered.

(4) Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

(5) A means is to be provided for mechanically fixing the door in the open position.

(6) Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices.

(7) Small and/or flexible devices such as cleats intended to provide load compression of the packing material are not generally to be included in the calculations.

(8) The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirements for redundant provision given in **Par 2** (6), (7) and the available space for adequate support in the hull structure.

(9) For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that $M_y > 0$. Moreover, the closing moment M_y as given in **103. 1,** (3) (A) is to be not less than:

$$M_{yo} = 10\,Wc + 0.1\sqrt{a^2+b^2} \times \sqrt{F_x^2+F_z^2} \quad \text{(kN-m)}$$

W, a, b, c, F_x and F_z = as specified in **103.**

2. Scantlings

(1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in **Table 4.3.1.**

(2) For visor doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door :

(A) Case 1 F_x and F_z

(B) Case 2 0.7 F_y acting on each side separately together with 0.7 F_x and 0.7 F_z
where F_x, F_y and F_z are determined as indicated in **103. 1** (2) and applied at the centroid of projected areas.

(3) For side-opening doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

(A) Case 1 F_x, F_y and F_z

(B) Case 2 0.7 F_x and 0.7 F_z acting on both doors and 0.7 F_y acting on each door separately.
where F_x, F_y and F_z are determined as indicated in **103. 1** (2) and applied at the centroid of projected areas.

(4) The support forces as determined according to above (2) (A) and (3) (A) shall generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

(5) The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

(6) The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 percent the permissible stresses as given in **Table 4.3.1.**

(7) For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in **Table 4.3.1.** The opening moment M_0, in kN-m, to be balanced by this reaction force, is not to be taken less than:

$$M_0 = 10\,Wd + 5A_x a \quad \text{(kN-m)}$$

where :

A_x = as specified in **103.1** (2)

a = as specified in **103.1** (3)

d = vertical distance from the hinge axis to centre of gravity of the door (m)

W = as specified in **103.1** (3)

(8) For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force ($F_z - 10W$), in kN, within the permissible stresses given in **Table 4.3.1.**

(9) All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

(10) For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent on leaf to shift towards the other one under effect of unsymmetrical pressure (See **Fig 4.3.4**). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices.

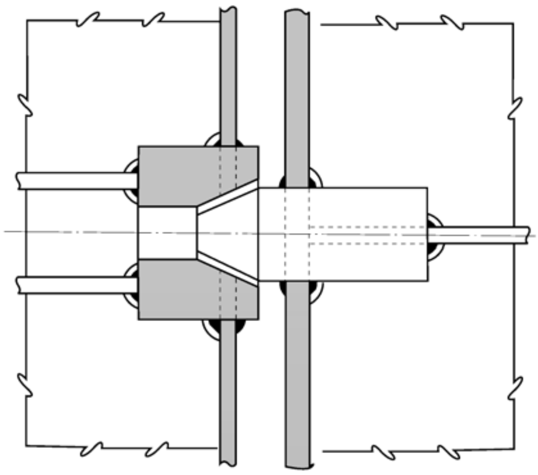


Fig 4.3.4 Example of thrust bearing

107. Securing and locking arrangement

Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or to be of the gravity type. Those devices are to comply with the requirements of the following **Par 1**. and **2.**

1. Operation

Securing devices are to be simple to operate and easily accessible. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

(1) Hydraulic securing devices
Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

(2) Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of
(A) the closing and opening of the doors, and
(B) associate securing and locking devices for every door.

(3) Remote control
Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to

be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

2. Indication and monitoring

(1) Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.
(2) The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system for operating and closing doors is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply e.g. UPS. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.
(3) The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that audible alarm is given on the navigation bridge if the vessel leaves harbour with the bow door or inner door not closed or with any of the securing devices not in the correct position.
(4) A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.
(5) Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to monitor the position of the doors and a sufficient number of their securing devices. Special consideration is to be given for the lighting and contrasting colour of objects under surveillance.
(6) A drainage system is to be arranged in the area between bow door and ramp or where no ramp is fitted between the bow door and inner door. The system is to be equipped with an audible alarm function to the navigation bridge being set off when the water levels in these areas exceed 0.5m or the high water level alarm, whichever is lesser.
(7) The indicator system is considered designed on the fail - safe principal in above (2) to (6) when:
  (A) The indication panel is provided with:
    - a power failure alarm
    - an earth failure alarm
    - a lamp test
    - separate indication for door closed, door locked, door not closed and door not locked.
  (B) Limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series).
  (C) Limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series).
  (D) Two electrical circuits (also in one multicore cable), one for the indication of door closed / not closed and the other for door locked / not locked.
  (E) In case of dislocation of limit switches, indication to show : not closed / not locked / securing arrangement not in place - as appropriate.
(8) For ro-ro passenger ships on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television suveillance, so that any movement of vehicles in adverse weather conditions or unauthorized access by passengers thereto, can be detected whilst the ship is underway.

108. Operating and maintenance manual

1. An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain necessary information after approval of this society.

(1) main particulars and design drawings
  (A) special safety precautions
  (B) details of vessel, class, statutory certificates
  (C) equipment and design loading (for ramps)

(D) key plan of equipment (doors and ramps)
(E) manufacturer’s recommended testing for equipment
(F) description of equipment
(a) bow doors
(b) inner bow doors
(c) bow ramp/doors
(d) side doors
(e) stern doors
(f) central power pack
(g) bridge panel
(h) engine control room panel
(2) service conditions
(A) limiting heel and trim of ship for loading/unloading
(B) limiting heel and trim for door operations
(C) doors/ramps operating instructions
(D) doors/ramps emergency operating instructions
(3) maintenance
(A) schedule and extent of maintenance
(B) trouble shooting and acceptable clearances
(C) maufacturer’s maintenance procedures
(4) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This Manual has is to be submitted for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

2. Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted in appropriate place.

Section 2 Side and Stern Doors

201. General

1. Application

(1) These rules give requirements for the arrangement, strength and securing of side shell doors, abaft the collision bulkhead, and stern doors leading into enclosed spaces.
(2) The side shell door and stern door of all existing ro-ro passenger ships constructed before or on 30 June 1996 are to be as deemed appropriate by the Society.

2. Arrangement

(1) Stern doors for passenger vessels are to be situated above the freeboard deck. Stern doors for ro-ro cargo ships and side shell doors may be either below or above the freeboard deck.
(2) The side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.
(3) In general, the lower edge of door openings is not to be below a line drawn parallel to the freeboard deck at side, which has at its lowest point the upper edge of the uppermost load line.
(4) Where side door and stern door are unavoidably provided below the line as stipulated in above (3), the following conditions are to be satisfied.
(A) Compartment being equivalent to watertight-bulkhead in strength and watertightness is to be provided and the second door is to be fitted for the compartment.
(B) Detecting device for sea water leakage is to be provided in the compartment and drainage means of the compartment with a screw-down stop valve capable of being controlled from easily accessible position is to be provided.
(5) Doors are generally to be arranged to open outwards.

3. Definitions

The definitions specified in this Section are to be in accordance with **101.4.**

202. Strength criteria

1. Primary structure and securing and supporting devices

Scantlings of the primary members, securing and supporting devices of doors are to be determined to withstand the design loads defined in **203.**, using the following permissible stresses of **Table 4.3.1.**

2. The bucking strength of primary members is to be verified as being adequate.

3. Steel of steel bearings in securing and supporting devices

For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8\sigma_y$.

σ_y = the yield stress of the bearing material.

4. Tensile stress on threaded bolts

The arrangements of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads bolts not carrying support forces is not to exceed $125/K$ (N/mm^2).

K = material factor as specified in **Table 4.3.2.**

203. Design Loads

The design forces considered for the scantlings of primary members, securing and supporting devices are not to be less than the following **Par 1** to **3.**

1. Design forces for securing or supporting devices of doors opening inwards :

External force : $F_e = AP_e + F_p$ (kN)

Internal force : $F_i = F_0 + 10W$ (kN)

2. Design forces for securing or supporting devices of doors opening outwards :

External force : $F_e = AP_e$ (kN)

Internal force : $F_i = F_0 + 10W + F_p$ (kN)

3. Design forces for primary members is to be taken as the greater of the following two formulae :

External force : $F_e = AP_e$ (kN)

Internal force : $F_i = F_0 + 10W$ (kN)

where :

A = area, in m^2, of the door opening

W = mass of the door (ton)

F_p = total paking force in kN, packing line pressure is normally not to be taken less than 5 N/mm.

F_0 = the greater of F_c and $5A$ (kN)

F_c = accidental force, in kN, due to loose of cargo etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.

P_e = external design pressure, in kN/m^2, determined at the centre of gravity of the door opening and not taken less than the value obtained from the following formulae.

for $Z_G < T$, $10(T - Z_G) + 25$

for $Z_G \geq T$, 25

However, for stern doors of ships fitted with bow doors, P_e is not to be taken less than:

$$P_e = 0.6 \lambda C_H (0.8 + 0.6 \sqrt{L})^2 \quad (\text{kN/m}^2)$$

where :

C_H = coefficient that obtained from ship's length as specified in **Table 4.3.3.**

L = ship's length, in m, as specified in **Pt 3, Ch 1, 102.** but need not be taken greater than 200 m

Z_G = height of the center of area of the door, in m, above the baseline

λ = coefficient depending on the area where the ship is intended to be operated :

for sea going ships λ = 1

for ships operated in coastal waters λ = 0.8

for ships operated in sheltered waters λ = 0.5

T = draught, in m, at the highest subdivision load line

204. Scantlings

1. General

(1) In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

(2) Side and stern door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

(3) Side and stern doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/maneuvering arms and hinges to the door structure and to the ship structure.

(4) Where side and stern doors also serve as vehicle ramps, the design of the hinges should take into account the ship angle of trim which may result in uneven loading on the hinges.

2. Plating

(1) The thickness of the side and stern door plating is not to be less than the side shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum shell plate thickness.

(2) Where side and stern doors also serve as vehicle ramps, the plating is not to be less than required for vehicle decks.

3. Stiffeners

(1) The section modulus of horizontal or vertical stiffeners is not to be less than required for side framing. Consideration is to be given, where necessary, to differences in fixity between ship's frame and door stiffeners.

(2) Where side and stern doors also serve as vehicle ramps, the stiffener scantlings are not to be less than required for vehicle decks.

(3) Where necessary, side and stern door stiffeners are to be supported by girders or stringers.

4. Primary members

(1) Scantlings of primary members are generally to be supported by direct calculations in association with the design forces given in **203. 3** and permissible stresses given in **Table 4.3.1.** Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

(2) The webs of girders and stringers are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

(3) The girder system is to be given sufficient stiffness to ensure integrity of the boundary support

of the door.

(4) Edge stiffeners/girders should be adequately stiffened against rotation and are to have a moment of inertia, I, not less than that obtained from following formula.

$$I = 8 P_I d^4 \quad (\text{cm}^4)$$

d = distance (m) between closing devices.

P_I = packing line pressure along edges, not to be taken less than 5 N/mm.

(5) For edge girders supporting main door girders between securing devices, the moment of inertia is to be increased in relation to the additional force.

205. Securing and supporting

1. General

(1) Side shell doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.
(2) A means is to be provided for mechanically fixing the door in the open position.
(3) The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.
(4) Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered.
(5) Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.
(6) Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices.
(7) Small and/or flexible devices such as cleats intended to provide local compression of the packing material are not generally to be included in the calculations.
(8) The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirement for redundant provision given in **Par 2,** (3) and the available space for adequate support in the hull structure.

2. Scantlings

(1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in **Table 4.3.1.**
(2) The distribution of the reaction forces action on the securing devices and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.
(3) The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 percent the permissible stresses as given in **Table 4.3.1.**
(4) All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

206. Securing and locking arrangement

Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or to be of the gravity type. Those devices are to comply with the requirements of the following **Par 1** and **2.**

1. Operation

Securing devices are to be simple to operate and easily accessible. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

(1) Doors which are located partly or totally below the free board deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the freeboard deck, of
(A) the closing and opening of the doors,
(B) associated securing and locking devices.
(2) Remote control
For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.
(3) Hydraulic securing devices
Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when closed position.

2. Systems for indication/monitoring

The following requirements apply to doors in the boundary of special category spaces or ro-ro spaces. For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this section need not be applied.

(1) Indicators
The indicator system is to be designed on the fail safe principle and in accordance with the following (A) to (D).
(A) Location and type
Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel on the navigation bridge is to be equipped with mode a section function "harbour/sea voyage", so arranged that audible alarm is given if vessel leaves harbor with side shell or stern doors not closed or with any of the securing devices not in the correct position.
(B) Indicator lights
Indicator lights are to be designed so that they cannot be manually turned off. The indication panel is to be provided with a lamp test-function
(C) Power supply
The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a backup power supply.
(D) Protection of sensors
The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.
(2) Water leakage protection
(A) For passenger ships, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the side shell and stern doors.
(B) For cargo ships, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge of leakage through the side shell and stern doors.

207. Operating and maintenance manual

1. An Operating and Maintenance Manual for the side shell and stern doors is to be submitted for the approval of the Society before providing it on board and contain the following (1) through (4).

(1) main particulars and design drawings,
(2) service conditions(e.g. service restrictions, emergency operations, acceptable clearances for supports)
(3) maintenance and function testing,
(4) register of inspections and repairs.

2. Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places. ⚓

CHAPTER 4 BULWARKS, FREEING PORTS, SIDE SCUTTLES, RECTANGULAR WINDOWS, SKYLIGHTS VENTILATORS AND PERMANENT GANGWAYS

Section 1 Bulwarks and Guardrails

101. Arrangements

Bulwarks or guardrails are to be provided on all exposed parts of the freeboard and superstructure decks and on top of all other exposed deck houses. The height of bulwarks and guardrails is to be at least 1 *metre* from the top of deck. Where this height is considered to interfere with the normal operation of the ship and where deemed necessary by the Society, a lesser height may be permitted subject to the Society's approval.

102. Strength of bulwarks

1. The bulwarks are to be strongly constructed and effectively stiffened on their upper edge.

2. The thickness of bulwarks on the freeboard decks is not to be less than 6 mm.

3. Bulwarks are to be supported by strong stays attached to deck in way of the beams and spaced not more than 1.8 *metres* apart on freeboard deck.

4. Stays are to be made of bulb plates or flanged plates and effectively attached to deck and bulwark.

103. Bulwarks of timber carriers

Decks which are designed to carry timber deck cargoes are to be provided with bulwarks more than 1 *metre* in height or with specially strong guardrails. The upper edges of the bulwarks are to be well stiffened and supported by specially strong stays spaced not more than 1.5 *metres* and attached to deck in way of the beams. Necessary freeing ports are to be provided in the bulwarks.

104. Reinforcement of bulwarks

1. Gangways and other openings in bulwarks are to be well clear of the breaks of superstructures.

2. Where bulwarks are cut to form gangways or other openings, stays of increased strength are to be provided at the ends of the openings.

3. The plating of bulwarks in way of mooring pipes or eye plates for cargo handling is to be doubled or increased in thickness.

4. At the ends of superstructures, the bulwark rails are to be bracketed either to the superstructure end bulkheads or to the stringer plates of the superstructure decks, or other equivalent arrangements are to be made so that the abrupt change of strength is avoided.

105. Expansion joint

Long bulwarks are to be so arranged that they are not affected as far as possible by the stress of the main hull structures and expansion joints are to be provided all suitable locations.

106. Guardrails

1. Guard rails fitted on superstructure and freeboard decks shall have at least three courses. The opening below the lowest course of the guard rails shall not exceed 230 mm. The other courses shall be not more than 380 mm apart. In the case of ships with rounded gunwales the guard rail supports shall be placed on the flat of the deck. In other locations, guardrails with at least two courses shall be fitted.

2. Fixed, removable or hinged stanchions shall be fitted about 1.5 m apart. Removable or hinged stanchions shall be capable of being locked in the upright position. At least every third stanchion shall be supported by a bracket or stay.

3. Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails. Wires shall be made taut by means of turnbuckles. And chains fitted between two fixed stanchions and/or bulwarks are acceptable in lieu of guard rails.

Section 2 Freeing Ports

201. General

1. Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

2. Ample freeing ports are to be provided for clearing any space other than wells, where water is liable to be shipped and to remain.

3. In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within superstructures is to be provided.

4. In ships having a reduced freeboard, guardrails are to be provided for at least a half of the length of the exposed parts of weather deck or other effective freeing arrangements are to be considered, as required by the Society.

202. Freeing port area

1. The freeing port area on each side of the ship for each well on the freeboard and raised quarter decks is not to be less than that obtained from **Table 4.4.1.**

Table 4.4.1 Total area of freeing port

Length of bulwarks	Total area of freeing ports (m^2)	
	Freeboard and raised quarter decks	Superstructure decks
$l \le 20$ m	$A = 0.035l + 0.7 + a$	$A = \dfrac{0.035l + 0.7 + a}{2}$
$l > 20$ m	$A = 0.07l + a$	$A = \dfrac{0.07l + a}{2}$

l = length of bulwark (m), but need not be taken as greater than $0.7L_f$
a = as obtained from the following table

Height of bulwarks (m)	Correction value (m^2)
$h < 0.9$	$a = -0.04l(0.9 - h)$
$0.9 \le h \le 1.2$	$a = 0$
$1.2 < h$	$a = 0.04l(h - 1.2)$

h = average height of bulwalks above the deck (m)

2. In ships either without sheer or with less sheer than the standard, the minimum freeing port area obtained from the formulae in **Par 1** is to be increased by multiplying the factor obtained from the following formula :

$$a_0 = 1.5 - \frac{S}{2S_0}$$

where:

S = average height of actual sheer (mm)

S_0 = average height of the standard sheer given by the International Convention on Load Lines, 1966 (mm)

3. Where a ship is provided with a trunk or a hatch side coaming which is continuous or substantially continuous between detached superstructures, the area of freeing port opening is not to be less than that given by **Table 4.4.2.**

Table 4.4.2 Area of freeing ports

Breadth of hatchway of trunk	Area of freeing ports in relation to the total area of bulwark
$0.4B_f$ or less	0.2
$0.75B_f$ or more	0.1
NOTE : The area of freeing ports at intermediate breath is to be obtained by interpolation.	

4. Notwithstanding the requirements in **Pars 1** to **3,** where deemed necessary by the Society in ships having trunks on the freeboard deck, guardrails are to be provided instead of bulwarks on the freeboard deck in way of trunks for more than half of the length of trunk.

203. Arrangement of freeing ports

The lower edges of the freeing ports are to be as near the deck as possible and two-thirds of the freeing ports area required by **202.** is to be provided in the half of the well near the lowest point of the sheer curve.

204. Construction of freeing ports

1. Where both the length and the height of freeing ports exceed 230 mm respectively, freeing ports are to be protected by rails spaced approximately 230 mm apart.

2. Where shutters are provided to freeing ports, ample clearance is to be provided to prevent jamming. Hinge pins or bearings of the shutters are to be of non-corrodible metal. Shutters are not to be provided with securing appliances.

Section 3 Side Scuttles, Rectangular Windows and Skylights

301. General

1. The requirements in this chapter apply to side scuttles and rectangular windows on the side shell, superstructure and deckhouse up to the third tier above the freeboard deck. The requirements for the side shell, superstructure and deckhouse above the third tier are to be as deemed appropriate by the Society.

2. Notwithstanding the above **1.** windows on the deckhouse up to the third tier above the freeboard deck may be as deemed appropriate by the Society subject that such windows do not interfere with watertightness of a ship and are deemed as necessary for the ship's operation such as those on a navigation bridge.

302. Position of side scuttles

1. No side scuttle is to be provided in such a position as its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point $0.025B_f$ or 500 mm, above the summer load line(or timber load line), whichever is the greater. All side scuttles sill of which is below the freeboard deck and which are of hinged type are to be provided with locking arrangements.

2. No side scuttle is to be provided to any space solely engaged in carriage of cargoes.

303. Application of side scuttles

1. Side scuttle inboard are to be class A, class B, class C side scuttles complying with the requirements in **Ch 8, Sec. 8.**

2. Class A, class B and class C side scuttles are to be so arranged that their design pressure is less than the maximum allowable pressure determined to their grades and nominal diameters.

3. Side scuttle to spaces below the freeboard deck and those provided to sunken poop are to be class A side scuttle, class B side scuttle or equivalent thereto.

4. Side scuttles to spaces below freeboard deck, within the first tier of superstructure, those fitted up to the first tier of the deckhouse on the freeboard deck which have unprotected deck openings leading to spaces below the freeboard deck inside, deckhouses considered buoyant in stability calculations and those exposed to direct blow of seas are to be class A, class B side scuttle with dead light or equivalent thereto.

5. Side scuttles fitted in spaces which give direct access to an open stairway and provided in deckhouse and companion which protect the openings specified in below, are to be class A, class B side scuttle with dead light or equivalent thereto. Where cabin bulkhead or doors separate side scuttles from a direct access leading below the freeboard deck, application of side scuttle is to be as deemed appropriate by the Society.

6. Side scuttles to the spaces in the second tier on the freeboard deck, protecting direct access below or considered buoyant in stability calculations, are to be class A, class B side scuttles or equivalent thereto.

7. In ships with specially reduced freeboard, side scuttles located below the waterline after flooding into compartments are to be of fixed type.

8. Side scuttles shall be of non-opening type in ships subject to damage stability regulations, if calculations indicate that they would become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case.

9. Deckhouses situated on a raised quarter deck or on the deck of a superstructure of less than standard height or on the deck of a deckhouse of less than standard height, may be regarded as being in the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarter deck, superstructure or deckhouse is equal to, or greater than, the standard quarter deck height.

304. Protection of side scuttles

All side scuttles in way of the anchor housing and other similar places where they are liable to be damaged are to be protected by strong gratings.

305. Design pressure and maximum allowable pressure of side scuttles.

1. The design pressure of side scuttle is to be less than the maximum allowable pressure determined to their nominal diameters and classes. The design pressure P is to be determined using the following equation.

$$P = 10ac(bf - y) \quad (kPa)$$

a, b, c and f: As specified **Pt 3, Ch 17, 201.**

y : Vertical distance from summer load line to sill of side scuttle(m). Where timber load line is given, vertical distance from timber load line to sill of side scuttle.

2. Notwithstanding the provision of **1.** above, the design pressure is not to be less than minimum design pressure as given in **Table 4.4.4.**

Table 4.4.3 Maximum allowable pressure of side scuttles

class	Nominal diameter(mm)	Glass thickness(mm)	Max. allowable pressure(kPa)
A	200	10	328
	250	12	302
	300	15	328
	350	15	241
	400	19	297
B	200	8	210
	250	8	134
	300	10	146
	350	12	154
	400	12	118
	450	15	146
C	200	6	118
	250	6	75
	300	8	93
	350	8	68
	400	10	82
	450	10	65

Table 4.4.4 Minimum design pressure

Ship's length	$L \leq 250$ m	$L > 250$ m
Exposed front bulkhead of the first tier superstructure(kPa)	$25 + L/10$	50
Othe places(kPa)	$12.5 + L/20$	25

306. Position of rectangular windows

No rectangular window is to be provided to spaces below the freeboard deck, the first tier of superstructure and the first tier of the deckhouse considered buoyant in stability calculations or which protect deck openings leading to spaces below the freeboard deck.

307. Application of rectangular windows

1. Rectangular windows inboard are to be class F, class E rectangular windows complying with the requirements in **Ch. 8, Sec. 9** or equivalent thereto.

2. Class E and class F rectangular windows are to be so arranged that those design pressure is less than the maximum allowable pressure determined to their nominal sizes and classes.

3. Rectangular windows to the spaces in the second tier on the freeboard deck which gives direct access to a space within the first tier of enclosed superstructure or below the freeboard deck, are to be provided with hinged deadlight or fixed shutter. Where cabin bulkhead or door separate the space within the second tier from spaces below the freeboard deck or spaces within the first tier of enclosed superstructure, application of rectangular windows to the spaces within the second tier is to be as deemed appropriate by the Society.

4. Rectangular windows to the space in the second tier on the freeboard deck considered buoyant in stability calculations are to be provided with hinged deadlight or fixed shutter.

308. Design pressure and maximum allowable pressure of rectangular windows.

1. The design pressure of rectangular window is to be less than the maximum allowable pressure determined to their nominal diameters and classes. The design pressure P is to be determined using the following equation.

$$P = 10ac(bf - y) \quad \text{(kPa)}$$

a, b, c and f : As specified **Pt 3, Ch 17, 201.**

y : Vertical distance from summer load line to sill of rectangular window(m). Where timber load line is given, vertical distance from timber load line to sill of rectangular window.

2. Notwithstanding the provision of **1.** above, the design pressure is not to be less than minimum design pressure as given in **Table 4.4.4.**

Table 4.4.5 Maximum allowable pressure of rectangular window

Class	Nominal size Width(mm) × Height(mm)	Glass thickness (mm)	Maximum allowable pressure(kPa)
E	300 × 425	10	99
	355 × 500	10	71
	400 × 560	12	80
	450 × 630	12	63
	500 × 710	15	80
	560 × 800	15	64
	900 × 630	19	81
	1000 × 710	19	64
F	300 × 425	8	63
	355 × 500	8	45
	400 × 560	8	36
	450 × 630	8	28
	500 × 710	10	36
	560 × 800	10	28
	900 × 630	12	32
	1000 × 710	12	25
	1100 × 800	15	31

309. Skylights

Fixed or opening skylights shall have glass thickness appropriate to their size and position as required for side scuttles and windows. Skylight glasses in any position shall be protected from mechanical damage and where fitted in position 1 or 2, shall be provided with robust deadlights or storm covers permanently attached.

Section 4 Ventilators

401. Construction of coamings

1. Ventilators placed in Position I or II, for spaces below the freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material and be efficiently connected to the deck. All ventilator coamings exceeding 900 mm in height are to be specially strengthened at the support.

2. Ventilators passing through superstructures other than enclosed superstructure are to have substantially constructed coamings of steel or equivalent at the freeboard deck.

3. Small hatches, fittings and equipment on the fore deck are to be comply with the provisions of **Ch 9.**

402. Height of coamings

The height of ventilator coamings above the upper surface of the deck is to be at least 900 mm in Position I, and 760 mm in Position II. Where the ship has an unusually large freeboard or where the ventilator serves spaces within unenclosed superstructures, the height of ventilator coamings may be suitably reduced.

403. Thickness of coamings

1. The thickness of ventilator coamings in Position I and II leading to spaces below the freeboard deck or within enclosed superstructures is not to be less than given by Line 1 in **Table 4.4.6.** Where the height of the coamings is reduced by the provisions in **402.** the thickness may be suitably reduced.

2. Where ventilators pass through superstructures other than enclosed superstructures, the thickness of ventilator coamings in the superstructures is not to be less than that given by Line 2 in **Table 4.4.6.**

Table 4.4.6 Thickness of ventilator coamings

Outside diameter of ventilator (mm)		80 and under	160	230 and over but less than 330
Thickness of coaming plate (mm)	Line 1	6	8.5	8.5
	Line 2	4.5	4.5	6

NOTES:
1. For intermediate values of outside diameter of ventilator, the thickness of coaming plate is to be obtained by linear interpolation.
2. Where the outside diameter of ventilator is over 330 mm, the thickness of coaming plate is to be in accordance with the discretion of the Society.

404. Connection

Where no steel deck exists, a steel plate is to be fitted in way of the coaming and efficiently stiffened between the beams as may be required

405. Length of cowl head housing

Ventilator cowls are to be fitted up closely to the outer surface of the coamings and are to have housing not less than 380 mm in length, except that a less housing may be permitted for ventilators not greater than 200 mm in diameter.

406. Closing appliances

1. Ventilators to machinery and cargo spaces are to be provided with means for closing openings capable of being operated from outside the spaces in case of a fire.

2. All ventilator openings in exposed positions on the freeboard and superstructure decks are to be provided with efficient weathertight closing appliances. Where the height of coaming of any ventilator exceeds 4.5 *metres* in Position I or 2.3 *metres* in Position II, such closing appliances may be omitted unless required in **Par 1.**

3. In ships not more than 100 *metres* in length for freeboard, the closing appliances mentioned in **Par**

2 are to be permanently provided; where not so provided in other ships, they are to be conveniently stowed near the ventilators to which they are to be fitted up.

407. Ventilators for deckhouses

The ventilators for the deckhouses which protect the companionways leading to spaces below the freeboard deck are to be equivalent to those for the enclosed superstructures.

Section 5 Permanent Gangways

501. General

Satisfactory means (in the form of guardrails, life lines, gangways or under deck passages, etc.) are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the ship.

502. Ships having reduced freeboard

In ships having a reduced freeboard, a fore and after permanent gangway is to be provided at the level of the Superstructure deck between the poop or after deckhouse and the midship bridge or deckhouse, or equivalent means of access is to be provided to carry out the purpose of gangway, such as a passage below deck. Safe and satisfactory access from the gangway level is to be available between separate crew accommodations and the machinery space.

503. Construction of gangways

The gangway specified in **502.** is to be efficiently constructed and situated as near the centre line of ship as practicable. The gangways are to be in general at least 600 mm wide and to be provided on their both sides with guardrails which are at least 1 *meter* high and comply with the requirements in **106. 1.** ⚓

CHAPTER 5 MASTS AND DERRICK POSTS

Section 1 Masts without Cargo Gear

101. Outside diameter

The outside diameter of steel masts which are not equipped with cargo derricks and are stayed with shrouds as specified in **104.** is not to be less than those obtained from the following formulae:

Outside diameter at the uppermost deck at which the mast is supported (hereinafter referred to as "**base**"):... $3.3H$ (cm)
Outside diameter at the outrigger or at the part to which the upper end of shrouds is connected (hereinafter referred to as "**top**"):.. $2.5H$ (cm)

where:
H = height of mast from the base to the top (m).

102. Thickness of plating

The thickness of plating of masts at each part is not to be less than that obtained from the following formula or 5 mm, whichever is the greater:

$$t = 0.1D_m + 2.5 \quad \text{(mm)}$$

where:
D_m = outside diameter of masts at each part (cm).

103. Reinforcement

The base and top of masts are to be properly strengthened.

104. Rigging

The rigging for masts is not to be less effective than would be obtained from two steel wire shrouds on each side of the ship, of the sizes given in **Table 4.5.1**, so placed that each distance from the forward and after chain plates to the base is not less than one-fourth of the height of mast from base to top or $B/4$, whichever is the greater.

Table 4.5.1 Diameter of steel wire for shrouds

Height of masts from base to top(m)	9	12	15	18
Diameter of steel wire(mm)	20	22	24	26
NOTE: The wire rope is to be No.1 or No. 3 wire rope specified in **Ch 8, Sec 5**				

Section 2 Derrick Posts

201. Application

The materials, construction and scantlings of masts, derrick posts and stays used for cargo handling will be considered in accordance with the requirements in **Pt 9, Ch 2.** ⚓

CHAPTER 6 CEILINGS AND SPARRINGS

Section 1 Bottom Ceilings

101. Ships with single bottoms

1. In ships with single bottoms, close ceilings are to be provided on the floors up to the upper turn of bilge.

2. The thickness of ceilings is to be as **Table 4.6.1.**

3. The ceilings on the flat on the floors are to be laid in portable sections, or other convenient arrangements are to be made for easy removal where required for cleaning, painting or inspection of the bottom.

Table 4.6.1 Thickness of ceiling

L	Thickness of ceiling(mm)
$L < 61$ m	50
61 m $\leq L \leq$ 76 m	57
$L > 76$ m	63

102. Ships with double bottoms

1. In ships with double bottoms, close ceilings are to be laid from the margin plate to the upper turn of bilge so arranged as to be readily removable for inspection of the limbers.

2. Ceilings are to be laid on the inner bottoms under hatchways, unless the requirements in **Pt 3, Ch 7, 501. 3** or **Pt 7, Ch 3, 204. 2** are applied.

3. Ceilings on the top of double bottom are to be laid on battens not less than 13 mm in thickness, or to be bedded on the covering required in **Ch 7, 104.**

4. The thickness of ceilings is to be as required in **101. 2.**

Section 2 Sparrings

201. Arrangements

In all cargo spaces where it is intended to carry general cargo, sparrings not less than 50 mm in thickness and 150 mm in breadth are to be provided not more than 230 mm apart above the bilge ceiling, or equivalent arrangements are to be provided for the protection of framing.

202. Special protections

Where it is intended normally to carry such cargoes as timbers which are liable to cause damage to the hull, special protection arrangements are to be provided.

203. Exemptions

1. Sparring may be omitted in cargo holds of ships such as coal carriers, bulk carriers, ore carriers and similar ships.

2. General cargo ships may omit sparring only subject to the approval of the Society at the request of Owner, in which case the ship is distinguished with the notation "*n.s.*" in the Register Book. ⚓

CHAPTER 7 CEMENTING AND PAINTING

Section 1 Cementing

101. General

The bottom in ships with single bottoms, the bilges in all ships and the double bottoms in the boiler spaces of all ships are to be efficiently protected by Portland cement or other equivalent materials which cover the plates and frames as far as the upper turn of bilge. However, cement protection may be dispensed with in the bottom of the space solely used for carriage of oil.

102. Portland cement

Portland cement is to be mixed with fresh water and sand or other satisfactory substances, in the proportion of about one part of cement to two of sand.

103. Thickness of cement

The thickness of cement is not to be less than 20 mm at the edges.

104. Special consideration

The top plating of tanks, where ceiled directly, is to be covered with good tar put on hot and well sprinkled with cement powder, or with other equally effective coatings.

Section 2 Painting

201. General

1. All steel works are to be coated with a suitable paint. Special requirements may be additionally made by the Society in accordance with the kind of ships, purpose of spaces, etc.
2. Notwithstanding the requirements in **Par 1,** where it is recognized by the Society that the spaces are effectively protected against corrosion of steel works by the means other than painting or due to quality of cargoes, etc., painting may be omitted.

202. Wash cement

Steelworks in tanks intended for water may be coated with wash cement in lieu of paint.

203. Cleaning before painting

The surface of steelworks is to be thoroughly cleaned and loose rust, oil and other injurious adhesives are to be removed before being painted. At least the outer surface of shell plating below the load line is to be sufficiently free from rust and mill scale before painting. ⚓

CHAPTER 8 EQUIPMENT NUMBER AND EQUIPMENT

Section 1 General

101. General and application

1. All ships, according to their equipment number of provisions in **Sec 2,** are to be provided with anchors, chain cables, ropes, etc. which are not less than given in **Table 4.8.1.**

2. Anchors, chain cables, ropes, etc. for ships having equipment number not more than **205** or more than 16,000 are to be as determined by the Society.

3. The bower anchors given in **Table 4.8.1** are to be connected to their cables and stored on board ready for use.

4. The anchors, chain cables and ropes (hereinafter referred to as "equipment") which are required to be tested and inspected to be used for ships classed with the Society are to comply with the requirements of this Chapter.

5. The equipment other than those prescribed in this Chapter may be used where specially approved in connection with the design and use. In such case, the detailed data relating to the process of manufacture of the equipment are to be submitted for approval.

6. All ships are to be provided with suitable appliances for handling of anchors

7. The inboard end of chain cable is to be secured to the hull through a strong eye plate by means of shackle or by other equivalent means.

102. Materials

1. The materials for equipment specified in this Chapter are to comply with the requirements in each Section and **Pt 2, Ch 1.**

2. The test pieces and testing procedures for materials of equipment are to comply with the requirements in each Section and **Pt 2, Ch 1.**

103. Process of manufacture

The process of manufactures for equipment specified in this Chapter is to comply with the requirements in each Section.

104. Tests and inspections

1. All equipment prescribed in this Chapter are to be tested and inspected in the presence of the Society's Surveyor in accordance with the requirements of this Chapter and are to comply with the requirements for the tests and inspections.

2. Where equipment having characteristics differing from those prescribed in this Chapter are to be tested and inspected according to the approved specification for the testing.

3. The tests and inspections for equipment may be dispensed with, where these equipment have appropriate certificates accepted by the Society.

105. Execution of tests and inspections

1. The manufacturers shall afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify that the approved process is adhered to.

2. All tests and inspections of equipment are to be carried out at the place of manufacturer prior to delivery.

106. Marking for accepted equipments

Equipment which have satisfactory complied with the required in this Chapter are to be stamped in accordance with the provisions in each Section.

Section 2 Equipment Number

201. Equipment number

Equipment number is the value obtained from the following formula:

$$E = \Delta^{\frac{2}{3}} + 2.0Bh + 0.1A$$

where:

Δ = molded displacement in *tonnes* to the summer load waterline.

h, A = values specified in the following (1), (2) and (3).

(1) h is the value obtained from the following formula:

$$h = f + h' \quad \text{(m)}$$

where:

f = vertical distance, at the midship, from the load line to the top of uppermost continuous deck beam at side (m).

h' = height from the uppermost continuous deck to the top of uppermost superstructures or deckhouses having a breadth greater than $B/4$ (m), In the calculation of h', sheer and trim may be ignored. Where a deckhouse having a breadth greater than $B/4$ is located above a deckhouse with a breadth of $B/4$ or less, the narrow deckhouse may be ignored.

(2) A is the value obtained from the following formula:

$$A = fL + \Sigma h'' l \quad (\text{m}^2)$$

where:

f = value specified in (1)

$\Sigma h'' l$ = summing up of the products of the height h'' (m) and length l (m) of superstructures, deckhouses or trunks which are located above the uppermost continuous deck within the length of ship and also have a breadth greater than $B/4$ and a height greater than 1.5 *metres*.

(3) In the application of (1) and (2), screens and bulwarks more than 1.5 *metres* in height are to be regarded as parts of superstructure or deckhouses.

202. Mass of anchors

1. The mass of individual bower anchors may vary by ±7 % of the mass given in **Table 4.8.1** provided that the total mass of stipulated number of bower anchors is not less than obtained from multiplying the mass per anchor by the number given in **Table 4.8.1.** Where, however, an approval by the Society is obtained, the anchors which are increased in mass by more than 7 % may be used.

2. Where stock anchors are used, the mass excluding the stock, is not to be less than 0.80 times the mass specified in **Table 4.8.1** for ordinary stockless bower anchors.

3. Where high holding power anchors are used, the mass of each anchor may be 0.75 times the mass specified in **Table 4.8.1.**

4. Where super high holding power anchors are used, the mass of each anchor may be 0.5 times the mass specified in **Table 4.8.1.** However, the mass of super high holding anchor is generally not to exceed 1500 kg.

203. Chain cables and stream lines

1. Chain cables for bower anchors are to be stud link chains of Grade 1, 2 or 3 specified in **Sec 4.** However, Grade 1 chains made of Class 1 chain bars (*RSBC* 31) are not to be used in association with high holding power anchors.

2. As for chain cables or wire ropes for stream lines, the breaking test load specified in **Sec 4** or **5** is not to be less than the breaking load given in **Table 4.8.1** respectively.

3. Steel wire rope instead of stud link chain cable are to be in accordance with the Guidance relating to the Rules specified by the Society for vessels of special design or operation such as crane barges.

204. Tow lines and mooring lines

1. As for wire ropes and hemp ropes used as tow lines and mooring lines, the breaking test load specified in **Sec 5** or **6** is not to be less than the breaking load given **Table 4.8.1** respectively.

2. For ships having the ratio A/E above 0.9, the following number of ropes should be added to the number required by **Table 4.8.1** for mooring lines.

$\frac{A}{E}$	Number of mooring line
$0.9 < \frac{A}{E} \leq 1.1$	1
$1.1 < \frac{A}{E} \leq 1.2$	2
$\frac{A}{E} > 1.2$	3

NOTES:
A = value specified in **201.** (2)
E = equipment number.

3. For individual mooring lines with required breaking load above 490 kN according to **Table 4.8.1** the required strength may be reduced by the corresponding increase of the number of mooring lines and vice versa, provided that the total breaking load of all mooring lines aboard the ship is not less than the value obtained from multiplying the required breaking load in **Table 4.8.1** by the sum of number required in **Table 4.8.1** and **Par 1,** irrespective of the requirements in **Par 1.** However, the number of mooring lines is not to be less than 6 in any case, and any one of the lines is not to have a breaking load less than 490 kN.

4. The requirements for synthetic fibre ropes used as tow lines or mooring lines are to be as stipulated elsewhere.

5. The length of individual mooring lines may be reduced up to 7 % of the length given in **Table 4.8.1** provided that total length of the stipulated number of mooring lines is not less than obtained from multiplying the length by the number given in **Table 4.8.1.**

Table 4.8.1 Bower anchors, chain cables and ropes

Equipment letter	Equipment number		Stockless bower anchors		Stud link chain cables for bower anchors				Tow line			Mooring line			
			Number	Mass per anchor (kg)	Total length (m)	Diameter (mm)			Length (m)	Breaking load		Number	Length (m)	Breaking load	
	Exceeding	Not exceeding				Grade 1	Grade 2	Grade 3		(kN)	(kg)			(kN)	(kg)
B3	205	240	2	660	302.5	26	22	20.5	180	● 129	13200	4	120	● 64	6500
B4	240	280	2	780	330	28	24	22	180	● 150	15300	4	120	● 69	7000
B5	280	320	2	900	357.5	30	26	24	180	● 174	17700	4	140	● 74	7500
C1	320	360	2	1020	357.5	32	28	24	180	● 207	21100	4	140	● 78	8000
C2	360	400	2	1140	385	34	30	26	180	⊕ 224	22800	4	140	● 88	9000
C3	400	450	2	1290	385	36	32	28	180	⊕ 250	25500	4	140	● 98	10000
C4	450	500	2	1440	412.5	38	34	30	180	⊕ 277	28200	4	140	● 108	11000
C5	500	550	2	1590	412.5	40	34	30	190	⊕ 306	31200	4	160	● 123	12500
D1	550	600	2	1740	440	42	36	32	190	⊕ 338	34500	4	160	● 132	13500
D2	600	660	2	1920	440	44	38	34	190	⊕ 371	37800	4	160	● 147	15000
D3	660	720	2	2100	440	46	40	36	190	⊕ 406	41400	4	160	● 157	16000
D4	720	780	2	2280	467.5	48	42	36	190	⊕ 441	45000	4	170	● 172	17500
D5	780	840	2	2460	467.5	50	44	38	190	⊕ 480	48900	4	170	● 186	19000
E1	840	910	2	2640	467.5	52	46	40	190	⊞ 518	52800	4	170	● 201	20500
E2	910	980	2	2850	495	54	48	42	190	⊞ 559	57000	4	170	● 216	22000
E3	980	1060	2	3060	495	56	50	44	200	⊞ 603	61500	4	180	⊕ 230	23550
E4	1060	1140	2	3300	495	58	50	46	200	⊞ 647	66000	4	180	⊕ 250	25500
E5	1140	1220	2	3540	522.5	60	52	46	200	⊞ 691	70500	4	180	⊕ 270	27500
F1	1220	1300	2	3780	522.5	62	54	48	200	⊞ 738	75300	4	180	⊕ 284	29000
F2	1300	1390	2	4050	522.5	64	56	50	200	⊞ 786	80100	4	180	⊕ 309	31500
F3	1390	1480	2	4320	550	66	58	50	200	⊞ 836	85200	4	180	⊕ 324	33000
F4	1480	1570	2	4590	550	68	60	52	220	⊞ 888	90600	5	190	⊕ 324	33000
F5	1570	1670	2	4890	550	70	62	54	220	⊞ 941	96000	5	190	⊕ 333	34000
G1	1670	1790	2	5250	577.5	73	64	56	220	⊞ 1024	104400	5	190	⊕ 353	36000
G2	1790	1930	2	5610	577.5	76	66	58	220	⊞ 1190	113100	5	190	⊕ 378	38500
G3	1930	2080	2	6000	577.5	78	68	60	220	⊞ 1168	119100	5	190	⊕ 402	41000
G4	2080	2230	2	6450	605	81	70	62	240	⊞ 1259	128400	5	200	⊕ 422	43000
G5	2230	2380	2	6900	605	84	73	64	240	⊞ 1356	138300	5	200	⊕ 451	46000
H1	2380	2530	2	7350	605	87	76	66	240	⊞ 1453	148200	5	200	⊕ 480	49000
H2	2530	2700	2	7800	632.5	90	78	68	260	⊞ 1471	150000	6	200	⊕ 480	49000
H3	2700	2870	2	8300	632.5	92	81	70	260	⊞ 1471	150000	6	200	⊞ 490	50000
H4	2870	3040	2	8700	632.5	95	84	73	260	⊞ 1471	150000	6	200	⊞ 500	51000
H5	3040	3210	2	9300	660	97	84	76	280	⊞ 1471	150000	6	200	⊞ 520	53000
J1	3210	3400	2	9900	660	100	87	78	280	⊞ 1471	150000	6	200	⊞ 554	56500
J2	3400	3600	2	10500	660	102	90	78	280	⊞ 1471	150000	6	200	⊞ 588	60000
J3	3600	3800	2	11100	687.5	105	92	81	300	⊞ 1471	150000	6	200	⊞ 618	63000
J4	3800	4000	2	11700	687.5	107	95	84	300	⊞ 1471	150000	6	200	⊞ 647	66000
J5	4000	4200	2	12300	687.5	111	97	87	300	⊞ 1471	150000	7	200	⊞ 647	66000
K1	4200	4400	2	12900	715	114	100	87	300	⊞ 1471	150000	7	200	⊞ 657	67000
K2	4400	4600	2	13500	715	117	102	90	300	⊞ 1471	150000	7	200	⊞ 667	68000
K3	4600	4800	2	14100	715	120	105	92	300	⊞ 1471	150000	7	200	⊞ 677	69000
K4	4800	5000	2	14700	742.5	122	107	95	300	⊞ 1471	150000	7	200	⊞ 686	70000
K5	5000	5200	2	15400	742.5	124	111	97	300	⊞ 1471	150000	8	200	⊞ 686	70000

Table 4.8.1 Bower anchors, chain cables and ropes (continued)

Equipment letter	Equipment number		Stockless bower anchors		Stud link chain cables for bower anchors				Tow line			Mooring line			
			Number	Mass per anchor (kg)	Total length (m)	Diameter (mm)			Length (m)	Breaking load		Number	Length (m)	Breaking load	
	Exceeding	Not exceeding				Grade 1	Grade 2	Grade 3		(kN)	(kg)			(kN)	(kg)
L1	5200	5500	2	16100	742.5	127	111	97	300	⊞ 1471	150000	8	200	⊞ 696	71000
L2	5500	5800	2	16900	742.5	130	114	100	300	⊞ 1471	150000	8	200	⊞ 706	72000
L3	5800	6100	2	17800	742.5	132	117	102	300	⊞ 1471	150000	9	200	⊞ 706	72000
L4	6100	6500	2	18800	742.5		120	107				9	200	⊞ 716	73000
L5	6500	6900	2	20000	770		124	111				9	200	⊞ 726	74000
M1	6900	7400	2	21500	770		127	114				10	200	⊞ 726	74000
M2	7400	7900	2	23000	770		132	117				11	200	⊞ 726	74000
M3	7900	8400	2	24500	770		137	122				11	200	⊞ 735	75000
M4	8400	8900	2	26000	770		142	127				12	200	⊞ 735	75000
M5	8900	9400	2	27500	770		147	132				13	200	⊞ 735	75000
N1	9400	10000	2	29000	770		152	132				14	200	⊞ 735	75000
N2	10000	10700	2	31000	770			137				15	200	⊞ 735	75000
N3	10700	11500	2	33000	770			142				16	200	⊞ 735	75000
N4	11500	12400	2	35500	770			147				17	200	⊞ 735	75000
N5	12400	13400	2	38500	770			152				18	200	⊞ 735	75000
O1	13400	14600	2	42000	770			157				19	200	⊞ 735	75000
O2	14600	16000	2	46000	770			162				21	200	⊞ 735	75000

NOTES :
1. Where steel wire ropes are used, the following wire ropes corresponding to the marks shown in the Table, ● (6×12), ⊕ (6×24), ⊞ (6×37), are to be provided.
2. Length of chain cables may be that including shackles for connection
3. Tow line is not a condition of Classification, but is listed in this table only for guidance.

6. For mooring lines connected with powered winches where the rope is stored on the drum, steel cored wire ropes of suitable flexible construction may be used instead of fibre cored wire ropes subject to the approval by the Society.

205. Emergency towing arrangements on tankers

1. For tankers which operate in international service area, emergency towing arrangements shall be fitted at both ends on board every tanker of not less than 20,000 *tonnes* deadweight.

2. Tankers constructed on or after 1 July 2002 are to be in accordance with the requirements in the following Sub-paragraphs.

(1) The arrangements shall, at all times, be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship. At least one of the emergency towing arrangements shall be pre-rigged ready for rapid deployment.

(2) Emergency towing arrangements at both ends shall be of adequate strength taking into account the size and deadweight of the ship, and the expected forces during bad weather conditions. The design, construction and prototype testing of emergency towing arrangement are to be in accordance with **Ch 3, Sec 7-1.** in **"Guidance for Approval of Manufacturing Process and Type Approval, etc".**

3. For tankers constructed before 1 July 2002, the design, construction and prototype testing of emergency towing arrangements are to be in accordance with **Ch 3, Sec 7-1.** in **"Guidance for Approval of Manufacturing Process and Type Approval, etc".**

Section 3 Anchors

301. Application

Anchors to be equipped on ships in accordance with the provisions in this Chapter are to be in compliance with the requirements in this Section or to be of equivalent quality.

302. Kinds

The kinds of anchors are as follows:
(1) Ordinary anchors
(A) Stocked anchors
(B) Stockless anchors
(2) HHP anchors
(3) SHHP anchors, not exceeding 1,500kg in mass

303. Materials

1. Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements in **PT 2, Ch 1, 501.** of the Rules and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with Aluminium. If test programme B is selected in **309. 1** then Charpy V notch (CVN) impact testing of cast material is required.

2. Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements in **PT 2, Ch 1, 601.** of the Rules. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction.

3. Rolled billets, plate and bar for fabricated steel anchors are to be manufactured and tested in accordance with the requirements in **PT 2, Ch 1, 301.** of the Rules.

4. Rolled bar intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements in **PT 2, Ch 1, 301.** and **601.** of the Rules.

5. Cast steels for super high holding power anchor are to be subjected to the impact test according to the followings.
(1) One set of three V notch impact test specimens specified in **Pt 2, Ch 1** are to be taken.
(2) The average absorbed energy is not to be less than 27 J at 0 °C. However, when the average absorbed energy of two or more test specimens among a set of test specimens is less than 27 J or when the average absorbed energy of a single test specimen is less than 19 J, the test is to be considered to have failed.
(3) Anchor rings of super high holding power anchor are to comply with the requirements of impact test for Grade 3 chain in **Ch 8, Table 4.8.10.**

304. Constructions and dimensions

1. The construction and form of anchors are to comply with the KS V 3311 (Anchors) or equivalent to this, the special forms of anchors are to be approved by the Society.

2. The high holding power anchors and super high holding anchors, except in accordance with the provision in the above **Par 1,** are to be tested by the holding power indicated by the Society and are to comply with the test requirements.

3. Welded construction of fabricated anchors is to be done in accordance with procedures approved by the Society. Welding is to be carried out by qualified welders, following the approved welding procedures, using approved welding consumables.

4. Assembly and fitting are to be done in accordance with the design details. Securing of the anchor pin, shackle pin or swivel nut by welding is to be done in accordance with an approved procedure.

305. Heat Treatment

1. Components for cast of forged anchors are to properly heat treated in accordance with the requirements in **Pt 2. Ch 1.**

2. The welding for rolled steel fabricated anchors may require stress relief after welding depending upon weld thickness. The manufacturers are to obtain approval by the Society in advance concerning stress relief after weld. Stress relief temperature are not to be exceed the tempering of the base material.

306. Quality and Repair of Defects

1. Anchors are to be free from cracks, notches, inclusions and other defects impairing the performance of the products.

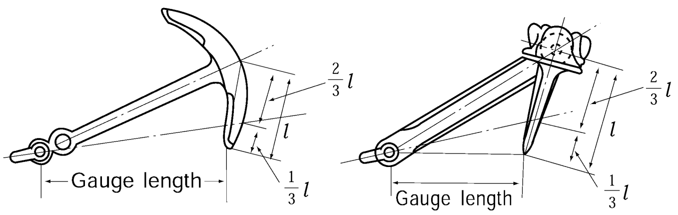
2. Any necessary repairs to forged and cast anchors are to be agreed by the Surveyor and carried out in accordance with the repair criteria indicated in **PT 2, Ch 1, 501.** and **601.** of the Rules. Repairs to fabricated anchors are to be agreed by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

307. Dimensions and Forms

1. Length of the arm is as follows.

(1) Length of the arm is the distance from the centre of the pin in case of anchors having the head pin and from the top of the crown in case of anchors of the other types to the tip of the flukes. (See **Fig 4.8.1**)

(2) Where the crown is of concave form, the intersection of the centre line of the shank with the plane in contact with the top of the arms is considered as the top of the crown.



Stock Anchor Stockless Anchor

Fig 4.8.1 Anchors

2. Assembly and fitting of anchors are as follows unless specially approved by the Society.

(1) The clearance either side of the shank within the shackle jaws is to be given in **Table 4.8.2** in accordance with the anchor mass.

(2) The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be given in **Table 4.8.3** in accordance with diameter of the shackle pins.

(3) The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

(4) The lateral movement of the shank is not exceed 3 degrees. (See **Fig 4.8.2**)

3. The dimensional inspections of anchors are to be performed by the manufacture. The manufacture is to show the data of measurement to the surveyor.

Table 4.8.2 The clearance either side of the shank within the shackle jaws

Anchor mass(t)	over up	- 3	3 5	5 7	7 -
Tolerance(mm)	up to	3	4	6	12

Table 4.8.3 The shackle pin to hole tolerance

The diameter of shackle pin(mm)	57 up	57 over
Hole tolerance(mm)	0.5 up	1.0 up

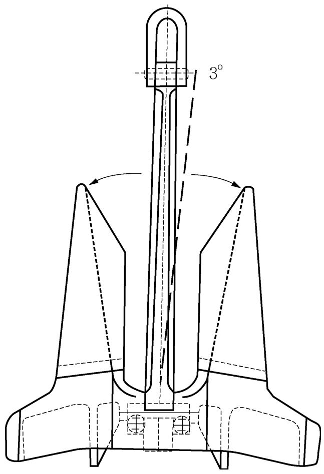


Fig 4.8.2 Allowable range of the lateral movement of the shank

308. Mass

1. The mass of the stock of a stock anchor is not to be less than one-fourth of the mass of anchor excluding stock.

2. The mass of stockless anchor excluding shank is not to be less than three-fifths of the total mass of the anchor.

3. The mass of the anchor is to exclude the mass of the swivel, unless this is an integral component.

4. The mass inspections of anchors are to be performed by the manufacture before executing proof test. The manufacture is to show the data of measurement to the surveyor.

5. In case of stock anchors, the mass of the anchor excluding stock and the mass of the stock are to be measured separately. In case of stockless anchors the total mass of anchor and the mass of shank are to be measured.

309. Testing and certification

1. Test programme

(1) The Society can request that either programme A or programme B be applied.

Programme A	Programme B
Drop test Hammering test Proof load test Visual inspection General NDE -	Drop test - Proof load test Visual inspection General NDE Extended NDE

(2) Applicable programmes for each product form are as belows.

Product test	Product form		
	Cast components	Forged components	Fabricated/Welded components
Programme A	O	X	X
Programme B	O(1)	O	O

Notes
(1) A. CVN impact tests are to be carried out to demonstrate at least 27 joules average at 0ºC.
B. The Drop test requirement in Programme B is intended for tankers applicable for Cast Components.

2. Drop and hammering tests

In case of test programme A, Cast steel anchors are to be subjected to the following tests prior to the execution of the proof tests and are to comply with the test requirements.

(1) *Drop tests*

(a) Each piece of the cast steel anchor is to be lifted to 4 *metres* in height and dropped on an steel slab on the hard ground without any crack or other defects.

(b) Where shank and arms are cast in one piece in stock anchors, the anchor is first to be lifted to the specified height with its shank and arms in a horizontal position and then dropped on the steel slab, and to be lifted once more to the specified height with the crown downwards and dropped on two steel blocks on the slab arranged to enable the anchor to give shock at the middle of each arm without making the crown touch the slab, and are to be found free from cracks, deformation or other defects.

(c) Where the slab is broken by the impact, the anchor is to be retested with a new slab.

(2) *Hammering tests*

After the drop test specified in (1), the anchor is to be slung clear of the ground and thoroughly hammered with a hammer which the mass is 3 kg and over, and is to be found free from cracks or other defects.

(3) For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the components is to be rejected.

3. Proof tests

(1) Anchors are to be tested in accordance with the requirements in **Table 4.8.4,** applying the required load corresponding to the mass of anchor (excluding the mass of stock for stock anchor) at the position of one-third of the length of the arm from the tip of the fluke, for every arm or for both arms simultaneously or for each position in case of the anchor having the head pin, and to be found free from cracks, deformation or other defects. In every test, the difference between the gauge lengths, where one-tenth of the required load was applied first and where the load has been released to one-tenth of the required load from the full load, may be permitted not to exceed 1 % of the gauge length. (See **Fig 4.8.1**)

(2) The proof test load, however, for high holding power anchors is to be the load specified for an ordinary anchor of which mass is equal to 4/3 times the actual total mass of high holding power anchor.

(3) The proof test load for super high holding power anchors is to be the load specified for an ordinary anchor of which the mass is 2 times the actual mass of super high holding power anchor.

Table 4.8.4 Proof test load for anchors

Mass of anchor (kg)	Proof test load (kN)	Mass of anchor (kg)	Proof test load (kN)	Mass of anchor (kg)	Proof test load (kN)	Mass of anchor (kg)	Proof test load (kN)
25	12.6	1000	199	4500	622	10000	1010
30	14.5	1050	208	4600	631	10500	1040
35	16.9	1100	216	4700	638	11000	1070
40	19.1	1150	224	4800	645	11500	1090
45	21.2	1200	231	4900	653	12000	1110
50	23.2	1250	239	5000	661	12500	1130
55	25.2	1300	247	5100	669	13000	1160
60	27.1	1350	255	5200	677	13500	1180
65	28.9	1400	262	5300	685	14000	1210
70	30.7	1450	270	5400	691	14500	1230
75	32.4	1500	278	5500	699	15000	1260
80	33.9	1600	292	5600	706	15500	1270
90	36.3	1700	307	5700	713	16000	1300
100	39.1	1800	321	5800	721	16500	1330
120	44.3	1900	335	5900	728	17000	1360
140	49.0	2000	349	6000	735	17500	1390
160	53.3	2100	362	6100	740	18000	1410
180	57.4	2200	376	6200	747	18500	1440
200	61.3	2300	388	6300	754	19000	1470
225	65.8	2400	401	6400	760	19500	1490
250	70.4	2500	414	6500	767	20000	1520
275	74.9	2600	427	6600	773	21000	1570
300	79.5	2700	438	6700	779	22000	1620
325	84.1	2800	450	6800	786	23000	1670
350	88.8	2900	462	6900	794	24000	1720
375	93.4	3000	474	7000	804	25000	1770
400	97.9	3100	484	7200	818	26000	1800
425	103	3200	495	7400	832	27000	1850
450	107	3300	506	7600	845	28000	1900
475	112	3400	517	7800	861	29000	1940
500	116	3500	528	8000	877	30000	1990
550	124	3600	537	8200	892	31000	2030
600	132	3700	547	8400	908	32000	2070
650	140	3800	557	8600	922	34000	2160
700	149	3900	567	8800	936	36000	2250
750	158	4000	577	9000	949	38000	2330
800	166	4100	586	9200	961	40000	2410
850	175	4200	595	9400	975	42000	2490
900	182	4300	604	9600	987	44000	2570
950	191	4400	613	9800	998	46000	2650

NOTE ;
Where mass of anchor is intermediate in this Table, proof test load is to be determined by linear interpolation

4. Visual inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

5. General non-destructive examination

(1) For ordinary anchors and HHP anchors, after proof loading, general non-destructive examination is to be carried out as indicated in the following Table.

Location	Method of NDE
Feeders of castings	PT or MT
Risers of castings	PT or MT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

(2) For SHHP anchors, after proof loading, general non-destructive examination is to be carried out as indicated in the following Tables.

Location	Method of NDE
Feeders of castings	PT or MT and UT
Risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

(3) The NDE methods and acceptance criteria are to comply with the **Pt 2, Annex 2-2** and **Annex 2-7** of the Guidance relating to the Rules

(4) If defects are detected by non-destructive test, repairs are to be carried out in accordance with **306. 2.**

6. Extended non-destructive examination

(1) In case of programme B, after proof loading, extended non-destructive examination is to be carried out as indicated in the following Table.

Location	Method of NDE
Feeders of castings	PT or MT and UT
Risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Random areas of castings	UT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

(2) The NDE methods and acceptance criteria are to comply with the **Pt 2, Annex 2-2** and

Annex 2-7 of the Guidance relating to the Rules

(3) If defects are detected by non-destructive test, repairs are to be carried out in accordance with **306. 2.**

310. Retests

Where the result of the impact test is unsatisfactory, retest is to be in accordance with the requirements in **Pt 2, Ch 1, 109.** of the Rules.

311. Marking

1. Where anchors have satisfactorily passed the tests and inspections, they are to be stamped with the mass of anchor (excluding the mass of stock in stock anchors), at the middle position of the shank and the Society's brand and the test number at the position two-thirds of the length of arm from the tip of the fluke on the same side. Where the anchor is formed with separate shank and arms, the Society's brand and the test number are also to be stamped on the shank in the neighbourhood of the head pin, and in case of stock anchor, the mass of stock, the Society's brand and the test number are also to be stamped on the stock.

2. In case of high holding power anchors, alphabet H is to be stamped in front of the Society's brand in addition to the stamps specified in the above **Par 1.**

3. In case of super high holding power anchors, alphabet SH is to be stamped before the Society's brand in addition to the stamps specified in the above **Par 1.**

312. Painting

Anchors are not to be painted until the tests and inspections are finished.

Section 4 Chains

401. Applications

1. The materials, design, manufacture and testing of stud link anchor chain cables to be equipped on ships, steering chains (hereinafter referred to as "chain"), shackles and swivels (hereinafter referred to as "accessories") are to comply with the requirements in this Section or to be of equivalent quality. Where, in exceptional cases, studless short link chain cables are used with the consent of this Society, they must comply with recognized national or international standards. Chafing chain for Emergency Towing Arrangements (ETA) are to be in accordance with the Guidance relating to the Rules specified by the Society.

2. Offshore mooring chains and chafing chain for Emergency Towing Arrangements (ETA) are to be in accordance with the Guidance relating to the Rules specified by the Society.

402. Chain cable grades

Depending on the nominal tensile strength of the chain cable steel used for manufacture, stud link chain cables are to be subdivided into Grades 1, 2 and 3.

403. Materials

1. Chains are to be made of the materials given in **Table 4.8.5** according to their grades and manufacturing processes, respectively.

2. The studs are to be made of steel corresponding to that of the chain or from rolled, cast or forged mild steels. The use of other materials, e.g. grey or nodular cast iron is not permitted.

Table 4.8.5 Mechnical properties of rolled steel bars

Chain cable grades \ Manufacturing Process \ Materials	Materials for Chain Links[1]			Materials for Accessories[2]	
	Flash butt welded	Cast	Forged	Cast	Forged
Grade 1 chain	Grade 1 chain bar (RSBC 31)	-		Grade 2 cast steel for chain (RSCC 50)	Grade 2 steel forging for chain (RSFC 50)
Grade 2 chain	Grade 2 chain bar (RSBC 50)	Grade 2 cast steel for chain (RSCC 50)	Grade 2 steel forging for chain (RSFC 50)		
Grade 3 chain	Grade 3 chain bar (RSBC 70)	Grade 3 cast steel for chain (RSCC 70)	Grade 3 steel forging for chain (RSFC 70)	Grade32 cast steel for chain (RSCC 70)	Grade 2 steel forging for chain (RSFC 70)

NOTE :
(1) Materials for Grade 2 chains may be used for Grade 1 chains.
(2) Materials for Grade 2 chains may be used for accessories for Grade 2 chains.

404. Design

1. Chains and accessaries must be designed according to a standard recognized by the Society, such as ISO 1704.

2. There is to be an odd number of links in each length of chains, except where swivels are fitted.

3. Where designs do not comply with this and where accessories are of welded construction, drawings giving full details of the design, the manufacturing process and the heat treatment are to be submitted to the Society for approval.

405. Manufacturing Process

1. Chains should preferably be manufactured by flash butt welding using Grade 1, 2 or 3 bar material. Manufacture of the links by drop forging or castings is permitted. Their manufactures are to obtain approval by the Society in advance concerning their manufacturing methods.

2. On request, pressure butt welding may also be approved for studless Grade 1 and 2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26 mm.

3. Studs are to be securely fastened by press fitting or welding with an approved procedure. Inserted studs are to be pressed completely to the centre position of the link and at right angles to the sides of the link and welding of studs is to satisfy the requirements specified in **408.** of the Rules.

4. Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade 2. The welded construction of these parts may also be approved.

406. Heat treatment

1. According to the grade of steel, chains and accessories are to be supplied in one of the conditions specified in **Table 4.8.6**. However Grade 2 flash butt welded chains subjected to sufficient preheating may not be required heat treatment on the approval by the Society.

2. The heat treatment shall in every case be performed before the proof load test, the breaking load test, and all mechanical testing.

Table 4.8.6 Condition of supply of chains and accessories

Grade	Chains	Accessories
1	As welded or Normalized	NA
2	As welded or Normalized(1)	Normalized
3	Normalized, Normalized and tempered or Quenched and tempered	Normalized, Normalized and tempered or Quench and tempered
NOTE : (1) Grade 2 chain cables made by forging or casting are to be supplied in the normalized condition.		

407. Quality and repair of defects

1. Chains and accessories must have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects imparing the performance of the product. The flashes produced by upsetting or drop forging must be properly removed.

2. Minor surface defects other than preceding **Par 1,** can be partly removed by grinder. In this case the grinding is so as to leave gentle transition to the surrounding surface and, in principle, local grinding up to 5 % of the nominal link diameter may be permitted.

408. Welding of studs

The welding of studs is to be in accordance with an approved procedure subject to the following conditions:

1. The studs must be of weldable steel

2. The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.

3. The welds, preferably in the flat position, shall be executed by qualified welders using suitable welding consumables.

4. All welds must be carried out before the final heat treatment of the chain cable.

5. The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects shall, where necessary, be ground off.

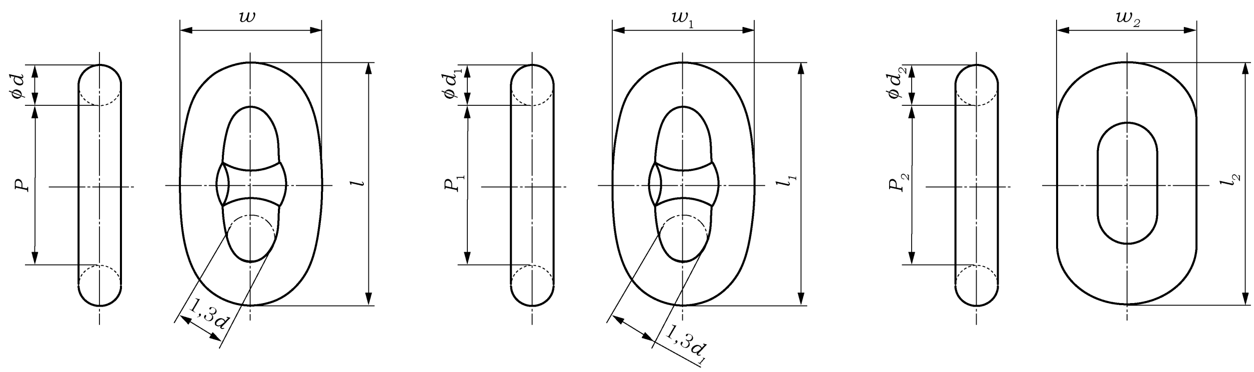
409. Shape and proportions

1. The shape and proportions of links and accessories must conform to a recognized standard, such as ISO 1704 or the designs specially approved, and are generally to be as given in **Fig 4.8.3.** and **4.8.4.**

2. The nominal diameter of chains is to be denoted by the diameter of the common link.

3. One length of chains is the distance from the outer end of the internal bent portion of the link at one end of the chain to that at the other end of the chain. The standard length of anchor chains is 27.5 m.

4. Links of every kind, shackles and swivels are to be of uniform shape and their bent portions are to be sufficient to allow each link to work smoothly.



d = nominal diameter of common link
l = 6 d
p = 4 d
w ≈ 3.6 d

(a) Common link

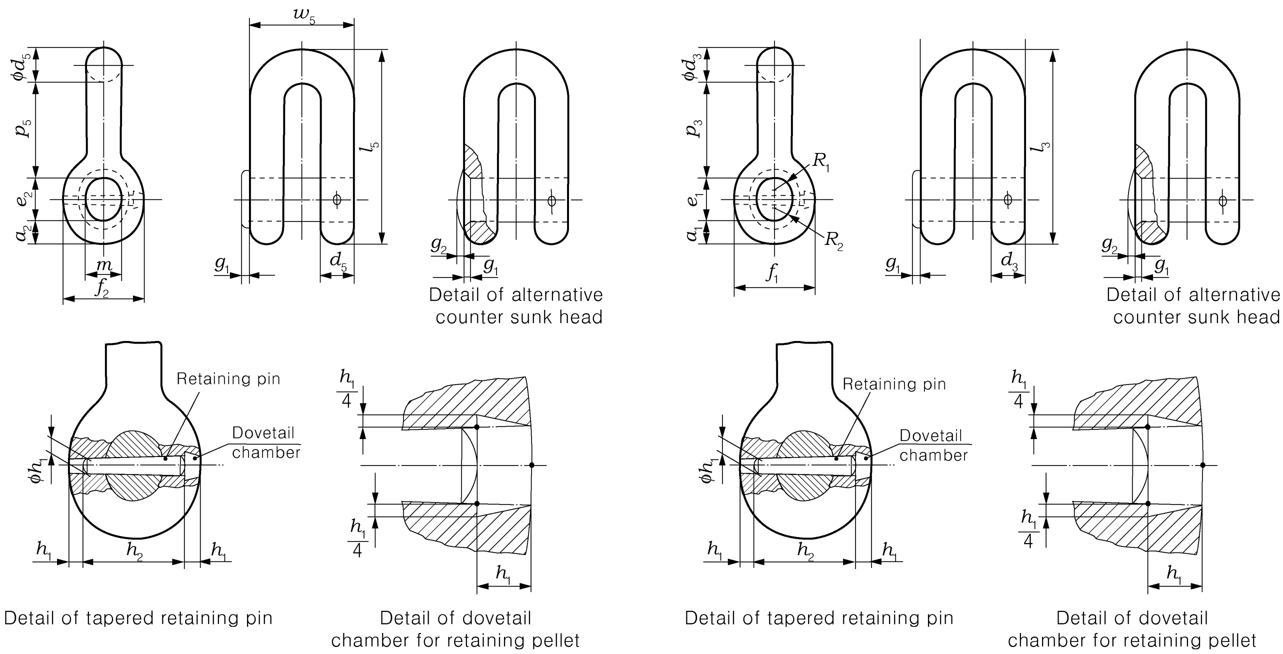
d = nominal diameter of common link
d_1 = diameter of enlarged link ≈ 1.1d
l_1 = 6 d_1
p_1 = 4 d_1
w_1≈ 3.6 d_1

(b) Enlarged link

d = nominal diameter of common link
d_2 = diameter of end link ≈ 1.2d
l_2 = p_2 + 2d_2 ≈ 6.75d
p_2 = 4.35 d
w_2 ≈ 4 d

(c) End link

Fig 4.8.3 Shape and proportions of links

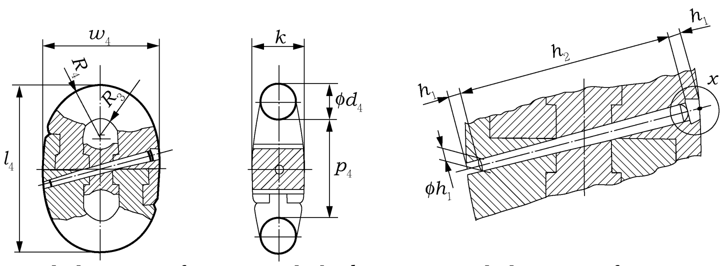


d = nominal diameter of common link
d_5 = diameter of anchor shackle ≈ 1.4 d
l_5 ≈ 8.7 d
p_5 = $l_5 - (d_5 + a_2 + e_2)$ ≈ 4.6 d
$w_5$5 = 5.2 d
a_2 ≈ 0.9 d
e_2 ≈ 1.8 d
f_2 ≈ 3.1 d
g_1 ≈ 0.2 d
g_2 ≈ 0.1 d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
m ≈ 1.4 d

(a) Anchor shackle

d = nominal diameter of common link
d_3 = diameter of joining shackle ≈ 1.3 d
l_3 ≈ 7.1 d
p_3 = $l_3 - (d_3 + a_1 + e_1)$ ≈ 3.4 d
w_3 = 4 d
a_1 ≈ 0.8 d
e_1 ≈ 1.6 d
f_1 ≈ 2.8 d
g_1 ≈ 0.2 d
g_2 ≈ 0.1 d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
R_1 ≈ 0.6 d
R_2 ≈ 0.5 d

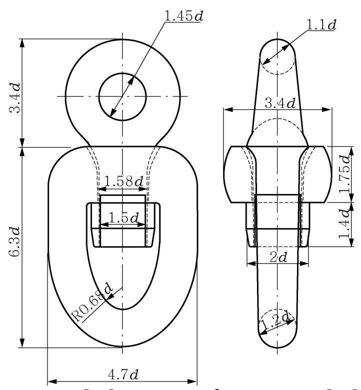
(b) Joining shackle



d = nominal diameter of common link
d_4 = diameter of kenter shackle = d
l_4 = 6 d
p_4 = 4 d
w_4 ≈ 4.2 d

h = nominal diameter of taper pin
h_2 ≈ 3.4d = length of taper pin
k ≈ 1.52d
R_3 ≈ 0.67d
R_4 ≈ 1.83d

(c) Kenter shackle



d = nominal diameter of common link

(d) Swivel

Fig 4.8.4 Shape and proportions of accessories

410. Dimension tolerances

The tolerances for chains and accessories are to comply with the following requirements in **Par 1** and **2** and the dimensions thereof are to be measured after the execution of a proof test.

1. Chain

(1) Two measurements are to be taken at the same location of each kind of link : one in the plane of the link (see d_p in **Fig 4.8.5**) and one perpendicular to the plane of the link. The negative tolerance at the crown part of each kind of link is to comply with the requirements in accordance with its nominal diameter as given in **Table 4.8.7** and the plus tolerance may be up to 5% of the nominal diameter. The cross sectional area of the crown must have no negative tolerance.

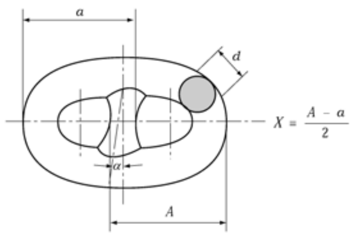


Fig 4.8.5 the position of studs

Table 4.8.7 Negative tolerances of diameters

Nominal Diameter (mm)	over		40	84	122
	up to	40	84	122	
Negative Tolerances (mm)		1	2	3	4

(2) The tolerances other than the crown part of each kind of link are to be up to +5 % of the nominal diameter, but are not to be negative. The approved manufacturer's specification is applicable to the plus tolerance of the diameter at the flush-butt weld.

(3) The maximum allowable tolerance on assembly measured over a length of 5 links are to be ±2.5 %, but not to be negative.(measured with the chain under tension after proof load test)

(4) The tolerances except for the requirements specified in (1) to (3) above are to be ±2.5 %.

(5) The tolerances of stud positions are to comply with the standard as follows, except the final link at each end of one length of chain.
(A) Maximum off-centre distance X : 10 % of the nominal diameter(d)
(B) Maximum deviation "α" from the 90° position : 4°
where, X and α are as specified in **Fig 4.8.5.**

2. Accessories

The tolerance of the diameter at the bent portions of center shackles are to be equal +5 %, but may not be negative. All other dimensions are subjected to manufacturing tolerances of ±2.5 %

411. Mass

The mass of chains is to comply with the standard mass given in **Table 4.8.8** in accordance with their kind, and to be measured after the execution of proof tests.

Table 4.8.8 Breaking and proof test loads for chains

Nominal dia. d (mm)	Grade 1 chain		Grade 2 chain		Grade 3 chain		Mass of chain per metre (kg)
	Breaking test load (kN)	Proof test load (kN)	Breaking test load (kN)	Proof test load (kN)	Breaking test load (kN)	Proof test load (kN)	
12.5	66	46	92	66	132	92	3.422
14	82	58	115	82	165	115	4.292
16	107	75	150	107	215	150	5.606
17.5	128	89	179	128	256	179	6.707
19	150	105	211	150	301	211	7.906
20.5	175	122	244	175	349	244	9.203
22	201	140	281	201	401	281	10.60
24	238	166	333	238	475	333	12.61
26	278	194	389	278	556	389	14.80
28	321	225	450	321	642	450	17.17
30	367	257	514	367	734	514	19.71
32	416	291	583	416	832	583	22.43
34	468	327	655	468	936	655	25.32
36	523	366	732	523	1045	732	28.38
38	580	406	812	580	1160	812	31.62
40	640	448	896	640	1280	896	35.04
42	703	492	984	703	1406	984	38.63
44	769	538	1076	769	1537	1076	42.40
46	837	585	1171	837	1673	1171	46.34
48	908	635	1270	908	1814	1270	50.46
50	981	686	1373	981	1961	1373	54.75
52	1057	739	1479	1057	2113	1479	59.22
54	1135	794	1589	1135	2269	1589	63.86
56	1216	850	1702	1216	2430	1702	68.68
58	1299	908	1818	1299	2597	1818	73.67
60	1384	968	1938	1384	2767	1938	78.84
62	1472	1029	2060	1472	2943	2060	84.18
64	1562	1092	2187	1562	3123	2187	89.70
66	1655	1157	2316	1655	3308	2316	95.40
68	1749	1223	2448	1749	3496	2448	101.3
70	1846	1291	2583	1846	3690	2583	107.3
73	1995	1395	2792	1995	3989	2792	116.7
76	2149	1503	3007	2149	4265	3007	126.5
78	2254	1576	3154	2254	4505	3154	133.2
81	2415	1689	3380	2415	4827	3380	143.7
84	2580	1805	3612	2580	5158	3612	154.5
87	2750	1923	3849	2750	5498	3849	165.8
90	2924	2045	4093	2924	5845	4093	177.4
92	3042	2127	4258	3042	6081	4258	185.4
95	3223	2254	4510	3223	6442	4510	197.6
97	3345	2339	4682	3345	6687	4682	206.1
98	3407	2382	4768	3407	6810	4768	210.3
100	3532	2470	4943	3532	7060	4943	219.0
102	3658	2558	5120	3658	7312	5120	227.8
105	3850	2692	5389	3850	7697	5389	241.4
107	3980	2783	5571	3980	7957	5571	250.7
108	4046	2829	5663	4046	8088	5663	255.4

Table 4.8.8 Breaking and proof test loads for chains (continued)

Nominal dia. d (mm)	Grade 1 chain		Grade 2 chain		Grade 3 chain		Mass of chain per metre (kg)
	Breaking test load (kN))	Proof test load (kN)	Breaking test load (kN)	Proof test load (kN)	Breaking test load (kN)	Proof test load (kN)	
111	4245	2968	5941	4245	8486	5941	269.8
114	4447	3110	6224	4447	8889	6224	284.6
117	4652	3253	6511	4652	9299	6511	299.8
120	4858	3398	6801	4859	9714	6801	315.4
122	4997	3496	6997	4999	9994	6997	326.0
124	5141	3595	7195	5141	10276	7195	336.7
127	5354	3744	7494	5354	10703	7494	353.2
130	5571	3895	7796	5571	11135	7796	370.1
132	5716	3997	8000	5716	11426	8000	381.6
137	6083	4254	8514	6083	12161	8514	411.0
142	6456	4515	9036	6456	12906	9036	441.6
147	6834	4779	9565	6834	13662	9565	473.2
152	7217	5046	10100	7217	14426	10100	506.0
157	7602	5316	10640	7602	15197	10640	539.8
162	7991	5588	11185	7991	15975	11185	574.7

NOTE :

Where nominal diameter is less than 12.5 mm or intermediate in this Table, breaking test loads, proof test loads and mass of chain per metre are to be determinated by the following table :

Kind	Breaking test load (kN)	Proof test load (kN)	Mass (kg)
Grade 1 chain	$0.00981d^2(44-0.08d)$	$0.00686d^2(44-0.08d)$	$0.0219d^2$
Grade 2 chain	$0.01373d^2(44-0.08d)$	$0.00981d^2(44-0.08d)$	$0.0219d^2$
Grade 3 chain	$0.01961d^2(44-0.08d)$	$0.01373d^2(44-0.08d)$	$0.0219d^2$

where :

d = Nominal diameter (mm)

412. Test and inspection of chain

1. General

(1) Finished chain cables are to be subjected to the proof load test and the breaking load test in the presence of the Surveyor, and shall not fracture or exhibit cracking.
(2) Special attention is to be given to the visual inspection of the flash-butt weld, if present. For this purpose, the chain cables must be free from paint and anti-corrosion media.

2. Breaking load tests

(1) For the breaking load test, one sample comprising at least of three links is to be taken from every four lengths or fraction of chain cables However, where one length of chain is short and the total length of two lengths of chain is less than 27.5 metres, such two lengths may be regarded as one length.
(2) The test specimens are to withstand satisfactorily the breaking test loads specified in **Table 4.8.8** according to their grades. The breaking load is to be maintained for a minimum of 30 seconds
(3) Where the capacity of the testing machine does not reach the breaking test loads specified in **Table 4.8.8**, the breaking test may be substituted by a method approved by the Society.
(4) The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it. Only after this they may be separated from the chain cable in the presence of the Surveyor.

3. Proof load tests

The proof tests are to be carried out for each length of the chains which satisfactorily complied with the breaking tests, and the chains are to withstand the proof test loads specified in **Table 4.8.8** without cracking, breakage or any other defects. The test is to be carried out after the chains were heat treated where necessary.

4. Retest

(1) Breaking load tests

(A) Where the test is not satisfactory, the chain may be retested by taking out another set of test specimens from the same length of chain, and where the test specimens comply with the requirements, the remaining three lengths of chain may be accepted. Where the retest fails, the length of chain from which the test specimen have been taken is rejected, and the remaining three chains are to be subjected to the breaking tests individually. If one of such test fails to meet the requirements, all the remaining three lengths of the chain are rejected.

(B) Where the missing chain links due to the preparation of the retest of **Par 5** above are replaced by new chain links, the test specimens manufactured by the same procedure are to be subjected to the breaking test, and are to comply with the requirements.

(2) Proof load tests
Where the test is not satisfactory, the chain may be retested only once more by link of same manufacturing process after replacing the defective link. Where, however, more than 5 % of the total links are found defective, the retest is not permitted. In addition, an investigation is to be made to identify the cause of the failure.

5. Mechanical tests on grade 2 and 3 chain cable

(1) Grade 2 and grade 3 chain cables are to be subjected to the mechanical tests, and are to comply with the requirements.

(2) Mechanical test specimens are to be taken from every four lengths in accordance with **Table 4.8.9.** For forged or cast chain cables where the batch size is less than four lengths, the sampling frequency will be by heat and heat treatment charge.

(3) An additional link (or where the links are small, several links) for mechanical test specimen removal is (are) to be provided in a length of chain cable not containing the specimen for the breaking test. The specimen link must be manufactured and heat treated together with the length of chain cable. Mechanical tests are to be carried out in the presence of the Surveyor.
Mechanical properties of chain links are to comply with requirements given in **Table 4.8.10.**

(4) Test procedure and forms of test specimens are to comply with the requirements in **Pt 2, Ch 1, Sec 2**.

(5) Where the test results of mechanical properties of chain links do not conform to the requirements, additional tests are to be carried out in accordance with the requirements specified in **Pt 2, Ch 1, 306. 9.**

413. Test and inspection of accessories

1. Proof load test

Each kind of accessory is to be tested to the proof test loads specified in **Table 4.8.8,** in accordance with the kinds and diameters of the chains to be connected therewith, and they are to withstand the test without crack, breakage or any other defect. This test may be carried out simultaneously with the proof test for the chains or together with any chains of the same diameter with which shackles and swivels are connected.

2. Breaking load test

(1) From each manufacturing batch (same accessory type, grade, size and heat treatment charge, but not necessarily representative of each heat of steel or individual purchase order) of 25 units or less of detachable links, shackles, swivels, swivel shackles, enlarged links, and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test at the break load specified for the corresponding chain given by **Table 4.8.8.** Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

(2) Where the test of Par (1) above is not satisfactory, the accessories may be retested by taking

out two units from the same lot. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

(3) Accessories used for the breaking load test must not be put into further use. However, the accessories, which have been successfully tested in accordance with Par (1) of the above and are manufactured with the following (A) or (B) may be used in service at the discretion of the Society.

(A) the material having higher strength characteristics than those specified for the part in question(e.g. grade 3 materials for accessories for grade 2 chain).

(B) the same grade materials as the chain but with increased dimensions subject to the successful procedure tests that such accessories are so designed that the breaking strength is not less than 1.4 times the breaking load of the chain which they are intended

(4) When the accessories are in accordance with the following requirements in (A) to (C), no impact testing is required subject to the approval by the Society.

(A) The breaking load test has been demonstrated on the occasion of the approval testing of parts of the same design.

(B) The tensile test and impact test have been demonstrated by each manufacturing lot.

(C) Non-destructive testing has been demonstrated before forwarding the products.

3. Mechanical properties and tests

(1) Unless otherwise specified, the forging or casting must at least comply with the mechanical properties given in **Table 4.8.10**, when properly heat treated. For test sampling, forgings or castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit.

(2) Mechanical tests are to be carried out in the presence of the Surveyor depending on the type and grade of material used. From each test unit, one tensile test specimen and three Charpy V-notch impact test specimens are to be taken in accordance with **Table 4.8.9.**

(3) Test procedure and forms of test specimens are to comply with the requirements in **Pt 2, Ch 1, Sec 2.**

(4) Where the test results do not conform to the requirements, additional tests are to be carried out in accordance with the requirements specified in **Pt 2, Ch 1, 306. 9.**

Table 4.8.9 Number of mechanical test specimens for finished chain cables and accessories

Grade	Manufacturing method	Condition of supply	Number of test specimens		
			Tensile test for base metal	Charpy V-notch impact test	
				Base metal	Weldment
2	Flush-butt welded	As welded	1	3	3
		Normalized	-	-	-
	Forged or Cast	Normalized	1	3[(1)]	-
3	Flush-butt welded	Normalized, Normalized and tempered, Quenched and tempered	1	3	3
	Forged or Cast	Normalized, Normalized and tempered, Quenched and tempered	1	3	-

NOTE :
(1) For chain cables, Charpy V-notch impact test is not required.

Table 4.8.10 Mechanical properties of finished chain cables and accessories

Grade	Tensile test				Impact test[1][2][3]		
	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation ($L=5d$) (%)	Reduction of area (%)	Testing temperature (°C)	Minimum mean absorbed energy(J)	
						Base Metal	Weldment
2	295 min.	490~690	22 min.	-	0	27	27
3	410 min.	690 min.	17 min.	40 min.	0	60	50

NOTE :
(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70 % of the specified minimum mean absorbed energy, the test is considered to have failed.
(2) For grade 3 chain, impact test can be carried out at -20℃ with the consent of the Society. The minimum mean absorbed energy to be not less than 27 J for weldment and 35 J for base metal
(3) For Grade 2 chain heat treated, no impact testing is required.

414. Marking and certification

1. Marking

Where chains and accessories have satisfactorily passed the tests and inspections, they are to be stamped with the Society's brand, kind of chain and certificated numbers. Chain cables which meet the requirements are to be stamped at both ends of each length at least with the following marks; cf. **Fig 4.8.6.**

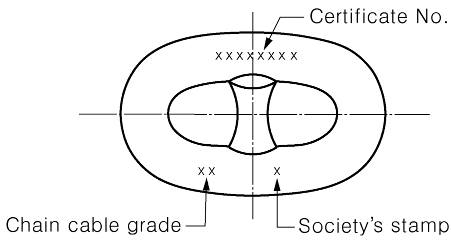


Fig 4.8.6 Marking of chain cables

2. certification

chains and accessories which meet the requirements are to be certified by the Society at least with the following items:
- Manufacturer's name
- Grade
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to chain
- Length
- Mechanical properties, where applicable

415. Painting

Chains and accessories are not to be painted until the tests and inspections are finished.

Section 5 Steel Wire Ropes

501. Application

1. The steel wire ropes used for steering ropes, mast riggings, stream wires, tow lines or mooring lines (hereinafter referred to as "steel wire rope") to be equipped on ships in accordance with the provisions in **Sec 2** are to comply with the requirements in this Section or to be of equivalent quality.

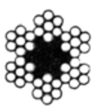
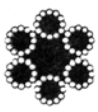
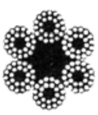
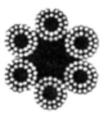
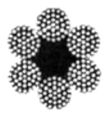
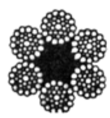
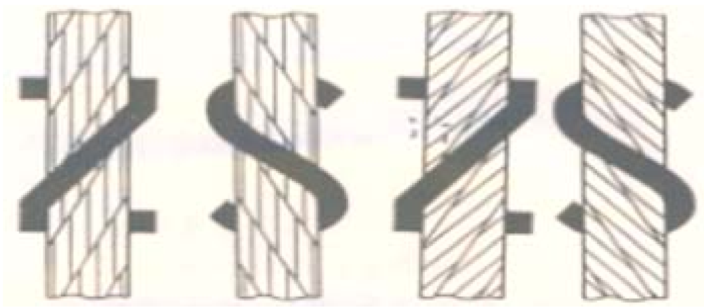
2. The provisions in this Section are applicable to the wire ropes constructed with fibre rope core and from individual wires having the tensile strength level of 1470 N/mm^2 [150 kgf/mm^2]. However, wire ropes constructed from other individual wires than those described above or steel wire ropes constructed with an independent wire rope core may be used where specially approved in connection with their manufacture.

502. Kinds

1. Steel wire ropes are classified by Composition, lay direction as specified in **Table 4.8.11.**

2. Generally, steel wire ropes having a great number of individual wires are used for running riggings since they provide more flexibility while ropes with fewer individual wires are used for standing riggings since they provide less elongation and greater wear-resistant.

Table 4.8.11 Designation system, Composition Mark, Sectional view of steel wire ropes

Designation system	7wires 6strands	12wires 6strands	19wires 6strands	24wires 6strands	30wires 6strands	37wires 6strands	Warrington seals 36wires 6strands
Composition mark	6 × 7	6 × 12	6 × 19	6 × 24	6 × 30	6 × 37	6 × WS(36)
Sectional view							
Lay direction	 Ordinary Z twisting(O/Z) Ordinary S twisting(O/S) Lang Z twisting(L/Z) Lang S twisting(L/S)						

503. Processes of manufacture

1. The individual wires composing the strands of steel wire ropes are to consist of wires of KS D 3559 (hard steel wires) or equivalent thereto or heat treated materials.

2. The individual wires are to have no joint for the whole length of a steel wire rope. However, in an unavoidable case in the manufacturing process, they may be jointed by welding, brazing or twisting at only one position for each 10 *metre* length of strand.

3. The individual wires are to be galvanized after being drawn or to be drawn after being galvanized.

4. Synthetic fabrics or natural fibres of good quality which suitably contains grease are to be used for fibre core of steel wire ropes and strands. The grease is to be free from acid or heavy alkali.

5. Steel wire ropes are to be left-hand lay and the strands are to be right-hand lay (called as "ordinary Z twisting").

6. Diameter, degree of twist, etc. are to be finished uniformly for the whole length of the steel wire ropes.

7. If not specified, basically grease is to be applied to steel wire rope.

504. Diameter of individual wires and steel wire ropes

1. The difference between the maximum and minimum diameters of the individual wires composing the strand of steel wire ropes is not to exceed the limits given in **Table 4.8.12.**

Table 4.8.12 Permissible variation in diameter of individual wires

Diameter of individual wire (mm)	Difference between maximum and minimum diameters (mm)
$0.20 < d \le 1.00$	0.06
$1.00 < d \le 2.24$	0.08
$2.24 < d \le 3.75$	0.12
$3.75 < d \le 4.50$	0.14

2. The diameter of steel wire ropes is the diameter of the circumscribed circle of ropes; cf. **Fig 4.8.7** and it is taken as an average diameter measured at any two or more positions except within 1.5 metres from the ends of ropes. In this case, the tolerance for the diameter less than 10 mm of ropes is to be within +10 % and 0 %, the tolerance for the diameter more than 10mm of ropes is to be within +7 % and 0 %.

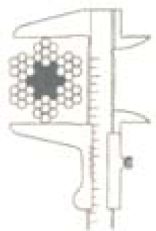


Fig 4.8.7 How to measure diameter of steel wire ropes

505. Mass

The mass of steel wire ropes is as given in **Table 4.8.13** according to the kind and diameter for the reference.

506. Breaking tests

1. Steel wire ropes are to be subjected to the breaking tests for each one length.

2. Where steel wire ropes are continuously manufactured by the same machine with the same wires and divided into several lengths, the test may be carried out on one length selected by the Surveyor at random. Where this test is satisfactory, the tests for the other lengths may be dispensed with.

3. The tests for steel wire ropes are to be carried out in accordance with the follows:

(1) Diameters and finished construction

(A) Diameter of steel wire ropes is to satisfy 504.

(B) Through the entire length, wire ropes should be free from defects such as dent, scratch which are detrimental to practical use.

(2) Breaking load tests

(A) The test piece of which both ends are either loosened and solidified to cone with suitable metal alloy or gripped by other suitable methods, is to be set to the testing machine and gradually pulled until breaks down.

(B) One test piece is to be taken from each length of steel wire ropes.

(C) The distance between the grips is taken table below. However, in case of exceeding 2 metres, the distance between the grips should be 2 metres.

Diameter of steel wire ropes	The distance between the grips
up to 6 mm	not less than 300 mm
over 6 mm 20 mm or less	not less than 600 mm
20 mm over	not less than 30 times of diameter of steel wire ropes

(D) The test pieces are to withstand the breaking test loads specified in **Table 4.8.13** according to the grade and diameter of steel wire rope.

(E) Where the test piece has broken down at the parts of the grips before reaching the required breaking load, one more test piece taken from the steel wire rope may be retested.

Table 4.8.13 Masses and breaking test loads for steel wire ropes

Composition mark	6 × 7		6 × 12		6 × 19		6 × 24		6 × 30		6 × 37		6 × WS(36)	
Diameter of steel wire rope (mm)	Breaking test load (kN)	Mass per metre in length (kg)	Breaking test load (kN)	Mass per metre in length (kg)	Breaking test load (kN)	Mass per metre in length (kg)	Breaking test load (kN)	Mass per metre in length (kg)	Breaking test load (kN)	Mass per metre in length (kg)	Breaking test load (kN)	Mass per metre in length (kg)	Breaking test load (kN)	Mass per metre in length (kg)
3.15	5.24	0.037												
4	8.45	0.059	5.22	0.044	8.03	0.058								
5	13.2	0.093	8.15	0.068	12.5	0.091								
6.3	21.0	0.147	12.9	0.108	19.9	0.144					19.6	0.143		
8	33.8	0.237	20.9	0.175	32.1	0.233	29.3	0.212			31.6	0.230	32.3	0.253
9	42.8	0.300	26.4	0.221	40.7	0.295	37.1	0.269			40.0	0.291	40.9	0.321
10	52.8	0.371	32.6	0.273	50.2	0.364	45.8	0.332			49.4	0.359	50.4	0.396
11.2	66.2	0.465	40.9	0.343	63.0	0.457	57.4	0.416			61.9	0.451	63.3	0.496
12	-	-	-	-	72.3	0.524	65.9	0.478			71.1	0.517	-	-
12.5	82.5	0.580	50.9	0.427	78.4	0.569	71.5	0.519			77.1	0.561	78.8	0.618
14	103	0.727	63.9	0.535	98.4	0.713	89.7	0.651			96.7	0.704	98.9	0.776
16	135	0.950	83.5	0.699	128	0.932	117	0.850			126	0.920	129	1.01
18	171	1.20	106	0.885	163	1.18	148	1.08			160	1.16	163	1.28
20	211	1.48	130	1.09	201	1.46	183	1.33			197	1.44	202	1.58
22.4	265	1.86	164	1.37	252	1.83	230	1.67			248	1.80	253	1.99
24	-	-			-	-	264	1.91			284	2.07	-	-
25	330	2.32			314	2.28	286	2.08	256	1.94	308	2.25	315	2.47
28	414	2.91			393	2.85	359	2.60	322	2.43	387	2.82	396	3.10
30	475	3.34			452	3.28	412	2.99	369	2.79	444	3.23	454	3.56
31.5	524	3.68					454	3.29	407	3.07	490	3.57	501	3.93
33.5	592	4.16					514	3.73	460	3.47	554	4.03	566	4.44
35.5	665	4.67					577	4.18	517	3.90	622	4.53	636	4.99
37.5	742	5.22					644	4.67	577	4.35	694	5.05	709	5.57
40	845	5.93					732	5.31	656	4.95	790	5.75	807	6.33
42.5							827	6.00			892	6.49	911	7.15
45							927	6.72			1000	7.28	1020	8.01
47.5							1030	7.49			1110	8.11	1140	8.93
50							1140	8.30			1230	8.98	1260	9.90
53											1390	10.1	1420	11.1
56											1550	11.3	1580	12.4
60											1780	12.9	1820	14.2
63											1960	14.3		

NOTES:
(1) The diameter of steel wire ropes not included in **Table 4.8.13** may be in accordance with the Guidance relating to the Rules specified by the Society.

507. Individual wire tests

1. Individual wire tests are to be carried out each one length.

2. Where steel wire ropes are continuously manufactured by the same machine with the same wires and divided into selected lengths, the test may be carried out on one length selected by the Surveyor at random. Where this test is satisfactory, the tests for the other lengths may be dispensed with.

3. For tests on the individual wires, a suitable length of a strand is to be cut off the rope and unstranded. The number of wires to be taken therefrom for tests is to be as specified in **Table 4.8.14.**(except for the core of the strand) Any straightening of test pieces which may be needed is to be done at the room temperature by a suitable method without injuring the test pieces.

4. In each of the individual wire tests, if some parts of the test results do not meet the requirements and the number of failed test pieces is not more than permissible number of failed test pieces given in **Table 4.8.15**, it may be considered as passed the tests. (except for Mass of Zinc Coating)

Table 4.8.14 Number of test pieces for individual wires tests

Composition mark	Number of test Pieces
6 × 7	3
6 × 12	6
6 × 19	6
6 × 24	8
6 × 30	10
6 × 37	12
6 × WS (36)	19

Table 4.8.15 Permissible number of failed test pieces in individual wire test

Composition mark	Permissible number of failed test pieces
6 × 7	0
6 × 12	1
6 × 19	1
6 × 24	1
6 × 30	1
6 × 37	1
6 × WS (36)	2

5. The individual wire tests are to be carried out in accordance with the following requirements:
(1) Inspection of diameter and appearance
(A) Diameter of individual wire is to meet the requirement specified in **504.**
(B) The full length of individual wire, very smooth at its surface and circular at the cross section, shall have no detrimental defects even for a scratch when use.
(2) Breaking tests
(A) The distance between grips is to be 100 mm where the diameter of test piece is less than 1.0 mm, or 200 mm where the diameter of test piece is 1.0 mm and over.
(B) The test piece is to be set to the testing machine and gradually pulled until broken down. The difference between individual breaking load and average value is to be within ±8 %.
(C) Where the test piece has broken down at the parts of the grips before reaching the required breaking load, one more test piece taken from the steel wire rope may be retested.
(3) Twisting Tests
(A) In twisting tests, the test piece with the length 100 times the diameter of the test piece is to be gripped hard at the ends, and then one end is to be revolved in twisting speed specified in **Table 4.8.16** until the test piece is broken down. The number of twisting is to be not less than minimum number of twisting specified in **Table 4.8.16.**

Table 4.8.16 Number of minimum twisting

Diameter of individual wire (mm)	Number of minimum twisting
$0.20 \leq d \leq 1.00$	21
$1.00 < d \leq 2.24$	20
$2.24 < d \leq 3.75$	18
$3.75 < d \leq 4.50$	17

NOTES:

1. Where it is necessary to modify the interval of the grips, the number of times of twisting is to be increased or decreased in direct proportion to the interval of the grips.
2. Twisting speed of individual wires is to be as table below.

Diameter of individual wire (mm)	Twisting speed(1 rpm)
$0.20 \leq d \leq 1.00$	up to 180
$1.00 < d \leq 3.60$	up to 60
$3.60 < d \leq 4.50$	up to 30

(B) Where the test piece has been broken down at the parts of the grips, and the results of the test do not comply with minimum number of twisting of the requirements, one more test piece taken from the steel wire rope may be retested.

(4) Wrapping Tests

(A) The test pieces are to be wrapped at least eight times around the wire with the same diameter as the test piece. Where they are unwrapped, the number of broken test pieces is to be measured.

508. Inspection

Steel wire ropes will be accepted, where the results of the breaking and individual wire tests and the inspection of the dimensions and appearance of each length are satisfactory.

509. Marking

The steel wire ropes which have satisfactorily passed the tests and inspections are to be sealed with lead and affixed with the Society's brand, the test number and grade number on the lead.

Section 6 Fibre Ropes

601. Application

1. Hemp ropes and synthetic fibre ropes used for tow lines and mooring lines to be equipped on ships in accordance with the provisions in **Section 2** (hereinafter referred to as "fibre rope") are to comply with the requirements in this Section.

2. Filaments and fibre ropes having characteristics differing from those specified in this Section are to comply with the requirements in **101. 4.**

602. Kinds of fibre ropes

Fibre ropes are classified into 9 kinds as shown in **Table 4.8.17.**

Table 4.8.17 Kinds of fibre rope

<table>
<tr><th colspan="3">Kind of fibre rope</th><th>Filament (material)</th></tr>
<tr><td colspan="3">Hemp rope</td><td>Manila hemp</td></tr>
<tr><td rowspan="5">Synthetic fibre rope</td><td>Vinylon rope</td><td>Grade 1
Grade 2</td><td>Vinylon</td></tr>
<tr><td>Polyethylene rope</td><td>Grade 1
Grade 2</td><td>Polyethylene</td></tr>
<tr><td colspan="2">Polyester rope</td><td>Polyester</td></tr>
<tr><td>Polypropylene rope</td><td>Grade 1
Grade 2</td><td>Polypropylene</td></tr>
<tr><td colspan="2">Polyamide rope</td><td>Polyamide</td></tr>
</table>

603. Processes of manufacture

Synthetic fibre ropes are to be manufactured by approved processes at approved works.

604. Materials

1. Hemp ropes are to be made of pure manila hemp not containing any other similar fibre.

2. Synthetic fibre ropes are to be made of pure filaments not containing any other filaments, which are not to be restored

605. Construction of fibre ropes and others

1. Hemp ropes are, in general, to be composed of three strands and synthetic fibre ropes are to be composed of three or eight strands.

2. Three strand ropes are, in general, to be made of strands twisted together with a *Z* lay, these strands themselves being made with an *S* lay. Eight strand ropes are, in general, to be formed of four pairs of strands, the pairs being constituted successively of two strands twisted in the *S* direction and than of two strands twisted in the *Z* direction.

3. The number of the yarns of a strand is to be same, and the dimensions and laying of the yarns composing ropes are to be uniform for the whole length of the rope.

4. The lead for the strand is, in general, to be below 3.2 times the nominal diameter for three strand rope and below 3.5 times the nominal diameter for eight strand rope.

5. Polyamide ropes are to be suitably heat treated by induction furnace or others to set the lay and obtain dimensional stability. Vinylon and polypropylene ropes may be subjected to suitable heat treatment, if necessary.

6. Synthetic fibre ropes may be subjected to resin treatment and dye treatment subject to the approval by the Society.

7. Oil of good quality is to be used in manufacturing hemp ropes. Ropes are not to contain excessive quantity of oil.

606. Diameter

The diameter of fibre ropes is to be measured on circumscribed circle of the ropes under the load equal to 5 % of the breaking test load specified in **Table 4.8.18** Its tolerance is to be ±3 % of its nominal diameter.

607. Breaking tests

Breaking tests for fibre ropes are to be carried out in accordance with the following requirements:

(1) One specimen is to be taken from each coil of the fibre ropes. Where fibre ropes are continuously manufactured by the same machine with the yarns of the same type and divided into several coils, one specimen may be taken from one coil of the ropes selected by the Surveyor at random.

(2) The length of the specimen is not to be less than 30 times the diameter of the hemp rope, but need not exceed one *metre*.

(3) Specimens for polyethylene and polypropylene ropes are to be subjected to breaking tests in as wet condition immediately after having been immersed in warm water at 35 ± 2 °C for more than 30 *minutes*. For other fibre ropes than the above ropes, specimens are to be subjected to breaking tests in as dry condition at room temperature.

(4) The load at the time of breaking is not to be less than given in **Table 4.8.18.**

Table 4.8.18 Breaking test loads for fibre ropes (kN)

Diameter of rope (mm)	Hemp rope[1]	Synthetic fibre rope							Polyamide[1]
		Vinylon[1]		Polyethylene[2]		Polyester[1]	Polypropylene[2]		
		Grade 1	Grade 2	Grade 1	Grade 2		Grade 1	Grade 2	
10	7.06	9.32	15.7	9.71	12.7	15.6	10.8	12.7	18.1
12	9.90	13.4	21.8	13.9	17.7	22.0	15.7	17.7	27.5
14	13.1	17.9	28.4	18.6	23.5	29.2	20.6	23.5	36.6
16	16.9	22.9	36.3	23.8	29.4	37.5	26.5	29.4	46.9
18	21.0	28.6	45.1	29.7	37.3	46.7	32.4	37.3	58.3
20	25.6	34.8	54.9	36.1	44.1	56.8	39.2	44.1	70.9
22	30.5	41.6	65.7	43.1	54.9	67.8	47.1	54.9	84.6
24	35.9	48.8	77.5	50.7	63.7	79.6	54.9	63.7	100
26	41.6	56.7	89.2	58.8	73.5	92.4	63.7	73.5	116
28	47.8	65.1	103	67.5	83.4	106	73.5	83.4	132
30	54.3	74.0	117	76.8	97.1	121	83.4	97.1	151
32	61.2	83.5	131	86.5	108	136	94.1	108	170
35	72.3	99.0	155	102	127	161	111	127	201
40	95.4	127	198	131	164	206	142	164	258
45	119	157	247	163	203	260	177	203	321
50	144	191	300	198	250	312	214	250	390
55	173	228	358	237	294	373	255	294	466
60	203	269	421	279	348	438	300	348	547
65	235	312	487	324	402	508	348	402	635
70	271	358	559	371	461	583	399	461	729
75	307	407	635	422	525	663	453	525	829
80	346	459	716	476	593	747	511	593	935
85	387	514	801	533	667	837	572	667	1050
90	431	571	895	592	735	931	635	735	1170
95	477	632	981	655	814	1030	702	814	1280
100	525	694	1080	721	897	1140	772	897	1410

(Note)
(1) Breaking load at room temperature in dried condition.
(2) Breaking load at room temperature after having been immersed in warm water at 35 ± 2 °C for more than 30 minutes.

608. Inspection of appearance and dimensions

Fibre ropes are to be inspected on the appearance and dimensions and they are to be in good order.

609. Marking

The fibre rope which has satisfactorily passed the tests and inspections is to be sealed with lead and affixed with the Society's brand indicating compliance with the rule requirements and the test number. Furthermore, diameter, mass, kind of ropes, coil length, manufacturing number and manufacturer are to be marked in proper way.

Section 7 Hatch Tarpaulins

701. Application

1. Hatch tarpaulins to be equipped on ships in accordance with the provisions in **Ch 2** are to comply with the requirements in this Section or to be of equivalent quality.

2. The tests and inspections for hatch tarpaulins made of synthetic materials are to be to the discretion of the Society.

702. Grades

The grades of tarpaulins are as follows:
Grade *A* tarpaulins (Mark, *TA*)
Grade *B* tarpaulins (Mark, *TB*)

703. Materials

Tarpaulins are to be made from cloths woven with flax yarn or cotton yarn of good quality.

704. Sewing

The overlapping, sewing threads and method of sewing for the purpose of joining the cloths used for tarpaulins are to be to the satisfaction of the Surveyor.

705. Mass

The mass of cloths used for tarpaulins before waterproof treatment is not to be less than 650 g/m^2 for Grade *A* tarpaulins and 490 g/m^2 for Grade *B* tarpaulins. Where, however, the waterproof mediums other than tar are used, the minimum mass may be reduced to 85 % of the above mass according to the characteristics of the mediums.

706. Tensile Tests

The strength of cloths used for tarpaulins before the waterproof treatment is not to be less than 80 kg for Grade *A* tarpaulins and 60 kg for Grade *B* tarpaulins in warp and woof, being tested with test pieces 30 mm wide and 200 mm long. Where, however, the waterproof mediums other than tar are used, the minimum strength may be reduced to 85 % of the above value according to the characteristics of the mediums.

707. Waterproof treatments

1. Waterproof mediums are to be made of suitable tar, grease or chemicals.

2. Tarpaulins are to pass the waterproofness tests which the Surveyor considers appropriate.

3. The waterproof medium applied to the tarpaulin is to prove free from adhesion, cracking or any other defect on its surface where it is folded at the temperature which is appropriate to this society.

708. Making

For the hatch tarpaulins which have been satisfactorily tested and inspected, the Society‘s brand, manufacturer, test number and grade identification of the hatch tarpaulins are to be marked on suitable places of the hatch tarpaulins.

Section 8 Side Scuttles

801. Application

The side scuttles to be fitted up on ships according to the requirements in **Ch 4** (hereinafter referred to as side scuttle) are to comply with the requirements in this Section or to be of equivalent quality.

802. Classes

Side scuttles are classified into following three classes and divided into "fixed type" and "hinged type" according to the types of glass holders of the scuttles, and divided into "bolted type" and

"welded type" according to the method of fastening the scuttles.
(1) Class A scuttle (Mark *RPA*)
(2) Class B scuttle (Mark *RPB*)
(3) Class C scuttle (Mark *RPC*)

803. Construction and dimensions

The construction and dimensions of the main parts of the side scuttles are to be in accordance with the requirements in the followings and **Table 4.8.19** through **Table 4.8.21** according to their nominal diameters and classes. And the area of opening of side scuttles is not to exceed $0.16\,m^2$, and those of other parts are to be determined at the discretion of the Surveyor.

(1) Maximum allowable pressure
The maximum allowable pressure for standard side scuttle is to be in accordance with the requirements as given **Table 4.8.19** through **Table 4.8.21**.

(2) Glazing
(A) An appropriate glazing material resistant to sea water and ultraviolet light is to be used.
(B) Mounting
When glazing, glass pane is to be centralized in the glass holder of hinged side scuttles or in the main frame of non-opening side scuttles so that there is the same clearance all round.

(3) Fasteners (closing devices and hinges)
(A) The minimum number of fasteners comprising closing devices and hinges with round hole for glassholders and deadlights of class A, B and C scuttles is to be in accordance with the requirements as given in **Table 4.8.19** through **Table 4.8.21**.
(B) The total number of the fasteners and their construction is to be such that the side scuttle meets the strength and weathertight test requirements according to **805.**
(C) Where the hole for the hinge of the glassholder and deadlight is oval, the hinge is not regarded as a fastener.

(4) Gaskets for glassholder and deadlight
(A) For ensuring watertightness between the glassholder and main frame and also between the deadlight and glassholder, gaskets type A or B according to ISO3902 are to be used.
(B) The gaskets are to be secured in the grooves by means of a suitable adhesive.

Table 4.8.19 Class A side scuttle

Main parts of side scuttle		Nominal dia. of scuttle (mm)				
		200	250	300	350	400
Max. allowable pressure (kPa)		328	302	328	241	297
Glass thickness (mm)		10	12	15	15	19
Obscured glass thickness (mm)*		15	19	-	-	-
Min. number of fasteners	Glass holder	2	3	3	3	3
	Deadlight	2	2	3	3	3

Table 4.8.20 Class B side scuttle

Main parts of side scuttle		Nominal dia. of scuttle (mm)					
		200	250	300	350	400	450
Max. allowable pressure (kPa)		210	134	146	154	118	146
Glass thickness (mm)		8	8	10	12	12	15
Obscured glass thickness (mm)*		12	12	15	19	19	-
Min. number of fasteners	Glass holder	2	3	3	3	3	4
	Deadlight	2	2	3	3	3	3

Table 4.8.21 Class C side scuttle

<table>
<tr><td colspan="2" rowspan="2">Main parts of side scuttle</td><td colspan="6">Nominal dia. of scuttle (mm)</td></tr>
<tr><td>200</td><td>250</td><td>300</td><td>350</td><td>400</td><td>450</td></tr>
<tr><td colspan="2">Max. allowable pressure (kPa)</td><td>118</td><td>75</td><td>93</td><td>68</td><td>82</td><td>65</td></tr>
<tr><td colspan="2">Glass thickness (mm)</td><td>6</td><td>6</td><td>8</td><td>8</td><td>10</td><td>10</td></tr>
<tr><td colspan="2">Obscured glass thickness (mm)*</td><td>10</td><td>10</td><td>12</td><td>12</td><td>15</td><td>15</td></tr>
<tr><td>Min. number of fasteners</td><td>Glass holder</td><td>2</td><td>2</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
</table>

* Thickness of obscured glass panes when the obscured surface is facing inwards

804. Materials

1. Main components of the side scuttle

The materials used for the main components of side scuttles (main frame, glassholder, glass retaining ring and deadlight) are to be in accordance with the requirements as given in **Table 4.8.22.** These materials are to have the following properties.

(1) Resistant corrosion

(2) Mechanical properties as given in **Table 4.8.23.**
One tensile test specimen is to be taken from each cast. Where the number of casting from one cast exceed 50, an additional specimen is to be taken from each 50 castings of fraction thereof.

Table 4.8.22 Material classes

<table>
<tr><td rowspan="2">Class</td><td rowspan="2">Method of fastening</td><td colspan="3">Material</td></tr>
<tr><td>Main frame</td><td>Glassholder and/or glass retaining ring</td><td>Deadlight</td></tr>
<tr><td rowspan="3">A</td><td>Bolted</td><td colspan="2">Copper alloy[1]</td><td>Iron or steel[2]</td></tr>
<tr><td rowspan="2">Welded</td><td>Mild steel</td><td>Copper alloy</td><td>Iron or steel[2]</td></tr>
<tr><td colspan="3">Mild steel</td></tr>
<tr><td rowspan="6">B</td><td rowspan="2">Bolted</td><td colspan="2">Copper alloy[1]</td><td>Iron or steel[2]</td></tr>
<tr><td colspan="3">Aluminium alloy[3]</td></tr>
<tr><td rowspan="4">Welded</td><td>Mild steel</td><td>Copper alloy</td><td>Iron or steel[2]</td></tr>
<tr><td colspan="3">Mild steel</td></tr>
<tr><td colspan="3">Aluminium alloy</td></tr>
<tr><td>Aluminium alloy[4]</td><td colspan="2">Aluminium alloy[3]</td></tr>
<tr><td rowspan="6">C</td><td rowspan="5">Bolted</td><td colspan="2">Copper alloy[1]</td><td rowspan="6">-</td></tr>
<tr><td colspan="2">Aluminium alloy[3]</td></tr>
<tr><td>Mild steel</td><td>Copper alloy</td></tr>
<tr><td colspan="2">Mild steel</td></tr>
<tr><td colspan="2">Aluminium alloy</td></tr>
<tr><td>Welded</td><td>Aluminium alloy[4]</td><td>Aluminium alloy[3]</td></tr>
<tr><td colspan="5">(Note)
[1] The use of brass(cast or wrought) or gun metal is optional.
[2] The use of iron(spheroidal graphite cast iron) or steel(mild steel or cast steel) is optional.
[3] The use of cast or wrought alloy is optional.
[4] The use of plate or extruded material is optional.</td></tr>
</table>

Table 4.8.23 Tensile strength and elongation for main components

Class	Minimum tensile strength (N/mm^2)	Minimum elongation (%)
A	300	15
B	180	10
C	140	3

2. Closing devices

The materials used for bolts, pins and nuts of closing devices and hinge pins for glassholder are to have the following properties. For aluminum alloy side scuttle, the swingbolts of closing device and the hinge pins of glassholder are to be made of non-corrodible steel, stainless steel or such alloy which are not likely to cause corrosion of side scuttle bolts or pins.

(1) Resistant corrosion

(2) Mechanical properties as given in **Table 4.8.24.**
One tensile test specimen is to be taken from each cast. Where the number of casting from one cast exceed 50, an additional specimen is to be taken from each 50 castings of fraction thereof.

3. Glass panes

Toughened safety glass panes according to ISO21005 or glass panes of equivalent quality are to be used. For fire resistant glass panes, glass panes according to ISO5797 or glass panes of equivalent quality are to be used.

4. Where steel or iron is used, the side scuttles are to be galvanized.

Table 4.8.24 Tensile strength and elongation for the closing devices

Class	Swing bolt and pin, hinge pin		Nut	
	Minimum tensile strength (N/mm^2)	Minimum elongation (%)	Minimum tensile strength (N/mm^2)	Minimum elongation (%)
A	350	20	250	14
B	350	15	250	14
C	250	14	180	8

805. Testing

1. Watertightness test

The side scuttles are to be tested by being subjected to the hydraulic pressure given in **Table 4.8.25.** An equivalent hydraulic test is to be carried out by means of batch tests (approximately 10% of the delivery patch, with a minimum of two side scuttle) with glass pane and open deadlight, and without glass pane and closed deadlight.

2. Mechanical strength test

(1) A prototype side scuttle without glass pane and with closed deadlight is to be subjected to a mechanical strength test by a punch method according to the test pressures given in **Table 4.8.26.** For this test, ISO614 is to be used as a guide.

(2) The punch is to be placed on that side of the deadlight which could be subjected to direct contact with the sea. Where the construction of the deadlight makes it necessary, a plate of 100 mm diameter and 10 mm thickness may be placed between the punch and the deadlight.

(3) When subjected to the pressure given in **Table 4.8.26**, the permanent deformation of the deadlight is not to exceed 1% of the normal size of the side scuttle.

3. Fire-resistant test

Side scuttles for fire-resistant constructions are to be subjected to prototype testing as given in

ISO5797.

Table 4.8.25 Test pressure for watertightness

Class	Test pressure (kPa)	
	With glass pane, deadlight open	Without glass pane, deadlight closed
A	150	100
B	75	50
C	35	-

Table 4.8.26 Test pressure of mechanical test

Class	Test pressure (kPa)
A	240
B	120

806. Dispensation with tests

The tensile test specified in **804.** and fire-resistance test specified in **805. 3.** for side scuttles may be dispensed with, where these scuttles have appropriate certificates accepted by the Society.

807. Marking

For the side scuttles which have been satisfactorily tested and inspected, the Society's brand, test number and grade identification of the side scuttles are to be stamped on suitable places of the side scuttles.

Section 9 Rectangular Windows

901. Application

The rectangular windows to be fitted up on ships according to the requirements in **Ch 4** are to comply with the requirements in this chapter or to be of equivalent quality.

902. Classes

Rectangular windows are classified into the following two classes, divided into "fixed type" and "hinged type" according to the types of glassholders of the windows and divided into "bolted type" and "welded type" according to the method of fastening the windows.

(1) Class E window(Mark RPE) (See **Table 4.8.27**)
(2) Class F window(Mark RPF) (See **Table 4.8.28**)

903. Construction and dimensions

The construction and dimensions of the main parts of the rectangular windows are to be in accordance with the requirements in the following Sub-paragraphs and are determined in **Table 4.8.27** and **Table 4.8.28** in accordance with their nominal diameters and classes. Other parts are to be determined at the discretion of the Surveyor.

(1) Maximum allowable pressure

The maximum allowable pressure for rectangular window is to be in accordance with the requirements as given in **Table 4.8.27** and **Table 4.8.28.** Where one or both dimensions(width and height) of a window are different from above, maximum allowable pressure(p) is to be determined using the following formula.

$$p = \frac{40000t^2}{\beta b^2} \quad \text{(kPa)}$$

t : glass thickness (mm)
β : factor obtained from the graph of **Fig 4.8.8**
b : minor dimension of the window (mm)

Table 4.8.27 Class E rectangular window

Items	Nominal size, width (mm) × height (mm)							
	300×425	355×500	400×560	450×630	500×710	560×800	900×630	1000×710
Maximum allowable pressure (kPa)	99	71	80	63	80	64	81	64
Glass thickness (mm)	10	10	12	12	15	15	19	19
Obscured glass thickness (mm)	15	15	19	19	-	-	-	-
Minimum number of fasteners	4	4	4	4	6	6	6	8

Table 4.8.28 Class F rectangular window

Items	Nominal size, width (mm) × height (mm)								
	300×425	355×500	400×560	450×630	500×710	560×800	900×630	1000×710	1100×800
Maximum allowable pressure (kPa)	63	45	36	28	36	28	32	25	31
Glass thickness (mm)	8	8	8	8	10	10	12	12	15
Obscured glass thickness (mm)	12	12	12	12	15	15	19	19	-
Minimum number of fasteners	4	4	4	4	6	6	6	8	8

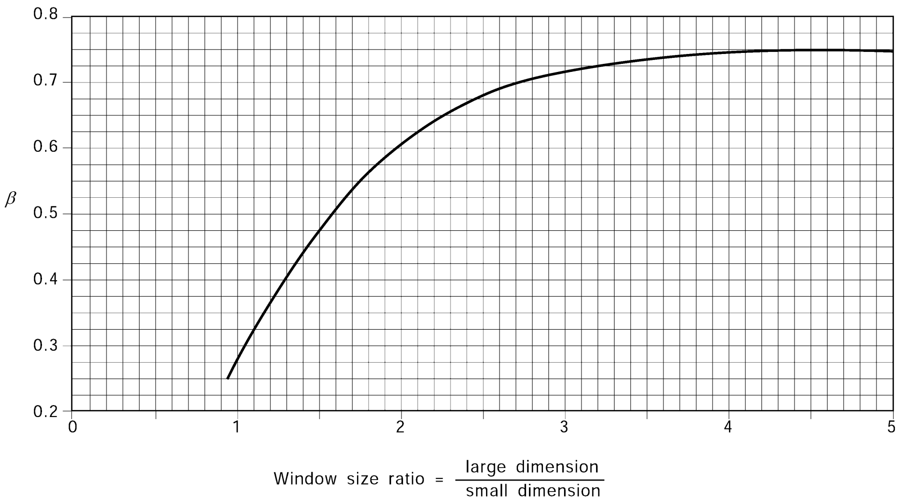


Fig 4.8.8 Curve for determination of β based on window size ratio

(2) Glazing
(A) Appropriate glazing material resistant to sea water and ultraviolet light is to be used.
(B) Mounting
When glazing, glass pane is to be centralized in the glassholder of hinged type rectangular windows or in the main frame of fixed type rectangular windows so that there is the same clearance all round.
(3) Fasteners (closing device and hinge)
(A) The fasteners of glassholders and deadlights of grade *E* and *F* windows are to be made up of the closing devices and hinges with round hole, and the number should be not less than that in the **Table 4.8.27** and **Table 4.8.28**.
(B) The total number of the fasteners and their construction is to be such that the rectangular window meets the strength and watertightness requirements in **905.**
(C) Where the hole for the hinge of the glassholder and deadlight is oval, the hinge is not regarded as a fastener.
(4) Gaskets for glassholder and glass retaining frame
(A) For ensuring watertightness between the glassholder and main frame, gaskets type A, B and C according to ISO3902 are to be used.
(B) The gaskets are to be secured in the grooves by means of a suitable adhesive.
(5) Fixing device
All sidewards opening rectangular windows are to be provided with a fitted fixing device like hook.

904. Materials

1. Main frame, glassholder and glass retaining frame

The materials used for the main components of the rectangular windows(such as main frame, glassholder and glass retaining frame) are to be in accordance with the requirements as given in **Table 4.8.29** and these materials are to have the following properties.

Table 4.8.29 Material

<table>
<tr><th rowspan="2">Type of rectangular window</th><th rowspan="2">Method of fastening the rectangular window</th><th colspan="3">Material</th></tr>
<tr><th>Main frame</th><th>Glassholder</th><th>Glass retaining ring</th></tr>
<tr><td rowspan="7">Hinged</td><td rowspan="2">Bolted</td><td colspan="3">Brass(1)</td></tr>
<tr><td colspan="3">Aluminium alloy(1)</td></tr>
<tr><td rowspan="5">Welded</td><td>Mild steel</td><td colspan="2">Brass(1)</td></tr>
<tr><td colspan="2">Mild steel</td><td>Brass(1)</td></tr>
<tr><td colspan="3">Mild steel</td></tr>
<tr><td>Mild steel</td><td colspan="2">Aluminium alloy(1)</td></tr>
<tr><td>Aluminium alloy
(only wrought or extruded)</td><td colspan="2">Aluminium alloy(1)</td></tr>
<tr><td rowspan="6">Fixed</td><td rowspan="2">Bolted</td><td>Brass(1)</td><td>-</td><td>Brass(1)</td></tr>
<tr><td>Aluminium alloy(1)</td><td>-</td><td>Aluminium alloy(1)</td></tr>
<tr><td rowspan="4">Welded</td><td>Mild steel</td><td>-</td><td>Brass(1)</td></tr>
<tr><td>Mild steel</td><td>-</td><td>Mild steel</td></tr>
<tr><td>Mild steel</td><td>-</td><td>Aluminium alloy(1)</td></tr>
<tr><td>Aluminium alloy
(only wrought or extruded)</td><td>-</td><td>Aluminium alloy(1)</td></tr>
<tr><td colspan="5">(Note)
(1) The use of cast or wrought alloy is optional.</td></tr>
</table>

(1) resistant to corrosion
(2) minimum mechanical properties as given in **Table 4.8.30**(One tensile test specimen is to be taken from each cast. Where the number of castings from one cast exceeds 50, an additional specimen is to be taken from each 50 castings of fraction thereof).

Table 4.8.30 Tensile strength and elongation for the main components

Type of rectangular window	Tensile strength (N/mm^2) min.	Elongation (%) min.
Class *E*	180	10
Class *F*	140	3

2. Closing device and hinge pin

The materials used for bolts, pins and nuts of closing devices and hinge pins for glassholder are to have the following properties.

For aluminum alloy rectangular windows, the bolts (screw-in bolt or swingbolt) of closing device and the hinge pin of the glassholder are to be made of non-corrodible steel, stainless steel or such alloy which are not likely to cause corrosion of rectangular windows, bolts and pins.
(1) resistant to corrosion
(2) no effect on the corrosion resistance of other parts
(3) minimum mechanical properties as given in **Table 4.8.31**(One tensile test specimen is to be taken from each cast. Where the number of casting from one cast exceeds 50, an additional specimen is to be taken from each 50 castings of fraction thereof. For aluminum extruded shapes of aluminum alloy, the extruded shapes of the same dimensions, made from same cast and heat treated simultaneously, are treated as one lot and one tensile test specimen is to be taken from every lot. Where the number of extruded shapes from every lot exceeds 50, an additional specimen is to be taken from each 50 lots of fraction thereof.)

Table 4.8.31 Tensile strength and elongation for the closing device

Type of rectangular window	Swingbolt and pin, hinge pin		Nut	
	Minimum tensile strength (N/mm^2)	Minimum elongation (%)	Minimum tensile strength (N/mm^2)	Minimum elongation (%)
Grade *E*	350	15	250	14
Grade *F*	250	14	180	8

3. Glass panes

Toughened safety glass panes according to ISO21005 of glass panes of equivalent quality are to be used. For fire resistant glass panes, glass panes according to ISO5797 or glass panes of equivalent quality are to be used. For heated glass panes, glass panes according to ISO3434 or glass panes of equivalent quality are to be used.

4. Where steel or iron is used, the rectangular windows are to be galvanized.

905. Testing

1. Watertightness test

An equivalent hydraulic test is to be carried out by means of batch tests(approximately 10% of the delivery batch, with a minimum one window) at a test pressure 25 kPa.

2. Mechanical strength test

A prototype rectangular window is to be subject to a mechanical strength test by a suitable test method, applying a load equivalent to the pressures in **Table 4.8.32.**

Table 4.8.32 Mechanical strength test pressure

Classes	Test pressure (kPa)
E	75
F	35

3. Fire-resistant test

Rectangular windows for fire-resistant constructions are to be subjected to prototype testing as given in ISO5797.

4. Test for heated windows

Heated rectangular windows are to be subjected to the electrical testing as given in ISO3434 clause 6.

906. Dispensation with tests

The tensile test specified in **904.** and fire-resistant test specified in **905. 3.** may be dispensed with, where these windows have appropriate certificates accepted by the Society.

907. Marking

For the rectangular windows which have been satisfactorily tested and inspected, the Society's brand, test number and grade identification of the rectangular windows are to be stamped on suitable. ⚓

CHAPTER 9 STRENGTH AND SECURING OF SMALL HATCHES, FITTINGS AND EQUIPMENT ON THE FORE DECK

Section 1 Application and Implementation

101. Application

1. For ships that are contracted for construction on or after 1 January 2004 on the exposed deck over the forward $0.25L$, applicable to:

All ship types of sea going service of length 80 m or more, where the height of the exposed deck in way of the hatch is less than $0.1L$ or 22 m above the summer load waterline, whichever is the lesser.

2. For ships that are contracted for construction prior to 1 January 2004 only for hatches on the exposed deck giving access to spaces forward of the collision bulkhead, and to spaces which extend over this line aft-wards, applicable to:

Bulk carriers, general dry cargo ships (excluding container vessels, vehicle carriers, Ro-Ro ships and woodchip carriers), and combination carriers (e.g. OBO ships, Ore/Oil Carriers, etc.), of length 100 m or more.

102. Implementation

The detail requirements for implementation of this chapter, refer to **Pt 1, Ch 2, Sec 15, 501.**

Section 2 Strength and Securing of Small Hatches on the Exposed Fore Deck

201. General

1. The strength of, and securing devices for, small hatches fitted on the exposed fore deck are to comply with the requirements of this Section.

2. Small hatches in the context of this Section are hatches designed for access to spaces below the deck and are capable to be closed weather-tight or watertight, as applicable. Their opening is normally 2.5 square meters or less.

3. Hatches designed for use of emergency escape are to comply with the requirements of this Section, excepting **203. 1.** (1) and (2) **204. 3.** and **205.**

202. Strength

1. For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with **Table 4.9.1**, and **Fig 4.9.1**. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in **204. 1.** (see **Fig 4.9.1.**) Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see **Fig 4.9.2.**

2. The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

3. For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to be in accordance with the requirement specified by the Society.

4. For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

203. Primary securing devices

1. Small hatches located on exposed fore deck subject to the application of this section are to be fitted with primary securing devices such that their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

(1) Butterfly nuts tightening onto forks (clamps),
(2) Quick acting cleats, or
(3) Central locking device.

2. Dogs (twist tightening handles) with wedges are not acceptable.

204. Requirements for primary securing

1. The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with **Fig 4.9.1** and of sufficient capacity to withstand the bearing force.

2. The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

3. For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is not to be less than 16 mm. An example arrangement is shown in **Fig 4.9.2**.

4. For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

5. On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

205. Secondary securing device

Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Table 4.9.1 Scantlings for small steel hatch covers on the fore deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Secondary stiffeners
		Flat Bar (mm x mm) ; number	
630×630	8	-	-
630×830	8	100×8 ; 1	-
830×630	8	100×8 ; 1	-
830×830	8	100×10 ; 1	-
1030×1030	8	120×12 ; 1	80×8 ; 2
1330×1330	8	150×12 ; 2	100×10 ; 2

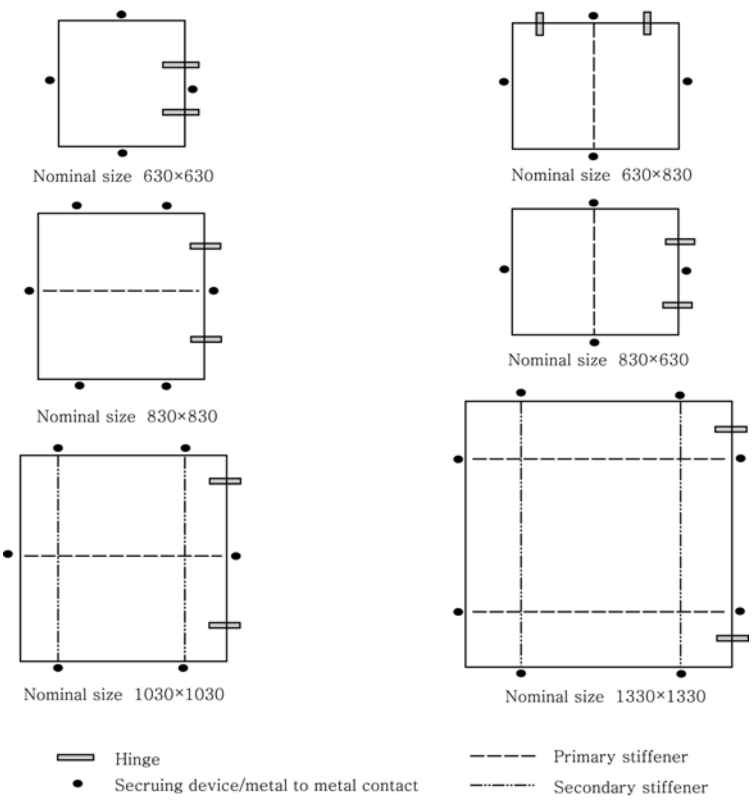


Fig 4.9.1 Arrangement of stiffeners

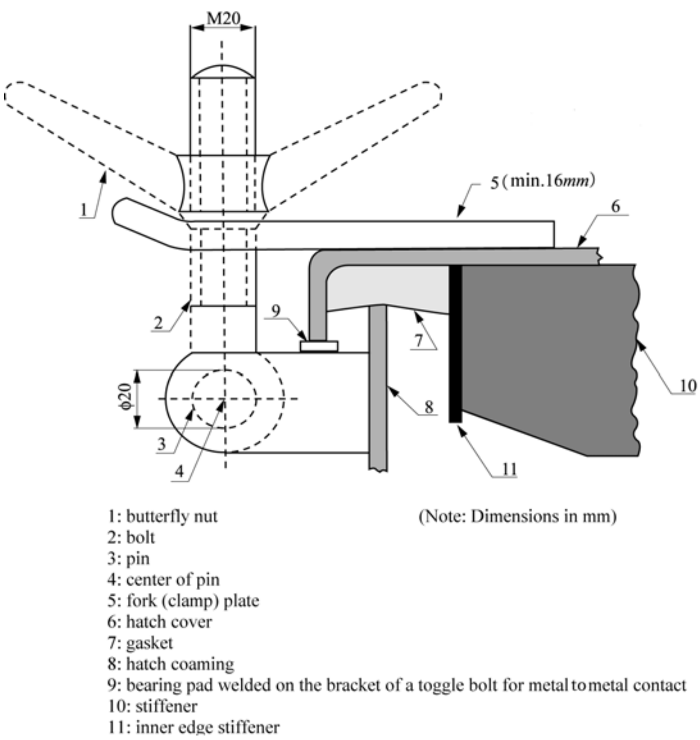


Fig 4.9.2 Example of a primary securing method

Section 3 Strength Requirements for Fore Deck Fittings and Equipment

301. General

1. This section provides strength requirements to resist green sea forces for the following items : air pipes, ventilator pipes and their closing devices, the securing of windlasses.

2. For windlasses, these requirements are additional to those appertaining to the anchor and chain performance criteria of **Pt 5, Ch 8.**

3. Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

302. Applied loading

1. Air pipes, ventilator pipes and their closing devices

(1) The pressures p, in kN/m^2 acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5\rho V^2 C_d C_s C_p \quad (\text{kN/m}^2)$$

where :

ρ = density of sea water (1.025 t/m^3)

V = velocity of water over the fore deck (13.5 m/sec)

C_d = shape coefficient

= 0.5 for pipes,

= 1.3 for air pipe or ventilator heads in general,

= 0.8 for an air pipe or ventilator head of cylinderical form with its axis in the vertical direction.

C_s = slamming coefficient (3.2)

C_p = protection coefficient:

= 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle,

= 1.0 elsewhere and immediately behind a bulwark.

(2) Forces acting in the horizontal direction on the pipe and its closing device may be calculated from (1) using the largest projected area of each component.

2. Windlasses

(1) The following pressures and associated areas are to be applied (see **Fig 4.9.3**):

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction,
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,

where f is defined as:
$f = 1 + B/H$, but not greater than 2.5

where:
B = width of windlass measured parallel to the shaft axis,
H = overall height of windlass.

(2) Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts, see **Fig 4.9.4.**

(3) The axial force R_i in bolt group (or bolt) i, positive in tension, may be calculated from:

$$R_{xi} = \frac{P_x h x_i A_i}{I_x}, \quad R_{yi} = \frac{P_y h y_i A_i}{I_y}, \quad R_i = R_{xi} + R_{yi} - R_{si}$$

where:

P_x = force (kN) acting normal to the shaft axis

P_y = force (kN) acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group i

h = shaft height above the windlass mounting (cm)

x_i, y_i = x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force (cm)

A_i = cross sectional area of all bolts in group i (cm^2)

I_x = $\Sigma A_i x_i^2$ for N bolt groups

I_y = $\Sigma A_i y_i^2$ for N bolt groups

R_{si} = static reaction at bolt group i, due to weight of windlass.

(4) Shear forces F_{xi}, F_{yi} applied to the bolt group i, and the resultant combined force F_i may be calculated from:

$$F_{xi} = \frac{P_x - \alpha g M}{N}, \quad F_{yi} = \frac{P_y - \alpha g M}{N}, \quad F_i = \sqrt{F_{xi}^2 + F_{yi}^2}$$

α = coefficient of friction (0.5)

M = mass of windlass (tonnes)

g = gravity acceleration (9.81 m/s^2)

N = number of bolt groups.

(5) Axial tensile and compressive forces in (3) and lateral forces in (4) are also to be considered in the design of the supporting structure.

303. Strength Requirements

1. Air pipes, ventilator pipes and their closing devices

(1) These requirements are additional to **Pt 5, Ch 6, Sec 2.**

(2) Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed $0.8\sigma_y$, where σ_y is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

(3) For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in **Table 4.9.2** Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to **Table 4.9.2** but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

(4) For other configurations, loads according to **302.** are to be applied, and means of support determined in order to comply with the requirements of (2). Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in **Pt 5, Ch 6, 102.**

(5) For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in **Table 4.9.3** Brackets, where required are to be as specified in (3).

(6) For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted according to the requirements of each Society. Pipe thickness is not to be taken less

than as indicated in **Pt 5, Ch 6, 102.**

(7) All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in **302. 1.**

(8) Rotating type mushroom ventilator heads are unsuitable for application on the exposed deck over the forward $0.25L$

2. Windlass mounts

(1) Tensile axial stresses in the individual bolts in each bolt group i are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations. The safety factor against bolt proof strength is to be not less than 2.0.

(2) The strength of above deck framing and hull structure supporting the windlass and its securing bolt loads as defined in **302. 2** is to be according to the requirements of the Society.

3. Chain stoppers

(1) A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. A chain stopper is to be capable of withstanding a load equal to 80% of the breaking load of the chain cable without undergoing permanent deformation.

(2) A chain stopper deemed appropriate by the Society, National Standards, internationally recognized Codes or Standards considered as equivalent for those may be applied instead of requirements of this Section. ⚓

Table 4.9.2 760 mm air pipe thickness and bracket standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm^2)	Height(1) of bracket (mm)
40A(3)	6.0	-	520
50A(3)	6.0	-	520
65A	6.0	-	480
80A	6.3	-	460
100A	7.0	-	380
125A	7.8	-	300
150A	8.5	-	300
175A	8.5	-	300
200A	8.5(2)	1900	300(3)
250A	8.5(2)	2500	300(2)
300A	8.5(2)	3200	300(2)
350A	8.5(2)	3800	300(2)
400A	8.5(2)	4500	300(2)

(1) Brackets (see **303. 1.** (3)) need not extend over the joint flange for the head.
(2) Brackets are required where the as fitted (gross) thickness is less than 10.5 mm, or where the tabulated projected head area is exceeded.
(3) Not permitted for new ships. Reference **Rules Pt 5 Ch 6**
Note: For other air pipe heights, the relevant requirements of **303. 1.** are to be applied.

Table 4.9.3 900 mm Ventilator pipe thickness and bracket standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm2)	Height of bracket (mm)
80A	6.3	-	460
100A	7.0	-	380
150A	8.5	-	300
200A	8.5	550	-
250A	8.5	880	-
300A	8.5	1200	-
350A	8.5	2000	-
400A	8.5	2700	-
450A	8.5	3300	-
500A	8.5	4000	-

Note: For other ventilator heights, the relevant requirements of **303. 1** are to be applied.

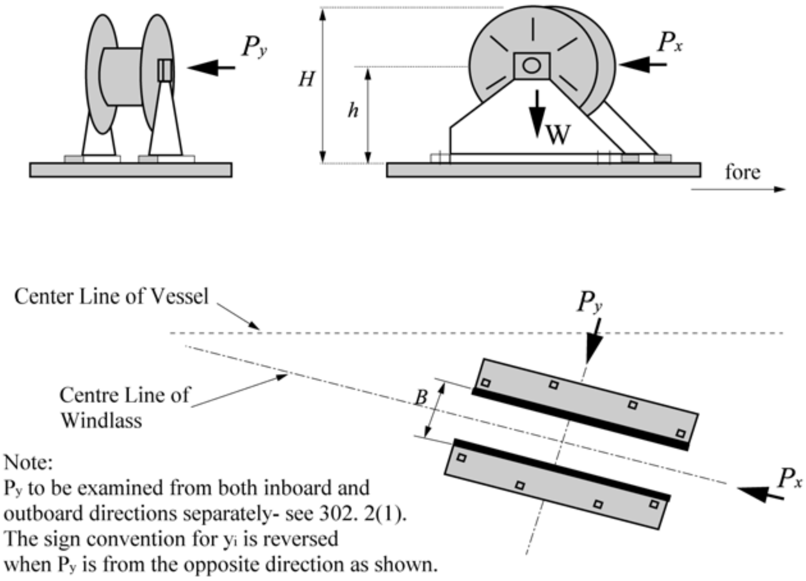


Fig 4.9.3 Direction of force and weight

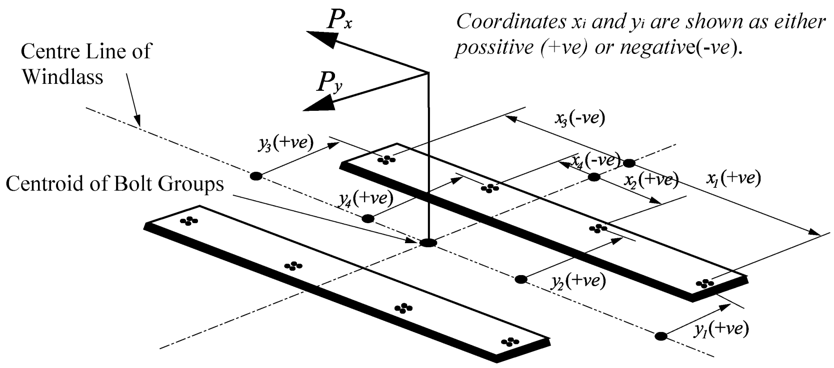


Fig 4.9.4 Sign convention

CHAPTER 10 SHIPBOARD EQUIPMENT, FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING

Section 1 Definitions and Scope of Application

101. Application

1. This Chapter is to be applied to new displacement ships of 500GT and above, except high speed craft, special purpose vessels and offshore units, which were keeling after 1 Jan. 2007.

2. This Chapter is to be applied to shipboard fittings and supporting hull structures used for the normal towing and mooring operations. For the emergency towing arrangements, ships subject to **Ch 8, Sec 2** are to comply with that regulation and Resolution MSC.35 (63) as may be amended.

3. The mooring equipment of single point moorings which fitted on ships such as oil tanker the delivery of which is after 1 January 2009 are to be in accordance with the Guidance relating to the Rules specified by the Society.

102. Definitions

1. Shipboard fittings mean bollards and bitts, fairleads, stand rollers and chocks used for the normal mooring of the ship and similar components used for the normal towing of the ship.

2. Other components such as capstans, winches, etc. are not covered by this requirement.

3. Any weld or bolt or other fastening connecting the shipboard fitting to the supporting hull structure is part of the shipboard fitting and subject to the industry standard applicable to such fitting.

4. Supporting hull structures means that part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting.

The net minimum scantlings of the supporting hull structure are to comply with the requirements given **201. 5** and **202. 5**. The required gross thickness is obtained by adding the total corrosion additions given in **201. 6** and **202. 6**. And the hull structure supporting capstans, winches, etc. used for the normal towing and mooring operations mentioned above should be also be subjected to this chapter.

5. Industry standard means international standard(ISO etc.) or standards issued by national association(KS, DIN, JMSA etc.) which are recognized in the country where the ship is built.

Section 2 Towing and Mooring

201. Towing

1. Strength

The strength of shipboard fittings used for normal towing operations at bow, sides and stern and their supporting hull structures are to comply with the requirements of this chapter.

2. Arrangement

Shipboard fittings for towing are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other equivalent arrangements may be accepted (for Panama chocks, etc.) provided the strength is confirmed adequate for the intended service.

3. Load considerations

Shipboard fittings and supporting hull structures for towing are to be complied with the following requirements.

(1) Unless greater safe working load (SWL) of shipboard fittings is specified, the minimum design load to be used is the following value of (A) or (B), whichever is applicable.
   (A) For normal towing operation (e.g. harbour/manoeuvring)
      1.25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangement plan.
   (B) For other towing service (e.g. escort)
      The normal breaking strength of the tow line based on the equipment number. Side projected area including maximum stacks of deck cargoes is to be taken into account for calculation of equipment number.
(2) The design load should be applied through the tow line according to the arrangements shown on the towing and mooring arrangements plan, the method of application of the design load to the fittings and supporting hull structure should be taken into account such that the total load need not be more than twice the design load specified in (A), (B), i.e. no more than one turn of one line. (See **Fig 4.10.1**)
(3) When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the fitting is to be designed using this specific design load.

4. Shipboard fittings

The selection of shipboard fittings is to be made by the shipyard in accordance with an Industry standard (e.g. ISO 3913: 1977 Shipbuilding-Welded steel bollards) accepted by the society. When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship should be in accordance with **3.**

5. Supporting hull structure

(1) Arrangement
   Arrangement of the reinforced members (carling) beneath shipboard fittings should consider any variation of direction (laterally and vertically) of the towing forces (which should be not less than the design load as per **3.**) acting through the arrangement of connection to the shipboard fittings.
(2) Acting point of towing force
   The acting point of towing force on shipboard fittings should be taken at the attachment point of a towing line or at a change in its direction.
(3) Allowable stresses
   Allowable stresses under the design load conditions are as follows, and no stress concentration factors being taken into account.
   Normal stress : 100 % of the specified minimum yield point of the material;
   Shearing stress : 60 % of the specified minimum yield point of the material;

6. Corrosion addition of supporting hull structures

The scantling of supporting hull structures is not to be less than the value of net thickness plus the following values (1) through (3).

(1) For bulk carriers specified in **Pt. 11**, corrosion addition specified in **Pt 11, Ch 3, Sec 3**
(2) For double hull oil tankers specified in **Pt. 12**, corrosion addition specified in **Pt 12, Ch 6, Sec 3**
(3) For other ships, the value will be considered by the Society, but not to be less than 2 mm.

7. Safe Working Load (SWL)

(1) The SWL used for nomal towing operations (harbour/manoeuvring) should not exceed 80 % of the design load as given in **Sec 2, 201. 3** (1) and the SWL used for other towing operations (e.g. escort) should not exceed the design load as given in **Sec 2, 201. 3** (2).
   For fittings used for both harbour and escort purposes, the greater of the design loads of **201. 3** (1) and **201. 3** (2) should be used.
(2) The SWL of each shipboard fitting should be marked (by weld bead or equivalent) on the deck fittings used for towing.
(3) The above provisions on SWL apply for a single post basis (no more than one turn of one line).
(4) The towing and mooring arrangements plan described in **203.** should define the method of use of towing lines.

202. Mooring

1. Strength

The strength of shipboard fittings used for mooring operations and their supporting hull structures are to comply with the requirement of this Chapter.

2. Arrangements

Shipboard fittings for mooring should be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other equivalent arrangements may be accepted (for Panama chocks, etc.) provided the strength is confirmed adequate for the service.

3. Load considerations

Shipboard fittings and supporting hull structures for mooring are to be complied with the following requirements.

(1) Unless greater safe working load(SWL) of shipboard fittings is specified, the design load applied to shipboard fittings and supporting hull structures should be 1.25 times the breaking strength of the mooring line based on the equipment number.
Side projected area including maximum stacks of deck cargoes is to be taken into account for calculation of equipment number.

(2) According to the requirements of **Ch 8, 204. 8**, above (1) breaking strength may be reduced with corresponding increase of number of the mooring lines. But the number of mooring lines is not to be less than 6 and no one line is to have a strength less than 490 kN.

(3) The design load applied to supporting hull structures for winches, etc. is to be 1.25 times the intended maximum brake holding load and, for capstans, 1.25 times the maximum hauling force.

(4) The design load should be applied through the mooring line according to the arrangement shown on the towing and mooring arrangement plan. The method of application of the design load to the fittings and supporting hull structures should be taken into account such that the total load need not be more than twice the design load specified in (1), i.e. no more than one line. (See **Fig 4.10.1**)

(5) When a specific SWL is applied for a shipboard fitting at the request of the applicant, by which the design load will be greater than the above minimum values, the strength of the fitting is to be designed using this specific design load.

4. Shipboard fittings

The selection of shipboard fittings is in accordance with **201. 4**.

5. Supporting hull structures

(1) Arrangements
Arrangement of the reinforced members (carling) beneath shipboard fittings should consider any variation of direction (laterally and vertically) of the towing forces (which should be not less than the Design Load as per **3.**) acting through the arrangement of connection to the shipboard fittings.

(2) Acting point of mooring force
The acting point of the mooring force on shipboard fittings should be taken at the attachment point of a mooring line or a change in its direction.

(3) Allowable stresses
Allowable stresses under the design load conditions are as follows, and no stress concentration factors being taken into account.
Normal stress : 100 % of the specified minimum yield point of the material;
Shearing stress : 60 % of the specified minimum yield point of the material;

6. Corrosion addition of supporting hull structures

Corrosion addition are to be followed **201. 6.**

7. Safe working load (SWL)

(1) The SWL should not exceed 80 % of the design load given in **202. 3.**

(2) The SWL of each shipboard fitting should be marked (by weld bead or equivalent) on the deck fittings used for mooring.

(3) The above provisions on SWL apply for a single post basis (no more than one turn of one line).
(4) The towing and mooring arrangements plan described in **203.** should define he method of use of mooring lines.

203. Towing and mooring arrangements plan

1. The SWL for the intended use for each shipboard fitting should be noted in he towing and mooring arrangements plan available on board for the guidance of the Master.

2. Information provided on the plan is to include in respect of each shipboard fitting.

(1) Location on the ship
(2) Fitting type
(3) SWL
(4) Purpose (mooring / harbour towing / escort towing)
(5) Method of applying load of towing or mooring line including limiting fleet angles

3. Where the arrangements and details of deck fittings and their supporting hull structures are designed based on the mooring arrnagements as permitted in **202. 3.** (2), the following information is to be clearly indicated on the plan.

(1) The arrangement of mooring lines showing number of lines (N)
(2) The breaking strength of each mooring line (BS)

4. This information is to be incorporated into the pilot card in order to provide the pilot proper information on harbour/escorting operations. ⚓

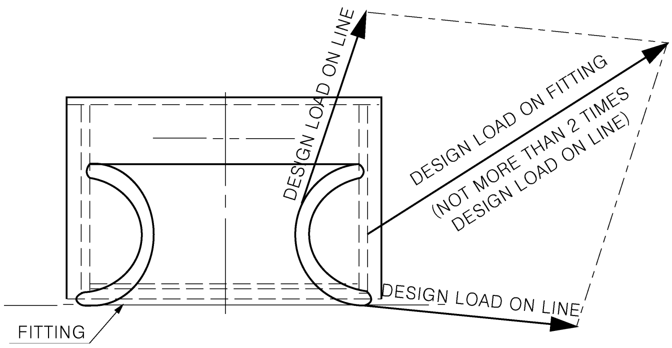


Fig 4.10.1 Application of design load

CHAPTER 11 ACCESS TO AND WITHIN SPACES IN, AND FORWARD OF, THE CARGO AREA OF OIL TANKERS AND BULK CARRIERS

Section 1 General

101. Application

1. This applies to oil tankers of 500 gross tonnage and over and bulk carriers, as defined in SOLAS Reg. II/1, of 20,000 gross tonnage and over, constructed on or after 1 January 2005.

2. This do not apply to the cargo tanks of combined chemical/oil tankers complying with the provisions of the IBC Code.

102. Means of access to cargo and other spaces

1. Each space shall be provided with means of access to enable, throughout the life of a ship, overall and close-up inspections and thickness measurements of the ship's structures to be carried out by this Society as necessary. Such means of access shall comply with the requirements of paragraph **105. and section 2.**

2. Where a permanent means of access may be susceptible to damage during normal cargo loading and unloading operations or where it is impracticable to fit permanent means of access, this Society may allow, in lieu thereof, the provision of movable or portable means of access, as specified in the **section 2**, provided that the means of attaching, rigging, suspending or supporting the portable means of access forms a permanent part of the ship's structure. All portable equipment shall be capable of being readily erected or deployed by ship's personnel.

3. The construction and materials of all means of access and their attachment to the ship’s structure shall be to the satisfaction of this Society. The means of access shall be subject to survey prior to, or in conjunction with, its use in carrying out surveys in accordance with SOLAS I/10.

103. Safe access to cargo holds, cargo tanks, ballast tanks and other spaces

1. Safe access to cargo holds, cofferdams, ballast tanks, cargo tanks and other spaces in the cargo area shall be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom spaces or to foreward ballast tanks may be from a pump-room, deep cofferdam, pipe tunnel, cargo hold, double hull space or similar compartment not intended for the carriage of oil or hazardous cargoes.

2. Tanks, and subdivisions of tanks, having a length of 35 m or more, shall be fitted with at least two access hatchways and ladders, as far apart as practicable. Tanks less than 35 m in length shall be served by at least one access hatchway and ladder. When a tank is subdivided by one or more swash bulkheads or similar obstructions which do not allow ready means of access to the other parts of the tank, at least two hatchways and ladders shall be fitted.

3. Each cargo hold shall be provided with at least two means of access as far apart as practicable. In general, these accesses should be arranged diagonally, for example one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side.

104. Ship structure access manual

1. A ship's means of access to carry out overall and close-up inspections and thickness measurements shall be described in a Ship structure access manual approved by this Society, an updated copy of which shall be kept on board. The Ship structure access manual shall include the following for each space ;

(1) plans showing the means of access to the space, with appropriate technical specifications and dimensions

(2) plans showing the means of access within each space to enable an overall inspection to be car-

ried out, with appropriate technical specifications and dimensions. The plans shall indicate from where each area in the space can be inspected

(3) plans showing the means of access within the space to enable close-up inspections to be carried out, with appropriate technical specifications and dimensions. The plans shall indicate the positions of critical structural areas, whether the means of access is permanent or portable and from where each area can be inspected

(4) instructions for inspecting and maintaining the structural strength of all means of access and means of attachment, taking into account any corrosive atmosphere that may be within the space

(5) instructions for safety guidance when rafting is used for close-up inspections and thickness measurements

(6) instructions for the rigging and use of any portable means of access in a safe manner

(7) an inventory of all portable means of access and

(8) records of periodical inspections and maintenance of the ship's means of access.

2. For the purpose of this regulation critical structural areas are locations which have been identified from calculations to require monitoring or from the service history of similar or sister ships to be sensitive to cracking, buckling, deformation or corrosion which would impair the structural integrity of the ship.

105. General technical specifications

1. For access through horizontal openings, hatches or manholes, the dimensions shall be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall not be less than 600 mm × 600 mm. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder shall be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm shall also have steps on the outside in conjunction with the ladder.

2. For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening shall be not less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.

3. For oil tankers of less than 5,000 tonnes deadweight, this Society may approve, in special circumstances, smaller dimensions for the openings referred to in above **1.** and **2**, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of this Society.

Section 2 Technical Provisions for Means of Access for Inspections

201. Definitions

1. Rung means the step of a vertical ladder or step on the vertical surface.

2. Tread means the step of an inclined ladder or step for the vertical access opening.

3. Flight of an inclined ladder means the actual stringer length of an inclined ladder. For vertical ladders, it is the distance between the platforms.

4. Stringer means:

(1) the frame of a ladder; or

(2) the stiffened horizontal plating structure fitted on the side shell, transverse bulkheads and/or longitudinal bulkheads in the space. For the purpose of ballast tanks of less than 5 m width forming double side spaces, the horizontal plating structure is credited as a stringer and a longitudinal permanent means of access, if it provides a continuous passage of 600 mm or more in width past frames or stiffeners on the side shell or longitudinal bulkhead. Openings in stringer plating utilized as permanent means of access shall be arranged with guard rails or grid covers to provide safe passage on the stringer or safe access to each transverse web.

5. Vertical ladder means a ladder of which the inclined angle is 70° and over up to 90°. A vertical ladder shall not be skewed by more than 2°.

6. Overhead obstructions mean the deck or stringer structure including stiffeners above the means of access.

7. Distance below deck head means the distance below the plating.

8. Cross deck means the transverse area of the main deck which is located inboard and between hatch coamings.

202. Technical provisions

1. Structural members subject to the close-up inspections and thickness measurements of the ship's structure referred to ESP, except those in double bottom spaces, shall be provided with a permanent means of access to the extent as specified in **Table 4.11.1** and **Table 4.11.2**, as applicable. For oil tankers and wing ballast tanks of ore carriers, approved alternative methods may be used in combination with the fitted permanent means of access, provided that the structure allows for its safe and effective use.

2. Permanent means of access should as far as possible be integral to the structure of the ships, thus ensuring that they are robust and at the same time contributing to the overall strength of the structure of the ship.

3. Elevated passageways forming sections of a permanent means of access, where fitted, shall have a minimum clear width of 600 mm, except for going around vertical webs where the minimum clear width may be reduced to 450 mm, and have guard rails over the open side of their entire length. Sloping structures providing part of the access shall be of a non-skid construction. Guard rails shall be 1,000 mm in height and consist of a rail and an intermediate bar 500 mm in height and of substantial construction. Stanchions shall be not more than 3 m apart.

4. Access to permanent means of access and vertical openings from the ship.s bottom shall be provided by means of easily accessible passageways, ladders or treads. Treads shall be provided with lateral support for the foot. Where the rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to the surface shall be at least 150 mm. Where vertical manholes are fitted higher than 600 mm above the walking level, access shall be facilitated by means of treads and hand grips with platform landings on both sides.

5. Permanent inclined ladders shall be inclined at an angle of less than 70° There shall be no obstructions within 750 mm of the face of the inclined ladder, except that in way of an opening this clearance may be reduced to 600 mm. Resting platforms of adequate dimensions shall be provided, normally at a maximum of 6 m vertical height. Ladders and handrails shall be constructed of steel or equivalent material of adequate strength and stiffness and securely attached to the structure by stays. The method of support and length of stay shall be such that vibration is reduced to a practical minimum. In cargo holds, ladders shall be designed and arranged so that cargo handling difficulties are not increased and the risk of damage from cargo handling gear is minimized.

6. The width of inclined ladders between stringers shall not be less than 400 mm. The treads shall be equally spaced at a distance apart, measured vertically, of between 200 mm and 300 mm. When steel is used, the treads shall be formed of two square bars of not less than 22 mm by 22 mm in section, fitted to form a horizontal step with the edges pointing upward. The treads shall be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders shall be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

7. For vertical ladders or spiral ladders, the width and construction should be in accordance with international or national standards accepted by this Society.

8. No free-standing portable ladder shall be more than 5 m long.

9. Alternative means of access include, but are not limited to, such devices as :

(1) hydraulic arm fitted with a stable base;
(2) wire lift platform;
(3) staging;

(4) rafting;
(5) robot arm or remotely operated vehicle (ROV);
(6) portable ladders more than 5 m long shall only be utilized if fitted with a mechanical device to secure the upper end of the ladder;
(7) other means of access, approved by and acceptable to this Society.
Means for safe operation and rigging of such equipment to and from and within the spaces shall be clearly described in the Ship Structure Access Manual.

10. For access through horizontal openings, hatches or manholes, the minimum clear opening shall not be less than 600 mm × 600 mm. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder shall be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm shall also have steps on the outside in conjunction with the ladder.

11. For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening shall be not less than 600 mm × 800 mm at a height of not more than 600 mm from the passage unless gratings or other foot holds are provided.

12. For oil tankers of less than 5,000 tonnes deadweight, this Society may approve, in special circumstances, smaller dimensions for the openings referred to in paragraphs **10.** and **11**, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of this Society.

13. For bulk carriers, access ladders to cargo holds and other spaces shall be :
(1) Where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is not more than 6 m, either a vertical ladder or an inclined ladder.
(2) Where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is more than 6 m, an inclined ladder or series of inclined ladders at one end of the cargo hold, except the uppermost 2.5 m of a cargo space measured clear of overhead obstructions and the lowest 6 m may have vertical ladders, provided that the vertical extent of the inclined ladder or ladders connecting the vertical ladders is not less than 2.5 m. The second means of access at the other end of the cargo hold may be formed of a series of staggered vertical ladders, which should comprise of one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder should be laterally offset from each other by at least the width of the ladder. The uppermost entrance section of the ladder directly exposed to a cargo hold should be vertical for a distance of 2.5 m measured clear of overhead obstructions and connected to a ladder-linking platform.
(3) A vertical ladder may be used as a means of access to topside tanks, where the vertical distance is 6 m or less between the deck and the longitudinal means of access in the tank or the stringer or the bottom of the space immediately below the entrance. The uppermost entrance section from deck of the vertical ladder of the tank should be vertical for a distance of 2.5 m measured clear of overhead obstructions and comprise a ladder linking platform, unless landing on the longitudinal means of access, the stringer or the bottom within the vertical distance, displaced to one side of a vertical ladder.
(4) An inclined ladder or combination of ladders should be used for access to a tank or a space where the vertical distance is greater than 6 m between the deck and a stringer immediately below the entrance, between stringers, or between the deck or a stringer and the bottom of the space immediately below the entrance.
(5) In case of (4) above, the uppermost entrance section from deck of the ladder should be vertical for a distance of 2.5 m clear of overhead obstructions and connected to a landing platform and continued with an inclined ladder. The flights of inclined ladders should not be more than 9 m in actual length and the vertical height should not normally be more than 6 m. The lowermost section of the ladders may be vertical for a distance of not less than 2.5 m.
(6) In double-side skin spaces of less than 2.5 m width, the access to the space may be by means of vertical ladders that comprise of one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder should be laterally offset from each other by at least the width of the ladder.
(7) A spiral ladder is considered acceptable as an alternative for inclined ladders. In this regard, the

uppermost 2.5 m can continue to be comprised of the spiral ladder and need not change over to vertical ladders.

14. The uppermost entrance section from deck of the vertical ladder providing access to a tank should be vertical for a distance of 2.5 m measured clear of overhead obstructions and comprise a ladder linking platform, displaced to one side of a vertical ladder. The vertical ladder can be between 1.6 m and 3 m below deck structure if it lands on a longitudinal or athwartship permanent means of access fitted within that range.

203. Protective coating

Permanent means of access in dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers shall be coated in accordance with the Guidance relating to the Rules specified by the Society.

Table 4.11.1 - Means of access for ballast and cargo tanks of oil tankers (Access to the underdeck and vertical structure)

1. Water ballast tanks, except those specified in 2., and cargo oil tanks

1.1 For tanks of which the height is 6 m and over containing internal structures, permanent means of access shall be provided in accordance with .1 to .6:
- .1 continuous athwartship permanent access arranged at each transverse bulkhead on the stiffened surface, at a minimum of 1.6 m to a maximum of 3 m below the deck head;
- .2 at least one continuous longitudinal permanent means of access at each side of the tank. One of these accesses shall be at a minimum of 1.6 m to a maximum of 6 m below the deck head and the other shall be at a minimum of 1.6 m to a maximum of 3 m below the deck head;
- .3 access between the arrangements specified in .1 and .2 and from the main deck to either .1 or .2;
- .4 continuous longitudinal permanent means of access which are integrated in the structural member on the stiffened surface of a longitudinal bulkhead, in alignment, where possible, with horizontal girders of transverse bulkheads are to be provided for access to the transverse webs unless permanent fittings are installed at the uppermost platform for use of alternative means, as defined in **202. 9.** of the Technical provisions, for inspection at intermediate heights;
- .5 for ships having cross-ties which are 6 m or more above tank bottom, a transverse permanent means of access on the cross-ties providing inspection of the tie flaring brackets at both sides of the tank, with access from one of the longitudinal permanent means of access in .4; and
- .6 alternative means as defined in 202. 9. of the technical provisions may be provided for small ships as an alternative to .4 for cargo oil tanks of which the height is less than 17 m.

1.2 For tanks of which the height is less than 6 m, alternative means as defined in 202. 9. of the technical provisions or portable means may be utilized in lieu of the permanent means of access.

Fore peak tanks

1.3 For fore peak tanks with a depth of 6 m or more at the centre line of the collision bulkhead, a suitable means of access shall be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure.

1.3.1 Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access.

1.3.2 In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access as defined in 202. 9. of the Technical provisions shall be provided.

2. Water ballast wing tanks of less than 5 m width forming double side spaces and their bilge hopper sections

2.1 For double side spaces above the upper knuckle point of the bilge hopper sections, permanent means of access are to be provided in accordance with .1 to .3:
- .1 where the vertical distance between horizontal uppermost stringer and deck head is 6 m or more, one continuous longitudinal permanent means of access shall be provided for the full length of the tank with a means to allow passing through transverse webs installed at a minimum of 1.6 m to a maximum of 3 m below the deck head with a vertical access ladder at each end of the tank;
- .2 continuous longitudinal permanent means of access, which are integrated in the structure, at a vertical distance not exceeding 6 m apart but permitted to exceed 6 m by a maximum of 10 %; and
- .3 plated stringers shall, as far as possible, be in alignment with horizontal girders of transverse bulkheads.

2.2 For bilge hopper sections of which the vertical distance from the tank bottom to the upper knuckle point is 6 m and over, one longitudinal permanent means of access shall be provided for the full length of the tank. It shall be accessible by vertical permanent means of access at each end of the tank.

2.2.1 The longitudinal continuous permanent means of access may be installed at a minimum 1.6 m to maximum 3 m from the top of the bilge hopper section. In this case, a platform extending the longitudinal continuous permanent means of access in way of the webframe may be used to access the identified structural critical areas.

2.2.2 Alternatively, the continuous longitudinal permanent means of access may be installed at a minimum of 1.2 m below the top of the clear opening of the web ring allowing a use of portable means of access to reach identified structural critical areas.

2.3 Where the vertical distance referred to in 2.2 is less than 6 m, alternative means as defined in 202. 9. of the technical provisions or portable means of access may be utilised in lieu of the permanent means of access. To facilitate the operation of the alternative means of access, in-line openings in horizontal stringers shall be provided. The openings shall be of an adequate diameter and shall have suitable protective railings.

Table 4.11.2 Means of access for bulk carriers

1. Cargo holds

Access to underdeck structure

1.1 Permanent means of access shall be fitted to provide access to the overhead structure at both sides of the cross deck and in the vicinity of the centreline. Each means of access shall be accessible from the cargo hold access or directly from the main deck and installed at a minimum of 1.6 m to a maximum of 3 m below the deck.

1.2 An athwartship permanent means of access fitted on the transverse bulkhead at a minimum 1.6 m to a maximum 3 m below the cross-deck head is accepted as equivalent to 1.1.

1.3 Access to the permanent means of access to overhead structure of the cross deck may also be via the upper stool.

1.4 Ships having transverse bulkheads with full upper stools with access from the main deck which allows monitoring of all framing and plates from inside do not require permanent means of access of the cross deck.

1.5 Alternatively, movable means of access may be utilized for access to the overhead structure of the cross deck if its vertical distance is 17 m or less above the tank top.

Access to vertical structures

1.6 Permanent means of vertical access shall be provided in all cargo holds and built into the structure to allow for an inspection of a minimum of 25 % of the total number of hold frames port and starboard equally distributed throughout the hold including at each end in way of transverse bulkheads. But in no circumstance shall this arrangement be less than 3 permanent means of vertical access fitted to each side (fore and aft ends of hold and mid-span). Permanent means of vertical access fitted between two adjacent hold frames is counted for an access for the inspection of both hold frames. A means of portable access may be used to gain access over the sloping plating of lower hopper ballast tanks.

1.7 In addition, portable or movable means of access shall be utilized for access to the remaining hold frames up to their upper brackets and transverse bulkheads.

Access to vertical structures

1.8 Portable or movable means of access may be utilized for access to hold frames up to their upper bracket in place of the permanent means required in 1.6. These means of access shall be carried on board the ship and readily available for use.

1.9 The width of vertical ladders for access to hold frames shall be at least 300 mm, measured between stringers.

1.10 A single vertical ladder over 6 m in length is acceptable for the inspection of the hold side frames in a single skin construction.

1.11 For double-side skin construction no vertical ladders for the inspection of the cargo hold surfaces are required. Inspection of this structure should be provided from within the double hull space.

Table 4.11.2 Means of access for bulk carriers (continued)

2. Ballast tanks
Top side tanks 2.1 For each topside tank of which the height is 6 m and over, one longitudinal continuous permanent means of access shall be provided along the side shell webs and installed at a minimum of 1.6 m to a maximum of 3 m below deck with a vertical access ladder in the vicinity of each access to that tank. 2.2 If no access holes are provided through the transverse webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails shall be provided to allow safe access over each transverse web frame ring. 2.3 Three permanent means of access, fitted at the end bay and middle bay of each tank, shall be provided spanning from tank base up to the intersection of the sloping plate with the hatch side girder. The existing longitudinal structure, if fitted on the sloping plate in the space may be used as part of this means of access. 2.4 For topside tanks of which the height is less than 6 m, alternative means as defined in paragraph 202. 9. of the technical provisions or portable means may be utilized in lieu of the permanent means of access.
Bilge hopper tanks 2.5 For each bilge hopper tank of which the height is 6 m and over, one longitudinal continuous permanent means of access shall be provided along the side shell webs and installed at a minimum of 1.2 m below the top of the clear opening of the web ring with a vertical access ladder in the vicinity of each access to the tank. 2.5.1 An access ladder between the longitudinal continuous permanent means of access and the bottom of the space shall be provided at each end of the tank. 2.5.2 Alternatively, the longitudinal continuous permanent means of access can be located through the upper web plating above the clear opening of the web ring, at a minimum of 1.6 m below the deck head, when this arrangement facilitates more suitable inspection of identified structurally critical areas. An enlarged longitudinal frame can be used for the purpose of the walkway.
Bilge hopper tanks 2.5.3 For double-side skin bulk carriers, the longitudinal continuous permanent means of access may be installed within 6 m from the knuckle point of the bilge, if used in combination with alternative methods to gain access to the knuckle point. 2.6 If no access holes are provided through the transverse ring webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails shall be provided to allow safe access over each transverse web frame ring. 2.7 For bilge hopper tanks of which the height is less than 6 m, alternative means as defined in paragraph 202. 9. of the technical provisions or portable means may be utilized in lieu of the permanent means of access. Such means of access shall be demonstrated that they can be deployed and made readily available in the areas where needed.
Double-skin side tanks 2.8 Permanent means of access shall be provided in accordance with the applicable sections of **Table 4.11.1**.
For Fore peak tanks 2.9 For fore peak tanks with a depth of 6 m or more at the centreline of the collision bulkhead, a suitable means of access shall be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure. 2.9.1 Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access. 2.9.2 In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access as defined in paragraph 202. 9. of the Technical provisions shall be provided.

* For ore carriers, permanent means of access shall be provided in accordance with the applicable sections of **Table 4.11.1** and **Table 4.11.2**. ⚓

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 4

Hull Equipment

GA-04-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance Relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.

As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 4 "HULL EQUIPMENT"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date : 18 January 2011 (based on the application date for classification survey)

Chapter 10 SHIPBOARD EQUIPMENT, FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING

Section 1 Definitions and Scope of Application
- 101. has been amended.

Effective Date : 1 July 2011

Chapter 8 EQUIPMENT NUMBER AND EQUIPMENT

Section 2 Equipment Number
- 203. has been newly added.

Section 4 Chains
- 401. has been amended.

Section 5 Steel Wire Ropes
- 506. has been newly added.

CONTENTS

<ANNEX>

CHAPTER 1 RUDDERS

Section 1 General

101. Application

1. Rudders having three or more pintles

The scantling of each member of rudders having three or more pintles is to be determined in accordance with the requirements in the **Pt 4, Ch 1** of the Rules correspondingly. However, the moment and the force acting on each member are to be determined by the direct calculation method, in accordance with the requirements in **Sec 4** of the Guidance.

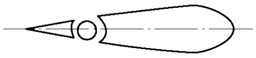
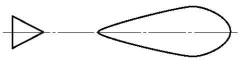
2. Rudders having a special shape or sectional form

Rudders with flaps, fish tail rudders and nozzle rudders are to be as specified in (1) and (2) below respectively, unless the rudder force and rudder torque are required to be determined by tests or detailed theoretical calculation.

In other rudders, the scantling of each member is to be determined by obtaining the rudder force and rudder torque through tests or detailed theoretical calculations, and correspondingly applying the requirements in **Pt 4, Ch 1** of the Rules. Results of tests or theoretical calculations are to be submitted to the Society.

(1) Nozzle rudders with flaps and fish tail rudders
The scantling of each member of a nozzle rudder with flaps and fish tail rudders is to be determined in accordance with the requirements in **Pt 4, Ch 1** of the Rules. In applying the Rules, however, values of factor K_2 in **Sec 2** and values of factor α in **Sec 3** are to be read as specified in **Table 4.1.1.**

Table 4.1.1 The value of factor K_2 and α in accordance with special sectional form of rudder

Sectional form	K_2		α	
	Ahead	Astern	Ahead	Astern
Nozzle rudder	1.9	1.5	(1)	(1)
Rudder with flaps 	1.7	1.3	0.45	0.55
Fish tail rudder 	1.4	0.8	0.45	0.55

NOTE :
(1) For the nozzle rudder, the value of α is to be in accordance with the discretion of the Society.

(2) Nozzle rudder area
In applying the Rules, the total rudder area and the rudder area ahead of the centreline of the rudder stock are to be calculated as follows:

Total rudder area (A) : $2h(b_1+b_2)+\Sigma h'(a_1+a_2)$ (m^2)

Rudder area ahead of the centreline of the rudder stock (A_f) : $2hb_2$ (m^2)

a_1, a_2, b_1, b_2, h and h' = as specified in **Fig 4.1.1**

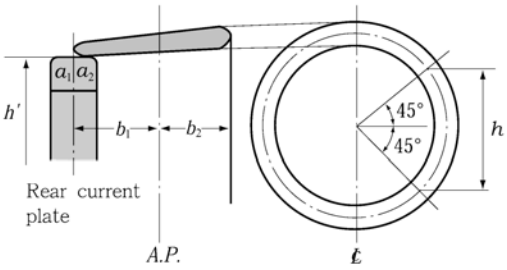


Fig 4.1.1 Nozzle rudder area

3. Rudders designed for helm angle exceeding 35°

The scantling of each member of a rudder designed for helm angle exceeding 35° is to be determined in accordance with the requirements in **Pt 4, Ch 1** of the Rules correspondingly, on the basis of the rudder force and rudder torque obtained through tests or detailed theoretical calculations. The results of tests and theoretical calculations are to be submitted to the Society.

4. For the single plate rudder, 1.0 may be taken as a coefficient K_2 for the ahead and astern conditions.

102. Materials

1. If the diameter of rudder stock is small, cast carbon steel is not to be used.

2. Rolled bar steel (*RSFB* 45) may be treated in the same way as forging steel (*RSF* 45)

Section 4 Rudder Strength Calculation

401. Rudder strength calculation

1. General

The bending moment, shear force, and supporting force acting on the rudder and rudder stock may be evaluated using the basic rudder models shown in **Fig 4.1.2** to **Fig 4.1.6.**

2. Moments and forces to be evaluated

The bending moment M_R and the shear force Q_1 acting on the rudder body, the bending moment M_b acting on the bearing, and the bending moment M_s acting on the coupling between the rudder stock and rudder main piece and the supporting force B_1, B_2, B_3 are to be obtained and to be used for analyzing the stresses in accordance with the **Pt 4, Ch 1** of the Rules.

3. Method of evaluating moments and forces

(1) General data
The data on the rudder basic models shown in **Fig 4.1.2** to **Fig 4.1.6** are as follows:

$l_{10} \sim l_{50}$ = Lengths of the each member of model (m)
$I_{10} \sim I_{50}$ = Moments of inertia of each member (cm^4)

For rudders supported by a shoe piece the length l_{20} is the distance between lower edge of rudder body and centre of shoe piece and I_{20} the moment of inertia of the pintle in the shoe piece. h_c is the vertical distance (m) from the mid-point of the length of that pintle to the centroid of the rudder area.

(2) Direct calculation
The standard data to be used for direct calculation are as follows :

Load acting on rudder body (Type B and C rudders) : $P_R = \dfrac{F_R}{1000\,l_{10}}$ (kN/m)

Load acting on rudder body (Type A rudder) :

$$P_{R10} = \frac{F_{R2}}{1000\,l_{10}} \quad \text{(kN/m)}, \qquad P_{R30} = \frac{F_{R1}}{1000\,l_{30}} \quad \text{(kN/m)}$$

Load acting on rudder body (Type D and E rudders) :

$$P_{R10} = \frac{F_{R2}}{1000\,l_{10}} \quad \text{(kN/m)}, \qquad P_{R20} = \frac{F_{R1}}{1000\,l_{20}} \quad \text{(kN/m)}$$

F_R , F_{R1} and F_{R2} is specified in **Pt 4, Ch 1, Sec 2.**

k = spring constant of the supporting point of the shoe piece or the rudder horn respectively, as shown below

For the supporting point of the shoe piece : $k = \dfrac{6.18 I_{50}}{l_{50}^3}$ (kN/m)(See the **Fig 4.1.2** and **4.1.3**)

I_{50} = the moments of inertia of shoe piece around Z-axis (cm^4)
l_{50} = effective length of shoe piece (m)

For the supporting point of rudder horn : $k = \dfrac{1}{f_b + f_t}$ (kN/m)(See the **Fig 4.1.2, 4.1.5** and **4.1.6**)

f_b = unit displacement of rudder horn due to a unit force of 1 kN acting in the centre of support as shown below.

$$f_b = 1.3 \frac{d^3}{6.18 I_n} \quad \text{(m/kN)}$$

I_n = the moments of inertia of rudder horn around the X-axis(cm^4)

f_t = unit displacement due to torsion, as shown below

$$f_t = \frac{dc^2 \Sigma u_i / t_1}{3.14 F_T^2} \times 10^{-8} \quad \text{(m/kN)}$$

F_T = mean sectional area of rudder horn (m^2)
u_i = breadth of individual plates forming the mean sectional area of rudder horn (mm)
t_i = plate thickness within the individual breadth u_i (mm)
c and d = See the **Fig 4.1.5** and **4.1.6** (For the rudder horn of Type A rudders, the same values are to be also applied correspondingly)

(3) Simplified method

The moments and forces for rudders of each type may be obtained from the following formula

(A) Type A rudders

$$M_R = \frac{B_1^2(l_{10}+l_{30})}{2F_R} \quad \text{(N-m)}$$

$$M_b = \frac{B_3(l_{30}+l_{40})(l_{10}+l_{30})^2}{l_{10}^2} \quad \text{(N-m)}$$

$$M_s = B_3 l_{40} \quad \text{(N-m)}$$

$$B_1 = \frac{F_R h_c}{l_{10}} \quad \text{(N)}$$

$$B_2 = F_R - 0.8B_1 + B_3 \quad \text{(N)}$$

$$B_3 = \frac{F_R l_{10}^2}{8 l_{40}(l_{10}+l_{30}+l_{40})} \quad \text{(N)}$$

(B) Type B rudder

$$M_R = \frac{B_1^2 l_{10}}{2F_R} \quad \text{(N-m)}$$

$$M_b = B_3 l_{40} \quad \text{(N-m)}$$

$$M_s = \frac{3M_R l_{30}}{l_{10}+l_{30}} \quad \text{(N-m)}$$

$$B_1 = \frac{F_R h_c}{l_{10}+l_{30}} \quad \text{(N)}$$

$$B_2 = F_R - 0.8B_1 + B_3 \quad \text{(N)}$$

$$B_3 = \frac{F_R(l_{10}+l_{30})^2}{8 l_{40}(l_{10}+l_{30}+l_{40})} \quad \text{(N)}$$

(C) Type C rudder

$$M_b = F_R h_c \quad \text{(N-m)}$$

$$B_2 = F_R + B_3 \quad \text{(N)}$$

$$B_3 = \frac{M_b}{l_{40}} \quad \text{(N)}$$

(D) Type D rudder

$$M_R = \frac{F_{R2} l_{10}}{2} \quad \text{(N-m)}$$

$$M_b = \frac{F_R l_{10}^2}{10(l_{20}+l_{30})} \quad \text{(N-m)}$$

$$M_s = \frac{2M_R l_{10} l_{30}}{(l_{20}+l_{30})^2} \quad \text{(N-m)}$$

$$B_1 = \frac{F_R h_c}{l_{20}+l_{30}} \quad \text{(N)}$$

$$B_2 = F_R - B_1, \quad \min B_2 = F_R/4 \quad \text{(N)}$$

$$B_3 = \frac{M_b}{l_{40}} \quad \text{(N)}$$

$$Q_1 = F_{R2} \quad \text{(N)}$$

(E) Type E rudder

$$M_R = \frac{F_{R2} l_{10}}{2} \quad \text{(N-m)}$$

$$M_b = \frac{F_R l_{10}^2}{10 l_{20}} \quad \text{(N-m)}$$

$$B_1 = \frac{F_R h_c}{l_{20}} \quad \text{(N-m)}$$

$$B_2 = F_R - B_1, \quad \min B_2 = F_R/4 \quad \text{(N)}$$

$$B_3 = \frac{M_b}{l_{40}} \quad \text{(N)}$$

$$Q_1 = F_{R2} \quad \text{(N)}$$

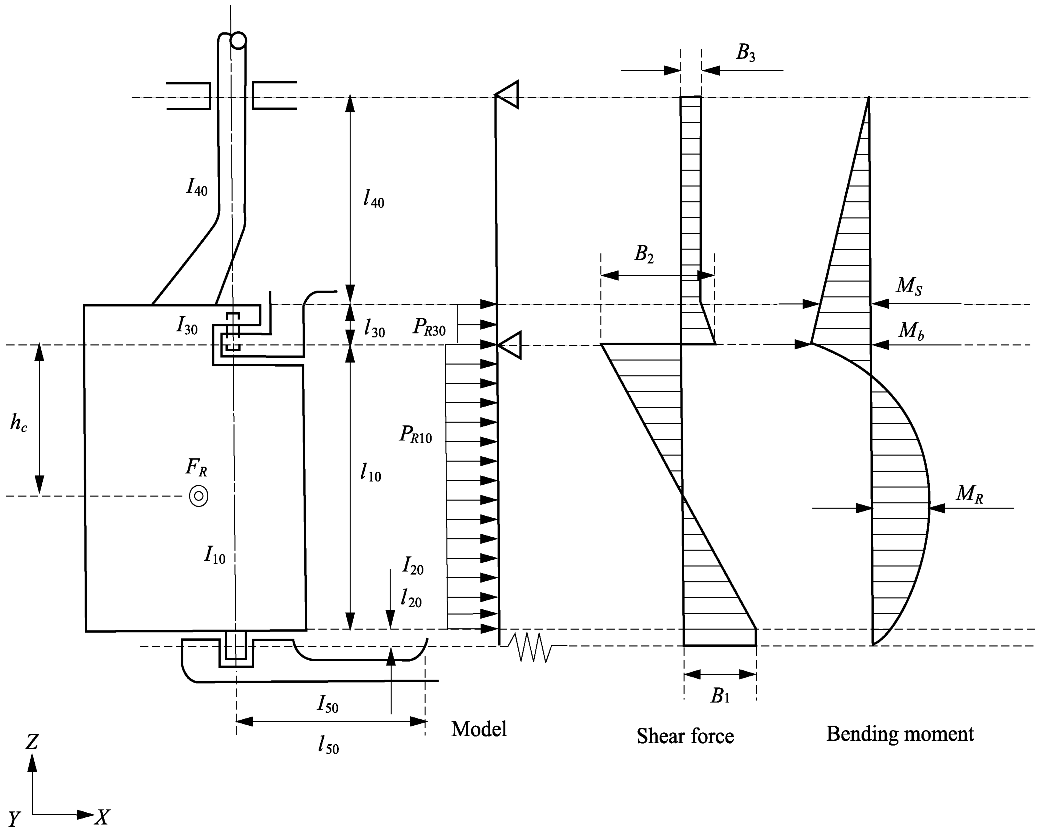


Fig 4.1.2 Type A rudder

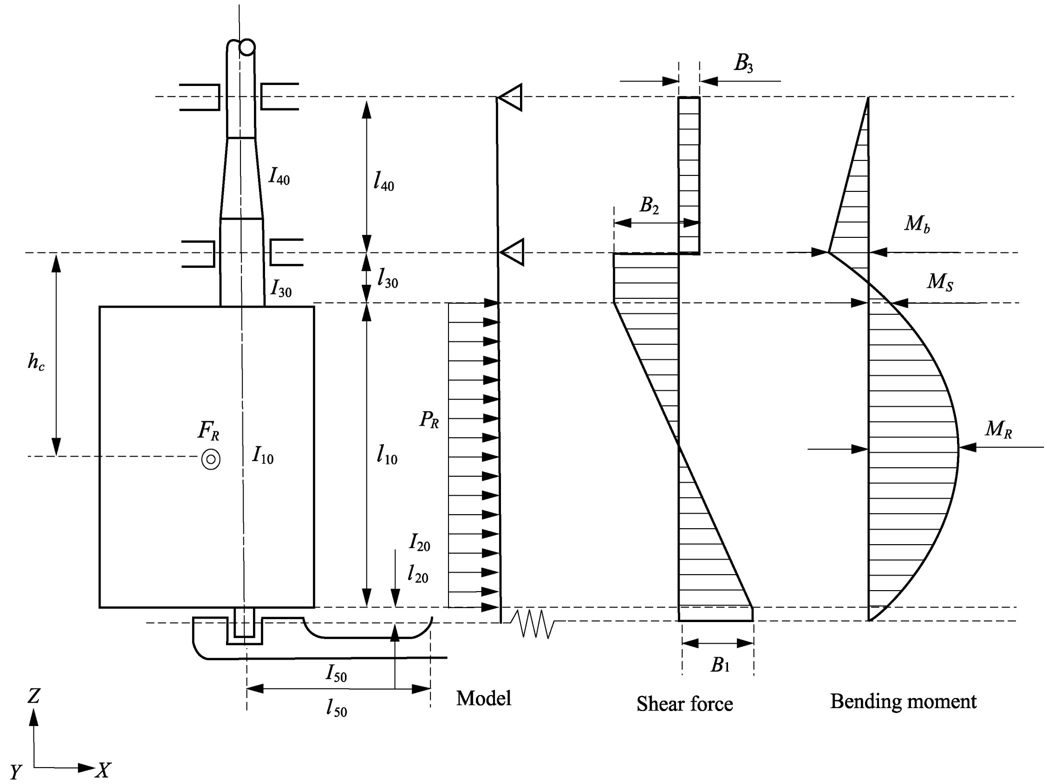


Fig 4.1.3 Type *B* rudder

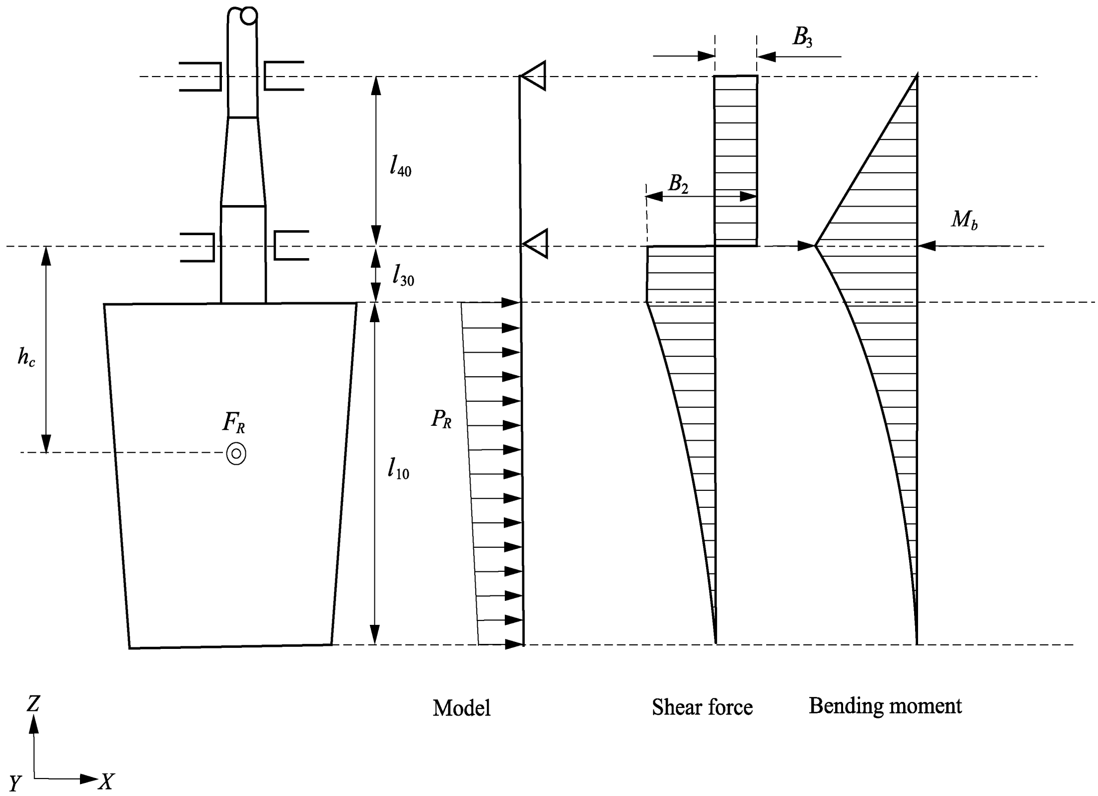


Fig 4.1.4 Type *C* rudder

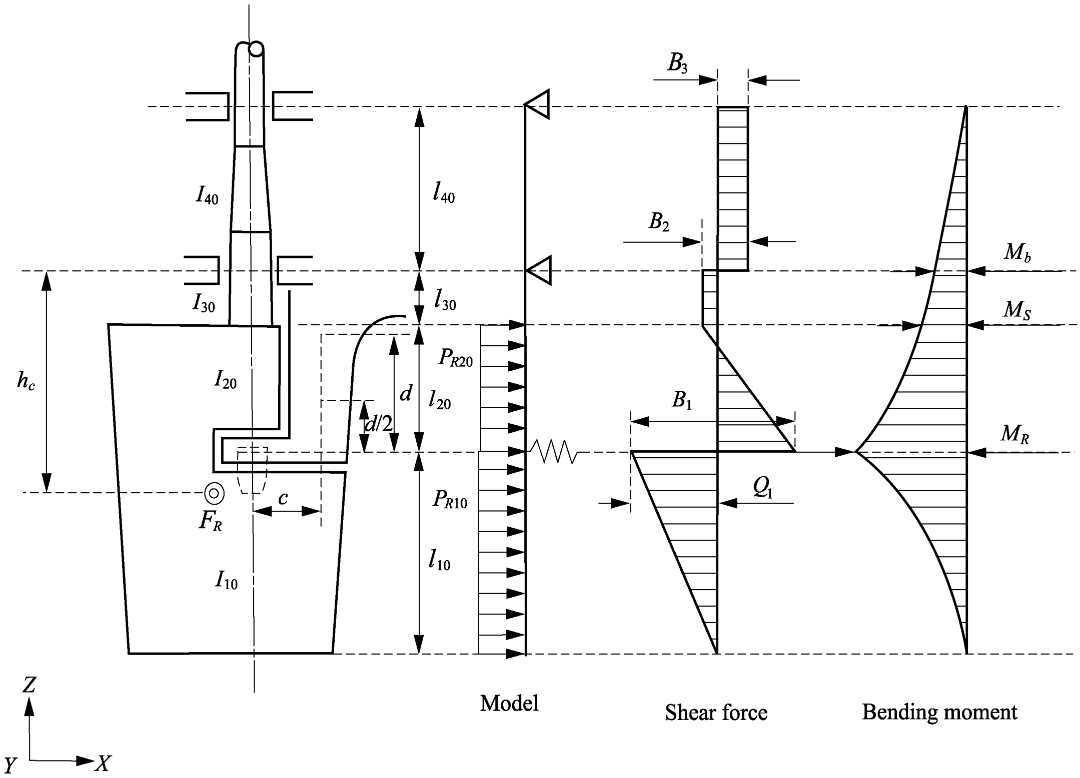


Fig 4.1.5 Type *D* rudder

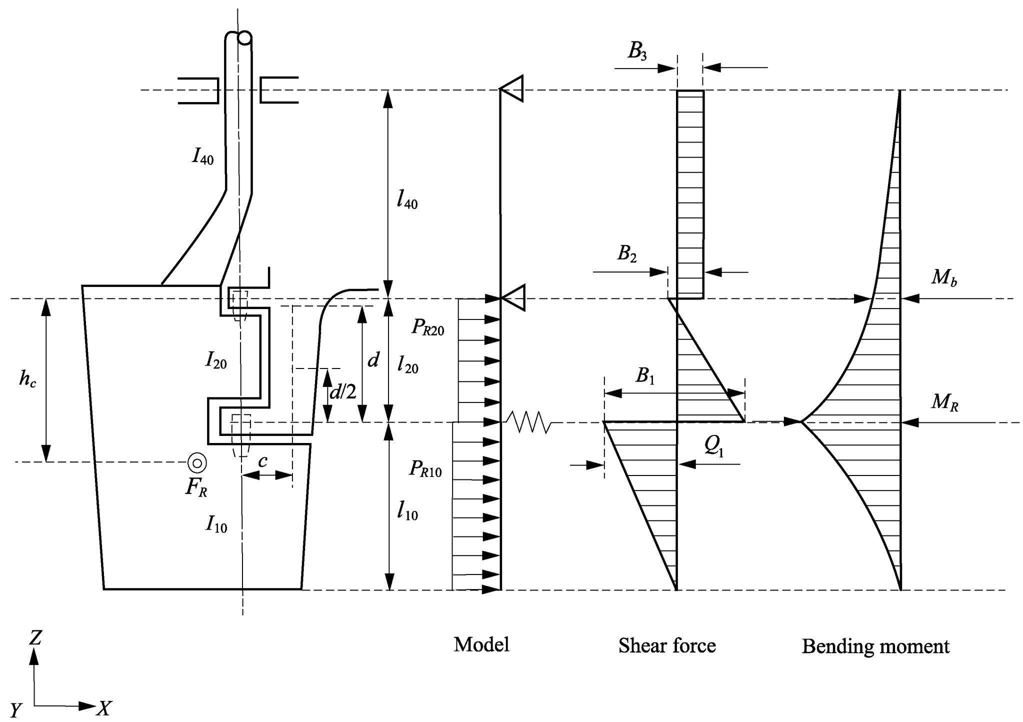


Fig 4.1.6 Type *E* rudder

Section 5 Rudder Stocks

501. Upper stocks

1. Taper of upper stock at joint with tiller

Where the upper stocks are tapered for fitting the tiller, the taper is not to exceed 1/12.5 in diameter.

2. Keyways

(1) The depth of the keyway may be neglected in determining the diameter of the rudder stock.
(2) All corners of keyways are to be properly rounded.

3. Each part of the rudder stocks of Type B, C and D rudders is to be so constructed as shown **Fig 4.1.7.**

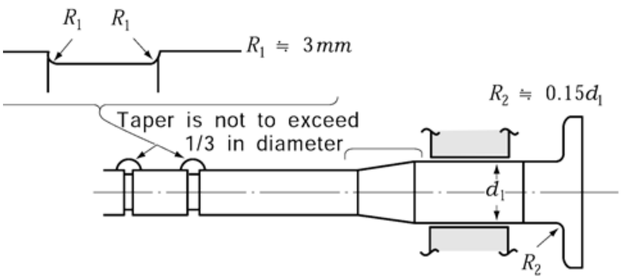


Fig 4.1.7 Rudder stock of type B, C and D rudder

Section 6 Rudder Plates, Rudder Frames and Rudder Main Pieces

603. Rudder main pieces

1. In Type D and Type E rudders, the effective breadth of rudder plate B_e to be as shown in **Fig 4.1.8.** However, the cover plate which is removed to lift up the rudder is not to be included into the section modulus. These requirements also apply to Type A rudders correspondingly.

2. Material factor K_m is to be for the lowest strength material among the materials used in the section considered.

605. Connections

1. The rudder plate is to be connected to rudder frames by spot welding as far as is practicable. **Fig 4.1.9** is to be referred to as the standard for spot welding.

2. In principle, edge bars are to be fitted to the aft end of the rudder. However, considering the size and form of the rudder, weld ability, etc., edge bars and or chill plates may be omitted. (See **Fig 4.1.10**)

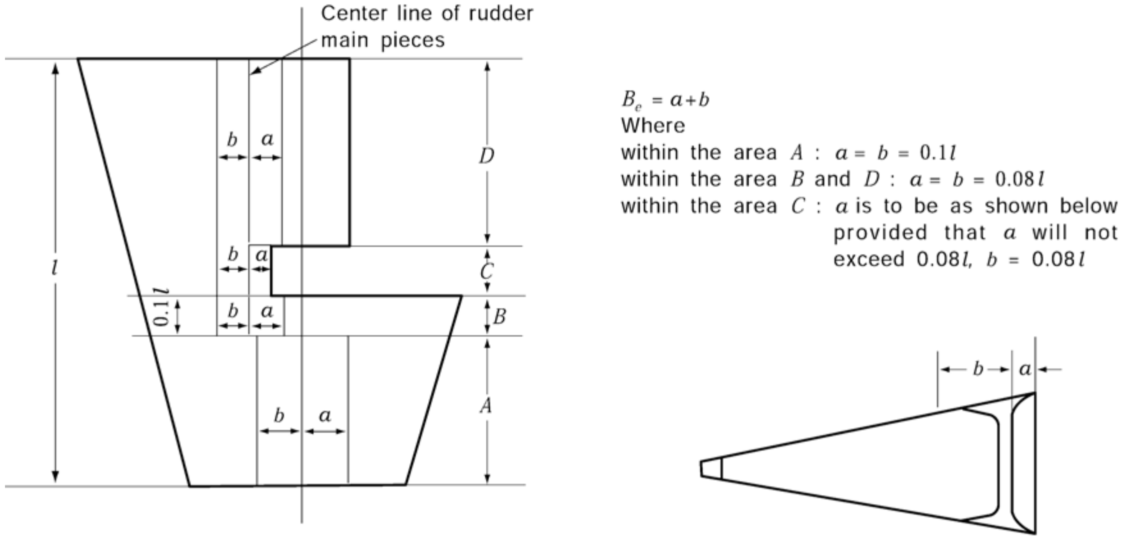


Fig 4.1.8 Effective breadth of rudder plate B_e

Section 7 Couplings between Rudder Stocks and Main Pieces

701. Horizontal flange coupling

1. Diameters of coupling bolts in Type A and Type E rudders

In appling to **Pt 4, Ch 1, 701.** of the Rules, the diameters of coupling bolts d_b in Type A and Type E rudders are to be determined in accordance with the requirements in **Pt 4, Ch 1, 502.** of the Rules, assuming that the lower stock is cylindrical.

2. Locking device for nuts of coupling bolts

The nuts of coupling bolts are to have locking devices. They may be split pins.

702. Vertical flange couplings

1. Diameter of coupling bolt in Type A and E rudders

In appling to **Pt 4, Ch 1, 701.** of the Rules, the diameter of the coupling bolt d_b in Type A and E rudders are to be determined in accordance with **Pt 4, Ch 1, 502.** of the Rules, assuming that the lower stock is cylindrical.

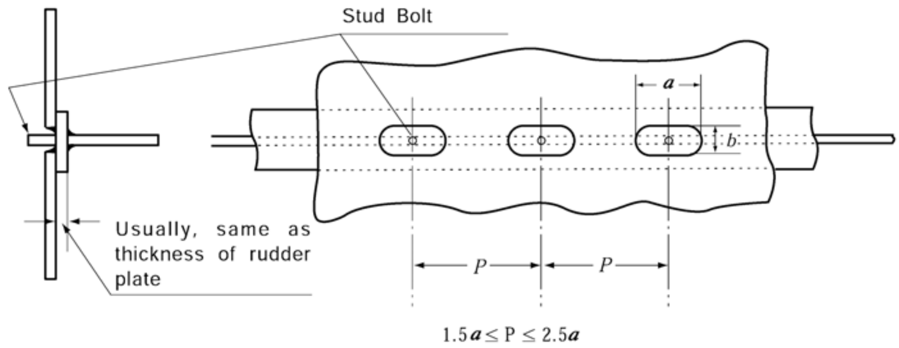
2. Locking devices for nuts of coupling bolts

The nuts of coupling bolts are to have locking devices. They may be split pins.

703. Cone coupling

1. General

(1) The lower stock is to be securely connected to the rudder body with slugging nuts or hydraulic arrangements. Shipbuilders are to submit data on this connection to the Society.
(2) Special attention is to be paid to corrosion of the lower stock.
(3) The minimum thickness t_b is of the cast steel part of rudder body (See **Fig 4.1.11**) not to be less than 0.25 times the required diameter of the lower stock.



Thickness of rudder plate(mm)	dimension (mm)		lag length
	a	b	
$t \le 6$	65	35	F_1
$7 \le t \le 18$	75	40	
$t \ge 19$	85	45	

Fig 4.1.9 Slot welding of rudder plate

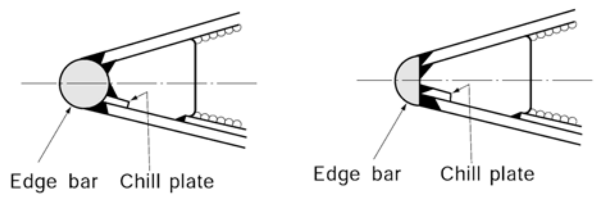


Fig 4.1.10 Structure of end part of rudder

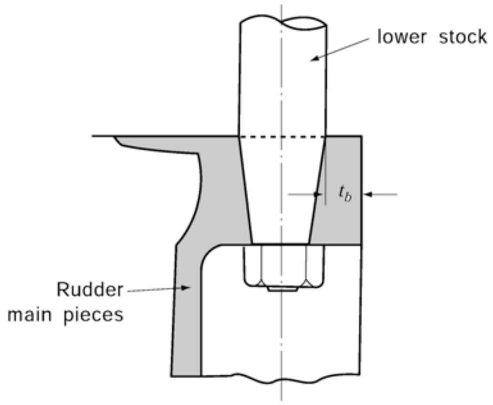


Fig 4.1.11 Coupling between rudder lower stock and rudder main pieces

2. Keys provided on the cone coupling for rudder stocks fitted into the rudder body and secured by a nut:

(1) The shear area A_k of keys is not to be less than:

$$A_k = \frac{30\, T_R K_k}{d_k} \quad (\mathrm{mm}^2)$$

d_k = rudder stock diameter at the mid-point of length of the key (mm)
K_k = material factor for the key as given in **Pt 4, Ch 1, 102.** of the Rules
T_R = rudder torque obtained from **Pt 4, Ch 1, Sec 3** of the Rules

(2) The abutting surface area A_c between key and rudder stock or between key and rudder body, respectively, is not be less than:

$$A_c = \frac{10\, T_R K_{\min}}{d_k} \quad (\mathrm{mm}^2)$$

where:

K_{min} = material factor for key, rudder stock, or rudder body as given in **Pt 4, Ch 1, 102.** of the Rules, whichever is smaller in comparison between the factors for key and rudder stock, and for key and rudder body in contact.

d_k and T_R = as specified in (1).

704. Coupling flange

In principle rudder stock and coupling flange consist with one body. However, for the ships which are not exceeding 60 m in length, if rudder stock constructed with full penetration weld with inserting coupling, it may be acceptable.

Section 8 Pintles

802. Construction of pintles

1. Locking device for pintle nut

Split pins are not recommendable as the locking device for the pintle nuts. Locking rings or other equivalent devices(Nut stopper or Nut lock, etc,.) are to be used, as shown in **Fig 4.1.12.**

2. Preventing corrosion of pintles

To prevent corrosion of pintles, the end of the sleeve is to be filled with red lead, grease packing, bituminous enamel, rubber(Neoprene) etc., as shown in **Fig 4.1.12.**

3. Combination of pintle and rudder frame in monoblock

In ships exceeding 80 m in length, combination of pintle and rudder frame into a monoblock is not recommended.

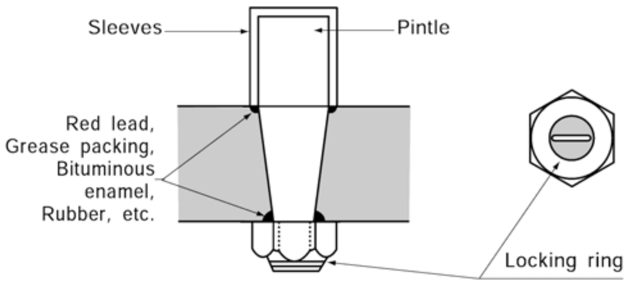


Fig 4.1.12 Locking device and preventing device of corrosion of pintle nut

Section 9 Bearings of Rudders Stock and Pintles

901. Minimum bearing surface

Where a metal bush is used, the sleeve is to be a different material from the bush (for example, sleeve : BC_3 and bush : BC_2).

902. Bearing clearances

Where a bush is non-metal, the standard bearing clearances is to be 1.5 ~ 2.0 mm in diameter.

Section 10 Rudder Accessories

1001. Rudder carriers

1. Materials of rudder carriers and intermediate bearings

Rudder carriers and intermediate bearings are to be of steel. They are not to be of cast iron.

2. Thrust bearing of rudder carrier

(1) The bearing is to be provided with a bearing disc made of bronze or other equivalent materials.
(2) The calculated bearing pressure is not to exceed 0.98 MPa(0.1 kg/mm^2) as a standard. In calculating the weight of rudder, its buoyancy is to be neglected.
(3) The bearing part is to be well lubricated by dripping oil, automatic grease feeding, or a similar method.
(4) The bearing is to be designed to be structurally below the level of lubricating oil at all times. (See **Fig 4.1.13**)

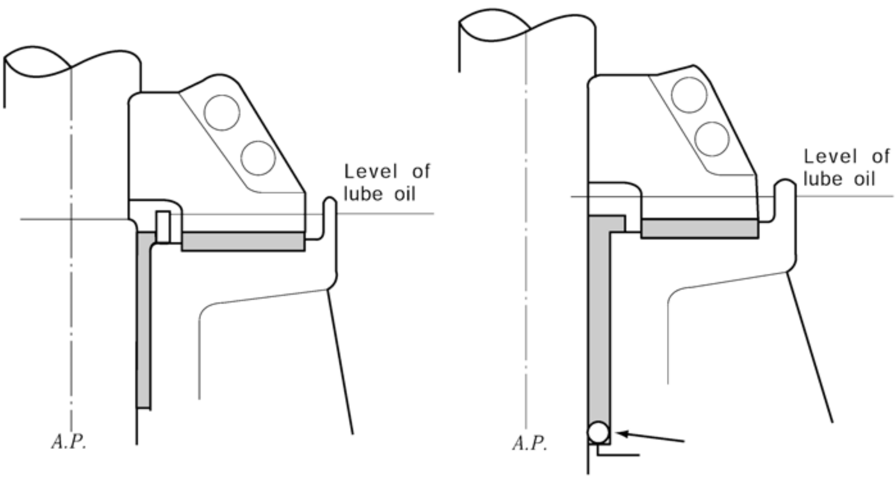


Fig 4.1.13 Rudder carrier

3. Watertightness of rudder carrier part

(1) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.
(2) It is recommended that the packing gland in the stuffing box have an appropriate clearance from the rudder stock corresponding to the position of the stuffing box. The standard clearance is to be 4 mm for the stuffing box provided at the neck or intermediate bearing, and 2 mm for the stuffing box at the upper stock bearing.

4. Assembling of rudder carriers

In split type rudder carriers, at least two bolts are to be used on each side of the rudder for assembling.

5. Installation of rudder carriers

(1) In ships exceeding 80 m in length, it is recommended that the rudder carrier is directly installed on the seat on a deck.
(2) A spigot type seat is not recommended to be installed on the deck.
(3) The hull construction in way of the rudder carrier is to be suitably reinforced.

6. Bolts fixing rudder carriers and intermediate bearing

(1) As a standard, at least one half of the bolts fixing the rudder carrier and the intermediate bearing are to be reamer bolts. If stoppers for preventing the rudder carrier from moving are to be fitted on the deck, all bolts may be of ordinary bolts. In using chocks as stoppers, all of them are to be carefully arranged not to be driven in the same direction. (See **Fig 4.1.14**)
(2) (A) In ships provided with electro hydraulic steering gears, the total sectional area of the bolts fixing the rudder carriers or the bearing just under the tiller to the deck is not to be less than that obtained from the following formula:

$$A = 0.1 d_u^2 \quad (\text{mm}^2)$$

d_u = required diameter of upper stock(mm)

(B) Where the arrangement of steering gear is such that each of two filler arms is connected with an actuator and two actuators function simultaneously, or is of any other type where the rudder stock is free from horizontal force, the total sectional area of bolts fixing the rudder carrier to the deck may be reduced to 60 % of the area required in (A).
(C) Where all the bolts fixing the rudder carrier to the deck are reamer bolts, the total sectional area of bolts may be reduced to 80 % of the area required by (A) and (B).

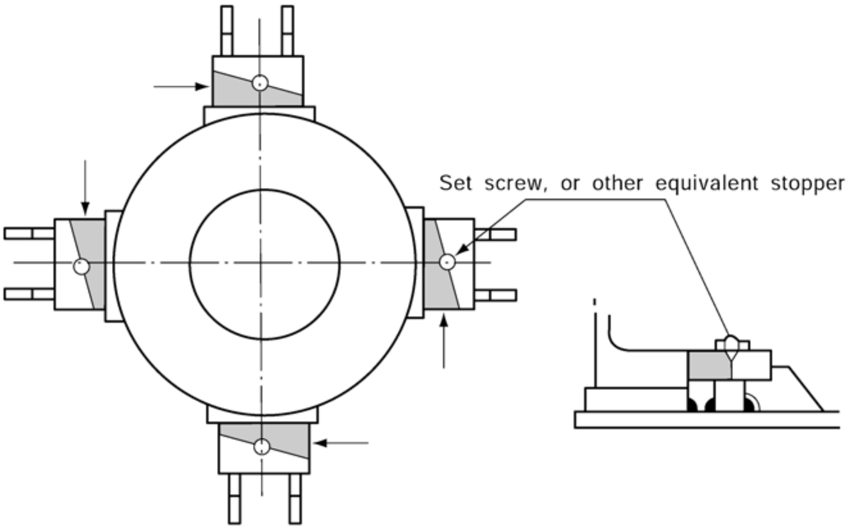


Fig 4.1.14 Fixing arrangement of rudder carrier on deck

1002. Jumping stoppers

The clearance between the jumping stopper and the rudder carrier is to be 2 mm as a standard. In ships provided with power-operated steering gears, this clearance is not to be exceed 2 mm. ⚓

CHAPTER 2 HATCHWAYS AND OTHER DECK OPENINGS

Section 1 General

101. Application

1. The regulation of 101.3 of the Rules is not to be applied to the vessel which engaged in domestic service only.

102. Position of exposed deck openings

1. Exposed superstructure deck of the Rules is in general exposed deck up to superstructure of second tier above freeboard deck. However, where actual deck height is less than standard height of superstructure(h_s), it is to be of exposed deck of nearest superstructure from the point above freeboard deck by $2\,h_s$.

2. Exposed deck of superstructure above the deck defined in 1. may be regarded as deckhouse or its exposed deck.

Section 2 Arrangements

201. Height of hatchway coamings

1. Where the openings of hatchways are comparatively small and weathertight steel hatch covers are provided with, height and thickness of their coamings are to be as follows.

(1) Coamings height is to be not less than the value given in **Table 4.2.1** according to the location and opening area of the hatchways.

(2) Thickness of coamings is to be not less than the value calculated in following formula.

$$L < 100\text{ m}: \quad 4 + 0.05L \text{ (mm)}$$
$$L \geqq 100\text{ m}: \quad 9.0 \text{ (mm)}$$

Table 4.2.1 Height of small hatchway coamings (mm)

Hatch Area (m^2) / Position of Hatchway	$A < 1.5$ Other type than stated in column of right side	$A < 0.45$, Which are fitted with hinge type closing means capable of opening and closing
Position I	450 mm	380 mm
Position II	380 mm	230 mm

2. Construction and scantlings of hatchway coamings for deep tanks are also to comply with the requirements of **Ch 2** of the Rules as well as **Pt 3, Ch 15** of the Rules.

202. Hatch covers

1. Steel hatchway covers provided on exposed upper deck in way of cargo holds used as deep water ballast tanks for bulk carrier, etc, and similar ones are to comply with the following requirements in addition **Ch 2** of the Rules.

(1) The thickness of top plating is not to be less than the obtained from the following formula. However, in case of double plating type hatch covers, the plates actually loaded are only to comply with.

$t = 1.15S\sqrt{h} + 3.0$ (mm)

S = Spacing of stiffeners(m)
h = As obtained from the following formula(m)

$h = 9.81 \times 0.85(16a/L + 0.25b + h')$ (kN/m^2)

a = Length of hatchways(m)
b = Breadth of hatchways(m)
h' = Vertical distance to the highest point of top plates from the highest points of hatch covers when ships are inclined angles of rolling 15°, pitching $(900/L)$°. However, h' is 0 when the h' has negative(-) value. (See **Fig 4.2.1**)

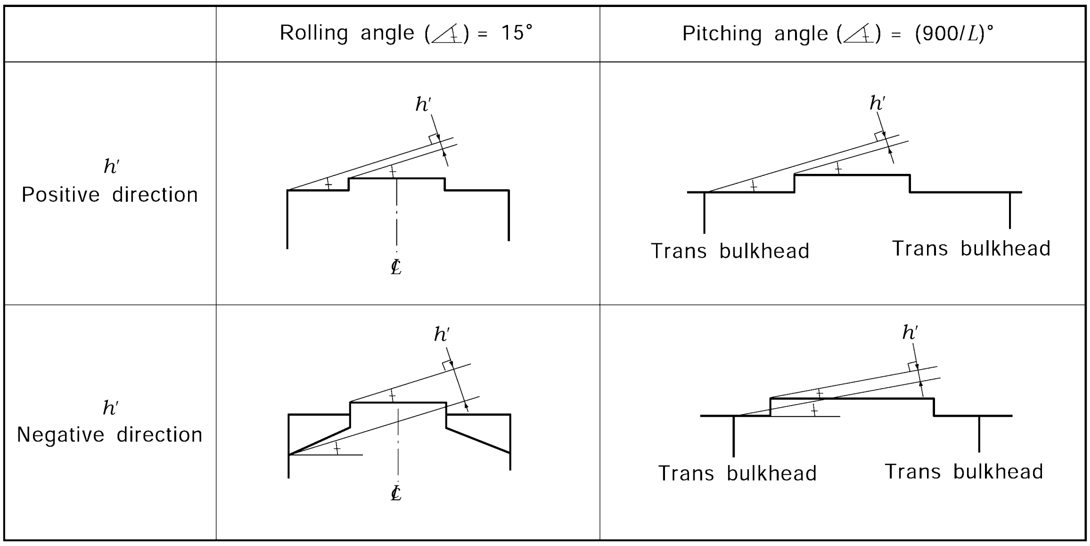


Fig 4.2.1 The direction of h'

(2) The scantlings of stiffeners are to comply with the following formulae.

- Section modulus at mid-span $C_1Kk_1Shl^2$ (cm^3)
- Moment of inertia at mid-span $C_2k_2Shl^3$ (cm^4)
- Cross sectional area of web plates at the ends of stiffeners C_3KShl (cm^2)

Where,
S : Spacing of stiffeners (m)
l : Distance between supported stiffeners (m)
K : Material factor
k_1, k_2 : Coefficient given by **504. 6** of the Rules is as follows.

$$k_1 = 1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}$$

$$k_2 = 1 + 8\alpha^3 \frac{1-\phi}{0.2+3\sqrt{\phi}}$$

C_1, C_2 and C_3 : Coefficients given by **Table 4.2.2**

h : As given by the following formulae according to the arranged direction of stiffeners, and a, b, h' are to be followed by (1)

- Transverse direction (in case hatch covers are opened/closed in the longitudinal direction)

  $h = 9.81 \times 0.85(12a/L + 0.125b + h')$ (kN/m^2)

- Longitudinal direction (in case hatch covers are opened/closed in the transverse direction)

  $h = 9.81 \times 0.85(8a/L + 0.188b + h')$ (kN/m^2)

Table 4.2.2 Coefficient C_1, C_2, C_3

C_1	C_2	C_3
1.07	1.81	0.064

(3) Thickness and depth of web of girders are not to be less than 7 mm and l/25. The girders are to be provided with tripping brackets at the intervals of about 3 m.

(4) The section modulus of stiffeners supported by girders and subjected to a uniformly distributed loads may be obtained from the direct strength calculations, or obtained from the following formulae in accordance with the type of covers as considered.

$0.71CKShl^2$ (cm^3)

Where,

K, S, h and l : As specified in the preceding (2)

C : Coefficient given below according to the type of end connections of stiffeners

In case of lug at both ends : 1.0

In case of snip at both ends or one end snip and another end lug : 1.5

2. Steel hatch covers in way of tanks loading cargo oil of flash point below 60 °C are to be paid enough attention in order to keep oil-tightness and air-tightness and to prevent occurring sparks due to striking of the surrounding metal fittings. And their gaskets are to be of materials certified as oilproof and fireproof by the relative standard.

3. In principle, double plating hatch covers are not to be used in way of oil tanks. However, if they are to be used, their construction is to be easily drained out and vented by air.

4. In this article sand carrier and dredger mean that the ships are be engaged in gathering, transporting, dredging or reclamation etc. for sand, soil, gravel etc. and are to be as follows

(1) For the ship which operates in domestic-costal service area, the requirement for exemption of hatchway covers of sand carrier and dredger is as follows.

(A) Barge and Ship having hopper door

Ships which is fitted with a buoyancy tank in each side and hopper door in bottom should have sufficient reserved buoyancy and stability in assumed the worst flooded condition of cargo hold.

(B) Barge not having a hopper door

Barge which is fitted with a buoyancy tank in each side and operates within 20 nautical miles out of the Korean peninsula(excluding those intend to sail to Che-ju Island) should have sufficient reserved buoyancy and stability in assumed the worst flooded condition of cargo hold.

(C) For the exemption of hatchway cover installation, it should be met with the following conditions in assumed the worst flooded condition.

(a) The upper deck side line should be not flooded

(b) For self-propelled ship : $G_0M \geq 0.15$ m

For non self-propelled ship : $G_0M \geq 0.095B$ m

(where, B = Breadth)

(2) For the ship which operates in international service area and is fitted with door or valve in bottom, the requirement for exemption of hatchway cover installation of sand carrier and dredger is as follows.

(A) The intact stability is to be met with the requirement of **Pt 1, Annex 1-2** of the Guidance. In this case, the calculation is to include the homogeneous full load condition of cargo in each cargo hold loaded up to the top of the hatchway coaming.

(B) When the wetted cargo with the design bulk density of minimum 2.2 ton/m^3 is homogeneously loaded to the assigned freeboard in each hold and assuming that the void space of the cargo hold above the cargo surface is filled with the sea water induced by the flooding, the stability of the above (A) is to be satisfied.

(C) The damage stability is to be met with **SOLAS Ch. II-1, B-1**

(D) The doors or valves on bottom area are to be met with following requirements.

(a) The opening of the bottom dump doors should be effective in less than one(1) minute.

(b) In the case of bottom door not to be opened by gravity, the opening should be possible even after the main power source or the ram mechanism actuating the bottom dump doors have been put out of order.

In this case, it should be possible to operate both systems from bridge, and the cargo releasing arrangements should be such that asymmetrical jettisoning of the cargo should not be possible even partially.

(E) Draft indicator is to be fitted on the bridge.

(F) Where the additional requirements other than described above are necessary, the ship is to be met with those requirements also.

Section 4 Load Model

401. Lateral pressure and concentrated loads

1. In addition to the above provisions, hatch covers for ships carrying deck cargoes are to be in accordance with the following (1) to (5)

(1) Hatch covers carrying deck cargo are to be effectively secured against the horizontal and vertical forces arising from ship motion.

(2) To prevent damage to hatch covers and ship structure, the location of stoppers is to be compatible with the relative movements between hatch cover and ship structure. The number should be as small as practically possible.

(3) Hatchway coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

(4) It is to be designed for preventing excessive relative vertical deflection between loaded/ unloaded panel.

(5) When the cargoes loaded on hatch covers of exposed parts and lower deck, the construction and scantlings are to be applied in the following requirements in addition to **Ch 2** of the Rules.

(A) The loading height, loading condition, etc, is to be clearly shown in the drawings for approval. In case of loading freight containers, the kind of them and loading position are to be additionally described.

(B) Girders or stiffeners are to be provided for reinforcement beneath the corner fittings of freight containers.

(C) Top plates of hatch covers, upon which wheeled vehicles are loaded, are to comply with **Pt 7, Ch 7** of the Rules.

(D) For the construction of hatch covers, stress and deflection of planed loading is to be calculated by calculation method which is to be to the discretion of the Society. Each calculated permissible stress and permissible deflection value is to be complied with **Table 4.2.3.** However when the high tensile steel is used, permissible stress is the values which are divided permissible stress in **Table 4.2.3** with material factor in K in **Table 4.1.2**

Table 4.2.3 Permissible stress and deflection

	Bending stress (N/mm^2)	Shear stress (N/mm^2)	Deflection (mm)
During the berthing, in case of using a vehicle for unloading as a pork lift and etc., (For the vehicles)	147	98	0.0035 times to hatch beam
Other than above column	118	78	

2. It is recommended that ships with steel weathertight covers are supplied with an operation and maintenance manual including following (1) to (5)

(1) Opening and closing instructions
(2) Maintenance requirement for packings, securing devices and operating items,
(3) Cleaning instruction for drainage system
(4) Corrosion prevention instructions.
(5) Lists of spare parts.

Section 5 Strength Check

501. General

1. Where scantlings of structural members of steel hatch covers are determined based upon the direct calculations, following requirements are to be applied. Those other than as specified in this paragraph are to comply with the requirements in **Pt 3, Annex 3-2** of the Rules.

(1) Loads
The design wave loads imposed on steel hatch covers are to comply with the requirements of **Table 4.2.3** of the Rules.

(2) Modelling of structure
(A) The modelling is to be such that the structural model can reproduce the behaviour of the structure with the highest possible fidelity.
(B) The net scantlings are to be used for modelling.
(C) When modelling into beam element, the plate of a width equal to 0.165 l on its each side may, as a rule, be in cluded, provided that the plate to be included is effectively reinforced by other members or is recognized by the Society to have a sufficient thickness, and, in addition, this width equal to 0.165 l does not exceed half of the distance to the neighbouring member, where l is the span of members.
(D) The structural model is to be supported at pads. If the arrangement of pads differs from the arrangement of stiffeners, the edge elements of steel hatch covers are also to be modelled.

(3) Allowable values
When the loads specified in (1) act the structural model specified above, the scantlings are to be determined so that the stress and deflection generated in each structural member satisfy the allowable values specified in **Table 4.2.3** and **504. 4** of the Rules.

2. Steel hatch covers intended to carry cargoes on them

(1) General
(A) The scantlings of steel hatch covers, steel pontoon covers, steel weathertight covers (hereinafter steel hatch covers) and portable beams intended to carry cargoes on them in exposed positions are to comply with the requirements **Ch 2** of the Rules in addition to the requirements of this paragraph.
(B) The values obtained from the requirements of this paragraph are including corrosion

addition.

(C) In case where cargo loads and wave loads act jointly due to the cargo loading height and cargo shapes, special consideration is to be required.

(2) Design cargo load h (kN/m^2) is not to be less than that obtained from following (A) or (B).

(A) h is to be equivalent to the standard by the 7 times the height from the upper surface of hatch covers to the above deck at side of the space (m), or 7 times the height from the deck concerned to the upper edge of hatchway coaming of the above deck (m). However, h may be specified as the maximum design cargo weight per unit area of hatch covers (kN/m^2). In this case, the value of h is to be determined by considering the loading height of cargo.

(B) Where cargoes are intended to be carried on the hatch covers in weather decks, h is to be the maximum design cargo weight per unit area of hatch covers (kN/m^2).

(3) For hatch covers on which cargoes are carried, the thickness of top plating t is not to be less than that obtained from following formula.

$$t = 1.25S\sqrt{Kh} + 2.5 \quad \text{(mm)}$$

Where,

S : Spacing of stiffeners (m)

h : Design cargo load specified in the preceding (2) (kN/m^2)

K : Material factor given in **Pt 3, Ch 1, Table 3.1.3** of the Rules.

(4) The section modulus of stiffeners supported by girders and subject to a uniformly distributed loads may be obtained from the direct strength calculations, or obtained from the relevant formulae of **202. 1** (4). And h is design cargo load specified in the preceding (2).

(5) The scantlings of primary supporting members of steel hatch covers, which are simply supported between hatch coamings with uniformly distributed loads imposed thereupon, and of portable beams are to comply with the relevant formulae of **202. 1** (2). For steel hatchway covers, S and l are to read as b and S, respectively. Where h is design cargo load specified in the preceding (2), and coefficient C_3 of **Table 4.2.2** is not to be applied to steel hatch covers.

(6) Compressive buckling stress for steel hatch covers are to satisfy the following formula. However, in case of double plating type steel hatch covers, the plate actually loaded the compressive stress are only to be complied with.

$$\sigma_{cr} / \sigma \geqq 1.2$$

σ_{cr} : Critical compressive buckling stress and given as follows.

$$\sigma_{cr} \leqq \frac{\sigma_y}{2} \quad : \sigma_{cr}'$$

$$\sigma_{cr}' > \frac{\sigma_y}{2} \quad : \sigma_y (1 - \sigma_y / 4\sigma_{cr}')$$

$$\sigma_{cr}' = 0.74(t/S)^2 \text{ (N/mm}^2\text{)}$$

t : Thickness of steel plate(mm)

S : Spacing of stiffeners(m)

σ_y : Yield stress of the material(N/mm^2)

(7) The vertical deflection of primary supporting members and portable beams are to be not more than 0.0035 l, where l is the greatest span of primary supporting members or portable beams.

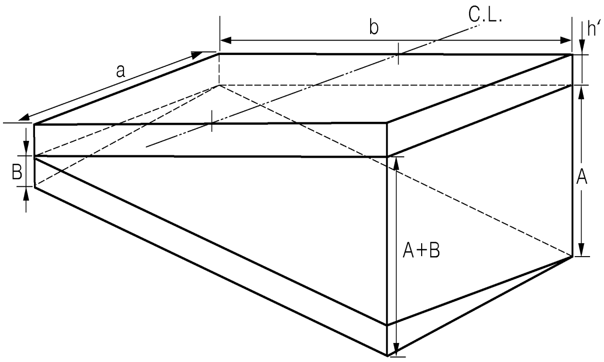
3. The direct calculations for steel hatch covers intended to carry cargoes on them are to be applied following requirements. Those other than as specified in this paragraph are to comply with the requirements in **Pt 3, Annex 3-2** of the Rules.

(1) Loads
The loads imposed on steel hatch covers are to comply with the followings according to the type of load. Except for the case **2** (1) (C), no loads are to be assumed to act jointly.
(A) The loads to be carried (excluding (B)), in case of a uniformly distributed load, is to be h specified in **2** (2), and in case of concentrated load, it is to be maximum design cargo load at each loading point.
(B) The load due to liquid cargo or water ballast, etc. is to be 0.85 times the values specified in **Fig 4.2.2**. However, the corner on which the maximum load acts is to be at an arbitrary place. In case of girders are only modelled and Society deems it to be appropriate, the values according to **202. 1** (2) may be used.

(2) Modelling of structure
(A) The modelling is to be such that the structural model can reproduce the behaviour of the structure with the highest possible fidelity.
(B) The scantlings including corrosion allowances which are shown on the plans may be used for modelling.
(C) When modelling into beam element, the plate of a width equal to 1/10 of a span of the member on its each side may, as a rule, be included, provided that the plate to be included is effectively reinforced by other members or its recognized by the Society to have a sufficient thickness, and, in addition, this width equal to 1/10 of the span does not exceed half of the distance to the neighboring member.
(D) The structure model is to be supported at pads(cleats in case of loads due to liquid cargo or water ballast, etc.) differs from the arrangement of stiffeners, the edge elements of hatch covers are also to be modelled.

(3) Allowable values
When the loads specified in (1) act the structural model specified above, the scantlings are to be determined so that the stress and deflection generated in each structural member safisfy the allowable values specified **Table 4.2.3**.

(4) Elsewhere
(A) The thickness of top plate of steel hatch covers is to comply with the requirements **2** (3) above and **202. 1** (1).
(B) The section modulus of stiffeners supported by girders and subjected to a uniformly distributed loads may be obtained from the direct strength calculations, or obtained from the requirements in **2** (4) above.



(Note)
A : Additional water head due to the rolling motion obtained from 0.25 b.
B : Additional water head due to the pitching motion obtained from 16 a/L.
h', a, b and L : As specified in **202. 1** (1).

Fig 4.2.2 Modelling of structure

Section 6 Hatch Coamings

602. Load models

1. In application with **Ch 2, 201** of the Rules, the pressure may be reduced by an amount equal to 25 % in case the hatchway covers concerned may be fitted to hatchways located on weatherdecks which are at least two standard superstructure heights above an actual freeboard deck or an as-

sumed freeboard deck from which the form freeboard can be calculated which will result in a draught not less than that corresponding to the freeboard actually assigned. Where any part of a hatchway is forward of a point located one quarter of the ship's length 0.25 L_f from the forward perpendicular, that hatchway is to be located on a weatherdeck at least three standard superstructure heights above the actual or assumed freeboard deck.

Section 7 Weathertightness, Closing Arrangement, Securing Devices and Stopper

702. Gaskets

In case of applying the requirement of **702.** of the Rules, "at the discretion of the Society" means the following (1) through (7).

(1) The vertical distance between the imaginary freeboard deck and the assigned load line is not to be less than the form freeboard in which the imaginary freeboard deck should be assumed to be situated at two or more of the standard height of superstructure (as per **Reg. 33** of the "**International Convention on Load Line, 1966**") below the deck the deck with the hatchway covers concerned. Here, in the calculation of the from freeboard, the ship should be assumed to have superstructure of one standard height above the above mentioned imaginary freeboard deck.

(2) Hatch openings of the hatchway covers concerned are to be located abaft the forward 0.25L_f. However, where any part of a hatchway is forward of a point located one quarter of the ship's length(0.25L_f) from the forward perpendicular, that hatchway is to be located on a weatherdeck at least three standard superstructure heights above the actual or assumed freeboard deck.

(3) The non-weathertight gaps between hatch cover panels should be considered as unprotected openings with respect to the requirements of intact and damage stability calculations. They should be as small as possible commensurate with the capacity of the bilge system and expected water ingress, and the capacity and operational effectiveness of the fire-fighting system and, generally, should not exceed 50 mm.

(4) The hatchway coamings should be not less than 600 mm in height.

(5) Labyrinths, gutter bars, or equivalents should be fitted proximate to the edges panel in way of the gaps to minimize the amount of water that can enter the container hold from the top surface of each panel.

(6) Scantlings of the hatch cover panels as well as details on the securing arrangements to the vessel's support structure and coamings are to be equivalent to those for weathertight covers and in accordance with the requirements of the Society.

(7) Bilge alarms should be provided in each hold fitted with non-weathertight cover.

703. Closing arrangement, securing devices and stoppers

6. Inertia of edge elements

(1) When calculating the moment of inertia ($I = 6 P_L S_S^4$) as specified in **703. 6** of the Rules, the spacing between securing devices S_S (m) is maximum of the distance between two consecutive devices, measured along hatch cover periphery(m), not to be taken as less than 2.5 S_c.

Where,
S_c = max ($S_{1.1}, S_{1.2}$) (m) (Refer to **Fig 4.2.3**)

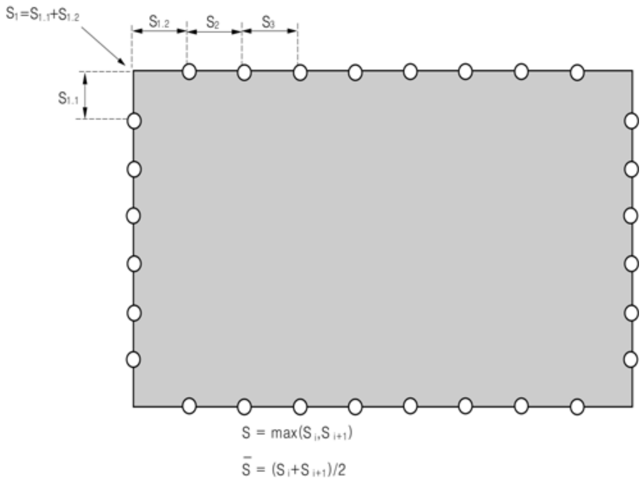


Fig 4.2.3 Spacing of securing devices

(2) When calculating the actual gross moment of inertia of the edge element, the effective breadth of the attached plating of the hatch cover is to be taken equal to the lesser of the following values.
(A) $0.165\,S_S$
(B) Half the distance between the edge element and the adjacent primary member

Section 8 Additional Requirements

801. Portable beam

1. The diameter of lighting holes provided in portable beams is to be smaller than one third of depth of portable beams in the section. Where the loading of lumber is planned, lighting holes are recommended not to provided.

2. The thickness of web plates is not to be less than the value obtained from the following formula.

$$10h + 4 \quad \text{(mm)}$$

Where,

h : Depth of web plates at mid-span of portable beams (m)

3. The width of upper face plates of portable beams supporting hatchboard is to be over 135 mm.

4. In applying regulations of **Sec 5** of the Rules, distance between inner sides of hatchway coamings may be used as the span of the portable beams.

Section 10 Miscellaneous Openings

1001. Companionways

1. Grouping into deckhouse and companionway

(1) A structure is regarded as a deckhouse where its inside is always accessible through access openings provided on the top of the structure or through under-deck passageways, even when all access openings in the boundary walls are closed
(2) A structure is regarded as a companionway where its inside is not accessible through any other way, when all access openings in the boundary walls are closed. ⚓

CHAPTER 3 BOW DOORS, SIDE AND STERN DOORS

Section 1 Bow Doors and Inner Doors

101. General

1. Application

(1) The following measures are to be complied with by all existing ro-ro passenger ships with the date of building before or on the 30th June 1996, including, when not differently deliberated by the competent flag Administrations, ships only engaged on domestic sea voyages.

(A) The structural condition of bow doors and inner doors, especially the primary structure, the securing and supporting arrangements and the hull structure alongside and above the doors, are to be specially examined and any defects rectified.

(B) The operating procedures of the bow door and inner door are to comply with the requirements of **Pt 4, Ch 3, 108.**

(C) The location and arrangement of inner doors are to comply with the applicable requirements of the **SOLAS** Convention and with **Pt 4, Ch 3, 101. 3.** (3) of the Rules.

(D) Ships with visor door are to comply with **Pt 4, Ch 3, 106. 2.** (7) requiring redundant provision of securing devices preventing the upward opening of the bow door. In addition, where the visor door is not self closing under external loads (i. e. the closing moment M_y calculated in accordance with **Pt 4, Ch 3, 103. 1.**(3)(A) is less than zero) then the opening moment M_0 is not to be taken less than $-M_y$. If drainage arrangements in the space between the inner and bow doors are not fitted, the value of M_0 is to be specially considered. Where available space above the tanktop does not enable the full application of **Pt 4, Ch 3, 106. 2.** (7), equivalent measures are to be taken to ensure that the door has positive means for being kept closed during seagoing operation.

(E) For visor doors, the securing and supporting device excluding the hinges to be capable of bearing the vertical design force ($F_z - 10W$), in kN, within the permissible stresses given in **Table 4.3.1** of the Rules.

(F) For side-opening doors, the structural arrangements for supporting vertical loads, including securing devices, supporting devices and, where applicable, hull structure above the door, are to be re-assessed in accordance with the applicable requirements of **Pt 4, Ch 3, 106.** and modified accordingly.

(G) The securing and locking arrangements for bow doors and inner doors which may lead to the flooding of a special category space or Ro-Ro cargo space as defined in the **Pt 4, Ch 3, 101. 4** of the rules, are to comply with the following requirements:

(a) Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

(b) The indication panel on the navigation bridge is to be equipped with a mode selection function harbour / sea voyage, so arranged that audible alarm is given if the vessel leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

(c) A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

Section 2 Side Shell Doors and Stern Doors

201. General

1. Application

(1) The following measures are to be complied with by all existing ro-ro passenger ships with the date of building before or on the 30th June 1997, including, when not differently deliberated by the competent flag Administrations, ships only engaged on domestic sea voyages.

(A) The structural condition of side shell doors and stern doors, especially the primary structure, the securing and supporting arrangements and the hull structure alongside and above the doors, are to be specially examined and any defects rectified.
(B) The structural arrangement of securing devices and supporting devices of inwards opening doors in way of these securing devices and, where applicable, of the surrounding hull structure is to be reassessed in accordance with the applicable requirements of **Pt 4, Ch 3, 205.** and modified accordingly.
(C) The securing and locking arrangements for side and stern doors which may lead to the flooding of a special category space or Ro-Ro cargo space as defined in the **Pt 4, Ch 3, 101. 4** of the rules, are to comply with the following requirements:
 (a) Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.
 (b) The indication panel on the navigation bridge is to be equipped with a mode selection function harbour / sea voyage, so arranged that audible alarm is given if the vessel leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.
 (c) A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.
(D) Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places. ⚓

CHAPTER 4 BULWARKS, FREEING PORTS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND PERMANENT GANGWAYS

Section 1 Bulwarks and Guardrails

101. Arrangements

1. The term "where deemed necessary by that Society" means when the ship is recognized adequate protection is equipped, the height of bulkwark may be more than 600 mm and may be provided with stormrail on the wall which is located with 1 m height in deckhouse on upperdeck.

106. Guardrails

1. At least every third stanchion shall be supported by a bracket or stay. In lieu of this, flat steel stanchions shall be of increased breadth as given in **Fig 4.4.1**, and aligned with member below deck unless the deck plating thickness exceeds 20 mm.

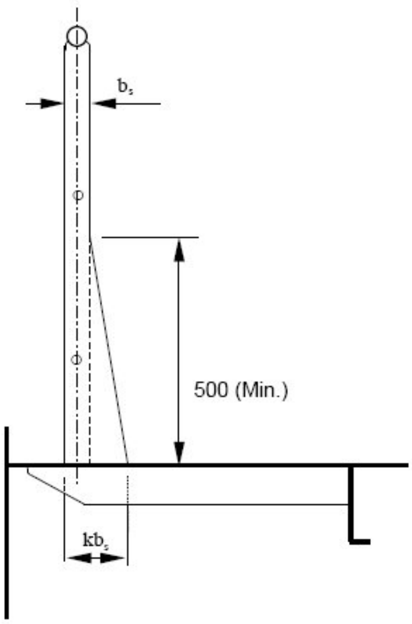


Fig 4.4.1 Guardrail stanchion of increased breadth

(1) At least every third stanchion : kbs = 2.9 bs
(2) At least every second stanchion : kbs = 2.4 bs
(3) Every stanchion : kbs = 1.9 bs
where, bs : breadth of normal stanchion according to the design standard.

2. Stanchions with increased breadth to be aligned with member below deck, min. 100 × 12 flat bar. The member below deck are to be welded to deck by double continuous fillet weld with leg size of min. 7 mm or as specified by the design standard.

3. In application of **106. 3.** of the Rules, wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths.

Section 2 Freeing Ports

201. General

1. The adequate provision for freeing the spaces which are open at either or both ends within superstructure referred to in **Ch 4, 201. 3** of the Rules is subject to the (1) through (3).

(1) The minimum freeing port area on each side of the ship for the open superstructure is not less than that obtained from the following formula.

$$A_s = \frac{A_1 b_0 h_s}{2 l_t h_w}\{1-(\frac{l_w}{l_t})\} \qquad (m^2)$$

Where,

A_1 = $0.7+0.035 l_t$ (m^2) l_t is not more than 20 m

= $0.07 l_t$ (m^2) l_t is more than 20 m

l_t : $l_w + l_s$ (m)

l_w : Where bulwark forms a well, the length of bulwark in well(m)

l_s : Length of the common space within the open superstructure(m)

b_0 : Breadth of the openings in the end bulkhead of the enclosed superstructure(m)

h_s : One standard superstructue height(m)

h_w : The distance of the well deck above the freeboard deck(m)

(2) The minimum freeing port area on each side of the ship for the open well is not less than that obtaibed fron the following formula.

$$A_w = \frac{A_2 h_s}{2 h_w} \qquad (m^2)$$

Where,

A_2 = $0.7+0.035 l_w + a$ (m^2) l_w is not more than 20 m

= $0.07 l_w + a$ (m^2) l_w is more than 20 m

a = $0.04 l_w (h-1.2)$ (m^2) h is moe than 1.2 m

= 0 h is not more than 1.2 m, but not less than 0.9 m

= $-0.04 l_w (0.9-h)$ (m^2) h is less than 0.9 m

h : Average height of bulwark above the deck (m)

(3) In ships either without sheer or with less sheer than the standard, the minimum freeing port area obtained from the above (1) and (2), is increased by multiply the factor obtained from **202. 2** of the Rules.

2. The requirements in **201. 4** of the Rules are applied to type A or B-100 ships with specially reduced freeboards.

3. The requirements in **202. 4** of the Rules are applied to type A or B-100 ships with specially reduced freeboard having trunks.

202. Freeing port area

1. A flush-decker having an effective deckhouse is to be considered to have two wells afore and abaft the deckhouse, and each of these wells is required to have freeing port area as prescribed in **202.** of the Rules. The term "effective deckhouse" means a structure having a breadth not less than 80 % of the breadth of ship and the width of passageways at its sides does not exceed 1.5 m.

2. Where a divisional bulkhead extending from side to side is provided at the forward end of deckhouse, the ship is to be considered to have two wells afore and abaft the bulkhead, irrespective of the breadth of deckhouse, and each of these wells is required to have the freeing port area as prescribed in **202.** of the Rules.

3. In ships which correspond to the requirements **201. 2**, the guardrails installed at both sides for more than half of the length of the exposed parts of the freeboard deck, and in ships which correspond to the requirements in **201. 3**, the guardrails installed at both sides for more than half of the length of trunks on the freeboard deck may be replaced by freeing ports of a total area not less than 33 % of the total area of bulwark in the lower parts of bulwarks.

4. In type B-60 ships, freeing ports in the lower parts of bulwarks are to have an area not less than 25 % of the total area of bulwark.

5. Where freeing ports are fitted with rails, etc., projected area of them is to be excluded from actual freeing port area in calculations.

6. Where set-in structure of side shell or superstructure from a well in pure car carrier, etc., adequate freeing ports are to be provided in accordance with the requirements of **202. 3** of the Rules.

7.

(1) The case where a ship is provided with a trunk or a hatch side coaming which is continuous or substantially continuous between detached superstructure specified in **202. 3** of the Rules means the case where F_0 is equal to, or less than F_1, where F_0 and F_1 are shown in the following.

F_0 : Free flow area through which water runs across the deck given by the following formula(m^2)

$$\Sigma(l_i h_i - a_i)$$

Where,

l_i : Distance between hatchways, and between hatchways and superstructures and deckhouse(m)

h_i : Height of bulwarks(m)

a_i : Projected area of structure which prevent free flow in $l_i \cdot h_i$.

F_1 : As specified in **202. 1** and **2** of the Rules.(m^2)

(2) Where F_0 is greater than F_1, but not greater than F_2, freeing port area (F) is increased by the following formula with the value obtained from **202. 1.** and **2.** of the Rules.
F_0 and F_1 are shown in the above (1), F_2 is specified in **202. 3** of the Rules.

$$F = F_1 + F_2 - F_0 \ (\text{m}^2)$$

(3) Where F_0 is greater than F_2, F is equal to F_1.

204. Arrangement of freeing ports

1. In ships having very small shear or without shear, the area of freeing ports is to be distributed throughout the whole length of the well.

2. Specially, for the ships having reduces freeboard, freeing ports having not less than 25 % of total area of bulwarks is to be provided in lower part of bulwarks.

205. Structure

In case fishing vessels etc. which are accepted to this Society are fitted securing and locking devices, its structure are to be of an approved one.

Section 3 Side Scuttles, Rectangular Windows and Skylights

301. General Application

1. With respect to the provisions of **Ch 4, 301.** of the rules, the term as deemed as appropriate by the Society means that the side scuttles and rectangular windows is to be in conformity corresponding to the position and to have appropriate weathertightness.

2. With respect to the provisions of **Ch 4, 301.** and **302.** of the rules, windows on a navigation bridge within the third tiers above the freeboard deck, which is granted to be of rectangular window in accordance with the provisions of **306.** of the rules, may be of rectangular window other than of class E or F subject to the following (1) and (2)

(1) The navigation bridge is to be separated from spaces below the freeboard deck and spaces within superstructures by the following

(A) Weathertightness closing devices

(B) Two or more cabin bulkheads or doors. In such case, the height of sills of the doorway to the navigation bridge are not to be less than those required for closing devices at the position of such doorway.

(2) The design pressure of such windows is not to be less than the value specified in **308.** of the rules and construction of frames, etc. for such windows is to be in conformity to those required for the class E, F rectangular window corresponding to the position of such windows and to have appropriate weathertightness.

303. Application of side scuttle

The wording as deemed as appropriate by the Society in **303. 5.** of the rules means that the side scuttles may be class A or class B side scuttles without deadlight.

305. Design pressure and maximum allowable pressure of side scuttle.

With respect to provisions of **305. 1.** of the rules, the value of coefficient "a" for the side scuttles for spaces below the freeboard deck or spaces within the superstructures may be determined in applying the provisions of **Pt 3, Ch 17, 201.** of the rules as the first tier deckhouse.

307. Application of rectangular window

The wording as deemed as appropriate by the Society in **307. 3.** of the rules means that the rectangular windows may be rectangular windows without shutter or deadlight.

Section 5 Permanent Gangways

501. General

1. Protection of crew provided in exposed freeboard deck, superstructure deck, crew accommodation area and machinery space and other area locations in question is to be in accordance with **Table 4.4.1.**

Table 4.4.1 Protection of crew

<table>
<tr><th rowspan="2">Type of ships</th><th rowspan="2">Location of access in ship</th><th rowspan="2">Assigned summer freeboard</th><th colspan="4">Acceptable arrangements according to type of freeboard assigned:</th></tr>
<tr><th>Type A</th><th>Type $B-100$</th><th>Type $B-60$</th><th>Type $B\&B+$</th></tr>
<tr><td rowspan="4">Other than tankers(Oil tankers, chemical tankers and gas carriers)</td><td rowspan="2">1. Access to Mid ship quarters.
(1) Between poop and bridge, or
(2) Between poop and deckhouse containing living accommodation or navigating equipments, or both</td><td>$\leq$ 3000 mm</td><td>a
b
e</td><td>a
b
e</td><td>a
b
c(1)
e
f(1)</td><td rowspan="4">a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td>$>$ 3000 mm</td><td>a
b
e</td><td>a
b
e</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td rowspan="2">2. Access to end.
(1) Between poop and bow(if there is no bridge),
(2) Between bridge and bow, or
(3) Between a deckhouse containing living accommodation or navigating equipments, or both, and bow, or
(4) In the case of a flush deck vessel, between crew accommodation and the forward and after ends of ship</td><td>$\leq$ 3000 mm</td><td>a
b
c(1)
e
f(1)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td></tr>
<tr><td>$>$ 3000 mm</td><td>a
b
c(1)
d(1)
e
f(1)</td><td>a
b
c(1)
c(2)
d(1)
d(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td rowspan="3">Tankers (Oil Tankers, Chemical Tankers and Gas Carriers)</td><td rowspan="2">1. Access to Bow
(1) Between poop and bow, or
(2) Between a deckhouse containing living accommodation or navigating equipment, or both, and bow, or
(3) In the case of a flush deck vessel, between crew accommodation and the forward ends of ship</td><td>$\leq (A_f^{*}+H_s^{**})$</td><td colspan="4">a
e
f(1)
f(5)</td></tr>
<tr><td>$> (A_f^{*}+H_s^{**})$</td><td colspan="4">a
e
f(1)
f(2)</td></tr>
<tr><td>2. Access to after end
In the case of a flush deck vessel, between crew accommodation and the after ends of ship</td><td></td><td colspan="4">as required in 2. (4) for other type of vessels.</td></tr>
</table>

Table 4.4.1 Protection of crew(continue)

1. A_f^* and H_s^{**} is to be as following.
   A_f^* : The minimum summer freeboard calculated as Type A ship regardless of the type freeboard actually assigned.
   H_s^{**} : the standard height of superstructure as defined in **ICLL Regulation 33.**
2. Protection methods are to be as following (a) to (f)
   (a) A well lighted and ventilated under-deck passageway (clear opening 0.8 m wide, 2.0 m high) as close as practicable to the freeboard deck, connecting and providing access to the locations in question.
   (b) A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the center line of the ship, providing a continuous platform at least 0.6 m in width and a non-slip surface, with guard rails extending on each side throughout its length. Guard rails shall be at least 1 m high with courses as required in Load Line Regulation 25(3), and supported by stanchions spaced not more than 1.5 m ; a foot-stop shall be provided.
   (c) A permanent walkway at least 0.6 m in width fitted at freeboard deck level consisting of two rows of guard rails with stanchions spaced not more than 3 m. The number of courses of rails and their spacing are to be as required by Regulation 25(3). On Type B ships, hatchway coamings not less than 0.6 m in height may be regarded as forming one side of the walkway, provided that between the hatchways two rows of guard rails are fitted.
   (d) A 10 mm minimum diameter wire rope lifeline supported by stanchions about 10 m apart, or A single hand rail or wire rope attached to hatch coamings, continued and adequately supported between hatchways.
   (e) A permanent and efficiently constructed gangway fitted at or above the level of the superstructure deck on or as near as practicable to the center line of the ship:
   - located so as not to hinder easy access across the working areas of the deck;
   - providing a continuous platform at least 1.0 m in width;
   - constructed of fire resistant and non-slip material;
   - fitted with guard rails extending on each side throughout its length; guard rails should be at least high with courses as required by Regulation 25(3) and supported by stanchions spaced not more than 1.5 m;
   - provided with a foot stop on each side;
   - having openings, with ladders where appropriate, to and from the deck. Openings should not be more than 40 m apart;
   - having shelters of substantial construction set in way of the gangway at intervals not exceeding 45 m if the length of the exposed deck to be traversed exceeds 70 m. Every such shelter should be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides.
   (f) A permanent and efficiently constructed walkway fitted at freeboard deck level on or as near as practicable to the center line of the ship having the same specifications as those for a permanent gangway listed in (e) except for foot-stops. On Type B ships (certified for the carriage of liquids in bulk), with a combined height of hatch coaming and fitted hatch cover of together not less than 1 m in height the hatchway coamings may be regarded as forming one side of the walkway, provided that between the hatchways two rows of guard rails are fitted.
3. Alternative transverse locations for (c),(d) and (f) above, where appropriate:
   (1) At or near center line of ship; or Fitted on hatchways at or near center line of ship.
   (2) Fitted on each side of the ship.
   (3) Fitted on one side of the ship, provision being made for fitting on either side.
   (4) Fitted on one side only.
   (5) Fitted on each side of the hatchways as near to the center line as practicable

2. Where the access way(gangway, walkway may be included in access way) is provided, it is to be complied with the followings.
   (1) Wire rope may only be accepted in lieu of guard rails in special circumstances and then only in limited length.
   (2) In all cases where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.
   (3) Lengths of chain may only be accepted in lieu of guard rails if fitted between two fixed stanchions.

(4) Where stanchions are fitted, every 3rd stanchion is to be supported by a bracket or stay.
(5) Removable or hinged stanchions shall be capable of being locked in the upright position.
(6) A means of passage over obstructions. if any, such as pipes or other fittings of permanent nature should be provided.
(7) Generally, the width of gangway or deck-level walkway should not exceed 1.5 m.

3. For oil tankers, chemical tankers and gas carriers constructed before 1st July 1998, existing arrangements which complied with (b) or (c) may be accepted in lieu of (e) or (f) provided such existing arrangements are fitted with shelters and means of access to and from the deck as required for the arrangements (e) or (f) as defined in **Table 4.4.1.**

4. For tankers less than 100 m in length (L_f), the minimum width of the gangway platform or deck level walkway fitted in accordance with arrangements (e) or (f), respectively, may be reduced to 0.6 m. ⚓

CHAPTER 7 CEMENTING AND PAINTING

Section 2 Painting

201. General

1. Limitation of using aluminium paint

In ships carrying oil of a flash point not exceeding 60°C chemical carrier, paints containing aluminium must not be used in cargo oil tanks, pump rooms, cofferdams, cargo tank deck area, or any other area where cargo vapour may accumulate, except that the paint concerned have been proven by tests to have no nature of increasing the danger of ignition which may lead to explosions.

Aluminized pipes may be permitted in hazardous areas on open deck provided they are protected from accidental impact, and in inerted cargo tanks and ballast tanks.

2. Special requirements

The cases that "Special requirements may be additionally made by the Society" stated in **Pt 4, Ch 7, 201.** of the Rules are as follows.

(1) The requirements **Pt 7, Ch 3, 107.** of the Rules
(2) The requirements **Pt 3, Ch 1, 803.** of the Rules

3. Omission of painting

In accordance with **Pt 4, Ch 7, 201.** of the Rules, the cases that painting may be omitted are as follows.

(1) Where ships are applied the requirements **Pt 7, Ch 3** of the Rules and their cargoes are intended to be regularly handled by grabs or similar mechanical appliances, painting for cargo holds may be omitted subject to the following (A) and (B)
  (A) Omission of painting is to be limited to those members such as inner bottom plates, slant plates of bilge hoper tanks and slant plates of lower stool transverse bulkheads whose thickness is increased in accordance with the requirements **Pt 7, Ch 3, 304. 2** and **3, 302. 2** or **502. 1** of the Rules. However, omission of painting is not accepted for areas within the extent of painting prescribed in above mentioned **2.**
  (B) The reason and area of omission of painting are to be prescribed in the plans submitted for the approval (for example : Midship Section, etc.)
(2) Where ships are specified in (1) above and intended to carry exclusively chips of wood, the area which are expected to be effectively protected against corrosion of steel by the secretion of chips of wood(the area except where has normally no touch with the cargoes such as inside of upper deck) may be added to the area of omission of painting specified in above item (1) (B) notwithstanding the requirements of the above item **2** (1). The salt beaten structural members in cargo holds used as ballast water tanks is to be thicker by 1.0 mm than the requirements of **Pt 7, Ch 3** of the Rules. However, those which are in cargo holds used as ballast water tanks only in port need not be thicker.
(3) Where tanks are exclusively loaded oils, painting for inside of them may be omitted in spite of kind of ships. ⚓

CHAPTER 8 EQUIPMENT NUMBER AND EQUIPMENT

Section 1 General

101. General and application

1. Consideration for restricted navigation area

(1) Ships assigned with class notation "Smooth water service" may be provided the equipment in accordance with the equipment letter of equipment number which is one grade lower class of equipment letter.

(2) In case of the above (1), the provisions of the used material may not be considered.

2. Due to be assigned scantling draft(d_s), if draft(d_f) for designed ship and draft assigning is smaller than designed draft(d), equipment number and equipment are to be as follows:

(1) For scantling draft(d_s), equipment number and equipment corresponded with scantling draft (d_s) is to be equipped. In this case, if $d_s - d$ is not less than 300 mm, ship length (L_s) corresponded with d_s is to be used.

(2) If d_f is not less than d (for ship assigned d_s, $d_f > d_s$), equipment number and equipment are to be decided by the scantling which is corresponded with d_f. If $d_f - d$ is not less than 300 mm, equipment number is to be calculated with ship length which is corresponded with d_f

3. Superstructure which is not regarded as a deckhouse due to strength

Even though superstructure is not regarded as a deckhouse due to strength, if side wall is extended to side shell and deck is provided, it may be regarded as a superstructure. However, for the superstructure having unusually short end parts of deckhouse may be regarded as a deckhouse.

Section 2 Equipment Number

201. Equipment number

1. The equipment number of tug boat is to be following formula;

$$E = \Delta^{\frac{2}{3}} + 2(B \times f + \Sigma bh) + 0.1A$$

b = maximum breadth of superstructure or deck house at each floor(m)

h = each height of superstructure having breadth greater than $B/4$ or each deckhouse(m).

2. Significant figures

(1) The scantling unit(m) of length, height, breadth has two significant figures and third figure is raised to a unit.

(2) Δ has a only positive number.

(3) Each item of formula

($\Delta^{\frac{2}{3}}, 2.0Bh, 0.1A$) has a only positive number with raising to unit from first figure.

3. Δ, f

(1) The values of Δ, f is to be in accordance with designed summer load line. However, ships assigned scantling draft d_s use the value d_s.

(2) When the principle dimensions(L, B and D) is changed (for example, L is changed when $d_f - d$ is greater than 300 mm), equipment number may be recalculated.

(3) When draft is changed, it is in accordance with the regulation **101. 2** of this chapter.

4. Extents of structures to be included in the second term ($2.0Bh$) of formula

(1) The following items are to be included into the calculation of h'.

(A) superstructures

(B) deckhouses having a breadth greater than $B/4$

(C) screens or bulwarks higher than 1.5 m and in continuation to deckhouse, the total breadth of which exceeds $B/4$ (See **Fig 4.8.4**)

(2) The structures specified in (1) above are to be treated as divided at the intermediate deck into the upper and lower structures, the breadths of which are to be measured as respective tiers.

5. Measurement of breadth of superstructures

(1) A continuous superstructure or deck-house situated on one tier is to be treated as a single structure irrespective of the mode of variation of their breadth and height-continuous or discontinuous, and the breadth is to be the largest one as shown in **Fig 4.8.1.**

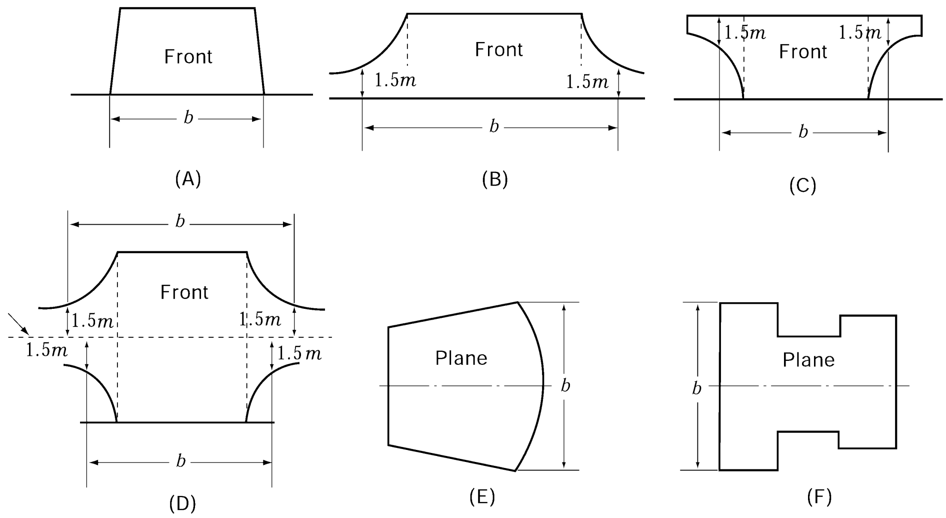
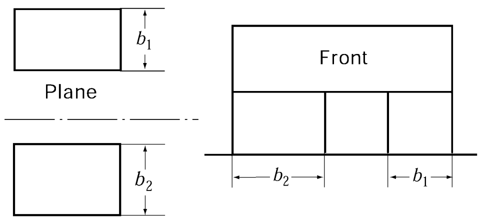
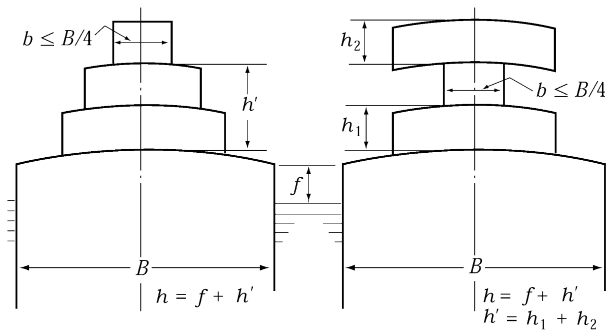


Fig 4.8.1



When b_1, $b_2 < B/4$ (regardless of b_1+b_2), it is not included.

Fig 4.8.2



f is to be measured from transverse section of ship

Fig 4.8.3

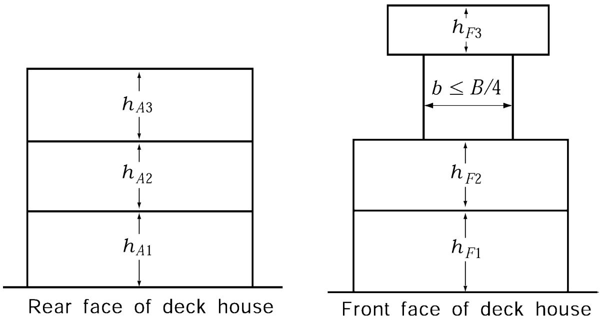
(2) As for detached independent deck-houses on one tier, breadths of respective deckhouses are to be measured separately to determine whether they should be included or not. (See **Fig 4.8.2**)

6. Measurement of heights(h') of structures

(1) h' is to be the height at the ship centreline and is to be measured as shown in **Fig 4.8.3.**

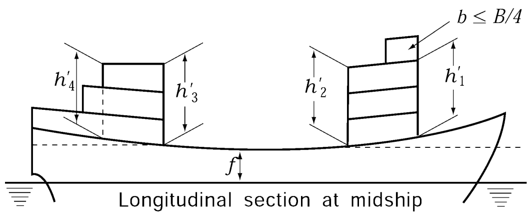
(2) Where there are detached structures, h' is to be determined for respective structures independently and the maximum value is to be taken as the height. (See **Fig 4.8.4**)

(3) Where the between deck height varies longitudinally, h' is to be the maximum value measured from the uppermost continuous deck in the longitudinal section along the ship centreline (See **Fig 4.8.5**)



$h' = h_{A1} + h_{A2} + h_{A3}$ / $h_{F1} + h_{F2} + h_{F3}$ whichever is greater

Fig 4.8.4



$h = f + h'$
h' : h'_1, h'_2, h'_3 and h'_4 whichever is greater

Fig 4.8.5

7. Extents of structures to be included in the third term (0.1A) of the formula.

(1) The following items are to be included in $\Sigma h'' l$.
 (A) Superstructures
 (B) Deckhouses and trunks having breadth exceeding $B/4$ and heights exceeding 1.5 m (See the above item **5**, as to measurement of breadth)
 (C) Screens and bulwarks higher than 1.5 m in continuation to superstructure or to deck- houses having breadth exceeding $B/4$ (See **Fig 4.8.7**)
 (D) The following items may be excluded from the calculation of $\Sigma h'' l$
  (a) portions outside the fore and aft ends of L
  (b) derrick posts, ventilators, etc. in continuation to superstructures or deckhouses
  (c) hatch coamings and hatch covers
  (d) funnels
  (e) cargoes on decks
(2) The structures specified in (1) above are to be treated as divided into the upper and lower structures at the intermediate deck, and the values of $\Sigma h'' l$ are to be calculated for respective tiers.

8. Measurement of length of structures

(1) A continuous superstructure or deck house situated on one tier to be treated as a single superstructure or deckhouse even when its breadth and/or height vary discontinuously. The length is to be the maximum extreme length of the structure. However, where the height is changeable of deckhouse, the end parts or deckhouse having less than 1.5 m height to the middle of deckhouse height may be neglected.(See **Fig 4.8.6**)
(2) Bulwarks in continuation to superstructures or deckhouses are to be treated in a the same manner as (1) above. (See **Fig 4.8.7**)

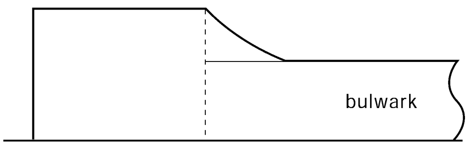
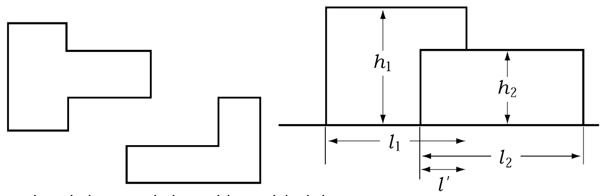


Fig 4.8.7



It is restricted that each breadth and height of deck house is over $B/4$ and 1.5 m.

$h'' l = h_1 l_1 + h_2 (l_2 - l')$

Fig 4.8.9

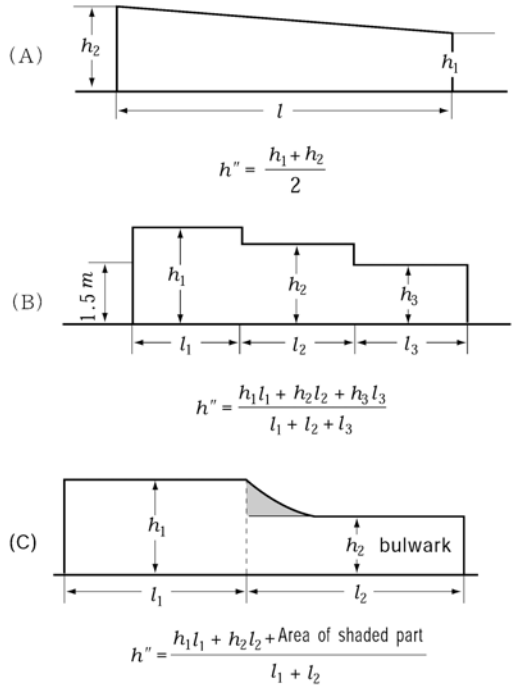


Fig 4.8.8

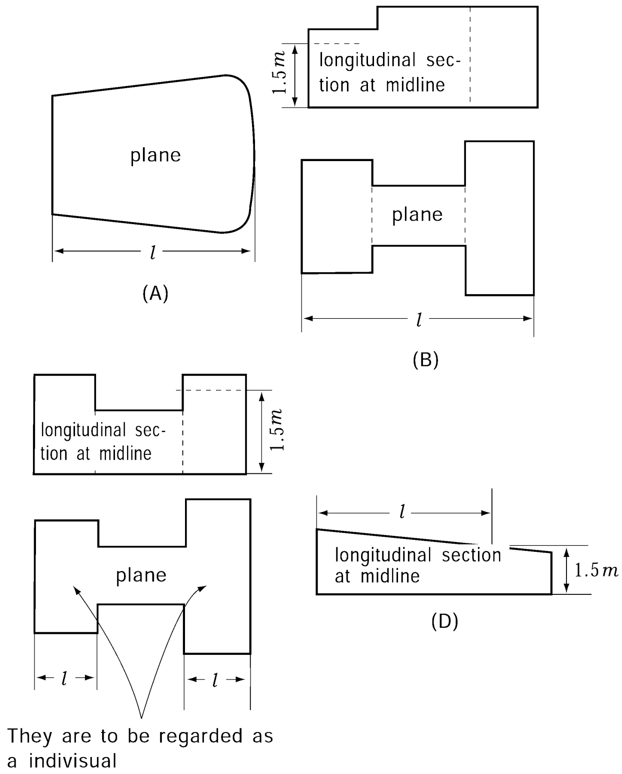


Fig 4.8.6

9. Measurement length to height(h'') of structures

(1) The height of structures (h'') covering the ship's centreline, such as super structures, deckhouse, etc. is to be the between deck height of respective tiers of structure at the centreline.

(2) Where the deck height varies longitudinally, h'' is to be determined as shown in **Fig 4.8.8.**

(3) The height of structures not covering the ship's centreline is to be measured at the side facing to the centreline.

10. Where structure stand side by side

(1) Where two or more deckhouse stand side by side transversely, $h''l$ may be the projected plane of longitudinal section. (See **Fig 4.8.9**)

(2) Screens and bulwark are to be treated in a same manner as (1) above.

11. Calculation $h''l$ of pressured LPG tanks

The $h''l$ of the upper portions of LPG tanks above the upper deck which is included into $h''l$ according to above **8.** is to be the projected area on the longitudinal section along the ship's centreline.

203. Chain cables and stream lines

1. Steel wire rope instead of stud link chain cable may be accepted for vessels of special design or operation such as crane barges if recognized by the Society. The acceptance will be based on a case-by-case evaluation, including consideration of operational and safety aspects. If steel wire rope is accepted, the following to be fulfilled.

(1) The steel wire rope shall have at least the same breaking strength as the stud link chain cable.

(2) The length of the steel wire rope shall be at least 50 % above the table value for the chain cable.

(3) The anchor weight shall be increased by 25 %.

(4) A length of chain cable shall be fitted between the anchor and the steel wire rope. The length shall be taken as the smaller of the follows.

(A) 12.5 m
(B) The distance between the anchor in stowed position and the winch

2. The Society may consider the acceptance if the effect of mooring equipment for operating condition is equivalent to the Rules to the satisfaction to the Society.

Section 3 Anchors

304. Constructions and dimensions

In the Rules, "holding power indicated by the Society" means 2 times of holding power to stockless anchor having same mass in case of high holding power anchors and 4 times of holding power to stockless anchor having same mass in case of super high holding power anchors by the results of holding power test by the type approval tests in **Ch 3, Sec 6** of the ″**Guidance for Approval of Manufacturing Process and Type Approval, etc.**″

Section 4 Chains

401. Application

1. "Chafing chain for Emergency Towing Arrangements (ETA)" specified in **Pt 4, Ch 8, 401. 2** of the Rules are as follows.

(1) Scope
These requirements apply to the chafing chain for chafing gear of two types of Emergency Towing Arrangements (ETA) with specified safe working load (SWL) of 1,000kN (ETA1000) and 2,000kN (ETA2000). Chafing chains other than those specified can be used subject to special agreement with the Society.

(2) Approval of manufacturing
The chafing chain is to be manufactured by works approved by the Society.

(3) Materials
The materials used for the manufacture of the chafing chain are to satisfy the requirements in **403.** of the Rules.

(4) Design, manufacture, testing and certification of chafing chain

(A) The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements in **Pt 4, Ch 8, Sec 4** of the Rules.

(B) The arrangement at the end connected to the strongpoint and the dimensions of the chafing chain are determined by the type of ETA. The other end of the chafing chain is to be fitted with a pear-shaped open link allowing connection to a shackle corresponding to the type of ETA and chain cable grade. A typical arrangement of this chain end is shown in **Fig 4.8.10.**

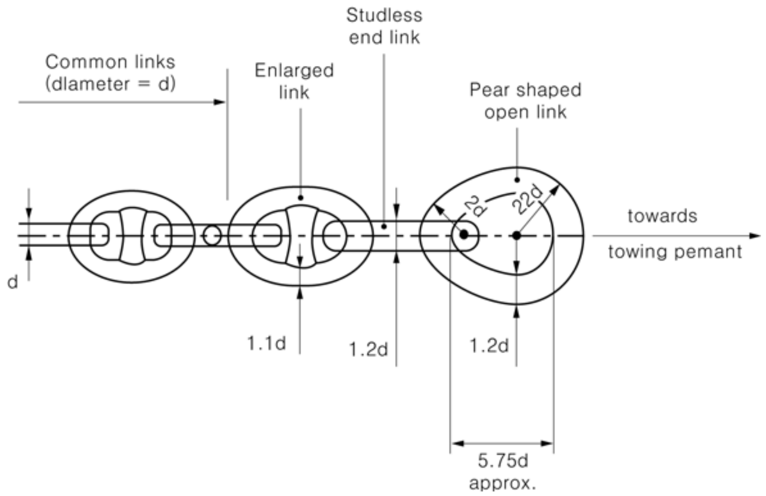


Fig 4.8.10 Typical outboard chafing chain end

(C) The common link is to be of stud link type grade 2 or 3.
(D) The chafing chain is to be able to withstand a breaking load not less than twice the SWL. For each type of ETA, the nominal diameter of common link for chafing chains is to comply with the value indicated in **Table 4.8.1.**

Table 4.8.1. Nominal diameter of common link for chafing chains

Type of ETA	Nominal diameter of common link, d min.	
	Grade 2	Grade 3
ETA1000	62mm	52mm
ETA2000	90mm	76mm

2. "The Offshore mooring chains deemed appropriate by the Society" specified in **Pt 4, Ch 8, 401. 2** of the Rules are as follows.

(1) Application
Offshore mooring chains (hereinafter referred to as "offshore chain") and shackles and swivels which are connected to the offshore chain (hereinafter referred to as "accessories for offshore chain") are to comply with these requirements or to be of equivalent quality. Where, offshore structure mean mobile offshore unit, fixed offshore structure and work vessel.

(2) General
(A) Offshore chains are to be manufactured in continuous length by flash butt welding and are to be heat treated in a continuous furnace.
(B) The connecting common links may be used in order to replace defective links which does not comply with tests and examinations required by these requirements. However, the use of connecting common links is restricted to 3 links in each 100 m of offshore chain.
(C) Notwithstanding the requirement of (B), the joining shackles may be used in order to replace defective links which does not comply with tests and examinations required by this Section. In this case, Number and type of joining shackles used are to be subject to the approval of the Society.

(3) Kinds of offshore chains
Depending on the nominal tensile strength of the steels used for manufacture, chains are to be subdivided into five grades, i.e.: *R* 3, *R* 3S, *R* 4, *R* 4S and *R* 5.

(4) Materials
(A) Offshore chains are to be made of the materials given in **Table 4.8.2** according to their grades and manufacturing processes, respectively.

Table 4.8.2 Materials for offshore chain link

Kind of offshore chain	Materials	Grade of material
Grade *R* 3	Grade *R* 3 offshore chain bar	*RSBCR* 3
Grade *R* 3S	Grade *R* 3S offshore chain bar	*RSBCR* 3S
Grade *R* 4	Grade *R* 4 offshore chain bar	*RSBCR* 4
Grade *R* 4S	Grade *R* 4S offshore chain bar	*RSBCR* 4S
Grade *R* 5	Grade *R* 5 offshore chain bar	*RSBCR* 5

(B) The studs are to be made of steel whose the carbon content is in general less than 0.25 %. If the studs are welded in place however, the studs may be made of steel bars corresponding to that of the offshore chain or of equivalent thereto considered by the Society.
(C) Accessories for offshore chains are to be made of the materials given in **Table 4.8.3** corresponding to the grades of the connected offshore chain.

Table 4.8.3 Materials for accessories of offshore chains

Kind of connected offshore chain	Manufacturing process			
	Casting	Grade of material	Forging	Grade of material
Grade *R* 3	Grade *R* 3 steel casting	*RSCCR* 3	Grade *R* 3 steel forging	*RSFCR* 3
Grade *R* 3S	Grade *R* 3S steel casting	*RSCCR* 3S	Grade *R* 3S steel forging	*RSFCR* 3S
Grade *R* 4	Grade *R* 4 steel casting	*RSCCR* 4	Grade *R* 4 steel forging	*RSFCR* 4
Grade *R* 4S	Grade *R* 4S steel casting	*RSCCR* 4S	Grade *R* 4S steel forging	*RSFCR* 4S
Grade *R* 5	Grade *R* 5 steel casting	*RSCCR* 5	Grade *R* 5 steel forging	*RSFCR* 5

(5) Processes of manufacture
(A) The manufacturers of offshore chains including connecting common links are to obtain approval of the Society in advance concerning their manufacturing methods.
(B) Records of bar heating, flash welding and heat treatment shall be made available for inspection by the Surveyor.
(C) For electric resistance heating, the heating phase shall be controlled by an optical heat sensor. For furnace heating, the heat shall be controlled and the temperature continuously recorded using thermocouples in close proximity to the bars. The controller shall be checked at least once every 8 hours and records made.
(D) The following welding parameters shall be controlled during flash welding of each link and the controls shall be checked at least every 4 hours and records made.
(a) Platen motion
(b) Current as a function of time
(c) Hydraulic pressure
(E) In cases where the studs for Grade *R*3 offshore chains and Grade *R*3S offshore chains are welded, they are to comply with following (a) to (d):
(a) Both ends of the stud are to be a good fit into the link and are not to be fitted on the flash butt weld of the link as far as practicable, and the full periphery of the stud end is to be welded. Welding of both ends of the stud is not permitted unless specially approved by the Society.
(b) Welding position is to be as flat as possible.
(c) All welds are to be carried out before the final heat treatment of offshore chains
(d) The welds are to be made by qualified welders using an approved procedure and low-hydrogen approved consumables.
(F) Welding of studs in Grade *R* 4 offshore chain, Grade R4S offshore chain and Grade *R*5 offshore chain is not permitted unless specially approved by the Society.
(G) Accessories of offshore chains are to be made by casting or forging. Their manufacturers are to obtain approval by the Society in advance concerning their manufacturing methods.
(H) Connecting common links are to comply with following (a) to (d):
(a) Single links to substitute for test links or defective links without the necessity for re-heat treatment of the whole length are to be made in accordance with an approved procedure. Separate approvals are required for each grade of chain and the tests are to be made on the maximum size of chain for which approval is sought.
(b) Manufacture and heat treatment of connecting common link is not to affect the properties of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C. However, an alternative procedure may be applied to this joining method where specially approved by the Society.
(c) Each link is to be subjected to the appropriate proof load and non-destructive examination.
(d) Each connecting common link is to be marked on the stud in accordance with **401. 2**

(16) plus a unique number for the link. The adjoining links are also to be marked on the studs.

(6) Manufacturers

Manufacturers which manufacturer the offshore chains and accessories of them are to obtain approval by the Society

(7) Heat treatment

(A) Offshore chains are to be heat treated as normalized, normalized and tempered or quenched and tempered in a continuous furnace. In principle, batch heat treatment is not permitted. Where length of offshore chains is shorter than 55 m and the heat treatment can be conducted for whole of them at the same time, batch heat treatment may be permitted.

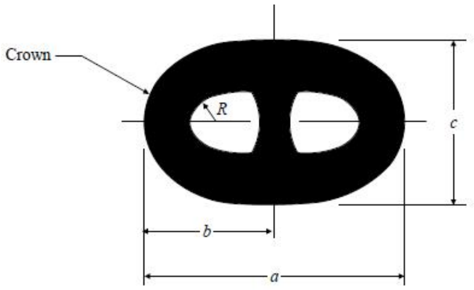
(B) Accessories of offshore chains are to be heat treated as normalized, normalized and tempered or quenched and tempered.

(C) Temperature and time or temperature and chain speed shall be controlled and continuously recorded.

(8) Dimension and forms

(A) The standard dimensions and forms of each kind of link and accessory are to be as given in **Fig 4.8.11**

Stud link - The internal link radii (R) and external radii should be uniform



Designation(1)	Description	Nominal Dimension of the Link	Minus Tolerance	Plus Tolerance
a	Link Length	$6d$	$0.15d$	$0.15d$
b	Link Half Length	$a^*/2$	$0.1d$	$0.1d$
c	Link Width	$3.6d$	$0.09d$	$0.09d$
e	Stud Angular Misalignment	0 degrees	4 degrees	4 degrees
R	Inner Radius	$0.65d$	0	-----

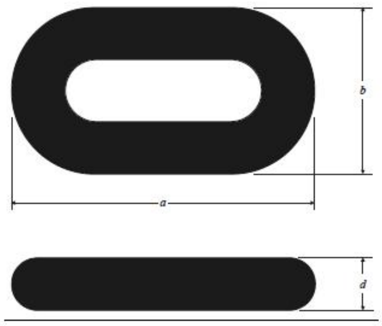
Notes:

(1) Dimension designation is shown in above figure.

d = Nominal diameter of chain

a^* = Actual link length

Studless - The internal link radii (R) and external radii should be uniform.



Designation(1)	Description	Nominal Dimension of the Link	Minus Tolerance	Plus Tolerance
a	Link Length	$6d$	$0.15d$	$0.15d$
b	Link Width	$3.35d$	$0.09d$	$0.09d$
R	Inner Radius	$0.65d$	0	-----

Notes:
(1) Dimension designation is shown in above figure.
d = Nominal diameter of chain
(2) Other dimension ratios are subject to special approval.

Fig 4.8.11 Stud link and studless common link, proportions dimensions and tolerances

(B) The nominal diameter of offshore chains is to be denoted by the diameter at the crown of the common link.
(C) Every kind of link and accessories is to be of uniform shape and their bent portions are to be sufficient to allow each link to work smoothly.
(D) Drawings showing the detailed design of the stud shall be submitted for information. The stud shall give an impression in the chain link which is sufficiently deep to secure the position of the stud, but the combined effect of shape and depth of the impression shall not cause any harmful notch effect or stress concentration in the chain link.
(E) Machining of Kenter shackles shall result in fillet radius min. 3 % of nominal diameter.

(9) Dimensional tolerances
(A) The dimensions of offshore chains are to be measured at least 5 % of all links after the execution of a proof test. If link diameter, length, width and stud alignment do not conform to the required dimensions, these shall be compared to the dimensions of 40 more links; 20 on each side of the affected link. If a single particular dimension fails to meet the required dimensional tolerance in more than 2 of the sample links, all links shall be examined.
(B) The tolerances of following (a) to (e) are to be applied to links
(a) The negative tolerance for nominal diameter measured at the crown is to be complied with the requirements in accordance with the nominal diameter as given in **Table 4.8.7** of the Rules. The plus tolerance may be up to 5 % of the nominal diameter. The cross sectional area of the crown is to be no negative tolerance.
(b) The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter.
(c) The plus tolerance of the diameter measured at the flash butt weld is to be left to the discretion of the Society.
(d) All other dimensions except (a) to (c) are subjected to a manufacturing tolerances of ± 2.5 %, provided always that all parts fit together properly.
(e) Tolerances with regard to the location of stud set are to comply with the requirements in **Pt 4, Ch 8, 401. 1** (5) of the Rules.
(C) For all offshore chain, a length of 5 common links which are connected is to be measured. The measurement of a length of 5 links are to be carried out in accordance with the following procedures while the offshore chain is loaded to 5~10 % of the minimum proof load.
(a) The first five links is to be measured
(b) The next set of five links, at least two links from the previous five links are to be included, is to be measured.
(c) The measurement procedure specified in (B) is to be followed for the entire offshore chain length.
(d) The five links held in the end blocks may be excluded from this measurement.
(D) The allowable manufacturing tolerance on a length of five links by measuring procedure specified in (C) is to comply with the requirements as given in **Table 4.8.4**. The allowable manufacturing tolerance on a length of five links is + 2.5 %, but may not be negative.
(E) If a length of five links is shorter than allowable value, offshore chain may be stretched by tensile loading. In this case, however, tensile load is not to exceed 110 % of minimum proof load required.
(F) If links are found to be defective or not to meet the dimensional tolerance requirement

specified in (A), defective links may be cut off and a connecting common link or joining shackle inserted in their place. In this case, proof tests are to be carried out again after insertion of a connecting common link or a joining shackle, and dimensions of a connecting common link or a joining shackle are to be measured.

(G) At least one accessory (of the same type, size and nominal strength) out of 25 is to be measured for dimensions after proof load testing. Dimensions are subjected to a manufacturing tolerance of the following (a) and (b). These tolerances do not apply to machined surface.

(a) The tolerance of the nominal diameter is to be equal +5 % but may not be negative.

(b) Other dimensions are subjected to a manufacturing tolerance of ±2.5 %.

(10) Testing and inspection of finished chain and accessaries

(A) All chain and accessaries are to be subjected to proof load tests, break load tests and mechanical tests after final heat treatment in the presence of a Surveyor. Where the manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the adequacy of the recording system, he need not witness all proof load tests.

(B) The Surveyor is to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition.

(C) Prior to test and inspection the chain is to be free from scale, paint or other coating. The chain shall be sand- or shot blasted to meet this requirement.

(D) Mass The mass of offshore chains is to comply with the standard mass given in **Table 4.8.4,** in accordance with their kind, and to be measured after the execution of proof tests.

Table 4.8.4 Breaking and proof test loads, mass and length over 5 links for offshore chains

Test Load	Grade $R3$ Stud Link	Grade $R3S$ Stud Link	Grade $R4$ Stud Link	Grade $R4S$ Stud Link	Grade $R5$ Stud Link
Proof test load (kN)	$0.0148d^2(44\text{-}0.08d)$	$0.0180d^2(44\text{-}0.08d)$	$0.0216d^2(44\text{-}0.08d)$	$0.0240d^2(44\text{-}0.08d)$	$0.0251d^2(44\text{-}0.08d)$
Breaking test load (kN)	$0.0223d^2(44\text{-}0.08d)$	$0.0249d^2(44\text{-}0.08d)$	$0.0274d^2(44\text{-}0.08d)$	$0.0304d^2(44\text{-}0.08d)$	$0.0320d^2(44\text{-}0.08d)$
Test Load	Grade $R3$ Studless	Grade $R3S$ Studless	Grade $R4$ Studless	Grade $R4S$ Studless	Grade $R5$ Studless
Proof test load (kN)	$0.0148d^2(44\text{-}0.08d)$	$0.0174d^2(44\text{-}0.08d)$	$0.0192d^2(44\text{-}0.08d)$	$0.0213d^2(44\text{-}0.08d)$	$0.0223d^2(44\text{-}0.08d)$
Breaking test load (kN)	$0.0223d^2(44\text{-}0.08d)$	$0.0249d^2(44\text{-}0.08d)$	$0.0274d^2(44\text{-}0.08d)$	$0.0304d^2(44\text{-}0.08d)$	$0.0320d^2(44\text{-}0.08d)$
Chain Weight (kg/m)	Stud Link = $0.0219d^2$				
	Studless chain Weight calculations for each design are to be submitted.				
Length over 5 links (mm)	over 22d up to $22.55d$				

(11) Breaking test

(A) The breaking test for offshore chain is to be carried out by the following procedures after final heat treatment.

(a) A breaking test specimen consisting of at least 3 links is to be either taken from the offshore chain or produced at the same time and in the same manner as the offshore chain.

(b) The breaking test frequency is to be based on tests at sampling intervals according to **Table 4.8.5** corresponding to its nominal diameter provided that every cast is represented.

Table 4.8.5 Number of breaking test

Nominal diameter of offshore chain d(mm)	Maximum sampling interval(m)
$d \leq 48$	91
$48 < d \leq 60$	110
$60 < d \leq 73$	131
$73 < d \leq 85$	152
$85 < d \leq 98$	175
$98 < d \leq 111$	198
$111 < d \leq 124$	222
$124 < d \leq 137$	250
$137 < d \leq 149$	274
$149 < d \leq 162$	297
$162 < d \leq 175$	322
$175 < d \leq 186$	346
$186 < d \leq 199$	370
$199 < d \leq 210$	395

(c) Each specimen shall be capable of withstanding the break load specified in **Table 4.8.4** without fracture and shall not crack in the flash weld. It shall be considered acceptable if the specimen is loaded to the specified value and maintained at that load for 30 seconds.

(d) Where the alternative test is carried out in lieu of the testing test due to the shortage of capacity of testing machine does not reach the breaking test loads specified in **Table 4.8.4,** the following (a) and (b) are to be complied with.

(i) Procedure of the alternative test is to be submitted to the Society for approval, and the results of breaking test which were carried out at the approval of manufacturing methods are also to be submitted to the Society

(ii) Where the breaking test is carried out, tests are to include the test for approval of manufacturing method of this chain except breaking test.

(e) If a breaking test fails, a thorough examination is to be carried out to identify the cause of failure.

(f) If a breaking test fails, two additional breaking test specimens representing the same sampling length of offshore chain are to be subjected to the breaking test. If two additional breaking test result satisfactorily, it will be decided what lengths of offshore chain can be accepted based upon the results of the failure investigation specified in (e).

(g) If either or both results of the additional test and failure investigation specified in (e) and (f) fail, the sampling length of offshore chain represented will be rejected. If a single link is found to be defective or not to meet the requirement of breaking test, defective links may be cut out and connecting common link or joining shackle inserted in its place and retest of breaking test may be carried out. If the result of the retest is found satisfactory, the sampling length of offshore chain represented may be passed

(B) The breaking test for accessories of offshore chain and connecting common link is to be carried out by the following procedures after final heat treatment.

(a) For accessories of offshore chain, the breaking test is to be carried out for the following frequency which is the least. However, for connecting common link and individually produced accessories or accessories produced in small batches, the frequency of the breaking test is at the discretion of the Society

(i) one accessory from each manufacturing lot, which have the same grade, size, and heat treatment, of 25 units or less of accessories.

(ii) one accessory out of every batch.

(b) Each specimen of accessories of offshore chain and connecting common link is to be capable of withstanding the break load specified for the grade and size of offshore chain for which they are intended without fracture maintained at that load for 30 seconds.

(c) Where the breaking test is not satisfactory, the accessories may be retested by taking out two units from the same lot specified in (a). If one such test fails to meet the requirements, the entire unit of the same lot is rejected.

(C) Accessories and connecting common links used for the breaking test are not to be put into further use. However, where the accessories are of increased dimension or alternatively a material with higher strength characteristics is used and where the accessories are manufactured with following (a) and (b), they may be used in service.

(a) The accessories or connecting common links are successfully tested at the breaking load appropriate to the offshore chain for which they are intended.

(b) It is verified by breaking test carried out by the manufacturer that such accessories are so designed that breaking strength is not less than 1.4 times the breaking load of the offshore chain for which they are intended.

(D) Where the accessories for offshore chains complied with requirement in (C) have not passed the breaking test specified in (11)(B)(a) and (11)(B)(b), the requirement of (11)(B)(c) is not to be applied thereto.

(12) Proof tests

(A) The proof test is to be carried out for the entire length of offshore chain by the following procedures after final heat treatment.

(a) Offshore chains are to withstand the proof test loads specified in **Table 4.8.4** without crack, breakage or any other defects.

(b) Notwithstanding the requirements of (a) above, where plastic straining is used to set studs, the applied proof load is not to be greater than that in approval tests for manufacturing.

(c) If a link fails during proof load testing, a thorough examination is to be carried out to identify the probable cause of failure of the proof test from the manufacturing records. Where the cause of failure is identified and the presence in other lengths of factors or conditions thought to be causal to failure is not found from the above failure investigation, this length of chain except a failure link may be accepted

(d) In the event that two or more links in the proof loaded length fail, that length of offshore chain is to be rejected. An investigation and retest are to be carried out in accordance with the following (i) to (iii) and where these results are found to be satisfactory, this length of offshore chain may be accepted.

(i) A thorough examination is to be carried out to identify the probable cause of failure of the proof test from the manufacturing records. The tests in order to identify the cause of failure may be required where deemed necessary by the Society.

(ii) A breaking test specimen is to be taken from each side of the one failed link according to (11)(A)(a) and subjected to the breaking test.

(iii) Defective links may be cut out and connecting common link or joining shackle inserted in its place and retest of proof load test is to be carried out.

(B) All kinds of accessories and connecting common links are to be tested to the proof test loads specified in **Table 4.8.4,** in accordance with the kinds and diameters of the offshore chains to be connected therewith, and they are to withstand the tests without crack, breakage or any other defect. This test may be carried out simultaneously with the proof test for the offshore chains or together with any offshore chains of the same diameter with which accessories are connected.

(13) Mechanical tests

(A) Mechanical tests for offshore chains are to be carried out in accordance with the following manner after final heat treatment.

(a) One tensile test specimen and 3 sets (9 pieces) impact test specimens are to be taken from the maximum sampling interval corresponding to the nominal diameter of offshore chain specified in **Table 4.8.5** provided that every cast is represented. Test specimens are to be taken from the location given in **Fig 4.8.12** of the part specified in the followings.

(i) The tensile test specimen is to be taken in the side opposite the flash weld.

(ii) One set (3 pieces) impact test specimens are to be taken across the flash butt weld with the notch centered in the middle, one set are to be taken across the unwelded side and one set are to be taken from the bent region.

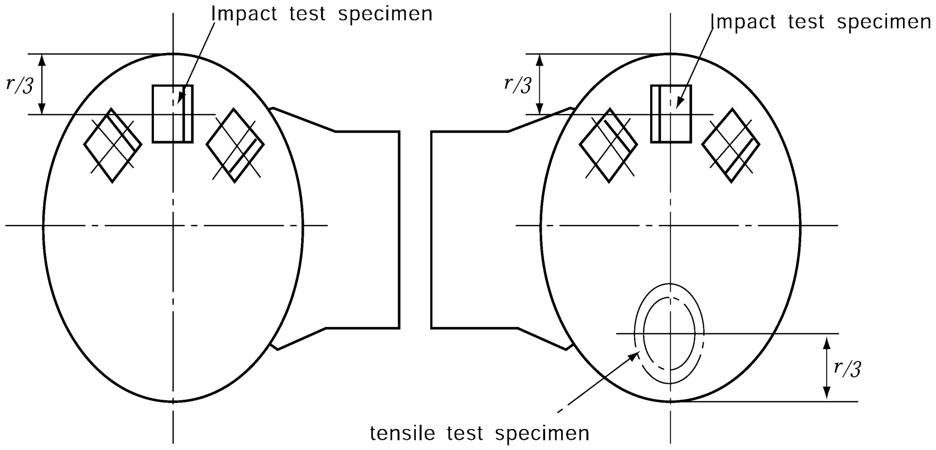


Fig 4.8.12 Location for sampling test specimens for links of offshore chains

(b) Test procedures and form of test specimen are to comply with the requirements in **Pt 2, Ch 1, Sec 2.**

(c) Mechanical properties are to comply with the requirements specified in **Table 4.8.6.**

(d) If the tensile test result does not conform to the requirements, a retest of two further specimens selected from the same sample may be carried out. Where both additional tensile tests show satisfactory results, the sampling length of offshore chain is considered acceptable.

(e) If the impact test results does not conform to the requirements, a retest of three further 1 set (3 pieces) specimens selected from the same sample may be carried out. The results of a retest are to be added to those previously obtained to form a new average. If the results of a retest comply with the requirements specified in **Table 4.8.6** and the new average comply with the requirements specified in **Table 4.8.6,** the sampling length of offshore chain is considered acceptable.

(B) Mechanical tests for accessories of offshore chains and connecting common links are to be carried out in accordance with the following manner after final heat treatment.

(a) One tensile test specimen and one set (3 pieces) impact test specimen are to be taken at the frequency specified in (11)(B)(a) of accessories of offshore chains and connecting common links and mechanical tests are to be carried out. Mechanical properties are to comply with the requirements specified in **Table 4.8.6.**

(b) Where the test results specified in (a) above do not conform to the requirements, additional tests may be carried out by the two tensile test specimens and 2 sets impact test specimens taken from the same lot specified in (a) above. The results of the retest of impact test specimens are to be added to those previously obtained to form a new average. Where one tensile test does not conform to the requirement specified in **Table 4.8.6,** the sampling rot represented is to be subjected to rejection and where the new average value does not comply with the requirements specified in **Table 4.8.6,** the sampling rot represented is to be subjected to rejection.

Table 4.8.6 Mechanical properties

Kinds of offshore chains	Tensile test				Impact test[1]		
	Yeild strength[2] (N/mm^2)	Tensile strength[2] (N/mm^2)	Elongation ($L=5d$)(%)	Reduction of area (%)	Testing temperature (°C)	Minimum mean absorbed energy (J)	
						except welded part	welded part
Grade *R* 3	410 min.	690 min.	17 min.	50 min.	-20(3)	40 min.[3]	30 min.[3]
Grade *R* 3S	490 min.	770 min.	15 min.	50 min.	-20(3)	45 min.[3]	33 min.[3]
Grade *R* 4	580 min.	860 min.	12 min.	50 min.	-20	50 min.	36 min.
Grade *R* 4S	700 min.	960 min.	12 min.	50 min.	-20	56 min.	40 min.
Grade *R* 5	760 min.	1000 min.	12 min.	50 min.	-20	58 min.	42 min.

(Notes)
[1] When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value 70 % of the specified minimum mean absorbed energy, the test is considered to have failed.
[2] Aim value of yield to tensile ration is maximum 0.92
[3] Impact test of Grade *R* 3 and *R* 3S offshore chains may be carried out at the temperature of 0°C where approved by the Society. In this case, minimum mean absorbed energy is not to be less than following values.

	except welded part	welded part
(a) Grade *R* 3	60 J	50 J
(b) Grade *R* 3S	65 J	53 J

(14) Non-destructive Test
(A) Offshore chains and accessories of offshore chains are to be free from harmful defects in use such as pipe, cracks, notches, cuts, flakes and lack of fusion.
(B) All offshore chains are to be subjected to the non-destructive test specified in the following (A) and (B) after proof tests.
(a) After proof testing, all surfaces of every link shall be visually examined. Burrs, irregularities and rough edges shall be contour ground. Links shall be free from mill defects, surface cracks, dents and cuts, especially in the vicinity where gripped by clamping dies during flash welding.
(b) Magnetic Particles test or Dye Penetrant Test
(i) Magnetic particles shall be employed to examine the flash welded area including the area gripped by the clamping dies. Procedures and equipment in accordance with those approved shall be used. Frequency of examination shall be every link. Link surface at the flash weld shall be free from cracks, lack of fusion and gross porosity.
(ii) All stud welds shall be visually examined. At least 10 % of all studs welds within each length of offshore chains are to be examined by magnetic particles test or dye penetrant test after proof testing. If cracks or lack of fusion are found, all welded parts are to be examined. The welds are to be of good quality and free from defects such as cracks, lack of fusion, gross porosity and undercuts exceeding 1 mm.
(c) Ultrasonic Test
(i) Ultrasonics shall be employed to examine the flash weld fusion. Frequency of examination shall be every link. Procedures and equipment in accordance with those approved shall be used. On-site calibration standards for chain configurations shall be approved.
(ii) The flash weld shall be free from defects causing ultrasonic back reflections equal

to or greater than the calibration standard.

(C) Magnetic particles test or dye penetrant test for all ac))ssories of offshore chain and connecting common link, is to be employed to examine after proof test.

(15) Repair of Defects

(A) Where insignificant defects are found from non-destructive test specified in (14) above, they are to be repaired by grinding down no more than 5 % of the link diameter in depth and streamlined to provide no sharp contours, and where their final dimensions are to be within the dimensional tolerances required by (9), those offshore chains and their accessories are considered acceptable.

(B) Where harmful defects are found from non-destructive test specified if (14)(B), a defective link may be cut out and connecting common link or joining shackle inserted in its place. Retests specified in (11) to (13) are to be carried out, and where the results comply with the requirements, these offshore chains and their accessories are considered acceptable.

(16) Markings

(A) Where offshore chains and accessories of offshore chains have satisfactorily passed the tests and inspections required in **Par 2**, they are to be marked as follows.

(a) Places of markings
- At stud of each end of offshore chains
- At stud of each end at intervals not exceeding 100 m
- On connecting common link
- On stud of common links next to connecting common links or joining shackles
- All kinds of accessories of offshore chains

(b) Kinds of markings
- Society's stamp
- The grade of offshore chains and accessories of offshore chains (e.g. KR-*R* 3, KR-*R* 3S, KR-*R* 4, KR-*R* 4S and KR-*R* 5)
- The nominal diameter of offshore chains and accessories of offshore chains
- Manufacturer's number

(B) The marking shall make it possible to recognize leading and tail end of the chain. The marking shall be permanent and legible throughout the expected lifetime of the chain.

(C) All marked links shall be stated on the certificate, and the chain certificate shall contain information on number and location of connecting common links.

(17) Painting

Offshore chains and accessories of offshore chains are not to be painted until the tests and inspections are finished.

(18) Record

Manufacturers producing offshore chains and accessories of offshore chains are to make records with regard to the manufacturing processes tests and inspections required to offshore chains and accessories of offshore chains, and the results of them, and such records are to readily available to the Surrey or when requested.

(A) Records of manufacturing processes such as heating of bar materials, flush butt welding, heat treatment are to include the followings.

(a) Checking records of bar materials by electric resistance heating and furnace heating specified in **2** (5) (C)

(b) Checking records of the welding parameters of flash butt welding process specified in **2** (5) (D)

(c) Process of heat treatment
Temperature and time of temperature and offshore chains speed are to be controlled and continuously recorded.

(B) Records of testings and inspections are to indicates the following (a) to (d).

(a) The results of dimension measurement required by **401. 2** (9) and (10).

(b) The results of testing required by **401. 2** (11) to (13)

(c) The results of non-destructive test required by **401. 2** (14)

(d) If the testings and inspections do not meet the requirements specified in (a) to (c), photographs of the failure of offshore chains and accessories of offshore chains as well as nonconformity, corrective actions and repair works are included in records.

3. "Chafing Chain for Single Point Mooring arrangements" specified in **Pt 4, Ch 8, 401. 2** of the Rules are as follows.

(1) Scope

These requirements apply to short lengths (approximately 8 m) of 76 mm diameter chain to be connected to hawsers for the tethering of oil carriers to single point moorings, FPSO's and similar uses.

(2) Approval of Manufacturing
The chafing chain is to be manufactured by works approved by the Society .

(3) Materials
The materials used for the manufacture of the chafing chain are to satisfy the requirements specified in **403.** of the Rules

(4) Design, manufacturing, testing and certification
(A) The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements specified in **401. 2.**
(B) The arrangement of the end connections is to be of an approved type.
(C) The common link is to be of the stud link type - Grade R3 or R4.
(D) The chafing chain is to be capable of withstanding the breaking test loads of 4884 kN (Grade R3) and 6001 kN (Grade R4). However documented evidence of satisfactory testing of similar diameter mooring chain in the prior six month period may be used in lieu of break testing subject to agreement with classification society.
(E) The chain lengths shall be proof load tested in accordance with **401. 2** (12). The test load for Grade R3 is 3242 kN and for Grade R4 is 4731 kN.

409. Dimensions and forms

1. In **Pt 4, Ch 8, 409. 1** of the Rules, when manufacturer would make chains different from standard dimensions, the dimension tables are to be approved by the Society except the case where the dimensions comply with KS or ISO.

2. For anchor chain cables for large anchor specified in **Pt 4, Ch 8, 203. 1** of the Rules, the length of the shackle and accessories may be included in one length of chain.

412. Breaking test of chains

1. The omissions of breaking test of chains due to the shortage of capacity of testing machine specified in **Pt 4, Ch 8, 412. 2** of the Rules, is to be in accordance with the following requirements in (1) to (3).

(1) Chains are to be comply with the requirements as follows.
(A) Chains are to be Grade 2 or Grade 3 chain.
(B) Breaking loads specified in **Table 4.8.7** of the Rules are to be above 6000 kN.
(C) Chains are to be heat treated.
(D) Breaking test had been demonstrated at approval test for manufacturing process for the nominal diameter or more.
(E) For welded chains specified in **Pt 4, Ch 8, 413** of the Rules is to pass the mechanical test of chain link.

(2) Following tests are to be carried out as an alternative test. Manufacturers are to obtain approval of the concrete testing plan by the Society in advance. The test is able to confirm the strength of welded part for welded chain.
(A) Non-destructive inspection
(B) Marco-structure inspection
(C) Bend test
(D) Tensile test
(E) For Grade 3 chain impact test may be required for reference.

(3) Where the test had been performed as specified in (2) without breaking test, "Alternative breaking test has been applied" is indicated in the certificate.

Section 5 Steel Wire Ropes

506. Rope test

1. The values not included in breaking loads of steel wire ropes in **Table 4.8.13** specified in **Pt 4,**

Ch 8, 506. are to be as follows.

Breaking loads of rope = area coefficient × strand efficiency coefficient × tensile strength(KN/mm^2) × (diameter of rope)^2

Area coefficient and strand efficiency coefficient according to composition mark of steel wire ropes are to be as follows.

Composition mark of steel wire ropes	Area coefficient	Strand efficiency coefficient
6 x 7	0.399	0.90
6 x 12	0.252	0.88
6 x 19	0.397	0.86
6 x 24	0.358	0.87
6 x 30	0.317	0.88
6 x 37	0.395	0.85
6 x WS(36)	0.429	0.80

Section 7 Hatch Tarpaulins

701. Application

Test and inspection of hatch tarpaulins made of synthetic materials is in accordance with **"Regulations for Type Approval Test and Inspection of Ship and Ship's Articles"** ⚓

CHAPTER 9 STRENGTH AND SECURING OF SMALL HATCHES, FITTINGS AND EQUIPMENT ON THE FORE DECK

Section 2
Strength and Securing of Small Hatches on the Exposed Fore Deck

201. General

In application of **201. 3.** of the Rules, securing devices of hatches designed for emergency escape are to be of a quick-acting type(e.g., one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover)operable from both sides of the hatch cover. ⚓

CHAPTER 10 SHIPBOARD EQUIPMENT, FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING

Section 1 Definitions and Scope of Application

101. Application

In application of **Pt 4, Ch 10, 101. 3.** of the Rules, the details are as follows.

1. General

(1) Application
This instruction, in case of survey requested by an applicants(shipowner's, shipyard's or manufacturer's, hereafter referred to as "applicants"), is to be applied to mooring equipment of SPM using standard equipment complying with the recommendations of the Oil Companies International Marine Forum(hereafter referred to as "OCIMF") fitted onboard ships such as oil tankers(hereafter referred to as "ships"), the delivery of which is after 1 January 2009.

(2) General arrangement of mooring equipment of SPM

(A) The components of the ship's equipment required for mooring equipment of SPM are the chain stopper, fairlead, pedestal roller, winch or capstan.(See **Fig 4.10.1**)
However, pedestal roller may not be installed according to arrangement of winch/capstan.

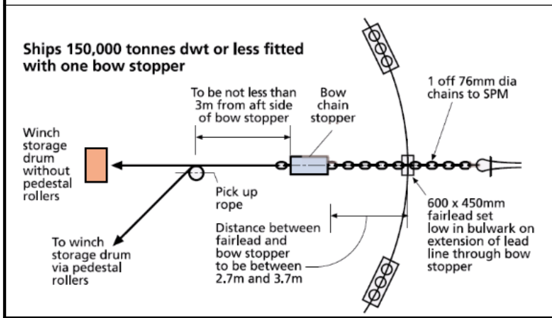
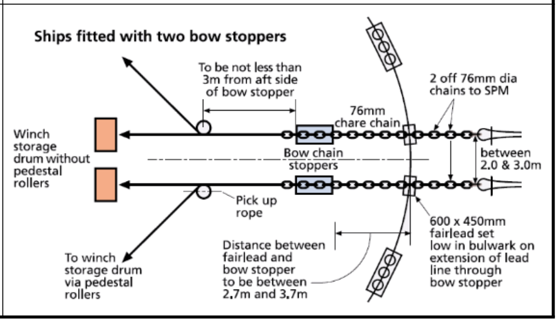
DWT ≤ 150,000	150,000 < DWT
	

Fig 4.10.1 General arrangement of mooring equipment of SPM

(B) For mooring at SPM terminals, ships are to be provided forward with equipment to haul a standardized chafing chain of 76 mm in diameter connection to structure of single point mooring or end of the hawser wire of single buoy mooring terminals.

(C) When the chafing chain is carried on board the ship as a component for mooring equipment of SPM, chafing chain is comply with the requirements in **Pt 4, Ch 8, 401. 3** of the Guidance.

2. Design and specification of material

(1) Forward chain stoppers

(A) Chain stopper is to secured the chafing chain as a strong point. The number of chain stoppers and their safe working loads(SWL) are defined in **Table 4.10.1**

Table 4.10.1 Number and SWL of chain stoppers

Deadweight (ton)	Chain stoppers	
	Number	Safe working load(SWL) (ton)
DWT ≤ 100,000	1	200
100,000 < DWT ≤ 150,000	1	250
150,000 < DWT	2	350

(B) Chain stoppers are to be capable of securing the 76 mm common stud links of the chafing chain when the stopping device is in the closed position, and capable of passing freely the chafing chain and its associated fittings when the stopping device is in the open position.
(C) Chain stoppers may be of the hinged bar or pawl type or of other equivalent design.
(D) The stopping device of the chain stopper is to be arranged, when in the closed position, to prevent it from gradually working to the open position, which would release the chafing chain and allow it to pay out. Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.
(E) Chain stoppers are to be located between 2.7 m and 3.7 m inward of the hull from the bow fairlead. Fairlead and pedestal roller are to be located in line with each other.
(F) Stopper supporting structures are to be trimmed to compensate for any camber and/or sheer of the deck. The leading edge of the stopper base plate is to be faired to allow for the unimpeded entry of the chafing chain into the stopper.
(G) Where the chain stopper is bolted to a seating welded to the deck, the bolts are to be satisfied with the following strength criteria. However, in such condition, efficient thrust chocks capable of withstanding a horizontal force equal to 2.0 times the required working strength are to be installed.

$$\sigma_{VM} \le \sigma_y$$

Where,

σ_{VM} : The equivalent stress in the equipment components(bolts, etc.) induced by the loads.

σ_y : Permissible stress, to be taken, in $\mathrm{N/mm^2}$, as the lower of 0.67 R_{eH} and 0.4 R_m

R_{eH} : Minimum yield stress, in $\mathrm{N/mm^2}$, of the material

R_m : Tensile strength, in $\mathrm{N/mm^2}$, of the material

(H) The steel grade of bolts is to be not less than grade 8.8 as defined by **KS B ISO898-1** (Grade 10.9 is recommended). Bolts are to be pre-stressed in compliance with appropriate standards and tightening is to be suitably checked.
(I) The chain stopper is to be made of rolled steel, steel forging or steel casting complying with the requirements of **Pt 2, Ch 1** of the Rules.
However, use of spheroidal graphite iron casting may be accepted for the main component of the chain stopper provided that:
(a) the component concerned is not to be a welded part
(b) the spheroidal graphite iron casting is of ferritic structure with an elongation not less than 12%
(c) the yield stress at 0.2% proof load is measured and surveyed
(d) the internal structure of the component is inspected by means of non-destructive examinations
(J) The material used for the stopping device (pawl or hinged bar) of chain stoppers is to have mechanical properties similar to Grade R3 chain cable.

(2) Fairleads
(A) One fairlead is to be fitted for each chain stopper.
(B) For ships of over 150,000 ton DWT, two fairleads are required and the fairleads are to be spaced 2.0 m or more center to center apart, if practicable, and in no case more than 3.0 m apart. For ships of 150,000 ton DWT or less, only one fairlead is to be fitted on the centerline.
(C) Fairleads are normally of a closed type such as Panama chocks and are to have an opening large enough to pass the largest portion of the chafing chain, pick-up rope and associated fittings. For this purpose, the inner dimensions of the bow fairlead opening are to be at least 600 mm in width and 450 mm in height.
(D) Fairleads are to be oval or round in shape. The lips of the fairleads are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when heaving inboard. The bending ratio(bearing surface diameter of the fairlead to chafing chain diameter) is to be not less than 7 to 1.
(E) Fairleads are to be located as close as possible to the deck and, in any case, to be in such

a position that the chafing chain is approximately parallel to the deck when it is pulled between the chain stopper and the fairlead.

(F) Fairleads are to be made of rolled steel, steel forging or steel casting complying with the requirements of **Pt 2, Ch 1** of the Rules.

(3) Pedestal roller

(A) Pedestal rollers are to be positioned to enable a direct pull to be achieved on the continuation of the direct lead line between the fairlead and chain stopper. They are to be fitted not less than 3.0 m behind the chain stopper.

(B) Pedestal rollers are to be capable of withstanding a horizontal force equal to the greater of the following values. Stresses generated by this horizontal force are to comply with the strength criteria indicated in **101. 2** (1) (G).

(a) 22.5 ton

(b) the resultant force due to an assumed pull of 22.5 ton in the pick-up rope

(C) It is recommended that the pedestal roller should have a diameter not less than 7 times the diameter of the pick-up rope. Where the diameter of the pick-up rope is unknown, the roller diameter should be at least 400 mm.

(4) Winches or capstans

(A) Winches or capstans used to handle the mooring gear are to be capable of heaving inboard a load of at least 15 ton. For this purpose winches or capstans are to be capable of exerting a continuous duty pull of not less than 15 ton and withstanding a braking pull of not less than 22.5 ton.

(B) If a winch storage drum is used to stow the pick-up rope, it is to be of sufficient size to accommodate 150 m of rope of 80 mm diameter.

3. Type approval

The prototype testing of mooring equipment of SPM is to be in accordance with **Ch 3, Sec 7-2.** in "**Guidance for Approval of Manufacturing Process and Type Approval, etc**".

4. Certificate Etc.

(1) Issuing, valid term and renewal for the approval certificate are to be complied with **Ch 3, Sec 1** in "**Guidance for Approval of Manufacturing Process and Type Approval, Etc**".

(2) Some components of mooring equipment of SPM may be also used for the bow emergency towing arrangements provided that the requirements of instruction are to be complied with and type approval of bow emergency towing arrangement complied with **Ch 3, Sec 7-1.** in "**Guidance for Approval of Manufacturing Process and Type Approval, Etc**".

5. Component's inspection of mooring equipment of SPM

Where components of mooring equipment of SPM have undergone the type approval of this Society and satisfactorily passed the tests and inspections required as followings, the certificate will be issued when applicants request the inspection of components.

(1) Chain stoppers used to mooring equipment of SPM are according to the followings.

(A) The materials are to comply with the requirements in **Pt 2, Ch 1** of the Rules and dimensions are to comply with an approved drawings.

(B) Performance of chain stopper is to comply with the requirements in **101. 2** (1).

(C) Chain stoppers are to be wholly examined by ultrasonic test in principle, but, if impracticable, may be examined by effective non-destructive test such as magnetic particle test.

(D) Where chain stoppers have satisfactorily passed the tests and inspections required in this Society, safe working load and identification numbers are to be marked permanently.

(2) Fairleads used to mooring equipment of SPM are to be in accordance with the following requirements.

(A) The materials are to comply with the requirements in **Pt 2, Ch 1** of the Rules and dimensions are to comply with an approved drawings.

(B) Performance of fairleads is to comply with the requirements in **101. 2** (2).

(C) Fairleads are to be wholly examined by ultrasonic test in principle, but, if impracticable, may be examined by effective non-destructive test such as magnetic particle test.

(3) Pedestal roller and winches or capstans used to mooring equipment of SPM are to comply with the requirements in **101. 2** (3), (4) and to be verified by means of certificate/report of inspection issued by manufacturer.

6. Installation inspection of mooring equipment of SPM on board

Where mooring equipment of SPM type approved by this Society is requested for the installation inspection onboard by ship owner or by shipyard, the equipment is to be satisfactorily passed drawing approval and the tests as followings, the fitness certificate including supporting hull structure is to be issued.

(1) Documentation
Prior to installation of the mooring equipment of SPM on a ship, the applicants are to submit the three copies of the following drawings and data for approval and information.
(A) Documentation for approval
(a) General layout of the forecastle arrangements and mooring at single point moorings
(b) Construction drawing of the bow chain stoppers, fairleads and pedestal roller, together with material specifications and relevant calculations
(c) Drawings and relevant calculations of the local ship structures supporting the loads applied to chain stoppers, fairleads, pedestals roller and winches or capstans
(B) Informations
(a) Specifications of winches or capstans giving the continuous duty pull and brake holding force
(b) Deadweight(ton) of the ship at summer load line
(c) Certificate and Type test record

(2) Design and material requirements
Design and material requirements are to comply with the requirements in **101. 2.**

(3) Supporting hull structures
(A) General arrangement of chain stopper and fairlead is comply with **Fig 4.10.1** and **Fig 4.10.2**
(B) The bulwark plating and stays are to be suitably reinforced in the region of the fairleads.
(C) Deck structures in way of bow chain stoppers, including deck seatings and deck connections, are to be suitably reinforced to resist a horizontal load equal to 2 times the required safe working load and, in such condition, to meet the strength criteria specified in **101. 2** (1) (G).
(D) Minimum thickness of the deck structures in way of the strongpoint and in way of fairlead as well as the deck connections is defined local structure strength calculation and to be at least 15 mm.
(E) For deck bolted chain stoppers, reinforcements are to comply with the requirements in **101. 2** (1) (G) and (H).
(F) The deck structures in way of the pedestal roller and in way of winches or capstans as well as the deck connections are to be reinforced to withstand, respectively, the horizontal force defined in **101. 2** (3) (B) or the braking pull defined in **101. 2** (4) (A) and to meet the strength criteria specified in **101. 2** (1) (G).

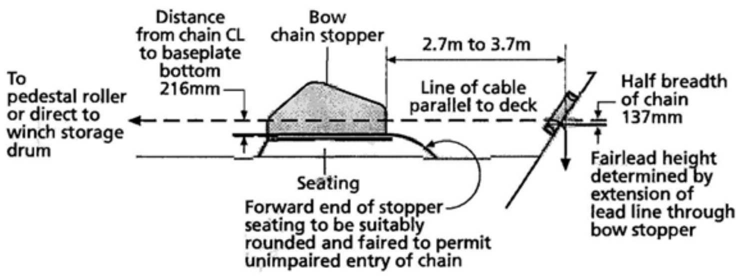


Fig 4.10.2 General arrangement of chain stopper and fairlead

(4) Installation inspection on a ship
(A) Components to be installed and inspected including support structure in accordance with an approved arrangement by this Society and components are to have no permanent deformation provided that proof test loads are equivalent to the required safe working load at least 1 minute as given **Table 4.10.1**. However, load test may be exempted in the following cases:
(a) where mooring equipment of SPM with type approved by this Society, inspection has

been approved in accordance with the requirements in **101. 5.**

(b) where mooring equipment of SPM without type approved by this Society, strength calculation sheets provided that 2 times the required safety factor should be submitted and approved by this Society and inspection has been approved in accordance with the requirements in **101. 5**., provided that proof test loads equivalent to safe working load.

(B) Supporting hull structures are to comply with the requirements in **101. 6** (3).

(C) Main welds of the chain stoppers with the hull structure are to be 100 % inspected by means of non-destructive examinations.

(D) Onboard status of an instruction manual and approved drawings are to be confirmed.

Section 2 Towing and Mooring

204. Survey after construction

The condition of deck fittings, their pedestals, if any, and the hull structures in the vicinity of the fittings are to comply with regulations specified in **Pt 1, Ch 2, 202.** of the Rules. ⚓

CHAPTER 11 ACCESS TO AND WITHIN SPACES IN, AND FORWARD OF, THE CARGO AREA OF OIL TANKERS AND BULK CARRIERS

Section 1 General

101. Application

1. In application of **101. 1.** of the Rules, the details are as follows.

(1) The contents of Res. MSC.151/8(78) can be applied for ships which were keeling on and after 1 Jan. 2005 instead of Res. MSC.133/4(76).

(2) Oil tankers:
The regulation is only applicable to oil tankers having integral tanks for carriage of oil in bulk, which is contained in the definition of oil in Annex 1 of MARPOL 73/78. Independent oil tanks can be excluded. Regulation II-1/3-6 is not normally applied to FPSO or FSO unless the Administration decides otherwise.

102. Means of access to cargo and other spaces

1. In application of **102. 2.** of the Rules, the details are as follows.

(1) Some possible alternative means of access are listed under paragraph 3.9 of TP. Always subject to acceptance as equivalent by the Administration, alternative means such as an unmanned robot arm, ROV's and dirigibles with necessary equipment of the permanent means of access for overall and close-up inspections and thickness measurements of the deck head structure such as deck transverses and deck longitudinals of cargo oil tanks and ballast tanks, are to be capable of:
- safe operation in ullage space in gas-free environment;
- introduction into the place directly from a deck access.

2. In application of **102. 3.** of the Rules, the details are as follows.

(1) Inspection
The MA arrangements, including portable equipment and attachments, are to be periodically inspected by the crew or competent inspectors as and when it is going to be used to confirm that the MAs remain in serviceable condition.

(2) Procedures

(A) Any company authorised person using the MA shall assume the role of inspector and check for obvious damage prior to using the access arrangements. Whilst using the MA the inspector is to verify the condition of the sections used by close up examination of those sections and note any deterioration in the provisions. Should any damage or deterioration be found, the effect of such deterioration is to be assessed as to whether the damage or deterioration affects the safety for continued use of the access. Deterioration found that is considered to affect safe use is to be determined as “substantial damage” and measures are to be put in place to ensure that the affected section(s) are not to be further used prior effective repair.

(B) Statutory survey of any space that contains MA shall include verification of the continued effectiveness of the MA in that space. Survey of the MA shall not be expected to exceed the scope and extent of the survey being undertaken. If the MA is found deficient the scope of survey should be extended if this is considered appropriate.

(C) Records of all inspections are to be established based on the requirements detailed in the ships Safety Management System. The records are to be readily available to persons using the MAs and a copy attached to the MA Manual. The latest record for the portion of the MA inspected should include as a minimum the date of the inspection, the name and title of the inspector, a confirmation signature, the sections of MA inspected, verification of continued serviceable condition or details of any deterioration or substantial damage found. A file of permits issued should be maintained for verification.

103. Safe access to cargo holds, cargo tanks, ballast tanks and other spaces

1. In application of **103. 1.** of the Rules, the details are as follows.

Access to a double side skin space of bulk carriers may be either from a topside tank or double bottom tank or from both.

2. In application of **103. 2.** of the Rules, the details are as follows.

A cargo oil tank of less than 35 m length without a swash bulkhead requires only one access hatch.

Where rafting is indicated in the ship structures access manual as the means to gain ready access to the under deck structure, the term "similar obstructions" referred to in the regulation includes internal structures (e.g., webs >1.5 m deep) which restrict the ability to raft (at the maximum water level needed for rafting of under deck structure) directly to the nearest access ladder and hatchway to deck. When rafts or boats alone, as an alternative means of access, are allowed under the conditions specified in resolution A.744(18), permanent means of access are to be provided to allow safe entry and exit. This means:

(1) access direct from the deck via a vertical ladder and small platform fitted approximately 2 m below the deck in each bay; or
(2) access to deck from a longitudinal permanent platform having ladders to deck in each end of the tank. The platform shall, for the full length of the tank, be arranged in level with, or above, the maximum water level needed for rafting of under deck structure. For this purpose, the ullage corresponding to the maximum water level is to be assumed not more than 3 m from the deck plate measured at the midspan of deck transverses and in the middle length of the tank. (See Figure below). A permanent means of access from the longitudinal permanent platform to the water level indicated above is to be fitted in each bay (e.g., permanent rungs on one of the deck webs inboard of the longitudinal permanent platform).

104. Ship structure access manual

1. In application of **104. 1.** of the Rules, the details are as follows.

Access manual should address spaces listed in paragraph 3 of SOLAS II-1/3-6.

As a minimum the English version should be provided

The ship structure access manual is to contain at least the following two parts:

Part 1: Plans, instructions and inventory required by paragraphs 4.1.1 to 4.1.7 of SOLAS II-1/3-6. This part is to be approved by the Administration or the organization recognised by the Administration

Part 2 : Form of record of inspections and maintenance, and change of inventory of portable equipment due to additions or replacement after construction. This part is be approved for its form only at new building.

The following matters are to be addressed in the ship structure access manual:

(1) The access manual should clearly cover scope as specified in the regulations for use by crews, surveyors and port state control officers.
(2) Approval / re-approval procedure for the manual, i.e. any changes of the permanent, portable, movable or alternative means of access within the scope of the regulation and the Technical provisions are subject to review and approval by the Administration or by the organization recognised by the Administration.
(3) Verification of MA is to be part of safety construction survey for continued effectiveness of the MA in that space which is subject to the statutory survey.
(4) Inspection of MA by the crew and/or a competent inspector of the company as a part of regular inspection and maintenance.
(5) Actions to be taken if MA is found unsafe to use.
(6) In case of use of portable equipment plans showing the means of access within each space indicating from where and how each area in the space can be inspected;

2. In application of **104. 2.** of the Rules, the details are as follows.

(1) Critical structural areas are to be identified by advanced calculation techniques for structural

strength and fatigue performance, if available, and feed back from the service history and design development of similar or sister ships.

(2) Reference is to be made to the following publications for critical structural areas, where applicable:
- Oil tankers: Guidance Manual for Tanker Structures by TSCF;
- Bulk carriers: Bulk Carriers Guidelines for Surveys, Assessment and Repair of Hull Structure by IACS;
- Oil tankers and bulk carriers: resolution A.744 (18), as amended.

105. General technical specifications

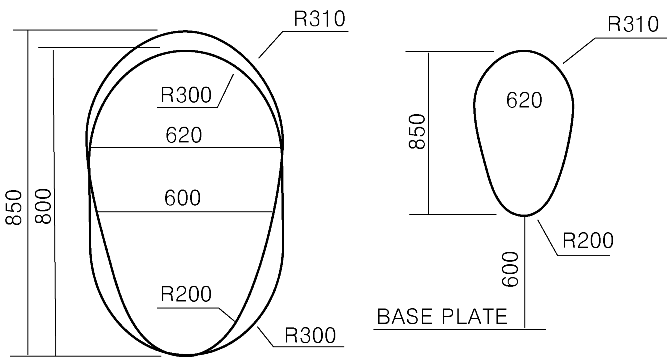
1. In application of **105. 1.** of the Rules, the details are as follows.

The minimum clear opening of 600 mm × 600 mm may have corner radii up to 100 mm maximum. The clear opening is specified in MSC/Circ.686 to keep the opening fit for passage of personnel wearing a breathing apparatus. In such a case where as a consequence of structural analysis of a given design the stress is to be reduced around the opening, it is considered appropriate to take measures to reduce the stress such as making the opening larger with increased radii, e.g. 600 mm × 800 mm with 300 mm radii, in which a clear opening of 600 mm × 600 mm with corner radii up to 100 mm maximum fits.

2. In application of **105. 2.** of the Rules, the details are as follows.

(1) The minimum clear opening of not less than 600 mm × 800 mm may also include an opening with corner radii of 300 mm. An opening of 600 mm in height × 800 mm in width may be accepted as access openings in vertical structures where it is not desirable to make large opening in the structural strength aspects, i.e. girders and floors in double bottom tanks.

(2) Subject to verification of easy evacuation of injured person on a stretcher the vertical opening 850 mm × 620 mm with wider upper half than 600 mm, while the lower half may be less than 600 mm with the overall height not less than 850 mm is considered acceptable alternative to the traditional opening of 600 mm × 800 mm with corner radii of 300 mm.



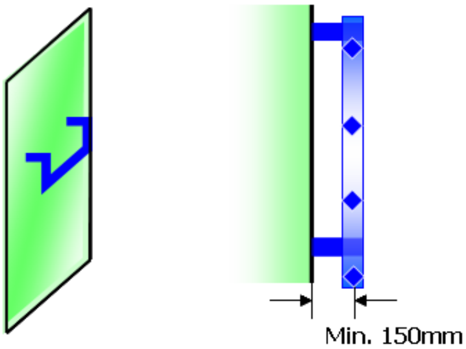
(3) If a vertical opening is at a height of more than 600 mm steps and handgrips are to be provided. In such arrangements it should be demonstrated that an injured person can be easily evacuated.

Section 2 Technical Provisions for Means of Access for Inspections

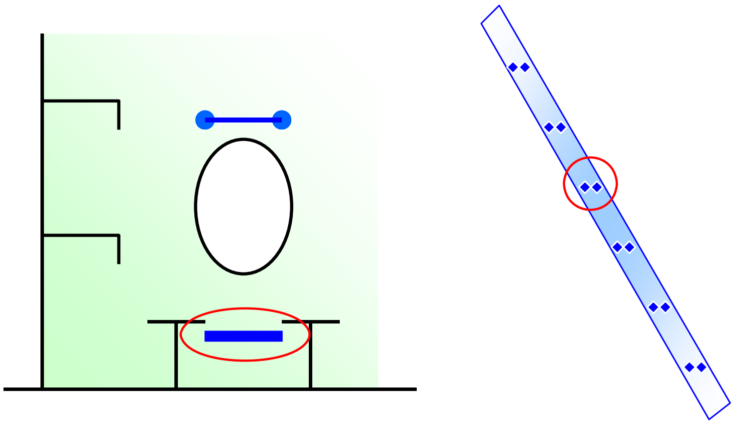
201. Definitions

1. In application of **201. 1.** of the Rules, the details are as follows.

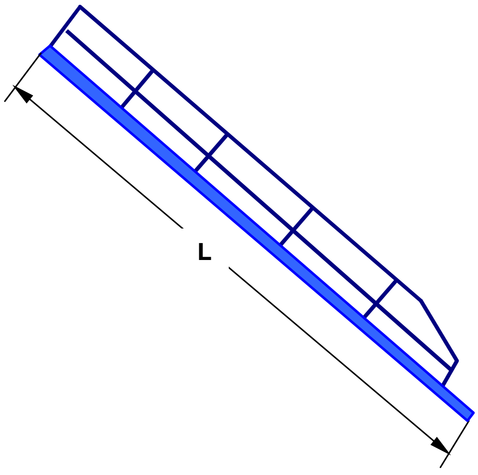
(1) rung



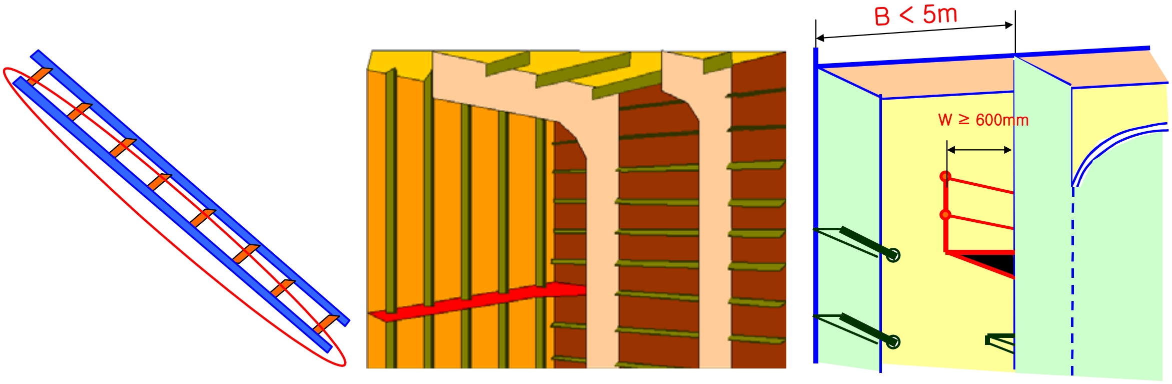
(2) tread



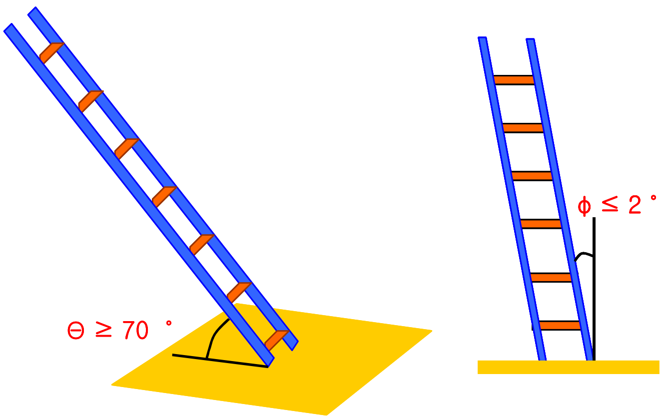
(3) flight of an inclined ladder



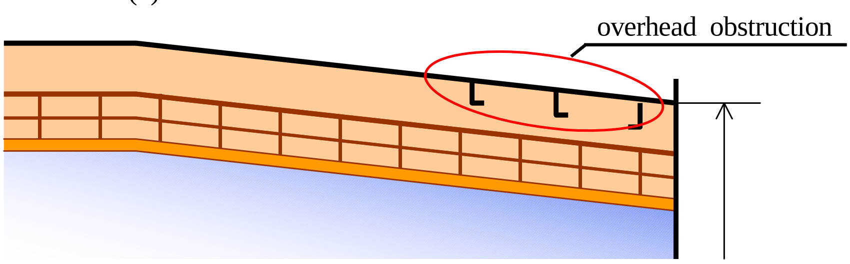
(4) stringer



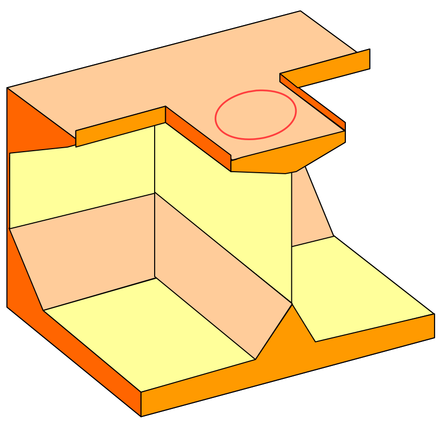
(5) vertical ladder



(6) overhead obstruction & (7) distance below deck head



(8) cross deck



202. Technical provisions

1. In application of **202. 1.** of the Rules, the details are as follows.

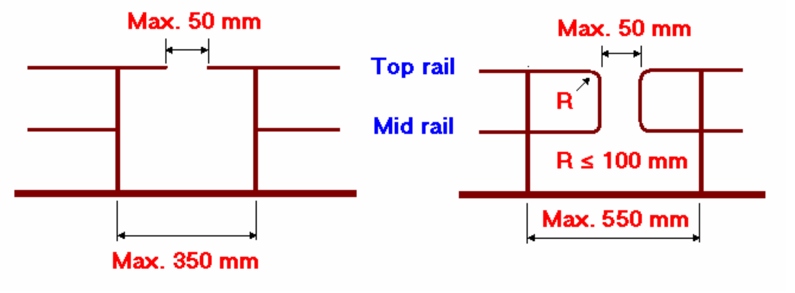
The permanent means of access to a space can be credited for the permanent means of access for inspection.

2. In application of **202. 3.** of the Rules, the details are as follows.

(1) Slopping structures are structures that are sloped by 5 or more degrees from horizontal plane when a ship is in upright position at even-keel.

(2) Guard rails are to be fitted on the open side. For stand alone passageways guard rails are to be fitted on both sides of these structures.

(3) Discontinuous top handrails are allowed, provided the gap does not exceed 50 mm.
The same maximum gap is to be considered between the top handrail and other structural members (i.e. bulkhead, web frame, etc.).
The maximum distance between the adjacent stanchions across the handrail gaps is to be 350 mm where the top and mid handrails are not connected together and 550 mm when they are connected together.
The maximum distance between the stanchion and other structural members is not to exceed 200 mm where the top and mid handrails are not connected together and 300 mm when they are connected together.
When the top and mid handrails are connected by a bent rail, the outside radius of the bent part is not to exceed 100 mm (see Figure below).

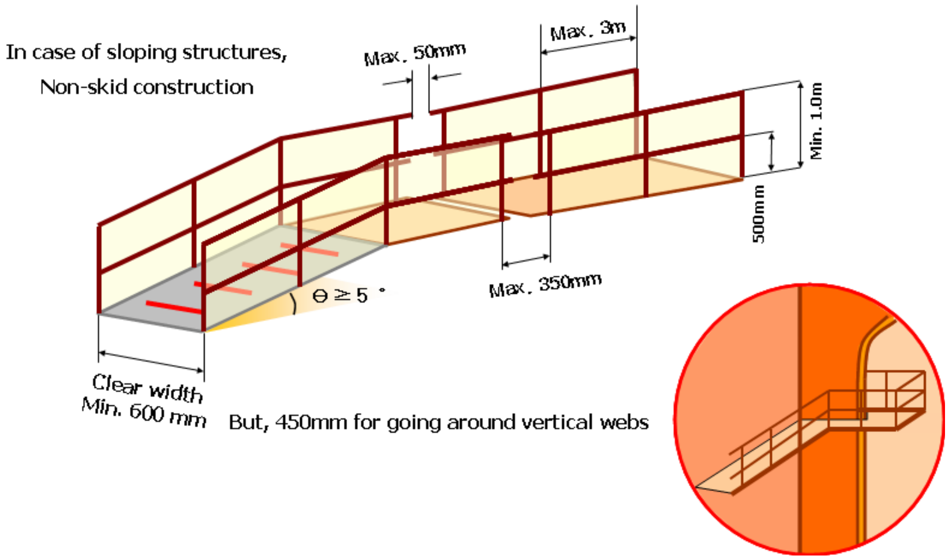


(4) Non-skid construction is such that the surface on which personnel walks provides sufficient friction to the sole of boots even the surface is wet and covered with thin sediment.

(5) "Substantial construction" is taken to refer to the as designed strength as well as the residual strength during the service life of the vessel. Durability of passageways together with guard rails should be ensured by the initial corrosion protection and inspection and maintenance during services.

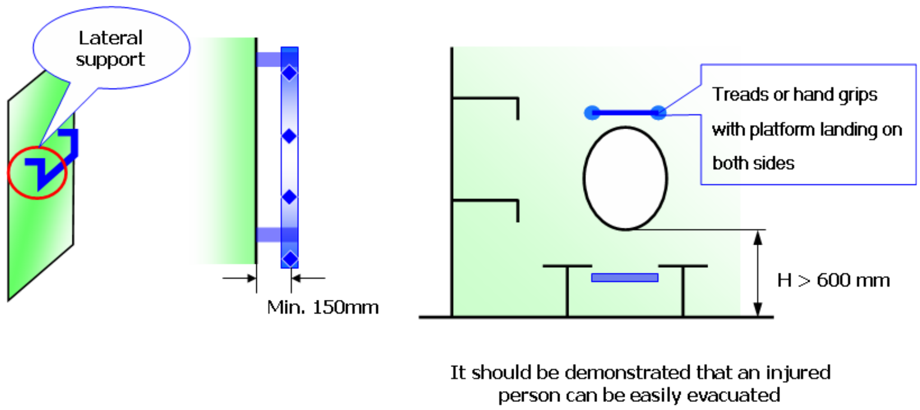
(6) For guard rails, use of alternative materials such as GRP should be subject to compatibility with the liquid carried in the tank. Non-fire resistant materials should not be used for means of access to a space with a view to securing an escape route at a high temperature.

(7) Requirements for resting platforms placed between ladders are equivalent to those applicable to elevated passageways.



3. In application of **202. 4.** of the Rules, the details are as follows.

Where the vertical manhole is at a height of more than 600 mm above the walking level, it should be demonstrated that an injured person can be easily evacuated.



4. In application of **202. 5.** of the Rules, the details are as follows.

(1) MA for access to ballast tanks, cargo tanks and spaces other than FPT:
For oil tankers:
(A) Tanks and subdivisions of tanks having a length of 35 m or more with two access hatchways:
(a) First access hatchway: Inclined ladder or ladders are to be used.
(b) Second access hatchway:
(i) A vertical ladder may be used. In such a case where the vertical distance is more than 6 m, vertical ladders should comprise one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. The uppermost section of the vertical ladder, measured clear of the overhead obstructions in way of the tank entrance, should not be less than 2.5 m but not exceed 3.0 m and should comprise a ladder linking platform which should be displaced to one side of a vertical ladder. However, the vertical distance of the upper most section of the vertical ladder may be reduced to 1.6 m, measured clear of the overhead obstructions in way of the tank entrance, if the ladder lands on a longitudinal or athwartship permanent means of access fitted within that range or
(ii) Where an inclined ladder or combination of ladders is used for access to the space, the uppermost section of the ladder, measured clear of the overhead obstructions in way of the tank entrance, should be vertical for not less than 2.5 m but not exceed

3.0 m and should comprise a landing platform continuing with an inclined ladder. However, the vertical distance of the upper most section of the vertical ladder may be reduced to 1.6 m, measured clear of the overhead obstructions in way of the tank entrance, if the ladder lands on a longitudinal or athwartship permanent means of access fitted within that range. The flights of the inclined ladders are normally to be not more than 6 m in vertical height. The lowermost section of the ladders may be vertical for the vertical distance not exceeding 2.5 m.

(B) Tanks less than 35 m in length and served by one access hatchway an inclined ladder or combination of ladders are to be used to the space as specified in (1) (ii) above.

(C) In double hull spaces of less than 2.5 m width the access to the space may be by means of vertical ladders that comprises one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. The uppermost section of the vertical ladder, measured clear of the overhead obstructions in way of the tank entrance, should not be less than 2.5 m but not exceed 3.0 m and should comprise a ladder linking platform which should be displaced to one side of a vertical ladder. However, the vertical distance of the upper most section of the vertical ladder may be reduced to 1.6 m, measured clear of the overhead obstructions in way of the tank entrance, if the ladder lands on a longitudinal or athwartship permanent means of access fitted within that range. Adjacent sections of the ladder should be laterally offset from each other by at least the width of the ladder. (Paragraph 20 of MSC/Circ.686)

(D) Access from deck to a double bottom space may be by means of vertical ladders through a trunk. The vertical distance from deck to a resting platform, between resting platforms or a resting platform and the tank bottom is not be more than 6 m unless otherwise approved by the Administration.

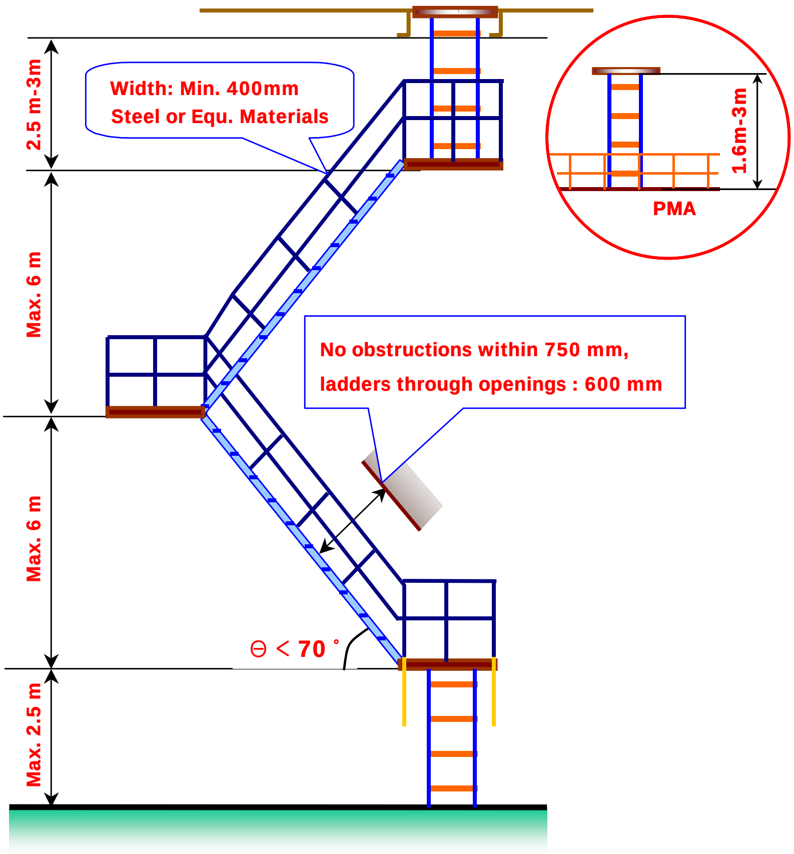
(2) MA for inspection of the vertical structure of oil tankers:

Vertical ladders provided for means of access to the space may be used for access for inspection of the vertical structure.

Unless stated otherwise in Table 1 of TP, vertical ladders that are fitted on vertical structures for inspection should comprise one or more ladder linking platforms spaced not more than 6 m apart vertically and displace to one side of the ladder. Adjacent sections of ladder should be laterally offset from each other by at least the width of the ladder. (Paragraph 20 of MSC/Circ.686)

(3) Obstruction distances

The minimum distance between the inclined ladder face and obstructions, i.e. 750 mm and, in way of openings, 600 mm specified in **202. 5.** of the Rules is to be measured perpendicular to the face of the ladder.



5. In application of **202. 6.** of the Rules, the details are as follows.

(1) Vertical height of handrails is not to be less than 890 mm from the center of the step and two course handrails are to be provided.

(2) The requirement of two square bars for treads specified in TP 3.6 is based upon the specification of construction of ladders in paragraph 3(e) of Annex 1 to resolution A.272(VIII), which addresses inclined ladders. TP.3.4 allows for single rungs fitted to vertical surfaces, which is considered for a safe grip. For vertical ladders, when steel is used, the rungs should be formed of single square bars of not less than 22 mm by 22 mm for the sake of safe grip.

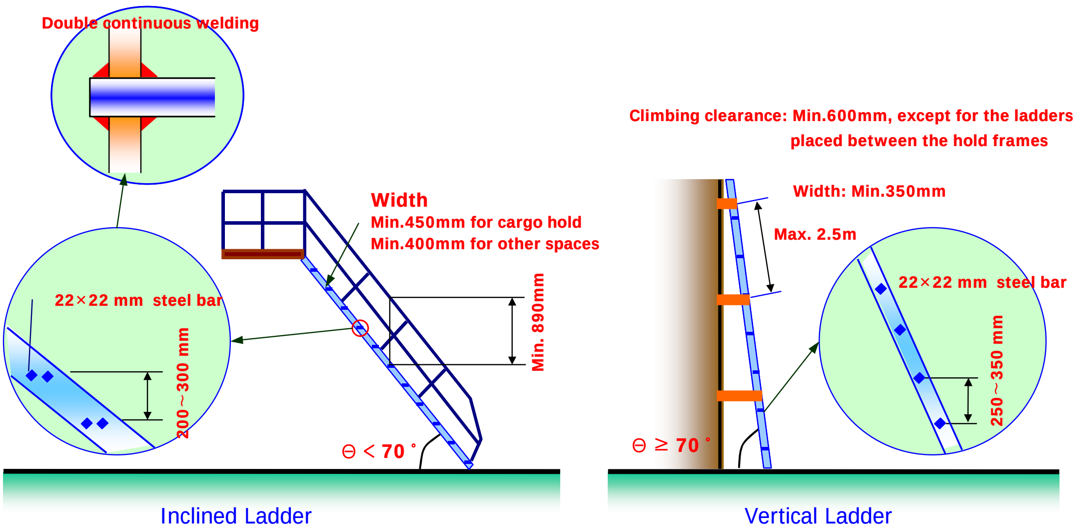
(3) The width of inclined ladders for access to a cargo hold is to be at least 450 mm to comply Australian AMSA Marine Orders Part 32, Appendix 17.

(4) The width of inclined ladders other than an access to a cargo hold is to be not less than 400 mm.

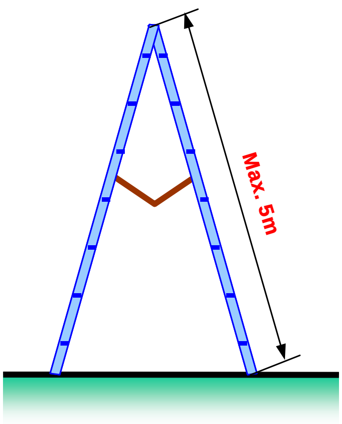
(5) The minimum width of vertical ladders is to be 350 mm and the vertical distance between the rungs is to be equal and is to be between 250 mm and 350 mm.

(6) A minimum climbing clearance in width is to be 600 mm other than the ladders placed between the hold frames.

(7) The vertical ladders should be secured at intervals not exceeding 2.5 m apart to prevent vibration.



6. In application of **202. 8.** of the Rules, the details are as follows.

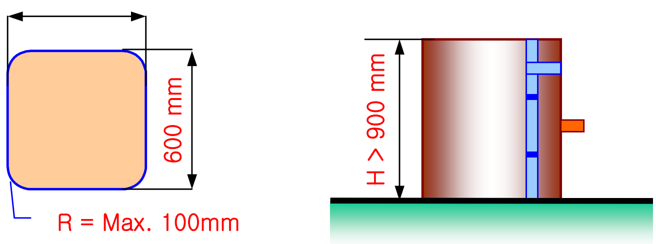


7. In application of **202. 9.** of the Rules, the details are as follows.

A mechanical device such as hooks for securing at the upper end of a ladder is considered an appropriate securing device if a movement fore/aft and sideways can be prevented at the upper end of the ladder.

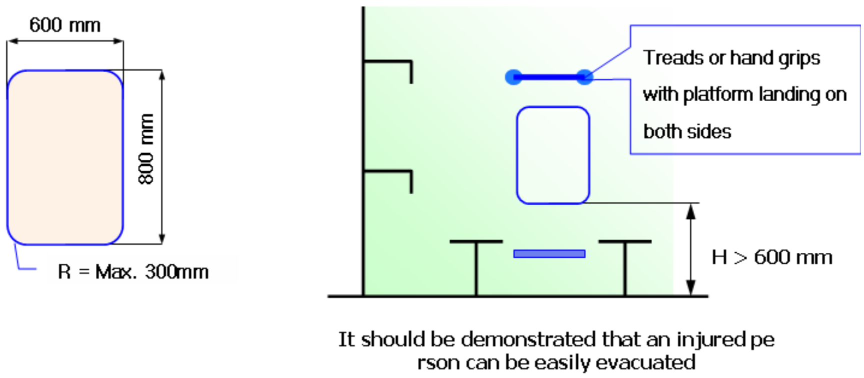
8. In application of **202. 10.** of the Rules, the details are as follows.

See interpretation for paragraphs 5.1 of the regulation



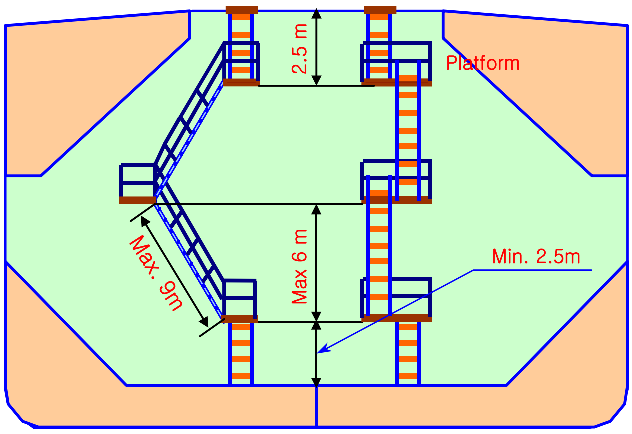
9. In application of **202. 11.** of the Rules, the details are as follows.

See interpretation for paragraphs 5.2 of the regulation

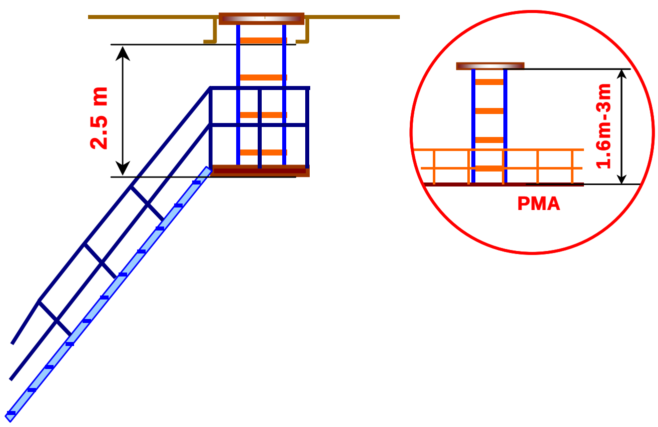


10. In application of **202. 13.** of the Rules, the details are as follows.

Either a vertical or an inclined ladder or a combination of them may be used for access to a cargo hold where the vertical distance is 6 m or less from the deck to the bottom of the cargo hold.



11. In application of **202. 14.** of the Rules, the details are as follows.



203. Corrosion protection

In application of **203.** of the Rules, the details are as follows.

1. Permanent means of access in dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers

(1) Permanent means of access arrangements that are integral to the ship structure shall be coated in accordance with the Performance standard for protective coatings for dedicated seawater ballast tanks of all types of ships and double-side skin spaces of bulk carriers (PSPC) (resolution MSC.215(82)).

(2) Guidelines for PMAs that are not part of the structural strength elements

(A) Hot dip galvanizing should be employed as the primary means for corrosion protection for the ladders, rails, walkways, gratings, stanchions, etc. Hot dip galvanizing and repairs of damages should be performed in accordance with KS D ISO 1461

(B) The galvanized items should be subsequently coated in accordance with KS M ISO 12944-5 or the coating manufacturer's recommendation.

(C) Where protective coating is applied as the sole means of corrosion protection for these PMAs, the standard in resolution MSC.215(82) should be applied to the extent possible. In such cases, the protective coating should at least comply with the requirements of the PSPC for the job specification, coating system (epoxy-based system) and total NDFT (320 µm).

2. Permanent means of access in void spaces

(1) Permanent means of access arrangements in void spaces that are integral to the ship structure should be coated in accordance with the Performance standard for protective coatings for void spaces (resolution MSC.244(83)).

(2) Guidelines for PMAs that are not part of the structural strength elements

(A) Hot dip galvanizing should be employed as the primary means for corrosion protection for these PMAs. The galvanized items should be subsequently coated according to the coating manufacturer's recommendation.

(B) Where protective coating is applied as the sole means of corrosion protection for these items, the Performance standard for protective coatings for void spaces (resolution MSC.244(83)), should be applied to the extent possible. In such case, the protective coating should at least comply with the requirements for the coating system (epoxy-based system) and total NDFT (200 µm) of that standard. ⚓

Annex 4-1
Cone Couplings of Rudder Stocks and Rudder Main Pieces

1. When rudder stocks and rudder main pieces consist with cone couplings without key (cone couplings having hydraulic devices which is consist with hydraulic nuts and oil infusion for assemble and disassemble of coupling), required push-up force and push-up length is to be standard base as obtained from the following formula.

Push-up force (F) : $F = \frac{2T_R f_{s1}}{\mu_2 d_m}\left(\mu_1 + \frac{1}{2k}\right)$ (kN)

Push-up length (l) : $l = 4k\left(\frac{T_R f_{s1} \times 10^3}{\pi E \mu_2 d_m l (1-c^2)} + R_t\right)$ (mm)

Permissible maximum push-up length (l_a) : $l_a = 2k\left(\frac{d_m \sigma_y}{E\sqrt{(3+c^4)} f_{s2}} + 2R_f\right)$ (mm)

d_m = mean diameter in corn part of rudder stock(mm)

d_c = outside diameter of gudgeon in the mid-part of taper in cone part(mm)

c = $\frac{d_m}{d_c}$

μ_1 = 0.02, the fabrication factor for the push-up

μ_2 = 0.15, the factor for slip

R_t = 0.01 mm, mean toughness of contact surface to outside of rudder stock and inside of gudgeons in the cone part.

k = a reciprocal number of taper(12～20) for the diameter of the cone part in rudder stock.

E = young's modulus of material used in gudgeons and rudder stocks. For steel, 2.06×10^5 (N/mm^2)

σ_y = yield stress of the material used in gudgeons(N/mm^2)

f_{s1} = not less than 3.0, The safety factor for slip

f_{s2} = not less than 1.25, The safety factor for the strength of gudgeons. However, special consideration is to be given to the coupling which has a large bending moment like as Type C rudder.

l = length of taper at the cone part(mm)

T_R = torque in the cone part of rudder stock(N・m)

2. When rudder stocks and rudder main pieces consist with cone couplings having sludging nuts and key (cone couplings without hydraulic devices), push-up force and push-up length may be applied to the formula described in above **1.** However in this case μ_1 and f_{s1} is 0.14 and 1.5 ⚓

Annex 4-2
Means of Access for Ballast and Cargo Tanks of Oil Tankers

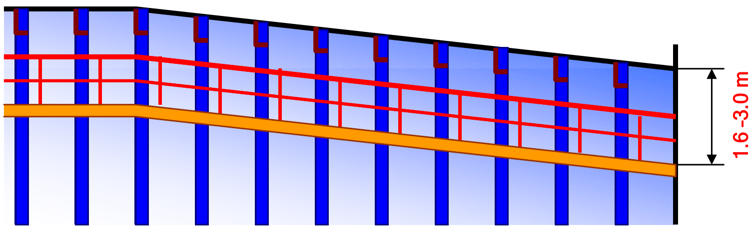
In application of **Ch11, Table 4.11.1** of the Rules, the details are as follows.

1. Water ballast tanks, except those specified in **2.**, and cargo oil tanks

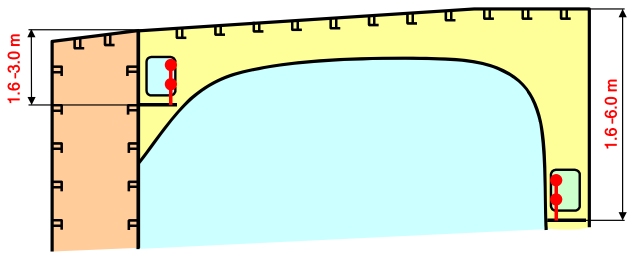
1.1

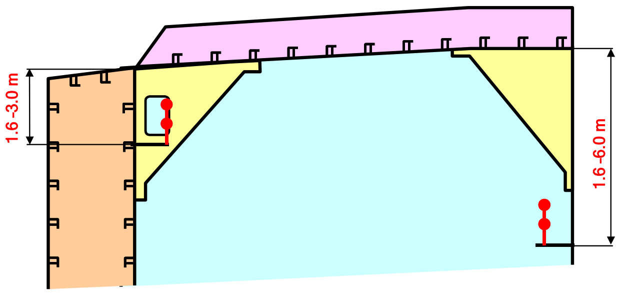
(1) Sub-paragraphs .1, .2 and .3 define access to underdeck structure, access to the uppermost sections of transverse webs and connection between these structures.
(2) Sub-paragraphs .4, .5 and .6 define access to vertical structures only and are linked to the presence of transverse webs on longitudinal bulkheads.
(3) If there are no underdeck structures (deck longitudinals and deck transverses) but there are vertical structures in the cargo tank supporting tranverse and longitudinal bulkheads, access in accordance with sub-paragraphs from .1 through to .6 is to be provided for inspection of the upper parts of vertical structure on transverse and longitudinal bulkheads.
(4) If there is no structure in the cargo tank, section 1.1 of Table 1 is not applicable.
(5) Section 1 of Table 1 is also to be applied to void spaces in cargo area, comparable in volume to spaces covered by the regulation II-1/3-6, except those spaces covered by Section 2.
(6) The vertical distance below the overhead structure is to be measured from the underside of the main deck plating to the top of the platform of the means of access at a given location.
(7) The height of the tank is to be measured at each tank. For a tank the height of which varies at different bays item 1.1 is to be applied to such bays of a tank that have height 6 m and over.

1.1.1



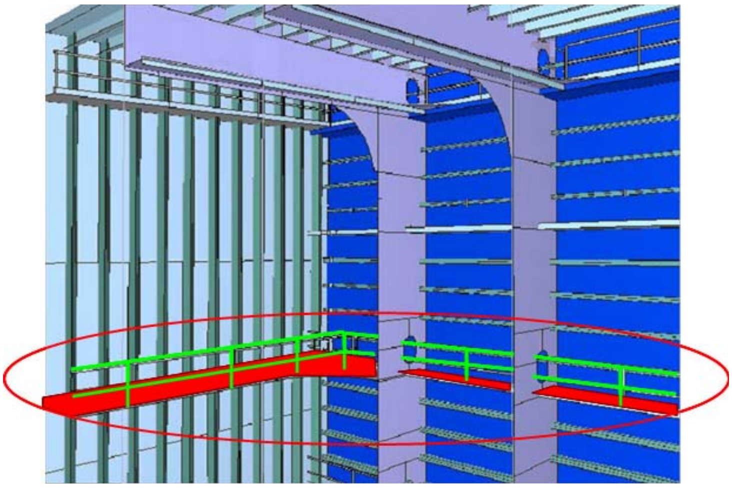
1.1.2 There is need to provide continuous longitudinal permanent means of access when the deck longitudinals and deck transverses are fitted on deck but supporting brackets are fitted under the deck.



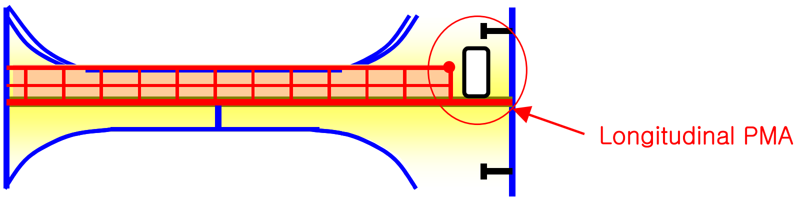


1.1.3 Means of access to tanks may be used for access to the permanent means of access for inspection.

1.1.4 The permanent fittings required to serve alternative means of access such as wire lift platform, that are to be used by crew and surveyors for inspection should provide at least an equal level of safety as the permanent means of access stated by the same paragraph. These means of access shall be carried on board the ship and be readily available for use without filling of water in the tank. Therefore, rafting is not acceptable under this provision. Alternative means of access are to be part of Access Manual which is to be approved on behalf of the flag State



1.1.5



2. Water ballast wing tanks of less than 5 m width forming double side spaces and their bilge hopper sections

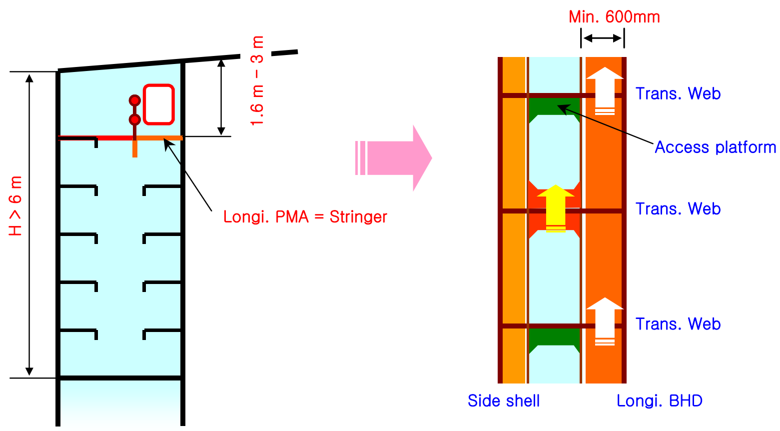
2.1 Section 2 of Table 1 is also to be applied to wing tanks designed as void spaces. Paragraph 2.1.1 represents requirements for access to underdeck structures, while paragraph 2.1.2 is a requirement for access for survey and inspection of vertical structures on longitudinal bulkheads (transverse webs).

2.1.1

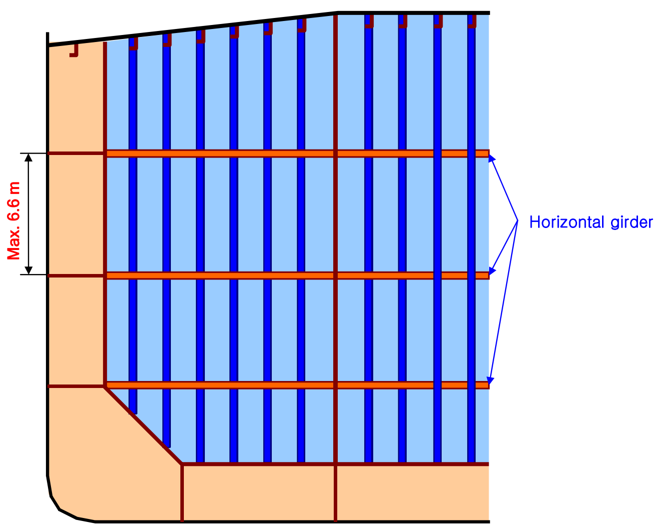
(1) For a tank the vertical distance between horizontal upper stringer and deck head of which varies at different sections item 2.1.1 is to be applied to such sections that falls under the criteria.

(2) The continuous permanent means of access may be a wide longitudinal, which provides access to critical details on the opposite side by means of platforms as necessary on web frames. In case the vertical opening of the web frame is located in way of the open part between the wide longitudinal and the longitudinal on the opposite side, platforms shall be provided on both sides of the web frames to allow safe passage through the web frame.

(3) Where two access hatches are required by SOLAS regulation II-1/3-6.3.2, access ladders at each end of the tank are to lead to the deck.



2.1.2 The continuous permanent means of access may be a wide longitudinal, which provides access to critical details on the opposite side by means of platforms as necessary on web frames. In case the vertical opening of the web is located in way of the open part between the wide longitudinal and the longitudinal on the opposite side, platforms shall be provided on both sides of the web to allow safe passage through the web. A "reasonable deviation" as noted in TP/1.4, of not more than 10% may be applied where the permanent means of access is integral with the structure itself.

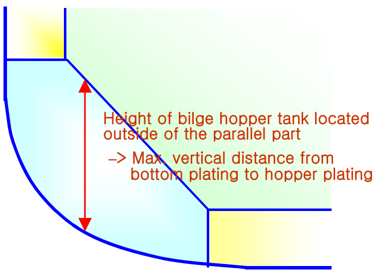


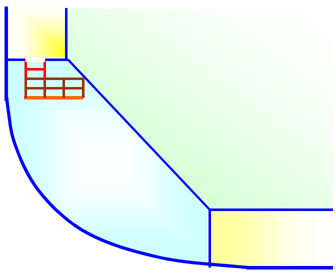
2.2

(1) Permanent means of access between the longitudinal continuous permanent means of access and the bottom of the space is to be provided.

(2) The height of a bilge hopper tank located outside of the parallel part of vessel is to be taken as the maximum of the clear vertical distance measured from the bottom plating to the hopper plating of the tank.

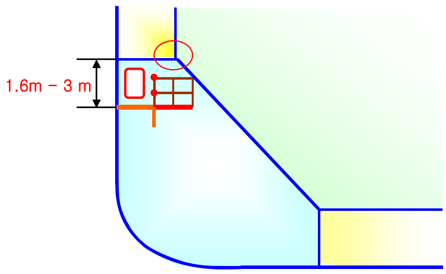
(3) The foremost and aftmost bilge hopper ballast tanks with raised bottom, of which the height is 6 m and over, a combination of transverse and vertical MA for access to the upper knuckle point for each transverse web is to be accepted in place of the longitudinal permanent means of access.

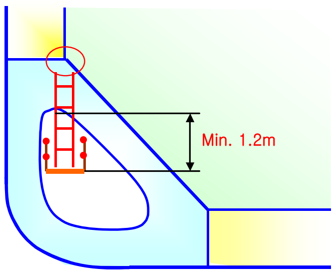




2.2.1

2.2.2





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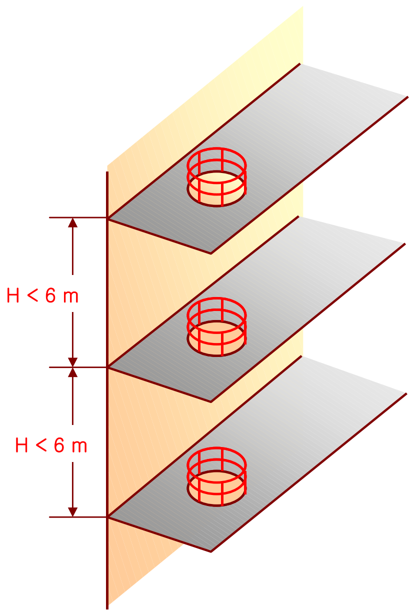


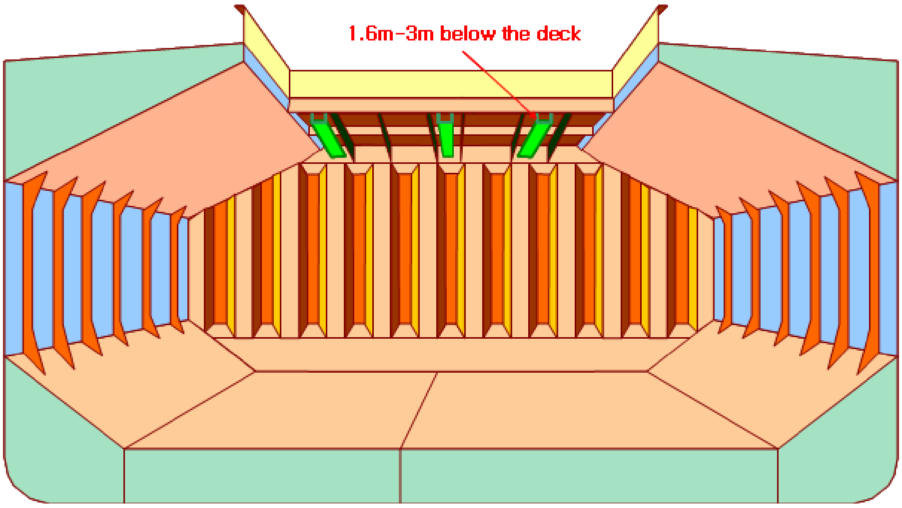
Annex 4-3 Means of Access for Bulk Carriers

In application of **Ch11, Table 4.11.2** of the Rules, the details are as follows.

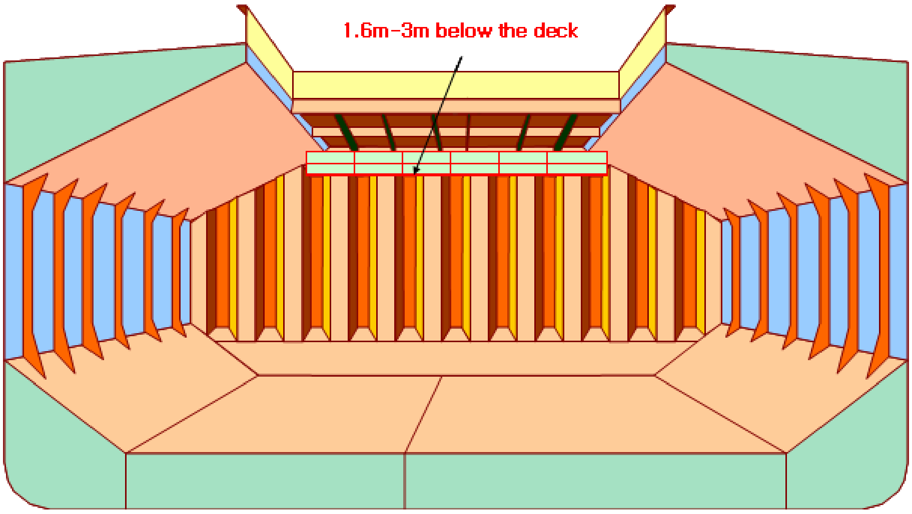
1. Cargo holds

1.1

(1) Means of access shall be provided to the crossdeck structures of the foremost and aftermost part of the each cargo hold.
(2) Interconnected means of access under the cross deck for access to three locations at both sides and in the vicinity of the centerline is acceptable as the three means of access.
(3) Permanent means of access fitted at three separate locations accessible independently, one at each side and one in the vicinity of the centerline is acceptable.
(4) Special attention is to be paid to the structural strength where any access opening is provided in the main deck or cross deck.
(5) The requirements for bulk carrier cross deck structure is also considered applicable to ore carriers.

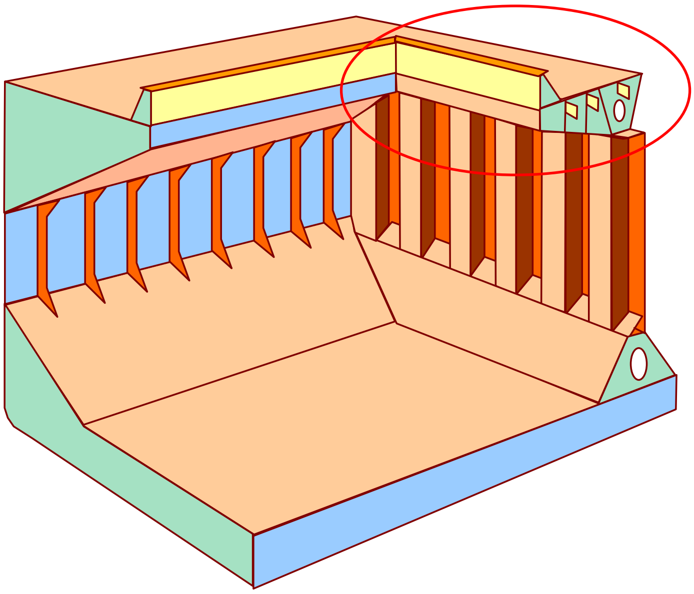


1.2



1.3 Particular attention is to be paid to preserve the structural strength in way of access opening provided in the main deck or cross deck.

1.4 "Full upper stools" are understood to be stools with a full extension between top side tanks and between hatch end beams.

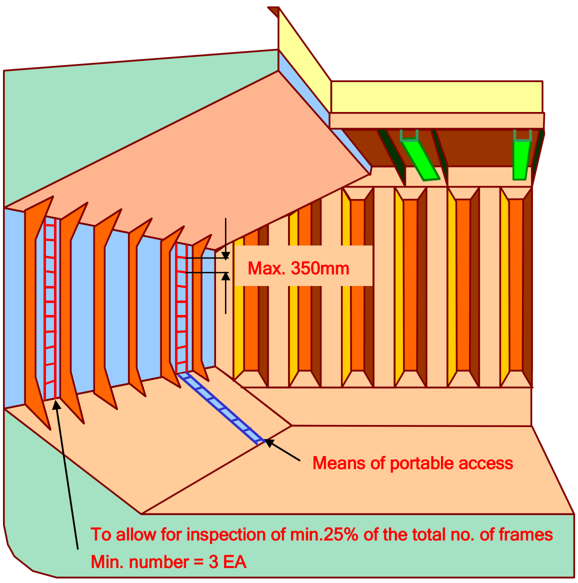


1.5

(1) The movable means of access to the underdeck structure of cross deck need not necessarily be carried on board the vessel. It is sufficient if it is made available when needed.
(2) The requirements for bulk carrier cross deck structure is also considered applicable to ore carriers.

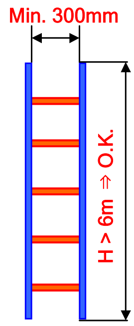
1.6

(1) The maximum vertical distance of the rungs of vertical ladders for access to hold frames is to be 350 mm.
(2) If safety harness is to be used, means should be provided for connecting the safety harness in suitable places in a practical way.



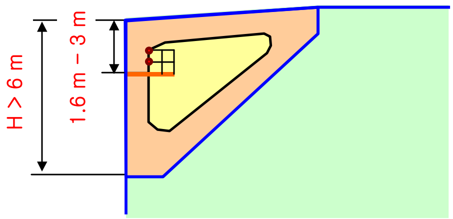
1.7 Portable, movable or alternative means of access also is to be applied to corrugated bulkheads.

1.10

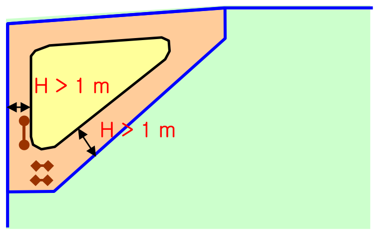


2. Ballast tanks

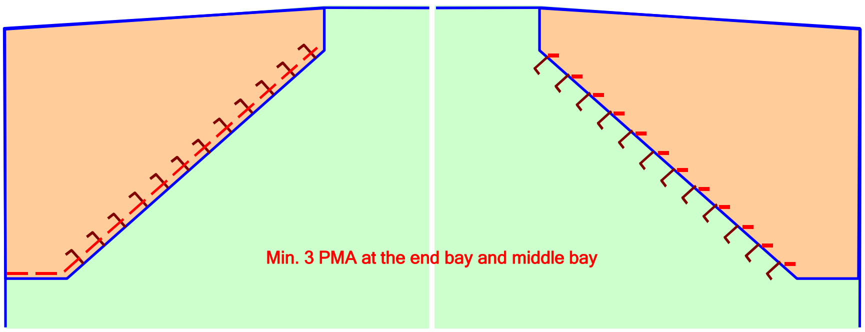
2.1



2.2



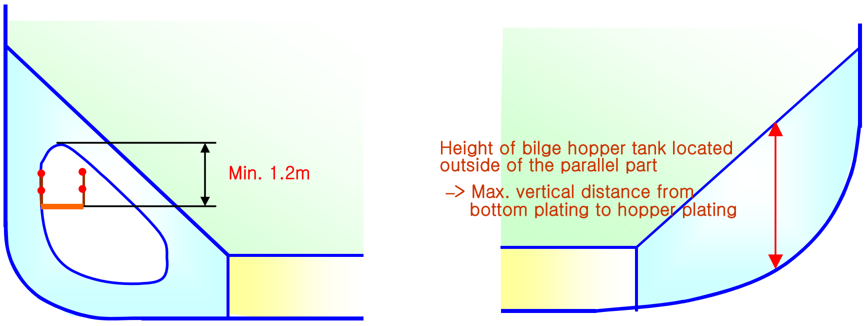
2.3 If the longitudinal structures on the sloping plate are fitted outside of the tank a means of access is to be provided.



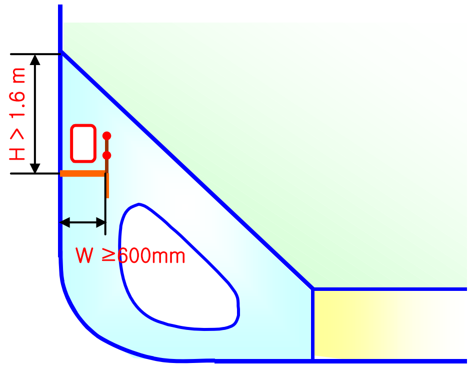
2.5

(1) The height of a bilge hopper tank located outside of the parallel part of vessel is to be taken as the maximum of the clear vertical height measured from the bottom plating to the hopper plating of the tank.

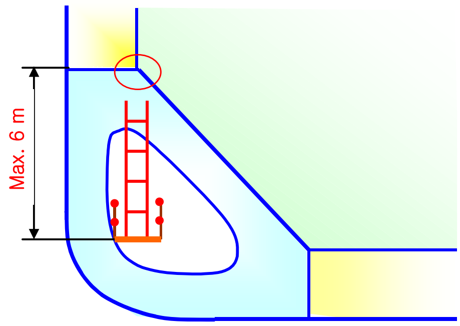
(2) It should be demonstrated that portable means for inspection can deployed and made readily available in the areas where needed.



2.5.2 A wide longitudinal frame of at least 600 mm clear width may be used for the purpose of the longitudinal continuous permanent means of access.



2.5.3



2.6 The height of web frame rings should be measured in way of side shell and tank base. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 4 HULL EQUIPMENT

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2011

Rules for the Classification of Steel Ships

Part 5 Machinery Installations

Rules

2011

Guidance Relating to the Rules for the Classification of Steel ships

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Guidance

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2011

Rules for the Classification of Steel Ships

Part 5

Machinery Installations

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KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 5 "MACHINERY INSTALLATIONS"

1. Unless expressly specified otherwise, the requirements in the rules apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date 1 July 2011 (based on the contract date for construction)

CHAPTER 1 GENERAL

Section 2 Plans and Documents
- 202. 1 has been amended.

Section 3 Tests and Inspections
- 305. has been amended.

CHAPTER 2 MAIN AND AUXILIARY ENGINES

Section 2 Internal Combustion Engines
- 203. 9 has been amended.

CHAPTER 3 PROPULSION SHAFTING AND POWER TRANSMISSIONS

Section 4 Power Transmission Systems
- 401. 5 has been amended.

CHAPTER 5 BOILERS AND PRESSURE VESSELS

Section 3 Pressure vessels
- 301. 3 has been amended.

CHAPTER 6 AUXILIARIES AND PIPING ARRANGEMENT

Section 2 Air Pipes, Overflow Pipes and Sounding Devices
- 203. 4 (3) has been amended.

Section 4 Bilge and Ballast System
- 401. 2 (3) has been amended.

Section 9 Fuel Oil System
- 901. 7. (3) (B) has been amended.

CHAPTER 7 STEERING GEARS

Section 1 General

- 102. 1 (1), (2) and (4) have been amended.
- 103. 1 (1) (B) has been amended.

Section 4 Materials, Constructions and Strength

- 401. has been amended.
- 407. 1 has been amended.
- 408. Steering chains, rods, blocks, etc. has been deleted.
- Article No. 409 has been modified to 408 and pars.1 and 3 have been amended.
- Article No. 410 has been modified to 409.

Section 6 Additional Requirements Concerning Tankers of 10,000 Gross Tonnage and Upwards and Other Ships of 70,000 Gross Tonnage and Upwards

- 601. 2 (1) has been amended.

CHAPTER 8 WINDLASSES AND MOORING WINCHES

Section 2 Windlasses

- 204. 1 and 2 have been amended.

CONTENTS

CHAPTER 1 GENERAL

Section 1 General

101. Application

1. The requirements of this Part apply to the machinery installations intended for the ships which have no special limitations for their service area and purpose. For machinery installations intended for the ships having any limitations for their service area or intended for the small ships, the requirements in this Part may be modified. Special consideration is to be given to the ships with any limitations for their purpose.

2. The machinery installations which do not comply with the requirements of this Part may be accepted, provided that they are considered acceptable by the Society.

3. For the strength and construction of the parts of machinery on which the requirements of the Rules cannot be applied, the manufacturer is to submit for approval the detailed methods of strength calculation and data to the Society and the reliability for the strength of the parts may be decided from the results of measuring strain or deformation of them by means of a proper loading method approved by the Society. For machinery of new design, the Society may request plans and design data of more detailed parts to be submitted in addition to those specified in the Rules.

4. Since the formulae for the strength of the parts of machinery in the Rules are based upon the consideration that there is no dangerous vibration in the installation within the range of operating speeds, the manufacturers of the machinery are required to pay special attention to this point and take responsibility in the application of these formulae.

5. For the purpose of determining the power of main and auxiliary internal combustion engines, the ambient reference conditions are to be such as given in **Table 5.1.1.** However, the engine manufacturers shall not be expected to provide simulated ambient reference conditions at a test bed.

6. The ship intended to be registered and classed as the ship strengthened for navigation in ice is to be in accordance with the relevant requirements of **Pt 3**, **Ch 20**, in addition to the requirements in this Part.

7. The ships for navigation in polar waters and the vessels for polar and ice breaking service are to comply with the relevant requirements in **Pt 3, Ch 21** and **Pt 3, Ch 22** respectively, in addition to the requirements in this part.

Table 5.1.1 Ambient Reference Conditions

Description	Ambient reference conditions
Total barometric pressure	0.1 MPa
Air temperature	45 °C
Relative humidity	60 %
Sea water temperature (charge air coolant-inlet)	32 °C

102. Definitions

1. The maximum continuous output of engine is the maximum output at which the engine can run safely and continuously in the running condition at full load draught, in the engine for propulsion (hereinafter referred to as "**main engine**"). In the engine excluding main engine (hereinafter referred to as "**auxiliary engine**"), the maximum continuous output of engine is the maximum output at which the engine can run safely and continuously in the intended condition.

2. Number of maximum continuous revolutions is the number of revolutions at the maximum continuous output.

3. Propeller shaft Kind 1 or Stern tube shaft Kind 1 is the shaft which is provided with effective measures against corrosion by sea water, or the shaft which is made of approved corrosion resistance material. The propeller shaft or stern tube shaft other than specified above is Kind 2.

4. Design pressure is a pressure used in the calculations made to determine the scantlings of each component and is the maximum permissible working pressure to the component. However, the design pressure is to be not less than the highest set pressure of any relief valve.

5. Essential auxiliaries are the auxiliary machinery for important use, and are those for propulsion of ships and for safety of lives and ships or those for facilities in relation to the purpose of ships.

6. Boiler is the plant which generates steam or hot water by means of flame, combustion gas or other hot gases, including the equipment subject to a boiler.

7. Main boiler means the boiler used in moving the propulsion steam engines.

8. Essential auxiliary boiler means the auxiliary boiler other than the main boiler, which is used in supplying steam need for operating generators, auxiliary machinery in relation to the propulsion of ships, safety of lives and ships or the purpose of ships.

9. Exhaust gas boiler is a boiler which generates steam or hot water solely by exhaust gas from internal combustion engine and has a steam space or a hot well and has an outlet of steam or hot water.

10. Exhaust gas economizer is the equipment without any steam space or hot well which generates steam or hot water solely by exhaust gas from internal combustion engine and supplies to other boiler.

11. Thermal oil installation is the arrangement in which thermal oil is heated and circulated for the purpose of heating cargo or fuel oil or for production of steam and hot water for auxiliary purpose.

12. Pressure vessel is a vessel which contains gas or liquid, intended for the pressure exceeding the atmospheric pressure at its top. It includes heat exchangers and does not contact with flame, combustion gas or hot gas.

13. Equipment subject to a boiler means the superheaters, reheaters and economizers (where a stop valve is fitted between them and the main body of the boiler) and the equivalent.

14. Attachment of boiler and pressure vessel means the following;

(1) Flanges, stand pipes and distance pieces attached directly to boilers, equipment subject to a boiler, and pressure vessels
(2) Valves attached directly to boilers, equipment subject to a boiler, and pressure vessels

15. Valve attached directly to boilers and pressure vessels is the valve attached to body of boilers or pressure vessels by stud bolts, flange, stand pipe or distance piece, and includes the screw down check valve specified in **Ch 5, 127. 1**.

16. Stand pipe means the following attached directly to body of boilers and pressure vessels;

(1) Pipe and nozzle
(2) Penetration piece consisting of flange and pipe attached directly to boilers and pressure vessels for the purpose of fitting the valve attached directly to body of boilers and pressure vessels.
(3) Rings for installation of manhole, mud holes and peep holes

17. Distance piece in boilers and pressure vessels is a piece used for keeping the distance between flange or stand pipe attached directly to boilers and pressure vessels, and valve attached directly to boilers and pressure vessels, or gauges.

18. Essential pressure vessel is a pressure vessel having relevance to main engines, essential auxiliary boilers, auxiliary machinery having relevance to propulsion, auxiliary machinery having relevance to safety of lives and ships, and auxiliary machinery having relevance to service of ships.

19. Nominal pressure of the boiler with superheater is the maximum steam pressure of superheater outlet designed by the manufacturer or the owner, and is used the standard for setting the safety valve of superheater.

20. Heating surface area of a boiler is the area calculated on the combustion gas side surface where one side is exposed to combustion gas and the other side to water, but the heating surface of superheater, reheater, economizer or exhaust gas economizer is excluded, unless specially specified.

21. Dead ship condition means a condition under which :

(1) the main propulsion plant, boilers and auxiliaries are not in operation due to the loss of the main source of electrical power, and
(2) in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed to be available. It is assumed that means are available to start the emergency generator at all times.

22. Piping system is a general term of pipes, valves and pipe fittings.

23. Flexible hose assembly is the short length of metallic or non-metallic hose normally with pre fabricated end fittings ready for installation.

24. Ship-side valve means the valve attached to bottom or side of ship in accordance with **Ch 6, 301. 1.**

103. Construction, materials and installation

1. The construction, installation, lubricating system and cooling system of machinery are to be such that they cause no hindrance to their proper operations under the condition as given in **Table 5.1.2.**

2. All components and systems of machinery are to be designed to ensure proper operation under the temperature conditions given in **Table 5.1.3.**

3. Means are to be provided to ensure that machinery installations can be brought into operation from the dead ship condition without external aid.

4. Materials intended for the main parts of machinery are to be of fine quality in accordance with the requirements of **Pt 2, Ch 1.** The process of manufacturing each part is to be in accordance with the best method based on the past experiences and results. The materials other than those prescribed in the Rules may, however, be used where sufficient data are submitted in connection with the design and are specially approved.

Table 5.1.2 Angle of inclination

Type of machinery installations	Angle of inclination (deg)(2)			
	Athwart-ships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery	15	22.5	5(4)	7.5
Safety equipment (emergency power installations, emergency fire pumps and their devices) Switch gear(1) (electrical and electronic appliances and remote control systems)	22.5(3)	22.5(3)	10	10

NOTES:
(1) Up to an angle of inclination of 45° no undesired switching operation or operational changes may occur.
(2) Athwartships and fore-and-aft inclinations may occur simultaneously.
(3) In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartships inclination up to a maximum of 30 degrees.
(4) Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as $500/L$ degrees. (L : Length of the ship as defined in **Part 3, Ch 1, 102.** of the Rules, m)

Table 5.1.3 Temperature conditions

Installed location		Temperature range(°C)
Air	In enclosed spaces	0~45(1)
	On machinery components, boilers in spaces subject to higher or lower temperature	According to specific local conditions
	On the open deck	-25~45(1)
Sea water	-	32(1)

NOTE:
(1) The Society may approve other temperatures in the case of ships intended for restricted service.

5. Astern power for main propulsion

(1) In order to maintain sufficient maneuverability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70 % of the ahead revolutions corresponding to the maximum continuous ahead power.
(2) For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern should not lead to the overload of propulsion machinery.
(3) The reversing characteristics of the propulsion plants are to be demonstrated and recorded during trials.
(4) Where steam turbines are used for main propulsion, they are to be capable of maintaining in free route astern at least 70 % of the ahead revolutions corresponding to the maximum continuous ahead power for a period of at least 15 minutes. The astern trial is to be limited to 30 minutes or in accordance with manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

6. The rotating, reciprocating and high temperature parts and electrically charged parts are to be arranged with suitable protections for the safety of watchmen, operators or men neighbouring to these parts. Nuts of important parts and moving parts are to be well secured by effective means to prevent from loosening.

7. All surfaces of machinery installations with high temperature above 220 °C e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers, turbo blowers, etc and which may be impinged as a result of leakage of flammable fluid, are to be effectively insulated with non-combustible material to prevent the ignition of combustible materials coming into contact with them. Where the insulation is oil absorbent or may permit the penetration of oil, the insulation are to be encased in steel sheathing or equivalent material.

104. Automatic control device

Automatic or remote control devices for propelling machinery, essential auxiliaries or cargo handling gears, and specifically, the facilities of unmanned operation of engines are to be in accordance with the requirements of **Pt 6, Ch 2.**

105. Anti-freezing devices

The machinery fitted in ships which may serve in cold districts are to be provided with equipment for prompt starting and adequate devices to prevent the fuel oil or lubricating oil from coagulation. Suction and discharge openings to sea are to be suitably protected from becoming blocked up with ice.

106. Communication between navigating bridge and machinery spaces

At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and direction of thrust of the propellers are normally controlled. One of these are to be an engine-room telegraph which provides visual indication of the orders and responses both in the machinery spaces and on the navigating bridge. Appropriate means of communication are to be provided from the navigating bridge and the engine-room to any other position from which the speed or direction of thrust of the propellers may be controlled.

107. Engineers′ alarm

An engineers' alarm is to be provided to be operated from the engine control room or at the manoeuvring platform as appropriate and is to be clearly audible in the engineers accommodation.

108. Ventilating systems in machinery spaces

Machinery spaces of *Category A* are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. And other machinery space is to be adequately ventilated appropriate for the purpose of that machinery space.

109. Protection against noise

Measures are to be taken to reduce machinery noise in machinery spaces to acceptable levels as determined by the Administration. If this noise can not be sufficiently reduced, the source of excessive noise is to be suitably insulated or isolated or a refuge from noise is to be provided if the space is required to be manned. Ear protectors are to be provided for personnel required to enter such spaces, if necessary.

Section 2 Plans and Documents

201. Plans and documents

1. Before the work is commenced, the shipyards or the manufacturers of machinery are to submit plans in triplicate and a copy of documents, specified in this Section, to the Society for approval. Where, however, the machinery is considered acceptable by the Society or is of the similar model already approved by the Society, the submission of plans and documents may be partially or wholly omitted according to the discretion of the Society. The plans intended for approval are to be contained such descriptions to be clearly stated the materials used, scantlings, arrangements, method of fixing and other matters in compliance with the requirements of the Rules. The Society, where considered necessary, may require further plans and documents other than those specified in this Section.

2. Where a licensee manufactures engines with the drawings and data of the engine licensor's which have been already approved by the Society, the licensee is to submit documents to the Society for each engine type, as follows;

(1) For drawings and data as per **Table 5.1.4**, the list including relevant drawing numbers and revision status from both licensor and licensee is to be submitted.
(2) Where licensee proposes design modification to components, relevant drawings and data are to be submitted. In case of significant modifications such as strength, safety and performance, a statement confirming the licensor's acceptance of the changes is also to be submitted.
(3) A complete set of drawings and data are to be provided for attending Surveyor's review at his request for test and inspection.

202. Plans and documents to be submitted by the shipyard

1. Plans for approval

(1) Machinery room arrangement.
(2) Installation of main engine, reduction gear, reversing gear and boiler.
(3) Shaft arrangement(including the structural details of strut)
(4) Various piping diagrams on board and in engine room of the ship.
(5) Details of fuel oil tanks not built in as the part of hull
(6) Calculation sheets for torsional vibration.(See **Ch 4, Sec 1**)

2. Documents

(1) Machinery part specification, and specification and instructions in connection with automation.
(2) List of particulars on main engine, boiler, shaft arrangement, main auxiliaries, etc. in engine room.
(3) Material specifications for main component parts.
(4) strength calculations for main component parts.
(5) Shafting alignment calculations.(where considered necessary by the Society)

203. Plans and documents to be submitted by the manufacturers of internal combustion engines

Table 5.1.4 Plans and documents of internal combustion engines

No.	A/R[(1)]	Plans and documents
1	R	Engine particulars (kind, type, maximum continuous output, maximum continuous revolution, firing order, maximum pressure in cylinders, mean effective indicated pressure, brake mean effective pressure, weight of reciprocating parts of each cylinder, weight and diameter of flywheel, weight and radius of balance weight as well as its position, and specifications of exhaust gas turbocharger, etc. are to be stated. They are to be submitted in accordance with the separated sheet of the Society as possible)
2	R	Engine transverse cross-section
3	R	Engine longitudinal section
4	R/A*	Bedplate and crankcase (Approval refers to welded design only. For cast design, plans are to be submitted for reference)[(2)]
5	R	Thrust bearing assembly[(3)]
6	R/A*	Thrust bearing bedplate (Approval refers to welded design only. For cast design, plans are to be submitted for reference)[(2)]
7	R/A*	Frame and column (Approval refers to welded design only. For cast design, plans are to be submitted for reference)[(2)]
8	R	Tie rod
9	R	Cylinder cover, assembly
10	R	Cylinder liner
11	A	Crankshaft, details (each cylinder No.)
12	A	Crankshaft, assembly (each cylinder No.)
13	A	Thrust shaft or intermediate shaft (if integral with engine)
14	A	Coupling bolts
15	R	Counter weights (if not integral with crankshaft)
16	R	Connecting rod
17	R	Connecting rod, assembly[(4)]
18	R	Crosshead, assembly[(4)]
19	R	Piston rod, assembly[(4)]
20	R	Piston, assembly
21	R	Camshaft drive, assembly
22	A	Material specifications of main parts with information on non-destructive material tests and pressure tests
23	A	Sectional assembly of exhaust gas turbocharger
24	R	Arrangement of foundation bolts (for main engine only)
25	A	Schematic layout or other equivalent documents of starting air system on the engine[(5)]
26	A	Schematic layout or other equivalent documents of fuel oil system on the engine[(5)]
27	A	Schematic layout or other equivalent documents of lubricating oil system on the engine[(5)]
28	A	Schematic layout or other equivalent documents of cooling water system on the engine[(5)]
29	A	Schematic diagram of engine control and safety system on the engine[(5)] (including plans for details and arrangements of oil mist detection and alarm arrangements of crankcase)
30	R	Shielding and insulation of exhaust pipes, assembly

Table 5.1.4 Plans and documents of internal combustion engines (continued)

No.	A/R(1)	Plans and documents
31	A	Shielding of high pressure fuel pipes, assembly(6)
32	A	Arrangement of crankcase explosion relief valve(7)
33	R	Operation and service manuals(8)
34	A	Schematic layout or other equivalent documents of hydraulic system (for valve lift) on the engine
35	A	Type test program and type test report
36	A	High pressure parts for fuel oil injection system(9)

(Notes)
1. Where a licensee manufactures engines with the drawings and data of the engine licensor's which have been already approved by the Society, plans and documents to be submitted are to be in accordance with **201. 2**.
2. (1) through (9) in this Table are subject to the following;
   (1) A : for approval, A* : for approval of materials and weld procedure specifications, R : for reference.
   (2) The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
   (3) If integral with engine and not integrated in the bedplate.
   (4) Only necessary if sufficient details are not shown on the transverse cross section and longitudinal section.
   (5) The system so far as supplied by the engine manufacturer. where engines incorporate electronic control systems a failure mode and effects analysis(FMEA) is to be submitted to demonstrate that failure of electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond an acceptable performance criteria of the engine.
   (6) all engines.
   (7) only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m^3 or more.
   (8) Operation and service manuals are to contain maintenance requirements(servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.
   (9) The documentations to contain specification of pressure, pipe dimensions and materials.

204. Plans and documents to be submitted by the manufacturers of steam turbines

1. Plans for approval

(1) Sectional assembly.
(2) Turbine casings, rotors and turbine blades.
(3) Details of turbine installation.
(4) Sectional assembly of main condenser.
(5) Welding details for main component parts.

2. Documents

(1) Main particulars of turbines at maximum continuous output (output, number of revolutions per minute of turbine rotor, steam pressure and temperature in steam chests, vacuum of condenser or status of exhaust chamber).
(2) Critical speed of turbine rotors, number of blades in each stage, the number of nozzles in each stage and its arrangement, various piping diagrams, diagrams of control and safety device system, the other data where this Society considers necessary.
(3) Material specifications of main component parts.
(4) Data regarding calculations for torsional vibration of shaftings.(See **Ch 4, Sec 1**)
(5) Strength calculation for turbine rotors and blades.

205. Plans and documents to be submitted by the manufacturers of gas turbine

1. Plans for approval

(1) Sectional assembly
(2) Discs (and/or rotors) of turbine and compressor

(3) Combustion chambers
(4) Details of fixing of moving and stationary blades
(5) Shaft couplings and bolts
(6) Piping arrangements fitted to turbine (including fuel oil, lubricating oil, cooling water, pneumatic and hydraulic system, and indicating pipe materials, pipe sizes and service pressures)
(7) Pressure vessels and heat exchangers (classified in Class I and Class II defined in **Ch 5**) attached to turbine
(8) Details of turbine installation
(9) Turbine Particulars (type and product number of turbine, power and number of revolutions per minute of turbine and compressors at maximum continuous rating, gas pressure and temperatures at turbine inlet and outlet, pressure losses in inlet and exhaust ducts, ambient condition intended for operation, service fuel oil and lubricating oil)
(10) Welding details of principal components
(11) Critical speeds of turbine rotors and compressors
(12) Number of moving blades in each stage
(13) Number and arrangements of stationary blades

2. Documents

(1) Material specifications of principal components
(2) General arrangement
(3) Starting arrangement (attached to turbine)
(4) Inlet air and exhaust gas arrangements
(5) Diagram of turbine control systems
(6) Calculation sheets for strength of principal components
(7) Calculation sheets for vibration of turbine blades
(8) Operation instructions for fuel oil control systems
(9) Illustrative drawing of cooling method for each part of turbine
(10) Maintenance instructions

206. Plans and documents to be submitted by the manufacturers of shafting system

1. Plans for approval

(1) Thrust shaft.
(2) Intermediate shaft.
(3) Propeller shaft.
(4) Stern tube, stern tube bearing and strut bearing.
(5) Coupling and coupling bolts.
(6) Propeller.

2. Documents

(1) Specified data for the calculation of shaft system.
(2) Data regarding calculations for torsional vibration of shaftings.(See **Ch 4, Sec 1**)
(3) Strength calculations for main component parts.

207. Plans and documents to be submitted by the manufacturers of power transmission system

1. Plans for approval

(1) Sectional assembly.
(2) Construction plan for the main component parts for gears, gear shafts, flexible coupling and flexible shafts.
(3) Welding details for main component parts.
(4) Piping arrangements fitted to the power transmission system.

2. Documents

(1) Main particulars (transmitted power and revolutions per minute for each pinion at maximum continuous output, number of teeth in each gear, module, pitch circle diameters, pressure angle of teeth, helix angles, face widths, centre distances, tool tip radius, shape of teeth backlash, amount of profile shift, amount of profile and tooth trace, finishing method of tooth flank, and

its modification are to be stated).
(2) Material specifications for power transmitting parts (chemical properties, heat treatment, quality of material, mechanical properties and its test method are to be stated).
(3) Strength calculations for main component parts.
(4) Data regarding calculations for torsional vibration of shaftings.(See **Ch 4, Sec 1**)

208. Plans and documents to be submitted by the manufacturers of boilers, Class 1 and 2 pressure vessels

1. Plans for approval

(1) General arrangement of boiler and pressure vessel.
(2) Details of boiler shells and headers.
(3) Details of washers for mountings and nozzles.
(4) Arrangement and details for boiler tubes, superheater, reheater, economizer and/or exhaust gas heater.
(5) Arrangement or its diagrams for air preheater and boiler mountings.
(6) Assembly of safety valve and assembly of relief valve.
(7) Welding details of main component parts.
(8) Detail of bursting disk (if installed in accordance with **Ch 5, 124. 5**)

2. Documents

(1) Main particulars (kind, type, design pressure and temperature, steam pressure and temperature at superheater outlet, maximum designed evaporation per hour, radiant heating surface, contact heating surface, temperature of feed water, furnace volume, fuel consumption at maximum evaporation, burning capacity and number of oil burners, setting pressure of safety valve are to be stated).
(2) Strength calculations for main component parts.
(3) Operation instructions (shell type exhaust gas economizer only)

209. Plans and documents to be submitted by the manufacturers of refrigerating machinery

1. Plans for approval

(1) Piping diagrams of refrigerating systems for provision chambers and air conditioning installations
(2) Drawings of pressure vessels exposed to a pressure of the primary refrigerant

2. Documents

(1) The particulars of refrigerating machinery

210. Plans and documents to be submitted by the manufacturers of essential auxiliaries

1. Plans for approval

(1) Sectional assembly (materials of main component parts are to be stated).
(2) Construction plan for shafts

2. Documents

(1) Main particulars (kind of prime mover, output, number of revolutions, capacity, and principal dimensions are to be stated).

3. For steering gears and windlasses, plans and documents in accordance with **Ch 7, 103.** and **Ch 8, 202.**, respectively.

Section 3 Tests and Inspections

301. Shop Tests

Before installation on board, machinery installations are to be tested and inspected at the plant provided with sufficient facilities necessary for the tests in accordance with the relevant requirements of each Chapter and shop trials deemed appropriate by the Society are to be carried out.

302. On board tests

After installation on board, machinery installations are to be tested and inspected in accordance with the relevant requirements of each chapter, and those are to be verified at the sea trials that they have normal functions and are free from excessive vibrations.

303. Omission of tests

Where machinery installations or materials have certificates which are considered appropriate by the Society, a part or all of the tests may be omitted.

304. Additional tests

The Society may require, when deemed necessary, other tests and inspections than those prescribed in this Part or the records of the tests carried out by the manufacturer.

305. Inspections based on Quality Assurance Scheme for Machinery

Where the machinery installations are manufactured by an approval of quality assurance scheme specified in **Guidance for Approval of Manufacturing Process and Type Approval, etc.,** a part or all of tests and inspections in the presence of the Society's Surveyor may be entrusted to the manufacturer.

Section 4 Spare Parts and Tools

401. Application

1. In general the spare parts and tools mentioned in the following Article are to be furnished in the engine room or other convenient places on board. The ships restricted in service area or fishing vessels are to comply with the special requirements given by the Society.

2. Where two or more machinery of same dimension, type and for same service are installed and their parts are exchangeable, the spare parts for one machinery may be acceptable. Where machinery installations whose number exceeds the required number and each capacity is adequate under the normal service condition of the ship, no spare parts are required for the machinery.

402. Internal combustion engines

Description and number of spare parts for main and essential auxiliary engines are to be as given in **Table 5.1.5.**

403. Steam turbine

Description and number of spare parts for main and essential auxiliary steam turbines are to be as given in **Table 5.1.6.**

404. Shafting and power transmission system

Description and number of spare parts for shafting and power transmission system are to be as given in **Table 5.1.7.**

405. Boiler

Description and number of spare parts for boilers are to be as given in **Table 5.1.8.**

406. Essential Auxiliary

Description and number of spare parts for essential auxiliaries are to be as given in **Table 5.1.9.**

407. Tools and Instruments

All ships are to be provided with various tools and instruments as shown in **Table 5.1.10.** ⚓

Table 5.1.5 Spare Parts for Internal Combustion Engines

Item	Remarks	Number required	
		Main engine	Aux. engine
Cylinder cover	Cylinder cover, complete with all valves, joint rings and gaskets.	1	-
	Cylinder cover bolts and nuts, for one cylinder	1/2 set	-
Cylinder liner	Cylinder liner, complete with joint rings and gaskets	1	-
Pistons	Crosshead type : Piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts	1	-
	Trunk piston type : Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod.	1	-
Piston rings	Piston rings for one cylinder	1 set	1 set
Piston cooling	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit	1 set	1 set
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets	2 sets
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder.	1 set	1 set
	Starting air valve, complete with casing, seat, springs and other fittings	1	1
	Relief valve, complete with casing, springs and other fittings	1	1
	Fuel valves, complete with casings, springs and other fittings for one engine (For engine with 3 or more fuel valves per cylinder, 2 fuel valves complete per cylinder and other fuel valves need no casing)	1 set	1/2 set
Fuel injection pumps	Fuel injection pump, complete. When replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.), or equivalent high pressure fuel pump	1	1
Fuel injection piping	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1	1
Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1 set	1 set
Connecting rod bearings	Bottom-end bearings or shells of each size and type fitted, complete with shims, bolts and nuts for one cylinder	1 set	1 set
	Top-end bearings or shells of each size and type fitted, complete with shims, bolts and nuts for one cylinder	1 set	-
	Trunk piston type : Gudgeon pin with bush for one cylinder	-	1 set
Cylinder lubricators	Lubricator, complete, of the largest size, with its driving chain or gear wheels, or equivalent spare part kit	1	-
Scavenging system	Suction and delivery valves for one pump of each type fitted, complete	1 set	-
Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder	-	1 set

Table 5.1.6 Spare Parts for Steam Turbines

Item	Remark	Number required
Turbine shaft	Carbon sealing rings, where fitted, with springs for each size sealing rings and type of gland, for one engine	1 set
Oil filters	Strainer baskets or inserts, for filters of special design, of each type and size	1 set

Table 5.1.7 Spare Parts for Shafting and Power Transmission System

Item	Remarks	Number required
Main thrust bearing	Pads for one face of tilting pad type thrust with liners, or rings for turbine adjusting block with assorted liners, for one engine. When the pad of one face differ from those of the other, a complete set of pads are to be provided.	1 set
	Complete thrust shoe for one face of solid ring type	1
	Inner and outer race with roller, where roller thrust bearings are fitted	1
Reduction and/or reversing gear	Complete bearing bush, of each size fitted in the gear case assembly	1 set
	Roller or ball race, of each size fitted in the gear case assembly	1 set

Table 5.1.8 Spare Parts for Boilers

Item	Remarks	Number required
Safety valve spring of each size	Including superheater safety valve springs	1
Oil burner nozzles, complete, for one boiler		1 set
Round type water gauge glasses	Including packings	12
Flat type water gauge glasses		2
Flat type water gauge frame		1
Smoke tubes and stay tubes	For each size	5 % of total number of tubes for one boiler
Water tubes and superheater tubes	For each size	5 % of total number of tubes for one boiler

NOTES:
The number of water gauge glasses of round type and flat type are required to be the number in this Table for each boiler. The number of flat type water gauge frames is required to be one for two boilers.

Table 5.1.9 Spare Parts for Essential Auxiliaries

Item	Remarks	Number required
Piston pumps	Valves with seats and springs of each size fitted	1 set
	Piston rings of each type and size for one piston	1 set
Central and gear type pumps	Bearing of each type and size	1
	Rotor sealings of each type and size	1
Compressors for essential service	Piston rings of each type and size for one piston	1 set
	Suction and delivery valves complete of each size	1/2 set

NOTES:
1. When sufficiently rated stand-by pump is available, the spare parts for other pumps except for bilge pump may be dispensed.
2. Where the stand-by cooling pumps, stand-by lubricating pumps or stand-by fuel oil supply pumps are not provided in accordance with the requirements of **Ch 6. 702. 7, 802. 3** and **903. 1,** one complete spare of each pump is to be carried on board.

Table 5.1.10 Tools and Instruments

Item	Remarks		Number required
Tube stoppers or plug	For main boiler and essential auxiliary boilers (including those for superheater and economizer tube)	Water tube boilers	12 for each size
		Other type boilers	12 for each size
Tube expanders	For main boiler and essential auxiliary boilers		1 for each size
Standard pressure gauge	For all boilers, gauge tester will be aceptable		1
Water tester	For all boilers, two salinometer will be acceptable		1
Special tools and instruments for maintenance or repair work of the machinery			1 set

CHAPTER 2 MAIN AND AUXILIARY ENGINES

Section 1 General

101. Application

1. The requirements of this Chapter apply to main engines and auxiliary engines driving generators and essential auxiliaries. For the small auxiliary engines and emergency generator driving engines, some requirements of this Part may be modified appropriately provided that the Society considers it acceptable.

2. Engines driving generators for electric propulsion are to comply with the requirements in **Pt 6, Ch 1, Sec 17,** in addition to the relevant requirements of this Chapter.

3. Internal combustion engines driving emergency generators are to comply with the requirements in **Pt 6, Ch 1, Sec 14.**

4. Piping arrangements

Piping arrangements are also to comply with the requirements of **Ch 6** in addition to the requirements of this Chapter.

5. Welding

Where main component parts of engines are to be welded, the Society, when considered necessary, may request preliminary tests or appropriate form of tests in connection with the work before the work is commenced. Welding methods, etc., are also to be approved. These requirements are also applicable in case of welding repairs to these parts.

6. Instruments

Tachometers, pressure gauges and thermometers which are necessary for safe operation are to be provided on main propulsion and auxiliary engines.

7. Electronic controlled diesel engines

Electronically controlled diesel engines for the main propulsion engines are to be in accordance with the separated requirements of the Society, in addition to the requirements prescribed in this Chapter.

Section 2 Internal Combustion Engines

201. Materials

1. Tests

Materials intended for the parts marked in **Table 5.2.1** are to be tested and inspected in the presence of Surveyors and to comply with the requirements of **Pt 2, Ch 1.**

2. Cylinders, cylinder liners, cylinder covers, pistons and other parts subject to high temperature or pressure are to be of materials suitable for the stress and temperature to which they are exposed.

202. Construction and installation

1. Frames and bed plates Frames and bed plates are to be of rigid and oiltight construction. The bedplate is to be provided with a sufficient number of holding down bolts to thoroughly secure it to the engine bed. Resin chocks or resilient mounting subjected to the type approval by the Society may be used.

2. Fire precaution Where the structures above engines and their surroundings are constructed with inflammable materials such as wood and the like, adequate measures are to be for the protection against fire.

3. Exhaust gas turbocharger

(1) Engines for propulsion purpose fitted with exhaust gas turbocharger are to be so arranged that the ship can proceed with safe voyage in case of failure in the part of the turbochargers.
(2) Where main engine can not be operable only with the exhaust gas turbochargers in case of starting or low speed range, the auxiliary scavenging blower is to be provided. Means are to be provided so that the engine can be started and operated in case of failure of the scavenging blowers.

Table 5.2.1 Tests

No.	Component parts	Material test	Magnetic particle test or liquid penetrant test	Ultrasonic test
1	Crankshafts (Solid forged shaft or arm, pin and journal of built up shaft)	○	○	○
2	Crankshaft coupling flanges (non-integral) for main power transmission and coupling bolts	□	-	-
3	Steel piston crowns	□	□	○
4	Piston rods	□	□	□
5	Connecting rods (together with upper and lower connecting rod bearing caps)	○	○	□
6	Crossheads	□	-	-
7	Cylinder liners (steel parts)	△	-	-
8	Steel cylinder covers	△	□	○
9	Bed plates and thrust blocks of welded construction, plates and transverse bearing girders made of forged or cast steel	○	○	○
10	Frames and crankcases of welded construction	○	○	○
11	Tie rods	○	□	-
12	Supercharger shaft and rotor, including blades	△	-	-
13	Bolts and studs for cylinder covers, crossheads, connecting rod bearing, and main bearings	△	□	-
14	Steel gear wheels for camshaft drive	□	□	-

NOTES:
1. Where, mark ○ for the parts of all engines, △ for the parts of engines with cylinders over 300 mm in diameter, □ for the parts of engines with cylinders over 400 mm in diameter, — for the parts of engines need not to be tested.
2. Supercharger described 12 is understood as turbochargers and engine driven compressors (including "root blowers"), but not auxiliary blowers.
3. This table does not apply to the internal combustion engines and superchargers which are manufactured in the way of mass produced methods.

4. Fuel oil valve

Fuel oil injection valves to cylinders are to be arranged operable by hand or other means without interrupting the oil supply, while the engine stops.

5. Starting arrangement

(1) Where compressed air is used for engine starting, the starting arrangements are to comply with the requirements of **Ch 6, Sec 11.**

(2) Where the main engine is arranged for electric starting, two separate batteries are to be fitted and cannot be connected in parallel. Each battery is to be capable of starting the main engine when in cold and ready to start conditions and the combined capacity of the batteries is to be sufficient without recharging to provide within 30 minutes the number of starts of main engines as required in **Ch 6, 1101. 1.**

(3) Where the auxiliary engine is arranged for electric starting, two separate batteries are to be fitted. The capacity of the batteries for starting the auxiliary engine is to be sufficient for at least three starts for each engine when in cold and ready to start conditions. In the case of a single auxiliary engine only one battery may be required.

(4) Electric starting arrangements for auxiliary engines may be supplied by separate circuits from starting batteries of the main engine when such are provided. In this case, the capacity of the batteries for starting the main engine is to be more than sum of the capacity required in (2) and (3) above, and the amount consumed for engine monitoring purposes.

(5) The starting batteries are to be used for starting and the engine's own monitoring purposes only. Provision is to be made to maintain continuously the stored energy at all times.

(6) Starting arrangement and capacity of prime movers driving emergency generating sets are to be in accordance with the requirements in **Pt 6, Ch 1, Sec 14.**

6. Lubricating oil arrangements

(1) Where the crankcases are of closed type, they are to be arranged so that the contained oil may be drained at any time. Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged at their outlet ends.

(2) Lubricating oil pipe lines are to be provided with a pressure gauge or other appropriate means at a suitable position to indicate that the proper circulation is maintained.

(3) Lubricating devices for rotor shafts of exhaust gas turbochargers are to be designed so that the lubricating oil may not be drawn into the charging air.

7. Cooling arrangements

(1) Provision is to be made for an uniform supply of cooling water or oil to each cylinder and piston. Drain cocks are to be fitted to water jackets and water pipe lines at their lowest positions.

(2) Cooling water or oil from each cylinder is to be arranged to discharge from the highest position and thermometer is to be fitted at the outlet.

203. Safety devices

1. Governors

(1) Each main engine is to be provided with a speed governor so adjusted that the engine speed can not exceed the maximum continuous revolutions by more than 15%. In addition to the normal governor, each main engine having a maximum continuous output of 220 kW and above, and which can be declutched or which drives a controllable pitch propeller, is to be provided with a separate over-speed protective device so adjusted that the speed can not exceed the maximum continuous revolutions by more than 20 %.

(2) Engines driving generators are to be provided with governors complying with the requirements of **Pt 6, Ch1, 202. 2** and **3.** In addition to the normal governor, each auxiliary engine driving electric generator and having a maximum continuous output of 220 kW and above is to be provided with a separate overspeed protective device so adjusted that the speed can not exceed the maximum continuous revolutions by more than 15 %.

2. Protection from overpressure of cylinder Each cylinder of engines having a bore exceeding 230 mm is to be provided with an effective sentinel valve, a relief valve adjusted to operate at not more than 40 % above the combustion pressure at the maximum continuous output, effective warning devices of an approved type for overpressure or other acceptable means.

3. Crankcase door

(1) Crankcase construction and crankcase doors are to be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

(2) A warning notice is to be fitted either on the control stand or, preferably, on a crankcase door

on each side of the engine. This warning notice is to specify that, "**whenever overheating is suspected within the crankcase, the crankcase doors or sight holes are not to be opened before a reasonable time, sufficient to permit adequate cooling after stopping the engine**".

4. Relief valve of crankcase

(1) Internal combustion engines having a cylinder bore of 200 mm and above or a crankcase volume of 0.6 m^3 and above shall be provided with relief valves of an approved type, for the purpose of relieving the excess pressure in the event of an internal explosion.

(2) The number and location of the relief valves are as follows.

(A) Engines having cylinder bore not exceeding 250 mm are to have at least one valve near each end, but, over eight crankthrows, an additional valve is to be fitted near the middle of the engine.

(B) Engines having a cylinder bore exceeding 250 mm but not exceeding 300mm are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves.

(C) Engines having a cylinder bore exceeding 300mm are to have at least one valve in way of each main crankthrow.

(3) The free area of each relief valve is to be not less than 45 cm^2. The combined free area of the valves fitted on an engine must not be less than 115 cm^2 per cubic metre of the crankcase gross volume. The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

(4) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the in rush of air thereafter.

(5) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

(6) Crankcase explosion relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0.02 MPa.

(7) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

(8) Additional relief valves are to be fitted in separate spaces of crankcase such as gear or chain case of camshaft or similar drives, when the gross volume of such spaces exceeds 0.6 m^3.

5. Ventilation of crankcase

(1) Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for dual fuel engines where crankcase ventilation is to be provided to prevent the accumulation of leaked gas.

(2) Crankcase ventilation pipes, where provided, are to be as small as practicable to minimize the in rush of air after a crankcase explosion.

(3) If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes for instance), the vacuum in the crankcase is not to exceed 25 mm of water head.

(4) To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

6. Protective devices for scavenge manifolds

(1) For crosshead type engines, scavenge spaces in open connection to the cylinders are to be connected to an approved fire extinguishing system, which is to be entirely separate from the fire extinguishing system of the engine room.

(2) Scavenge spaces in open connection to the cylinders are to be provided with explosion relief valves for preventing an overpressure in the event of explosion and minimizing the possibility of injury to personnel.

7. Protection of starting air pipes The starting air mains are to be protected against the explosion arising from improper functioning of starting valves by the following arrangements:

(1) An isolating non-return valve or equivalent thereto is to be provided at the starting air supply connection to each engine.

(2) In direct reversing engines having a main starting manifold, a bursting disc or flame arrester is to be fitted at the starting valve on each cylinder; in non-reversing engines having a main start-

ing manifold, at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. However, the above mentioned device may be omitted for engines having bore not exceeding 230 mm.

8. Alarms of lubricating oil system

Lubricating system to be used for main and auxiliary engines above 37 kW is to be provided with alarm devices which give visual and audible alarm in the event of failure of lubricating oil pressure supply or appreciable reduction in pressure of the lubricating oil supply.

9. Protection of high pressure fuel pipe All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to comply with the requirements specified in **Pt 8, Ch 2, 101. 2** (5) (B).

10. Oil mist detection arrangements of crankcase

(1) Following engines are to be provided with oil mist detection arrangements(or engine bearing temperature monitors or equivalent devices) obtained type approval.
  (A) Low speed diesel engines(crosshead type) of 2,250 kW and above or having cylinders of more than 300 mm bore : alarm and slow down purposes.
  (B) Medium and high speed diesel engines(trunk piston type) of 2,250 kW and above or having cylinders of more than 300 mm bore : alarm and automatic shutoff purposes.
(2) The oil mist detection arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions and recommendations.
(3) Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.
(4) Each engine is to be provided with its own independent oil mist detection arrangements and a dedicated alarm.
(5) Oil mist detection, and alarm systems are to be capable of being tested on the test bed of shop and onboard under engine at standstill and engine running at normal operating conditions.
(6) Alarms and shutdowns for the oil mist detection system and the system arrangements are to be in accordance with the requirements in **Pt 9, Ch 3, Sec 3**.
(7) The equipment together with detectors is to be tested when installed on the test bed of shop and on board ship to demonstrate that the detection and alarm system functionally operates.
(8) Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, the details are to be submitted for consideration.

204. Crankshafts

1. Application

The following requirements are to be applied to the crankshafts of diesel engines. For the crank shafts of internal combustion engines other than diesel engines, special consideration will be given.

2. Required diameter

The required diameter of crankpins or journals is not to be less than that given by the following formula:

$$d_c = \left\{ D^2 \left(M + \sqrt{M^2 + T^2} \right) \right\}^{\frac{1}{3}} \quad \text{(mm)}, \qquad M = 10^{-2} APL, \qquad T = 10^{-2} BP_i S$$

where:

D = Diameter of cylinder (mm)

S = Length of stroke (mm)

L = Span of bearings adjacent to crank measured from centre to centre (mm)

P = Maximum pressure in cylinder (MPa)

P_i = Indicated mean effective pressure (MPa)

A and B = Coefficients given in **Table 5.2.2** for engines having equal firing intervals (in case of vee engines, equal firing intervals on each bank). Special consideration will be given to the values of A and B for engines having unequal firing intervals or not covered by the **Table.**

Table 5.2.2 Coefficients A and B

(1) Single Acting In-line Engine

Number of cylinders		1	2	3	4	5	6	7	8	9	10	11	12
2-stroke cycle	A	1.00											
	B	8.8	8.8	10.0	11.1	11.4	11.7	12.0	12.3	12.6	13.4	14.2	15.0
4-stroke cycle	A	1.25											
	B	4.7	4.7	4.7	4.7	5.4	5.4	6.1	6.1	6.8	6.8	7.4	7.4

(2) Single Acting Vee Engine with Parallel Connecting Rods

Number of cylinders		Minimum firing interval between two cylinders on one crankthrow											
		45°		60°		90°		270°		300°		315°	
		A	B	A	B	A	B	A	B	A	B	A	B
2 stroke cycle	6	1.05	17.0	1.00	12.6	1.00	17.0						
	8		17.0		15.7		20.5						
	10		19.0		18.7		20.5						
	12		20.5		21.6		20.5						
	14		22.0		21.6		20.5						
	16		23.5		21.6		23.0						
	18		24.0		21.6		23.0						
	20		24.5		24.2		23.0						
4 stroke cycle	6	1.60	4.1	1.47	4.0	1.40	4.0	1.40	4.0	1.30	4.4	1.20	4.3
	8		5.5		5.5		5.5		5.5		5.3		5.2
	10		6.7		7.0		6.5		6.5		6.1		5.9
	12		7.5		8.2		7.5		7.5		6.9		6.6
	14		8.4		9.2		8.5		8.5		7.5		7.3
	16		9.3		10.1		9.5		9.5		8.2		7.9
	18		10.1		11.1		10.5		10.5		8.8		8.5
	20		11.5		14.0		11.5		11.5		9.5		9.2

205. Dimensions of crank arms

1. Solid shaft

For solid shafts, the thickness and breadth of crank arms are to comply with the following formula or the conditions shown in **Fig 5.2.1** in connection with the diameters of crankpin and journal. However, the thickness of crank arms is not to be less than 0.36 times the diameter of crankshaft. When the actual diameter of crankshaft is larger than the minimum required diameter of crankshaft, the left side of the following formula may be multiplied by $(d_c/d)^3$.

$$\{0.122(2.20 - b/d)^2 + 0.337\}(d/t)^{1.4} \le 1$$

where:

b = Breadth of crank arm (mm)

t = Thickness of crank arm (mm)

d = Actual diameter of crankpin or journal (mm)

d_c = Minimum required diameter of crankshaft (mm)

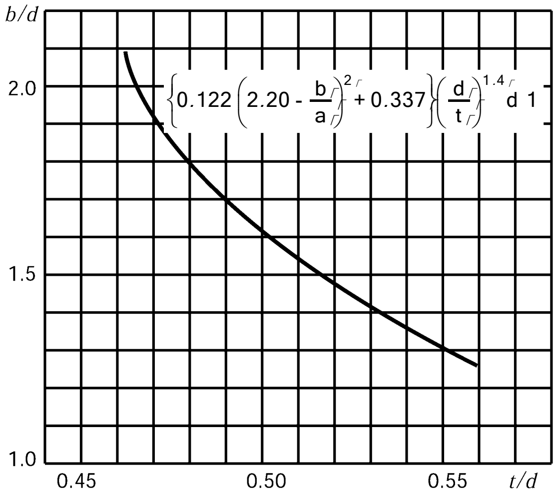


Fig. 5.2.1 Relationship between b/d and t/d

2. The fillet radius at the root of crank arms with crankpins or journals in solid crank shaft is not to be less than 0.05 times the actual diameter of the crankpins or journals respectively.

3. Semi-built-up crankshaft

In semi-built-up crankshafts, the dimensions of crank arms in way of the shrinkage fit are to comply with the following formulae. However, the dimensions of crank arms in way of the fillet parts with crankpin are to be in accordance with the requirements of **Pars 1** and **2.**

$$t_1 \geq \frac{C_1 T D^2}{C_2 {d_h}^2} \times \frac{1}{\left(1 - \frac{1}{A_s^2}\right)}$$

$$t_2 \geq 0.525 d_c$$

where:

t_1, t_2 = Thickness of crank arm measured parallel to the axis (mm)

C_1 = 10 for 2 cycle in-line engines

= 16 for 4 cycle in-line engines

T = $10^{-2} B P_i S$ (see **204. 2**)

$C_2 = 12.8\alpha - 2.4\alpha^2$, but in case of the hollow shaft, C_2 is to be multiplied by $(1 - R^2)$

$$\alpha = \frac{Shrinkage\ interference}{d_h} \times 10^3$$

$$R = \frac{Inside\ Diameter}{Outside\ Diameter}$$ for hollow shafts

d_h = Diameter of the hole at shrinkage fit (mm)

$$A_s = \frac{External\ diameter\ of\ arm}{d_h}$$

d_c = Minimum required diameter of crankshaft specified in **204. 2** (mm)

4. Built-up crankshaft

In built-up crankshafts, the dimensions of crank arms in way of the shrinkage fit are to be in accordance with the requirements of **Par 3.**

5. Shrinkage interference

In case of built-up or semi-built-up crankshafts, crank arms are to be securely shrunk on the crankpins or journals. The shrinkage interference "α_s" is to be as given below.

$$\frac{\sigma_y \cdot d_h}{E_m} \le \alpha_s \le \left(\frac{\sigma_y \cdot d_h}{E_m} + \frac{0.8 d_h}{1{,}000}\right)\frac{1}{1-R^2}$$

where:

σ_y = Specified minimum yield stress of material for crank web ($\mathrm{N/mm^2}$)

E_m = Young's modulus ($\mathrm{N/mm^2}$)

d_h, R = As specified in **Par 3.**

206. Material consideration

Where it is proposed to make the crankshafts or arms by carbon steel or low alloy steel having a specified tensile strength greater than 440 $\mathrm{N/mm^2}$, the diameter of crankshafts may be reduced by multiplying the following coefficient, K_m. This provision, however, is not to be applied to d_c in **205. 3** and K_m for other materials will be determined in each case by the Society.

$$K_m = \sqrt[3]{\frac{440}{440 + \frac{2}{3}(S-440)}}$$

where:

S = Specified minimum tensile strength of proposed material. For the high tensile strength exceeding 1,000 $\mathrm{N/mm^2}$, S is to be taken as 1,000 $\mathrm{N/mm^2}$.

207. Hollow shaft

Where crankpins or journals are hollow, the required outside diameter of the hollow shaft is not to be less than that obtained from the formula in **204. 2** multiplying by the following coefficient except where the inside diameter is less than one-third of the outside diameter.

$$K_h = \sqrt[3]{\frac{1}{1-R^4}}$$

where:

$R = \frac{Inside\ Diameter}{Outside\ Diameter}$ for hollow shafts.

208. Special consideration

Special consideration may be given to the diameter of crankshafts or the dimensions of the arms not complying with the requirements of the Rules, if the detailed data and calculations on the strength of these shafts or arms are submitted. In special cases where different manufacturing methods are made, the detailed information connected there-with and test results concerned are to be submitted to the Society for consideration. Where they are considered superior to the material strength available by the ordinary manufacturing methods, the diameter of crankshafts and dimensions of crank arms may be reduced.

209. Flywheel shafts and other shafts

Where flywheels or eccentric sheaves for pumps are fitted on crankshafts or additional shafts between the aftermost journal bearing and the thrust shaft, the shaft diameter in way of the part is not to be less than the required diameter of the crankshaft determined by the formula in **204. 2.**

210. Shaft couplings and coupling bolts

1. The required diameter of coupling bolts between crankshafts and thrust shaft, and others mentioned in **209.** at the joining faces of the coupling is to be determined by the following formula:

$$d_b = 0.7\sqrt{\frac{d_c^{\,3}}{nD} \cdot \frac{440}{T_b}} \quad (\mathrm{mm})$$

where:

d_b = Diameter of coupling bolts (mm)

n = Number of bolts

D = Diameter of pitch circle (mm)

d_c = Required diameter of crankshaft determined by the formula in **204. 2** (mm)

T_b = Specified minimum tensile strength of proposed material ($\mathrm{N/mm^2}$). For the tensile strength exceeding 1,000 $\mathrm{N/mm^2}$, T_b is to be taken as 1,000 $\mathrm{N/mm^2}$.

2. The thickness of shaft coupling flanges at the pitch circle of bolt holes is not to be less than the required diameter of coupling bolts given in **Par 1.** The fillet radius at the root of shaft coupling is not to be less than 0.08 times the actual diameter of applicable shaft. Where, however, the curvature at fillet is recessed in way of nuts and bolt heads, the radius of curvature is to be 0.125 times and above the diameter of the shaft at flanged coupling.

3. Where the shaft couplings are separate from the shaft, the couplings are to be of forged or cast steel and are to have strength enough to resist the transmitting torque of shaft and the astern pull. In this case, the shaft is to be of construction to avoid excessive stress concentration.

211. Tests and Inspections

1. Hydraulic test

Items and associated components for engines are to be tested by hydraulic pressure as indicated in **Table 5.2.3.**

2. Balancing test

The rotating assemblies of exhaust gas turbochargers are to be subjected to dynamic balancing tests after their assembly.

3. Type approval of engine

For diesel engines with novel design features or those with no service records, in case where deemed necessary by the Society, they are to be type approved in accordance with the procedure as deemed appropriate by the Society.

Table 5.2.3 Test pressure

Item	Test Pressure
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space	0.7 MPa
Cylinder jacket, cooling space Exhaust valve and exhaust pipe, cooling space Turbocharger cooling jacket, cooling space	0.4 MPa or 1.5P, whichever is the greater
Fuel injection pump body, pressure side Fuel injection valve Fuel injection pipe	1.5P or P + 30 MPa, whichever is the less
Scavenge pump cylinder	0.4 MPa
Heat exchanger	Apply the requirements of **Ch 5, 319. 1**
Auxiliary machinery and engine piping system	Apply the requirements of **Ch 6, Sec 13.**
Hydraulic piping for exhaust valve drive	1.5P

NOTES:
1. P : Design pressure (MPa)
2. In case of steel forging, the tests other than hydraulic test may be accepted.
3. Where the Society accepts, connected with the hydraulic test pressure indicated in the Table may be lowered or the test may be omitted.

Section 3 Steam Turbines

301. Emergency propulsion

Ships equipped with steam turbines are to be provided with means to maintain emergency propulsion in the event of failure of one main boiler.

302. Materials

1. Materials intended for turbine rotors, blades and turbine casings are to comply with the requirements of **Pt 2, Ch 1.**

2. Turbine casings and associated components that are subjected to high temperature and pressure are to be made of the material suitable for the stresses and heat to which they are exposed, and are to be properly heat-treated to remove residual stresses. Cast iron is not to be used where the maximum working temperature exceeds 230 °C.

303. General construction

1. Steam turbine cylinders are to be provided with suit-able drain devices.

2. Built-up turbine rotors of shrinkage fit type are to be properly secured by keys, dowel pins, or other approved means.

3. Thermal expansion

The structure of the parts of a turbine is to have proper fits and clearances, and to be free from distortions and other harmful deformations against thermal expansion. Turbines are to be installed on the seatings without excessive restriction against thermal expansion.

4. Devices for emergency operation of propulsion steam turbines

(1) In single screw ships fitted with cross compound steam turbines, the arrangements are to be

such as to enable safe navigation when the steam supply to any one of the turbines is required to be isolated. For this emergency operation purpose, the steam may be led directly to the L.P. turbine and either the H.P. or M.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

(2) The necessary pipes and valves for these arrangements are to be readily available and properly marked.

(3) The permissible power and speeds when operating without one of the turbines(all combinations) is to be specified and information provided on board.

(4) The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

5. Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

6. The turning gear of propulsion steam turbines is to be driven by independent power and where driven by electric motors, they shall be of the continuous rated.

304. Safety devices

1. All main and auxiliary turbines are to be provided with overspeed protective devices to prevent the design speed from being exceeded by more than 15 %. Where two or more turbines are coupled to the same main gear wheel set, the Society may agree that only one overspeed protective device be provided for all the turbines. Where main turbine installation incorporates a coupling which can be declutched or which drives a controllable pitch propeller, a separate speed governor in addition to the overspeed protective device is to be fitted and is to be capable of controlling the speed of unloaded turbine without bringing the overspeed protective device into action. Turbines driving electric generator are to be provided with governors complying with the requirements of **Pt 6, Ch 1, 202. 2** and **3,** in addition to the above.

2. Steam turbines are to be provided with a quick acting device which will automatically shut off the steam supply in the case of dangerous lowering of oil pressure in bearing lubricating system, and the device is also to be manually operated.

3. Propulsion steam turbines and main turbogenerators are to be provided with a satisfactory emergency supply of lubricating oil which will come into use automatically when the pressure drops below predetermined value. The emergency supply may be obtained from a gravity tank containing sufficient amount of oil to maintain adequate lubrication until the turbine is brought to rest or by equivalent means. For other safety devices of lubricating systems, the requirements of **Ch 6, Sec 8,** are to be applied.

4. Main turbines are to be provided with devices which automatically shut off the steam supply for ahead turbines in the case of low main condenser vacuum and the device is also to be manually operated.

5. Where the exhaust steam is extracted from turbine cylinders, approved means are to be provided to prevent the steam flowing backward to cylinders. A sentinel relief valve is to be fitted at the exhaust end of all turbines.

305. Turbine rotors

1. Turbine rotors (or discs) are to be so designed that excessive vibration may not occur within the operating range of speeds, and since the strength calculation of following **Par 2** does not include the factors of creep and others of the materials, special considerations are to be given by each manufacture to these points, as considered necessary.

2. Mean tangential stress

Mean tangential stress of turbine rotors (or discs) is to satisfy the following conditions.

$$T_m = \frac{1.10N^2}{A}\left(\rho I + \frac{rW}{2\pi}\right) \quad (\mathrm{mm})$$

$$T_m \le \frac{Y}{3}, \qquad T_m \le \frac{T_s}{4}$$

where:

T_m = Mean tangential stress ($\mathrm{N/mm^2}$)

N = Number of maximum continuous revolutions per minute divided 1,000 (rpm/1,000)

A = Sectional area of wheel profile on one side of axis of rotation ($\mathrm{cm^2}$)

I = Moment of inertia of area A on one side of axis of rotation ($\mathrm{cm^4}$)

ρ = Specific weight of turbine rotor (or disc) material. ($\mathrm{kg/cm^3}$)

W = Total weight of blade including roots (kg)

r = Distance between the center of gravity of blade (including root) and the center line of shaft (cm)

Y = Specified minimum yield stress or proof stress of the material ($\mathrm{N/mm^2}$)

T_s = Specific minimum tensile strength of the material ($\mathrm{N/mm^2}$)

306. Strength and sectional area of turbine blades

Turbine blades are to be so designed as to avoid abrupt changes in section and to provide an ample amount of stiffness to minimize deflection and vibration. The minimum sectional area at the root of the blade is to be determined by the following formula:

$$A = \frac{4.395\,WN^2 r}{S} \quad (\mathrm{cm^2})$$

where:

W = Weight of one blade (kg)

N = Number of maximum continuous revolutions per minute divided by 1,000 (rpm/1,000)

r = Distance between the centre of gravity of blade and centre line of shaft (cm)

S = Specified minimum tensile strength of blade material ($\mathrm{N/mm^2}$)

307. Tests and inspections

1. Hydraulic test

Turbines and accessory parts are to be tested by hydraulic pressures given in **Table 5.2.4.**

2. Balancing test

Turbine rotors are to be dynamically balanced after attaching the blades.

3. Tests after installation on board

A fit up test, to ensure the availability of the operation in compliance with **303. 4.** (1) and (2), is to be carried out prior to the sea trials. This test may be carried out at the shop tests.

Table 5.2.4 Test Pressure

Item		Test pressure	Remark
Turbine cylinders, high pressure turbine steam chests, steam receivers		$1.5P$ or 0.2 MPa, whichever is the greater	P = Design pressure (MPa)
Steam strainers, manoeuvring valve chests, other accessories		$2P$	
Main condenser	Steam space	0.1 MPa	-
	Water space	$P_1 + P_2 + 0.1$ MPa or 0.2 MPa, whichever is the greater	Where the scoop system is adopted, $P_1 + P_2 + 0.1$ MPa or 0.35 MPa, whichever is the greater.

NOTES:
P_1 = Maximum discharge pressure which the circulating pumps can develop with the discharge valve closed. (MPa)
P_2 = Maximum suction pressure which is developed under the full draught condition. (MPa)

Section 4 Gas Turbines

401. Materials, Construction and Strength

1. Materials

(1) Materials of the components of gas turbine specified below (hereinafter referred to as the principal components of gas turbine) are to comply with the requirements in **Pt 2, Ch 1**.
(A) Discs (or rotor), stationary blades and moving blades of turbine
(B) Discs, stationary blades and moving blades of compressor
(C) Turbine and compressor casings
(D) Combustion chambers
(E) Turbine output shaft
(F) Connecting bolts for main components of turbine
(G) Shaft coupling and bolts
(H) Pipes, valves and fittings attached to gas turbine classified in Class I or Class II in Pt **5, Ch 6.**

(2) The principal components of gas turbine (excluding bolts, pipes, valves and fittings) are to be subjected to the non-destructive tests specified in **Pt 2, Ch 1, 501. 10** and **601. 10**.

(3) The materials used in high temperature parts are to have properties suitable for the design performance and service life against corrosions, thermal stresses, creeps and relaxations. In case where the base material coated with corrosion-resistant surfacing, the coating material is to have such properties that it is hardly detached from the base material as well as not to impair the strength of the base material.

2. Construction and installations

(1) Gas turbines are to be so designed that no excessive vibration and surging are induced within the speed range of normal operation.

(2) Each part of a gas turbine is to have such constructions as no detrimental deformations caused by their thermal expansion.

(3) Where the main components of gas turbines are of welded construction, they are to comply with the requirements in **Ch 5, Sec 4**.

(4) In the event of failure of the main source of electrical power, the gas turbines for main propulsion are to be so designed as not to cause gas generator to stop, or to enable to restart immediately after the gas generator stopping.

(5) Gas turbines are to be installed on the seatings so that no excessive structural constraints are caused by thermal expansion.

402. Safety devices

1. Governors and overspeed protective devices

(1) Main gas turbines are to be provided with over speed protective devices to prevent the turbine speed from exceeding more than 15 % of the maximum continuous speed. Where a main gas turbine incorporates a reverse gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, a speed governor independent of the over speed protective device is to be fitted and is to be capable of controlling the speed of the unloaded gas turbine without bringing the over speed protective device into operation.

(2) The governors of gas turbines to drive generators are to conform to the requirements in **Pt 6, Ch 1, 202. 2**. However, when gas turbines used for main propulsion machinery in electric propulsion ships are used to drive generators to supply electric power exclusively to propulsion motors, the requirements in **Pt 6, Ch 1, 1702. 2.** are to be applied.

2. Emergency stopping devices

(1) Hand trip gear for shutting off the fuel in an emergency is to be provided at the maneuvering station.

(2) Gas turbines are to be provided with automatic fuel oil shut-off devices that operate in the following cases. In addition, means are to be provided so that alarms will be issued at the control station when the automatic fuel oil shut-off devices come into action.

(A) Overspeed
(B) Unaccepted lubricating oil pressure drop
(C) Unacceptable lubricating oil pressure drop of reduction gear
(D) Loss of flame during operation
(E) Excessive vibration
(F) Excessive axial displacement of each rotor (Except for gas turbines with rolling bearings)
(G) Excessive high temperature of exhaust gas
(H) Excessive high vacuum pressure at the compressor inlet

3. Alarms

Audible and visible alarming devices listed in **Table 5.2.5** are to be provided.

Table 5.2.5 Alarming Device

Monitored parameter	Alarm	Shutdown(2)
Overspeed	○	○
Unaccepted lubricating oil pressure drop	○(1)	○
Unaccepted lubricating oil pressure drop of reducing gear	○(1)	○
High differential pressure across lubricating oil filter	○	
High lubricating oil temperature	○	
Low oil fuel supply pressure	○	
High oil fuel temperature	○	
High cooling medium temperature	○	
High bearing temperature	○	
Loss of flame during operation	○	○
Automatic starting failure	○	
Excessive vibration	○(1)	○
Excessive axial displacement of each rotor (Except for gas turbines with rolling bearings)	○	○
Excessive high temperature of exhaust gas	○(1)	○
Excessive high vacuum pressure at the compressor inlet	○(1)	○
Loss of control system	○	

NOTES :
(1) Alarms are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.
(2) Suitable alarms are to be operated by the activation of shutdown devices.

4. Automatic temperature controls

The following turbine services are to be fitted maintain steady state conditions throughout the normal operating range of the main gas turbine :

(1) Lubricating oil supply
(2) Oil fuel supply (or automatic control of oil fuel viscosity as alternative)
(3) Exhaust gas

5. Fire detection and extinction in acoustic enclosures

Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the enclosure.

403. Associated Installations

1. Air inlet systems

The air inlet system is to have such construction and arrangement that intrusion of harmful particles and water into the compressor can be minimized. Additionally, means are to be provided so that the detrimental effects caused by salt deposits in suction air can be minimized.

2. Exhaust gas arrangement

(1) The open ends of exhaust gas pipes are to be located so as to prevent exhaust gas from entering into the air inlet system.
(2) Boilers and heat exchangers utilizing the exhaust heat of gas turbines are additionally to comply with the requirements specified in **Ch 5**.
(3) Exhaust gas arrangement is correspondingly to comply with the requirements specified in **Ch 6, 602.**.

3. Starting arrangements

(1) Automatic purging
Prior to commencing the ignition process, automatic purging is to be required for all starts and restarts. The purge phase is to be of sufficient duration to clear all parts of turbine of accumulation of liquid or gaseous fuel.
(2) Preset time
Starting control system is to be fitted with ignition detection devices. If light off does not occur within a preset time, the control system is to automatically abort the ignition, shutoff the main fuel valve, and commence a purge phase.
(3) Where compressed air or batteries are used for starting, the starting arrangement is correspondingly to comply with the requirements in **Ch 2, 202. 5**.

4. Ignition arrangements

(1) Each device in ignition arrangements is to be composed of two or more systems independent with each other.
(2) The cable of electric ignition device is to have good electrical insulation and to be laid in such a way that it is hardly damaged.
(3) Ignition distributors are to be of explosion-proof construction or to be provided with proper shielding. No coils for ignition device are to be situated in areas where explosive gases may be accumulated.

5. Fuel oil arrangements

(1) Sufficient consideration is to be given to the prevention of clogging of the fuel manifolds and fuel nozzles due to solid particles contained in the fuel, and also to the prevention of corrosions of turbine blades and other parts due to salts and similar corrosive substances.
(2) The fuel oil arrangements are additionally to comply with the requirements in **Ch 6, Sec 9**.

6. Lubricating oil arrangements

(1) Gas turbines for main propulsion are to be provided with an effective emergency supply of lubricating oil which comes into service automatically and has sufficient amount of oil to ensure adequate lubrication until the turbine is brought to rest, in case of failure of the lubricating oil supplying system. The emergency supply may be obtained from a gravity tank or from an aux-

iliary lubricating oil pump driven by the turbine.

(2) Lubricating oil arrangements are additionally to comply with the requirements in **Ch 6, Sec 8**.

404. Tests

1. Shop tests

(1) For gas turbines and their accessories hydrostatic tests are to be carried out at pressures specified below.
  (A) Casing : 1.5 times the design pressure
  (B) Piping system : Pressures specified in **Ch 6, 1304.**

(2) For rotating assemblies of turbines and compressors, dynamic balancing tests are to be carried out after their assembly.

(3) For turbine rotors, excess speed tests are to be carried out at 115 % of the maximum continuous rotational speed or over at least for 2 minutes after completion of manufacture.

(4) For gas turbines, shop tests are to be carried out including the test of safety devices specified in **402.** above by the test procedure deemed appropriate by the Society. In this case the Society may request tests regarding starting characteristics and critical speeds of rotor shafts. ⚓

CHAPTER 3 PROPULSION SHAFTING AND POWER TRANSMISSION SYSTEMS

Section 1 General

101. Welded construction components

Where the main components are to be welded, the Society may require the preliminary test and other tests for the fabrication of welding before the work is commenced when considered specifically necessary. The welding procedure is to be approved. This requirement also applies to repair of main component parts by welding.

102. Other propulsion and maneuvering machinery

The propulsion and maneuvering machinery not specified in this chapter are to comply with the special requirements given by the Society.

103. Installation of propulsion shafting system

1. Where resin chocks are used for the power transmission systems, stern tube, shaft bearing, etc., their arrangements and installation procedures, materials specification, etc. are to be approved by the Society.

2. Where propeller shaft or stern tube shaft is to be supported by the strut, this strut is to have sufficient strength.

3. Propulsion shafting systems are to be installed so that the excessive bending stress and shear stress are not occurred on the shaft and the appropriate reactive force is acted on each bearing.

Section 2 Shaftings

201. Application

1. The requirements of this Section apply to the shaftings of ships having diesel engines, steam turbines and gas turbines as their main engines and of ships of electric propulsion.

2. Where alternative calculation methods other than this section are used for calculating dimensions of shafts, they are considered appropriate by the Society.

202. Materials

1. The materials for intermediate shaft, thrust shaft, stern tube shaft, propeller shaft, shaft coupling and coupling bolts are to comply with the requirements for steel forging of **Pt 2, Ch 1.** Built-up type shaft couplings may be of steel castings conforming to the requirements in **Pt 2, Ch 1.**

2. The elongation of the material(L-direction) in **Par 1** is not to be less than 16 % except when an approval is specially obtained by the Society.

3. Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength(σ_B) of 500 $\mathrm{N/mm^2}$.

203. Intermediate shaft and thrust shaft

The diameters of intermediate shaft and thrust shaft are not to be less than those obtained by the following formula:

$$d_0 = F \cdot K_1 \sqrt[3]{\frac{P}{n} \times \frac{560}{(T+160)}} \quad (\mathrm{mm})$$

where:

P = Shaft output of engine at maximum continuous output (kW)

n = Number of shaft revolution at maximum continuous output (rpm)

F = Factor for the type of propulsion installations

- 95 for intermediate shafts in turbine installation, diesel installations with hydraulic(slip type) couplings, electric propulsion installations
- 100 for all other diesel installations and all propeller shafts

T = Specified minimum tensile strength (N/mm^2) of proposed material.

- For the minimum specified tensile strength of carbon steels exceeding 760 N/mm^2, T is to be taken 760 N/mm^2
- For the minimum specified tensile strength of alloy steels exceeding 800 N/mm^2, T is to be taken 800 N/mm^2

K_1 = Factor for different shaft design features, the values given by **Table 5.3.1.**

Table 5.3.1 Values of K_1

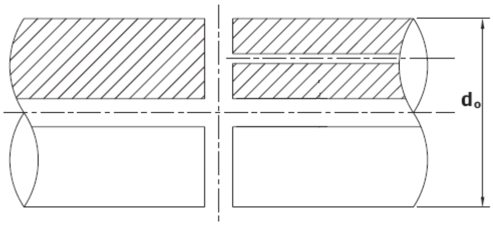
For intermediate shafts with					For thrust shafts with	
Integral coupling flange	Shrink fit coupling flange	Keyways	Radial holes	Longitudinal slots	On both side of thrust collar	In way of bearing when a roller bearing is used
1.00	1.00(1)	1.10(2)	1.10(3)	1.20(4)	1.10	1.10

NOTES:

(1) K_1 refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase of 1 to 2 % in diameter to the shrink fit diameter and a blending radius nearly equal to the change in diameter are to be provided,

(2) After a length of not less than $0.2d_0$ from the end of the keyway the shaft diameter may be reduced to the diameter calculated with K_1=1.0. The fillet radius in the transverse section of keyway bottom is to be $0.0125d_0$ or more. However, keyways are in general not to used in installations with a barred speed range.

(3) Diameter of radial hole not to exceed $0.3d_0$ When a transverse hole intersects an eccentric axial hole(see below), the values is to be determined by the Society based on the submitted data in each case.



(4) Subject to limitations as slot length(l)/outside diameter(d_o) < 0.8 and inner diameter(d_i)/outside diameter (d_o) < 0.8 and slot width(e)/outside diameter(d_o) > 0.10. The end rounding of the slot is not to be less than e/2. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The number of slots is to be 1, 2 or 3 and they are to be arranged 360, 180 or 120 degrees apart from each other respectively.

204. Propeller shaft and stern tube shaft

1. The diameter of propeller shaft and stern tube shaft is not to be less than that obtained by the following formula:

$$d_p = 100 \times K_2 \sqrt[3]{\frac{P}{n} \times \frac{560}{(T+160)}} \quad (\mathrm{mm})$$

where:

P, n = As specified in **203.**

K_2 = Factor concerning different shaft design features, the values given by **Table 5.3.2**

T = Specified minimum tensile strength ($\mathrm{N/mm^2}$), where the tensile strength of the steel used shall be between 400~800 $\mathrm{N/mm^2}$. For the tensile strength exceeding 600 $\mathrm{N/mm^2}$, T is to be taken as 600 $\mathrm{N/mm^2}$.

Table 5.3.2 Value of K_2

Kind of shaft	Propeller fitting method(1)	K_2(3)
Propeller shaft	Keyed	1.26
	Keyless fitting by shrink fit	1.22
	Flange(2)	1.22
Stern tube shaft		1.15

NOTES:
(1) Other propeller fitting methods are subject to special consideration.
(2) The fillet radius in the base of the flange is to be at least the order of $0.125d_p$.
(3) K_2 is applied to the shafts to which effective measures against corrosion by sea water are taken. The diameters of Kind 1 shaft made of approved corrosion-resistant materials and Kind 2 shaft are taken are to be dealt with as considered appropriate by the Society.

2. Reducing diameter

The diameter of the propeller shaft of the length of the forward edge of the bearing immediately forward of the propeller or the length of $2.5d_p$ ($4.0d_p$ in water-lubricated) from the forward face of the propeller boss or, if applicable, the forward face of the propeller flange, whichever is greater, may be reduced to the diameter in accordance with the formula in **Par 1** with the K_2 values as 1.15. The diameter of inboard end of the propeller shafts or stern tube shafts may be gradually reduced at the coupling to the value determined in **Par 1** with the values of K_2 replaced by K_1 the same as intermediate shafts in **Table 5.3.1.**

3. Sleeves

(1) Propeller shafts or stern tube shafts which are not made of corrosion resistant materials and run in seawater are to be protected against contact with sea water by sea water resistant metal sleeves.

(2) Manufacturing of sleeves
Sleeves are to be of bronze of high grade, stainless steel or above its equivalent thereto and free from porosity and other defects.

(3) thickness of sleeves

(A) The thickness of bronze sleeves fitted with propeller shafts and stern tube shafts is not to be less than that given by the following formula.

$$t_1 = 0.03d_p + 7.5 \quad (\mathrm{mm})$$

$$t_2 = 0.75t_1 \quad (\mathrm{mm})$$

Where :

t_1 : Thickness of sleeves in contact with stern tube bearing of strut bearing (mm)

t_2 : Thickness of sleeves of other parts than the above (mm)

d_p : Minimum required diameter of propeller shaft (mm)

(B) The thickness of stainless steel sleeves fitted with propeller shafts and stern tube shafts is not to be less than one-half that required for bronze sleeves or 6.5 mm, whichever is greater.

(4) Security of sleeves

(A) Sleeves are to be shrunk or forced on the shaft by pressure and they are not to be secured by pins or bolts.

(B) Sleeves are to be made in a single piece. if made of two or more lengths, the jointing of the separate pieces is to be done by an approved method of the Society.

4. Taper of propeller shaft cone

The propeller shaft cone is to be provided with the 1/10 (the 1/15 in keyless propeller) or less taper at the stern end of the propeller shaft.

5. Key of propeller shaft

(1) Key and keyway

Where a key is provided to the taper part of the propeller shaft, the key is to be tightly fitted in the keyway and to be secured by use of a set bolt. Sufficient radius is to be provided at the bottom fillet, in general, the fore end of the keyway is to be made a spoon shaped ending. For fitting part of small ship's propeller, it may be complied with *KS V* 4811.

(2) Set bolt for key

Two screw pins are to be provided for securing the key in the keyway, and the forward set bolt is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the set bolt is not to exceed the bolt diameters, and the edges of the holes are to be bevelled slightly.

205. Hollow shaft

In accordance with the kind of shafts, the outside diameter of hollow shaft is not to be less than that given by the corresponding formula specified in **203.** and **204.** multiplying by the following coefficient K_h. For the R not exceeding $0.04d_0$, K_h is to be taken as 1.

$$K_h = \sqrt[3]{\frac{1}{1-R^4}}$$

where:

$$R = \frac{Inside\ Diameter}{Outside\ Diameter}$$ for hollow shafts

206. Stern tube bearing and sealing device

1. The length of stern bearing in the stern tube or of strut bearing supporting the weight of propeller is to comply with the following requirements.

(1) The bearings are to be type approved by the Society in their materials, construction and lubricating arrangements when rubber or synthetic materials are used.

(2) For sea water lubricated bearings of lignum vitae, rubber or synthetic materials, the length of the bearing is to be not less than 4 times the required diameter of the shaft in way of the bearing.

(3) For oil lubricated bearings of white metal or synthetic materials, the length of the bearing is to be not less than 2 times the required diameter of the shaft in way of the bearing. The length of the bearing may be less provided the nominal bearing pressure is not more than 0.8 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing divided by the projected area of the shaft. For oil lubricated bearings of synthetic materials, the length of the bearing may be less provided the nominal bearing pressure is not more than 0.6 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be ex-

erted solely on the aft bearing divided by the projected area of the shaft. However, the minimum length is to be not less than 1.5 times the actual diameter.

(4) The oil lubricated stern tube is always to be filled with oil and the lubricating oil is to be cooled by submerging the stern tube in the water of the after peak tank or by other suitable means. Means for ascertaining the temperature of the oil in the stern tube are also to be provided. Where a gravity tank supplying lubricating oil to the stern tube bearing is fitted, it is to be located above the load water line and provided with a low level alarm device. Adequate means are to be provided to supply ample amount of sea water for lubrication and cooling in the sea water lubricated stern tube.

(5) Where the material has been proven satisfactory through testing and operating experience, consideration may be given to an increased bearing pressure or a lessened bearing length.

2. The sealing devices other than gland packing type sea water sealing device are to be type approved by the Society in their materials, construction and arrangement.

207. Shaft coupling and coupling bolts

1. Coupling bolt

The diameter of the coupling bolts at joining face of the couplings is not to be less than that given the following formula:

$$d_b = 0.65\sqrt{\frac{d_0^3(T+160)}{n \times D \times T_b}} \quad (\mathrm{mm})$$

where:

d_0 = Minimum required diameter of intermediate shaft calculated with K_1=1.0 (mm)

n = Number of bolts

D = Diameter of pitch circle (mm)

T = Specified minimum tensile strength of the intermediate shaft material ($\mathrm{N/mm^2}$)

T_b = Specified minimum tensile strength of bolt material, while in general $T \le T_b \le 1.7T$, but not higher than 1,000 $\mathrm{N/mm^2}$.

2. Shaft coupling

(1) The thickness of coupling flange at the pitch circle is not to be less than that obtained by the following formulae, whichever is the greater.

$$t_1 = d_b \quad (\mathrm{mm})$$
$$t_2 = 0.2d \quad (\mathrm{mm})$$

where:

d_b = Minimum required diameter of bolts calculated for the material having the same tensile strength as the corresponding shaft

d = Minimum required diameter of corresponding shaft

(2) The fillet radius at the base of the flange is not to be less than 0.08 times the diameter of the shaft. Where the fillet is recessed in way of nuts and bolt heads, the fillet radius at the base of the flange is not to be less than 0.125 times the diameter of the shaft.

3. Built-up type couplings

Where the shaft couplings are separate from the shaft, the couplings are to have strength enough to resist the transmitting torque of shaft and the astern pull. In this case, the shaft is to be of construction to avoid excessive stress concentration.

208. Tests and inspections

1. Hydraulic test of stern tube

Stern tubes are to be tested by hydraulic pressure of 0.2 MPa after manufacturing.

2. Leakage test

The oil sealing devices in stern tubes are to be tested for leakage under working oil pressure after being installed in ships.

3. Hydraulic test of sleeve

Propeller shaft sleeves and stern tube shaft sleeves are to be tested by hydraulic pressure of 0.1 MPa before they are to be shrunk or forced on the shaft.

Section 3 Propellers

301. Application

The requirements of this Section apply to screw propellers. The structure and strength of propellers of special design are to be in accordance with the requirements which the Society considers appropriate.

302. Materials

The materials of propellers and blade fixing bolts of built-up propeller are to be in accordance with the requirements of **Pt 2, Ch 1.**

303. Thickness of blade

1. The thicknesses of the propeller blades for solid propellers and controllable pitch propellers (fillet at the root of the blades is not to be considered in the determination of blade thickness) are not to be less than obtained from the formula in **Table 5.3.3.** In case of high speed ship, the higher requirement may be requested.

2. For the controllable pitch propellers of tugs, trawlers or other special duty ships with similar operating profiles, the diameter/pitch ratio for the maximal bollard pull has to be used in formula. For the controllable pitch propellers of other ships, the diameter/pitch ratio applicable to open-water navigation at maximum engine power(MCR) can be used in formula.

3. Consideration

For the blades of different materials from those specified in **Table 5.3.3,** the value of K_m will be determined by the Society in each case. For propellers having a diameter of 2.5 m and less, the value of K may be taken as the value in **Table 5.3.3** multiplied by the following factors.

for $D \leq 2.0$ m : 1.2
for $D > 2.0$ m : $2.0 - 0.4D$

D : Diameter of propeller

Table 5.3.3 Thickness of Blade

Thickness of blade (mm)	$t_x = \sqrt{\dfrac{0.1K_1 \cdot P}{C_x K_2 \cdot Z \cdot N \cdot l_x}}$

P : Maximum continuous output of main propulsion machinery (kW)
Z : Number of blades
N : Number of maximum continuous revolution per minute devided by 100
C_x : Section modulus values at the blade position x (Actual section modulus÷$l_x t_{ax}{}^2$), where C_x exceeds 0.1, C_x is to be taken as 0.1
l_x : Width of blade at the radius xR (m) (x : 0.25, 0.35, 0.6)
R : Radius of propeller (m)
x : Radius position having no dimension
t_{ax} : Actual thickness of Blades (m)
K_1, K_2 : Coefficient given by the following table

Coefficient / x	Solid propeller	Controllable pitch propeller
0.25	$K_1 = \dfrac{61}{\sqrt{1+1.62\left(\dfrac{P_{0.25}}{D}\right)^2}}\left[0.092+0.329\left(\dfrac{D}{P_{0.7}}\right)+0.238\left(\dfrac{P_{0.25}}{D}\right)\right]$ $K_2 = K_m - \dfrac{D^3 \cdot N^2 \cdot \xi}{1{,}000\, l_{0.25} \cdot Z}\left[2.02+\dfrac{1.17\left(\dfrac{100E}{D}\right)+2.39}{\sqrt{1+1.62\left(\dfrac{P_{0.25}}{D}\right)^2}}\right]$	
0.35		$K_1 = \dfrac{61}{\sqrt{1+0.827\left(\dfrac{P_{0.35}}{D}\right)^2}}\left[0.074+0.264\left(\dfrac{D}{P_{0.7}}\right)+0.131\left(\dfrac{P_{0.35}}{D}\right)\right]$ $K_2 = K_m - \dfrac{D^3 \cdot N^2 \cdot \xi}{1{,}000\, l_{0.35} \cdot Z}\left[2.29+\dfrac{1.23\left(\dfrac{100E}{D}\right)+2.51}{\sqrt{1+0.827\left(\dfrac{P_{0.35}}{D}\right)^2}}\right]$
0.6	$K_1 = \dfrac{61}{\sqrt{1+0.281\left(\dfrac{P_{0.6}}{D}\right)^2}}\left[0.028+0.096\left(\dfrac{D}{P_{0.7}}\right)+0.026\left(\dfrac{P_{0.6}}{D}\right)\right]$ $K_2 = K_m - \dfrac{D^3 \cdot N^2 \cdot \xi}{1{,}000\, l_{0.6} \cdot Z}\left[1.48+\dfrac{0.68\left(\dfrac{100E}{D}\right)+1.38}{\sqrt{1+0.281\left(\dfrac{P_{0.6}}{D}\right)^2}}\right]$	$K_1 = \dfrac{61}{\sqrt{1+0.281\left(\dfrac{P_{0.6}}{D}\right)^2}}\left[0.028+0.100\left(\dfrac{D}{P_{0.7}}\right)+0.026\left(\dfrac{P_{0.6}}{D}\right)\right]$ $K_2 = K_m - \dfrac{D^3 \cdot N^2 \cdot \xi}{1{,}000\, l_{0.6} \cdot Z}\left[1.70+\dfrac{0.78\left(\dfrac{100E}{D}\right)+1.59}{\sqrt{1+0.281\left(\dfrac{P_{0.6}}{D}\right)^2}}\right]$

D : Diameter of propeller (m)
E : Rake of blade at propeller shaft center line (Distance between a cross of perpendicular line of blade tip and a cross of extension line of backface at shaft center line in the projection of maximum thickness section of the blade) (m)
P_x : Pitch at the radius xR (m) (x : 0.25, 0.35, 0.6, 0.7)
$\xi = \dfrac{A_E}{\dfrac{\pi}{4}D^2}$: Expanded area ratio
A_E : Expanded area of propeller

K_m : Values given by the following table

Materials		K_m
Grey cast iron		0.6
Cast steel	*RSC* 42	0.9
	RSC 46	
	RSC 49	1.0
Copper alloy casting	*CU* 1	1.15
	CU 2	
	CU 3	1.3
	CU 4	1.15

304. Fixing of blade

1. Fixing

Blade fixing bolts are to have sufficient strength as considered appropriate by the Society,and corrosion resistant materials are to be used or effective means precluding their direct contact with sea water are to be provided. Bolts are to be fitted tightly into the boss by flanging or other effective means, and nuts are to be secured by appropriate means to prevent loosening.

2. Recess

The recess for the blade fixing bolts are to be so provided that it has no significant influence to the strength at the root of blades.

3. Flange

The face of the flange of the blade is to be fitted tightly to the face of the boss, and the circumferential clearance of the edge of flange is to be kept to a minimum.

305. Fitting of propeller

1. The propeller is to be force-fitted on the taper of the propeller shaft or to be firmly fixed to the shaft by other appropriate means. Propeller, on force fitting or drawing out, is not to be heated partially to a high temperature.

2. Where the propeller is force-fitted to the propeller shaft without the use of a key, the calculation sheets of the pull-up length are to be submitted for approval. Where the propeller is bolted to the shaft, the blade fixing bolts are to have sufficient strength.

3. Anti-corrosion

Effective constructions are to be provided to prevent sea water from having access to the part between propeller cap or propeller boss and propeller shaft.

306. Hydraulic oil pump

Where, in controllable pitch propeller, pitch controlling devices are operated by hydraulic oil pump, a stand-by oil pump or other suitable means are to bo provided so that the ship can keep the normal voyage condition in the event of failure of the oil pump.

307. Tests and inspections

1. Balancing tests

Propellers are to be subjected to static balancing tests.

2. Contact tests

Where the propeller is force-fitted to the taper of the propeller shaft cone, the contact marking between the mating surfaces is to be verified by contact facing-up test or other suitable means.

3. Confirmation of the pull-up length

Where a propeller is force-fitted to the propeller shaft without the use of a key, the pull-up length is to be confirmed and recorded.

Section 4 Power Transmission Systems

401. General

1. Application

The requirements of this Section apply to power transmission systems which transmit power from main propulsion machinery and prime movers driving generators (excluding emergency generator) and essential auxiliaries for propulsion and safety of ships.

2. Special requirement

The construction of other power transmission systems not specified in this Section is to be such that the Society considers appropriate, functioning safely and reliably and having sufficient strength against transmitted power.

3. Hydraulic pump or air compressor, etc.

Where the clutching device of power transmission systems for propulsion is operated with hydraulic oil or air pressure, the stand-by hydraulic oil pumps or air compressor which can be used at any time or any other appropriate unit is to be provided, thereby to ensure that a ship can keep the normal service condition. However, in the case of small ships the requirement for this stand-by unit can be dispensed with at the discretion of the Society.

4. Electro-magnetic slip coupling

The electro-magnetic slip couplings are also to comply with the requirements of **Pt 6, Ch 1, 1603. 4.**

5. Materials

The materials used for main components of the power transmission system are to comply with the requirements in **Pt 2, Ch 1**. However, for small transmitted power, an attendance of Surveyor for material tests may be omitted.

402. General construction of gearing

1. Gear of built-up type

Where a gear is of built-up type, the rim is to be of a thickness to ensure sufficient strength and is to have an enough shrinkage fit against transmitted power. Where shrinkage fit is made after cutting of the teeth, the construction is to be such as to fully guarantee the accuracy of gearing, or the final tooth finishing is to be carried out after the shrinkage fit. Where gears are of welded construction, they are to have sufficient rigidity and are to be stress relieved before cutting of the teeth.

2. Casing

Gear casings are to have sufficient rigidity, and their construction is to be such that all possible facility is provided for inspection and maintenance. Where the casing is of welded structure, its construction and materials are to be approved by the Society.

3. Machining

Gear teeth are to be machined by hobbing machines of high accuracy, and it is recommended that the finishing, if available, is to be carried out as far as possible in a temperature controllable room. After the final machining, both edges of the teeth or any other sharp parts are to be properly hand finished. The surface hardening processes are to be carried out considering the influence of the thermal deformation to ensure that the necessary flank hardness and depth of hardened zone are obtained.

4. Other components of gears

Other components of the gears are also to be of reliable quality and their attachment are to be so arranged that they have no influence to the centers of gear shafts.

5. Noise

Gears are to be adjusted to give minimum noise in the normal range of revolution.

6. Lubricating oil arrangement

(1) Lubricating oil arrangement is also to comply with the requirements of **Ch 6, Sec 8**. Oil strainers used for gearing are to be those with a magnet if available.
(2) The gearing of the forced lubrication system with the driving units above 37 kW are to be pro-

vided with alarm devices which give visual and audible alarm in the event of failure of lubricating oil pressure supply or appreciable reduction in pressure of lubricating oil supply. For the lubricating oil arrangements other than forced lubrication system, suitable means are to be provided to ascertain oil level in sump.

403. Allowable tangential load for gears

1. Application

These provisions are applied to the external tooth cylindrical gears having an involute tooth profile. The external tooth cylindrical gears having tooth profiles other than the involute tooth profile are to comply with the requirements which the Society deems appropriate.

2. Allowable tangential load by bending strength

Allowable tangential loads decided for the bending strength of the teeth are to conform to the following condition:

$$P_{MCR} \le P_b$$

P_{MCR} = Tangential loads of gears at maximum continuous output, being the value to be obtained from the following formula:

$$P_{MCR} = \frac{1.91P}{nd_1 b} \times 10^6 \quad (\mathrm{N/cm})$$

where:

P = Output which the pinion shares at maximum continuous output (kW)

n = Revolutions of the pinion at maximum continuous output (rpm)

d_1 = Pitch circle diameter of the pinion (cm)

b = Effective face width of the gears on the pitch circle of the shaft parallel section (cm)

P_b = Allowable tangential loads decided for the bending strength, being obtained from the following formula:

$$P_b = 9.81(K_1 \cdot S_b - K_2) \times K_3 \left(4.85 - \frac{30.6}{Z}\right) M \quad (\mathrm{N/cm})$$

K_1 = External load magnification coefficient, being the value to be decided for the size of fluctuating loads working on the gears and to be given by the following formula. Where the value of K_1 can not be calculated, the values in **Table 5.3.4** may be used.

$$K_1 = \frac{1.10 P_{MCR}}{P_{MAX}}$$

P_{MAX} = Instantaneous maximum tangential loads occurring within the continuous revolution range (N/cm)

Table 5.3.4 Values of K_1

Driving engine	Construction or method of connection	$K_1^{(3)}$	
		Gear for propulsion	Gear for auxiliaries
Steam turbine or electric motor	Single stage reduction gear	1.00	1.15
	Multiple stage reduction gear	1.00[(1)], 1.10[(2)]	1.15
Internal combustion engine	Hydro-dynamic or electro-magnetic coupling	1.00	1.15
	High elastic coupling	0.90	1.05
	Elastic coupling	0.80	0.95
	Rigid coupling	0.50	0.60

NOTES:
(1) marked is applicable only to the gearing connected directly with the propulsion shaft system.
(2) marked is applicable only to the gearing connected directly with the propulsion shaft system through effective flexible couplings.
(3) Where one pinion meshes with more than two wheels, 0.9 times these values may be applied as the value of K_1.

K_2 = Internal load magnification value, being the value to be derived from the following formula or **Fig 5.3.1** which is dependent on the accuracy of gears and their overlap ratio.

$$K_2 = k_2 (d \times n)^{0.8}$$

where:

d = Pitch circle diameter of gears (cm)

n = Number of revolution per minute of gears divided by 1,000 (rpm/1,000)

k_2 = Value given in **Table 5.3.5.**

K_3 = Load magnification coefficient, being the value to be derived from the following formula or **Fig 5.3.2** which is dependent on the face width and pitch circle diameter.

Table 5.3.5 Values of k_2

Expected accuracy of finishing gears	k_2	
	$\varepsilon \geq 1.25$	$\varepsilon < 1.25$
Those corresponding to finishing by shaving or grinding	0.044	0.088
those corresponding to finishing by hobbing	0.11	0.22

$$\varepsilon = \frac{10 b_e \sin\beta_0}{\pi M}$$

b_e = Face width (in case of double helical gears, the face width is for one side) (cm)

β_0 = Helix angle

M = Normal module

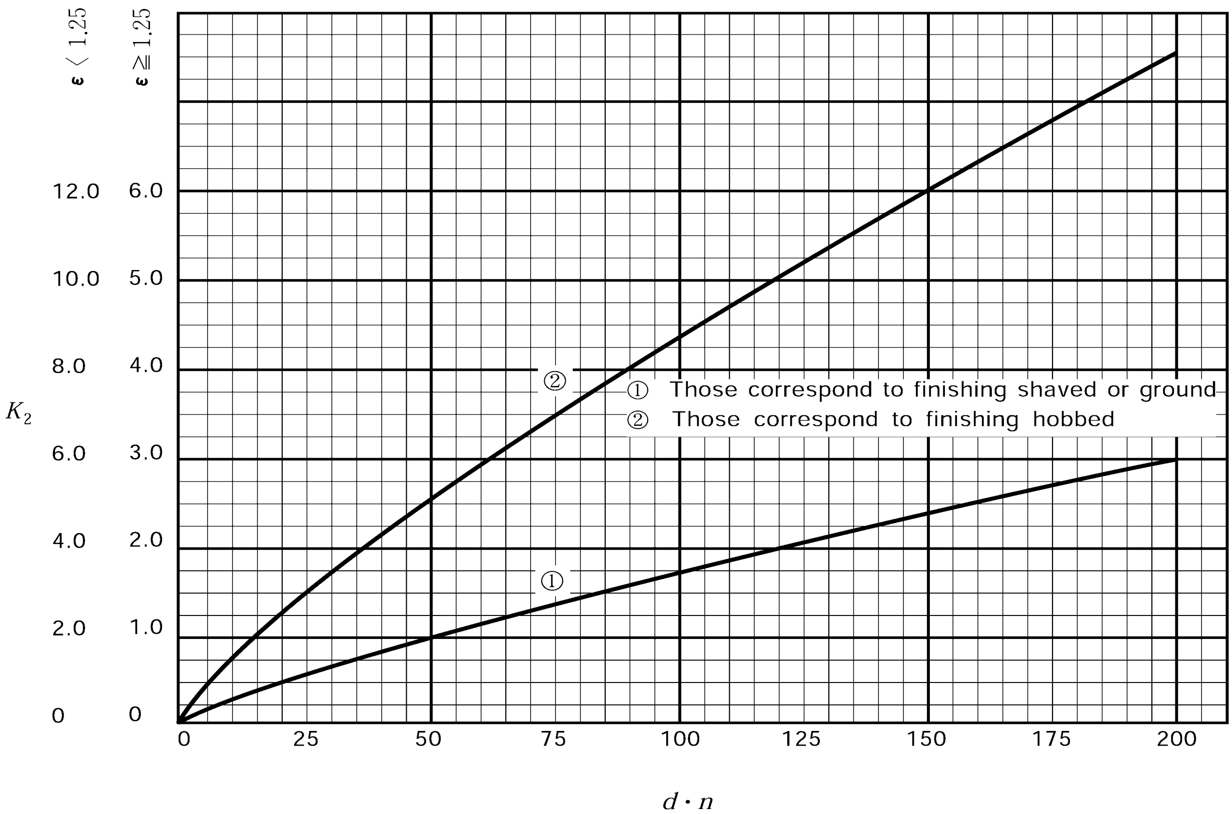


Fig 5.3.1 Values of K_2

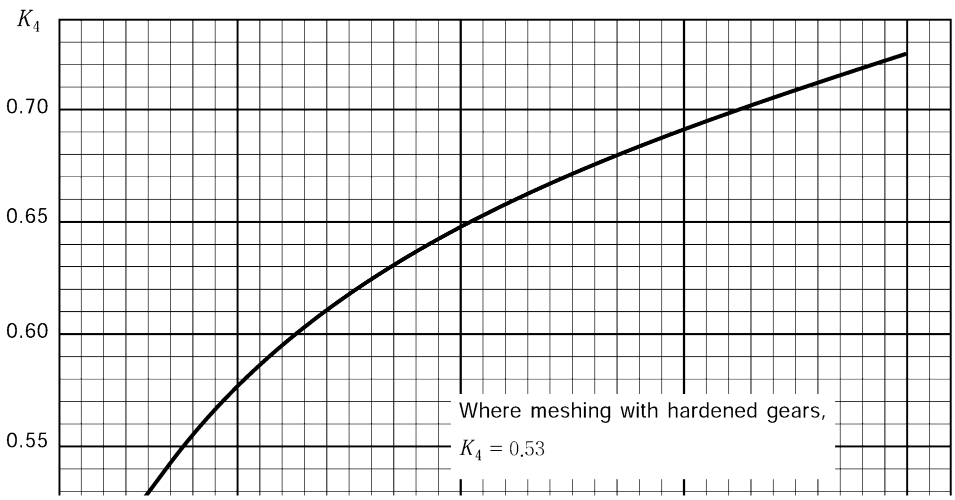


Fig 5.3.2 Values of K_3

$$K_3 = 1 - k_3 \left(\frac{b_t}{d_1} \right)^3$$

where:

b_t = Total face width of pinions (in case of double helical gears, central gap is included) (cm)

d_1 = Pitch circle diameter of pinion (cm)

k_3 = Value given by **Table 5.3.6.**

Table 5.3.6 Values of k_3

	k_3
When one pinion meshes with one wheel	0.01
When two wheels mesh with one pinion in the direction of the diameter	0.003

Z = Number of teeth

S_b = The value related mainly to the material of gears, given by the following formula. In case of ahead idle gears and astern gears, however, 0.7 times and 1.2 times respectively such value are regarded as S_b values. In any case, S_b value is not to exceed 25.

Gears to which surface hardening process was applied including bottom land:
$S_b = 0.83\sqrt{S}$

Other gears : $S_b = \frac{S+Y}{49} \times \frac{1}{F}$

$$F = 1 + (0.0096S - 2.4)\left(\frac{0.04}{\gamma_0} + 0.02\right) \times (0.023M + 0.75)$$

where:

S = Specified minimum tensile strength of gear material (N/mm^2)

Y = Specified minimum yield stress of gear material (N/mm^2)

γ_0 = Ratio between the tooth tip radius and module

M = Normal module

3. Tangential load by surface durability

The tangential loads of gears decided for surface durability of the teeth flank are to conform to the following condition, but these are not applicable to astern gears.

$$P_{MCR} \le P_S$$

P_{MCR} = As specified in **Par 2.**

P_S = Allowable tangential loads decided for the surface durability of the teeth flank and obtained by the following formula:

$$P_S = 9.81(K_1 S_S - K_2) K_3 K_4 \frac{i}{1+i} d_1 \quad (N/cm)$$

where:

K_1, K_2, K_3 = As specified in **Par 2.**

S_S = Decided by the material of gears and as given by the following formula:

Combination of gears both of which have been subjected to surface hardening process:

$$S_S = 2.236\sqrt{S_W}$$

Combination of other gears:

$$S_S = \left(0.005\frac{H_{BP}}{H_{BW}} + 0.007\right) S_W + 7.5$$

where:

S_W = Specified minimum tensile strength of wheel material ($\mathrm{N/mm^2}$)

H_{BP} = Hardness of tooth face of pinion (Brinell hardness $\mathrm{H_B}$)

H_{BW} = Hardness of tooth face of wheel (Brinell hardness $\mathrm{H_B}$)

K_4 = Lubricating coefficient, being the value decided for the following formula or **Fig 5.3.3,** which is dependent on pitch circle diameter and number of revolution. In case of meshing with hardened gears, however, K_4 = 0.53.

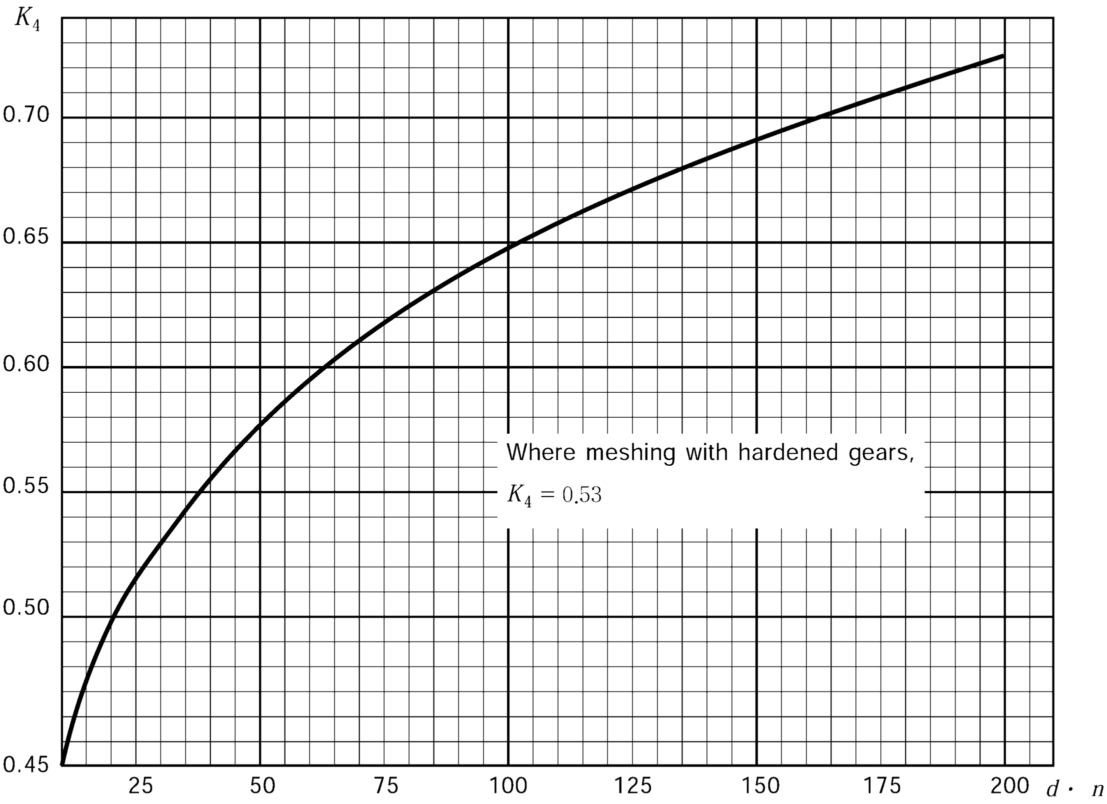


Fig 5.3.3 Values of K_4

$$K_4 = 0.3(d \cdot n)^{\frac{1}{6}}$$

where :

d = Pitch circle diameter of gears (cm)

n = Number of revolution per minute of gears divided by 1,000 (rpm/1,000)

i = Gear ratio (number of teeth of wheel/number of teeth of pinion)

d_1 = Pitch circle diameter of pinion (cm)

4. Consideration

The Society may approve special gearing devices, notwithstanding the requirements of **Pars 2** and **3,** provided that the detailed data for design, machining, using and calculations on the strength are submitted.

404. Gear shaft

1. Gear shaft

The diameter of gear shafts by which power is transmitted is not to be less than the value given by the formula in **203.** In this case, P and n in this formula represent respectively the output and the number of revolutions of the shaft at the maximum continuous output. For the tensile strength exceeding 1,000 N/mm^2 in the pinion shafts, T is to be taken as 1,000 N/mm^2. However, the diameter between the wheel shaft bearings is not to be less than the above values that multiplied by coefficient given in **Table 5.3.7.**

Table 5.3.7 Values of C

Arrangement of pinions	C
When one pinion is gearing, or when two pinions which are arranged at an angle less than 120° each other are gearing	1.16
When two pinions which are arranged at an angle more than 120° each other are gearing	1.10

2. Pinion shaft

The diameter of pinion shaft is to have sufficient rigidity against the bending force generated by meshing of gears.

405. Flexible shaft

The diameter of flexible shaft is not to be less than that given by the following formula:

$$d_f = 100\sqrt[3]{\frac{P}{n} \times \frac{440}{S}} \quad (\mathrm{mm})$$

where:

P = Output shared by flexible shaft at the maximum continuous output (kW)

n = Number of revolution per minute of flexible shaft at the maximum continuous output (rpm)

S = Specified minimum tensile strength of shaft material (N/mm^2)

406. Shaft couplings

1. Shaft couplings and coupling bolts

The dimensions of couplings and coupling bolts are applied to the related requirements in **207.** In case where they support heavy materials in cantilever style, they are to be designed so as to have sufficient strength to resist the weight.

2. Flexible couplings

The flexible couplings are to have sufficient strength against the torque to be transmitted to the shaft, and the constructions and materials are to be type approved by the Society.

407. Tests and inspections

1. Finishing accuracy

For the parts subjected to surface hardening process, the hardened depth are to be measured on sample materials, and hardness test and suitable non-destructive tests are to be carried out. The finishing accuracy of final machining of gears is to be measured minutely.

2. Dynamical balancing test

In the case of gears where the value given by the following formula exceeds 50, dynamic balancing tests are to be carried out, except for the case where specially approved by the Society to omit such test.

$$\frac{Dn}{1{,}000}$$

where:

D = Pitch circle diameter of the gear (cm)

n = Number of revolution of the gear (rpm)

3. Contact marking of teeth

The contact marking of the teeth of all gearing is to be verified under appropriate loads by coating suitable paint thinly and uniformly. And, in the case of propulsion gears where the total face width (in the case of double helical gears, the central gap is included) exceeds 300 mm or where the ratio between the total face width and pitch circle diameter of the pinion exceeds 2, the contact marking of the teeth is to be verified at sea trial by coating with copper sulphate or suitable paint on teeth flank thinly and uniformly.⚓

CHAPTER 4 TORSIONAL VIBRATION OF SHAFTINGS

Section 1 General

101. Application

1. The requirements of this Chapter apply to power transmission systems for propulsion and propulsion shafting systems, shafting systems to transmit power from main engines to generators, crankshafts of diesel engines used as main engines and shafting systems of generators driven by diesel engines.

2. Where alternative calculation methods other than this section are used for calculating dimensions of allowable torsional vibration stresses, they are to be complied with the requirements in **Ch 3, 201.3.**

102. Data to be submitted

1. For the shafting of ships, the calculation sheets for the torsional vibration are to be submitted in accordance with **Ch 1, 202.** and are to include the following particulars:

(1) Natural frequencies and modes for one node and two nodes vibration, also more nodes vibration if necessary.
(2) Estimated vibratory stresses for shafting system at each resonant critical within a speed range up to 120 % of the maximum continuous revolutions, and estimated torsional vibration stresses for the frank appearing at each non-resonant critical in the service speed range caused by a resonance having its critical speed above 120 % of the maximum continuous revolutions.
(3) Estimated vibratory torques for shafting system, gearings and flexible couplings.
(4) For propulsion shafts, estimated vibratory stresses for operation with any one cylinder misfiring(i.e. no injection but with compression)

2. Notwithstanding the requirements specified in **Par 1,** submission of the torsional vibration calculation sheets may be omitted in the following cases provided that approval of the Society is obtained:

(1) In case where the shafting system is of the same types as previously approved one.
(2) In case where there is a slight alternation in specifications of the vibration system, and the frequency and torsional vibration stress can be deduced with satisfactory accuracy on the basis of the previous result of calculations or measurements.
(3) In case where the maximum continuous output of engine is 100 kW and below.

103. Measurements

1. The alternating torsional stress amplitude can be measured on a shaft in a relevant condition over a repetitive cycle.

2. For the shafting systems where the submission of the torsional vibration calculation sheets is required, measurements to confirm correctness of the estimated value are to be carried out. However, where the submission of the calculation sheets is omitted according to the requirement in **102. 2,** and the Society considers that there is no critical vibration within the service speed range, the measurement of torsional vibration may be omitted.

Section 2 Allowable Limit of Vibration Stresses

201. Crankshafts

The torsional vibration stresses on the crankshafts of main propulsion diesel engines are to be in accordance with the following requirements. However, where the strength calculation for crankshafts is carried out according to the special requirements given by the Society, these stresses are to comply with this special requirements.

1. For continuous operation within the range below the maximum continuous revolution, the torsional vibration stresses are not to exceed τ_1 given in following.

(1) For 4 cycle in-line diesel engines and 4 cycle vee type diesel engines with firing intervals of 45° or 60°, the value of τ_1 is given by the following formula:

$$\tau_1 = 45 - 24\lambda^2 \quad (0 \le \lambda \le 1)$$

(2) For 2 cycle diesel engines and 4 cycle vee type diesel engines other than shown in (1) above, the value of τ_1 is given by the following formula:

$$\tau_1 = 45 - 29\lambda^2 \quad (0 \le \lambda \le 1)$$

where:

τ_1 = Allowable limit of torsional vibration stresses for continuous operation (N/mm^2)

λ = Ratio of the number of revolutions to the number of maximum continuous revolutions.

2. Within the range below and at 80 % of the maximum continuous revolutions, the torsional vibration stresses not exceeding τ_2 given in the following formula may be accepted, only for transient operation by passing through rapidly the range where the stresses exceed τ_1:

$$\tau_2 = 2\tau_1 \quad (0 \le \lambda \le 0.8)$$

where:

τ_2 = Allowable limit of torsional vibration stresses for transient operation (N/mm^2)

3. The torsional vibration stresses are not to exceed τ_3 given in the following, within the range from the maximum continuous revolutions to 115 %.

(1) For 4 cycle in-line diesel engines and 4 cycle vee type diesel engines with firing intervals of 45° or 60°, the value of τ_3 is given by the following formula:

$$\tau_3 = 21 + 237(\lambda - 0.8)\sqrt{\lambda - 1} \quad (1.0 \le \lambda \le 1.15)$$

(2) For 2 cycle diesel engines and 4 cycle vee type diesel engines other than shown in (1) above, the value of τ_3 is given by the following formula:

$$\tau_3 = 16 + 237(\lambda - 0.8)\sqrt{\lambda - 1} \quad (1.0 \le \lambda \le 1.15)$$

where:

τ_3 = Allowable limit of torsional vibration stresses in the range over the maximum continuous revolutions (N/mm^2)

§ = As specified in **Par 1.**

4. In case where the specified minimum tensile strength of the shaft material exceeds 440 N/mm^2, or its yield strength exceeds 225 N/mm^2, the values of τ_1, τ_2 and τ_3 given in **Pars 1** to **3** may be increased by multiplying the factor f_m given in the following formula:

(1) For τ_1 and τ_3

$$f_m = 1 + \frac{2}{3}\left(\frac{T_s}{440} - 1\right)$$

(2) For τ_2

$$f_m = \frac{Y}{225}$$

where:

f_m = Correction factor for allowable limit of torsional vibration stresses concerning the shaft material

T_s = Specified minimum tensile strength of shaft material ($\mathrm{N/mm^2}$). However, in case where the specified minimum tensile strength exceeds 590 $\mathrm{N/mm^2}$ for carbon steel forgings, or 835 $\mathrm{N/mm^2}$ for low alloy steel forgings, the value of T_s for calculating f_m is to be as deemed appropriate by the Society.

Y = Specified minimum yield stress of the shaft material ($\mathrm{N/mm^2}$).

202. Intermediate shafts, thrust shafts, propeller shafts and stern tube shafts

1. For ships equipped with main propulsion diesel engine, the torsional vibration stresses on the intermediate shafts, thrust shafts, propeller shafts and stern tube shafts are to be in accordance with the following requirements (1) and (2).

(1) For continuous operation, the torsional vibration stresses are not to exceed τ_1 given in the following formulae:

$$\tau_1 = \frac{T_s + 160}{18} C_k C_d (3 - 2\lambda^2) \qquad (0 \le \lambda \le 0.9)$$

$$\tau_1 = 1.38 \frac{T_s + 160}{18} C_k C_d \qquad (0.9 \le \lambda \le 1.05)$$

where:

τ_1 = Allowable limit of torsional vibration stresses for continuous operation $\mathrm{N/mm^2}$.

λ = As specified in **201. 1.**

T_s = Specified minimum tensile strength of shaft material ($\mathrm{N/mm^2}$). However, the values of T_s for using in the formulae is not to exceed 600 $\mathrm{N/mm^2}$ for carbon steel forgings and 800 $\mathrm{N/mm^2}$ for low alloy steel forgings in intermediate shafts and thrust shafts, and 600 $\mathrm{N/mm^2}$ in propeller shafts and stern tube shafts. Where propeller shafts and stern tube shafts are made of the approved corrosion resistant materials or other materials having effective means against corrosion by seawater, the value of T_s for using in the formulae is to be as deemed appropriate by the Society.

C_k = Coefficient concerning to the type and shape of the shaft, given in **Table 5.4.1.**

C_d = Coefficient concerning to the shaft size and determined by the following formula:

$$C_d = 0.35 + 0.93 d^{-0.2}$$

d = Diameter of the shaft (mm)

Table 5.4.1 Values of C_k

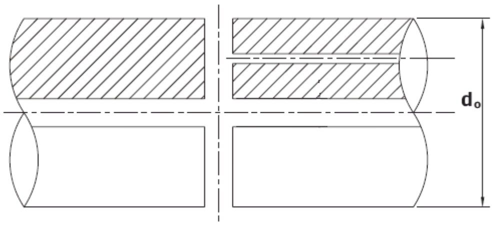
Intermediate shaft						Thrust shafts		Propeller shaft	Stern tube shaft
Integral coupling flanges	Shrink fit coupling flanges	Keyways (tapered connection)	Keyways (cylinderical connection)	Radial hole	Longitudinal slot	On both sides of thrust collar	In way of bearing when a roller bearing is used	-	
1.0	1.0 (1)	0.6 (2)	0.45 (2)	0.50 (3)	0.30 (4)(5)	0.85	0.85	0.55 (6)	0.8

NOTE:

(1) C_k refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase of 1 to 2 % in diameter to the shrink fit diameter and a blending radius nearly equal to the change in diameter are to be provided,

(2) Keyways are in general not to used in installations with a barred speed range.

(3) Diameter of radial bore not to exceed $0.3d_0$ When a transverse hole intersects an eccentric axial hole(see below), the values is to be determined by the Society based on the submitted data in each case.



(4) Subject to limitations as slot length(l)/outside diameter(d_o) < 0.8 and inner diameter(d_i)/outside diameter(d_o) < 0.8 and slot width(e)/outside diameter(d_o) > 0.10. The end rounding of the slot is not to be less than e /2. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The number of slots is to be 1, 2 or 3 and they are to be arranged 360, 180 or 120 degrees apart from each other respectively.

(5) C_k= 0.3 is a safe approximation within the limitations in (4) above. If the slot dimensions are outside of the above limitations, or if the use of another C_k is desired, the actual stress concentration factor is to be as deemed appropriate by the Society.

(6) Application to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller boss(or propeller flange), but not less than $2.5d_s$. Where ; d_s : required diameter of propeller shaft or stern tube shaft.

(2) Within the range below 80 % of the maximum continuous revolutions, the torsional vibration stresses not exceeding τ_2 given in the following formula may be accepted, only for transient operation by passing through rapidly the range where the stresses exceed τ_1.

$$\tau_2 = \frac{1.7\tau_1}{\sqrt{C_k}}$$

where:

τ_2 = Allowable limit of torsional vibration stresses for transient operation (N/mm^2)

τ_1, C_k = As specified in (1)

2. For main propulsion system formed by steam turbines, gas turbines, diesel engines having slide couplings such as electro-magnetic coupling or fluid couplings, or electric propulsion systems having reduction gear, allowable limits of the torsional vibration stress on the intermediate shafts, thrust shafts, propeller shaft and stern tube shafts are to be as deemed appropriate by the Society.

203. Shafting system of generators

1. Torsional vibration stresses on the crankshafts of diesel engines to drive generators are to be in accordance with the following requirements (1) and (2). However, where the strength calculation for crankshafts is carried out according to the special requirements given by the Society, these stresses are to comply with the special requirements.

(1) The torsional vibration stresses are not to exceed τ_1 given in the following, within the range from 90 % to 110 % of the maximum continuous revolutions.

(A) For 4 cycle in-line diesel engines and 4 cycle vee type diesel engines with firing intervals of 45° or 60°, the value of τ_1 is given by the following formula:

$$\tau_1 = 21 \text{ N/mm}^2$$

(B) For 2 cycle diesel engines and 4 cycle vee type diesel engines other than shown in (A), the value of τ_1 is given by the following formula:

$$\tau_1 = 16 \text{ N/mm}^2$$

(2) Within the range below and at 90 % of the maximum continuous revolutions, the torsional vibration stresses not exceeding τ_2 given in the following formula may be accepted, only for transient operation by passing through rapidly the range where the stresses exceed τ_1.

$$\tau_1 = 90 \text{ N/mm}^2$$

2. The torsional vibration stresses on the generator shafts driven by diesel engines are to be in accordance with the following requirements (1) and (2).

(1) The torsional vibration stresses are not to exceed τ_1 given in the following, within the range from 90 % to 110 % of the maximum continuous revolutions.

$$\tau_1 = 31 \text{ N/mm}^2$$

(2) Within the range below and at 90 % of the maximum continuous revolutions, the torsional vibration stresses not exceeding τ_2 given in the following formula may be accepted, only for transient operation by passing through rapidly the range where the stresses exceed τ_1.

$$\tau_2 = 118 \text{ N/mm}^2$$

3. In case where the specified minimum tensile strength of the shaft material exceeds 440 N/mm^2, or its yield strength exceeds 225 N/mm^2, the values of τ_1 and τ_2 given in **Pars 1** and **2** may be increased by multiplying the factor f_m given in **201. 4.**

204. Avoidance of major criticals

The major criticals of one node vibration in in-line diesel engine, e.g. the n th and n/2th order for 4 cycle and the nth order for 2 cycle (n denotes the number of cylinders), are not to exist within the following speed range except when an approval is specifically obtained by the Society:

For main propulsion shafting system	$0.8 \le \lambda \le 1.1$
For generator shafting system	$0.9 \le \lambda \le 1.1$

where

λ = Ratio of the number of revolutions at the major critical to the maximum continuous revolutions

205. Detailed evaluation for strength

Special consideration will be given to the allowable limit of torsional vibration stresses not complying with the requirements in **201.** to **203.** provided that detailed data and calculations are submitted to the Society and considered appropriate.

206. Barred speed range

1. In case where the torsional vibration stresses exceed the allowable limit τ_1 specified in 201. to 203., the barred speed ranges are to be imposed in accordance with the following. The barred speed ranges are to be marked with red zones on the engine tachometers for passing through the ranges as rapidly as possible.

(1) the barred speed ranges are to be imposed between the following speed limits.

$$\frac{16N_c}{18-\lambda} \le N \le \frac{(18-\lambda)N_c}{16}$$

where:

N = The number of revolutions to be barred (rpm)

N_c = The number of revolutions at the resonant critical (rpm)

λ = Ratio of the number of revolutions at the resonant critical to the maximum continuous revolutions

(2) For controllable pitch propellers, both full and zero pitch conditions are to be considered.

(3) Restricted speed ranges in one cylinder misfiring conditions are to enable safe navigation even where the ship is provided with one propulsion engine.

2. In case where there are problems such as chattering or generation of heat caused by excessive alternating torque arising from the torsional vibration in the gears and flexible couplings, the requirement for those speed ranges is to comply with preceding **Par 1.** However, excessive alternating torque is not to be occurred in the speed range specified in **204.**

3. In case where the range in which the stresses exceed the allowable limit τ_1 specified in **201.** to **203.** is verified by measurements, such range may be taken as the barred speed range for avoiding continuous operation, notwithstanding the required range specified in the preceding **Par 1,** having regard to the tachometer accuracy.⚓

CHAPTER 5 BOILERS AND PRESSURE VESSELS

Section 1 Boilers

101. Application

1. The requirements in this Section apply to welded type boilers and their accessories, provided that the following are excluded from the scope.

(1) Steam boilers with design pressure not exceeding 0.1 MPa and heating surface not exceeding 1 m^2.

(2) Hot water boilers with design pressure not exceeding 0.1 MPa and heating surface not exceeding 8 m^2.

2. In cases where boilers are of unconventional construction and the requirements of this Section are unsuitable to be applied, the manufacturer is to submit the detailed plans, data and strength calculations for the construction to the Society for its approval.

102. Materials

1. The materials used in the construction of the pressure parts of boilers are to comply with the following requirements.

(1) All materials used for boilers are to comply with the requirements in **Pt 2, Ch 1.**

(2) The materials of fittings for boilers and piping systems are to comply with the requirements in **Pt 2. Ch 1.** However, where deemed as appropriate by the Society, the Society may accept to use the materials which meet Korean Industrial standards or equivalent.

(3) In case where heat treatment, such as hot working or stress relieving, is carried out on steel plates during the manufacturing process of boilers, the manufacturer is to inform of such intention with an order for the materials. What are expected of the manufacturer of steel plates in this case, are prescribed in **Pt 2, Ch 1, 302.3.**

(4) Appropriate heat treatments are to be carried out on the cold-formed steel plates, where it is considered that the cold-forming affects the safety of boiler.

2. Cast steel may be used in the shell plates or the end plates of the boilers where the thickness does not exceed 50 mm and the maximum working temperature does not exceed 350 °C.

3. Steel tubes

(1) Tubes used for boilers, which are subjected to the internal pressure and come in contact with fire or combustion gas, are to be either seamless steel tubes or electric resistance welded steel tubes.

(2) *RSTH* 33 as electric resistance welded steel tubes may be used for a boiler which has the design pressure of 2 MPa or below, at the places where wall temperatures are estimated to be 350 °C or below.

(3) *RSTH* 35 and *RSTH* 42 as electric resistance welded steel tubes may be used for a boiler which has the design pressure of 3 MPa or below, at the place where wall temperatures are estimated to be 400 °C or below.

4. Pipe fittings for boiler

(1) Stand pipes, flanges or distance pieces attached directly to boiler drums are to be made of steel.

(2) Valve chests or other pipe fittings which are connected to a boiler and are subjected to its pressure, are to be made of steel except for the following cases :

(A) The copper alloy castings may be used in cases where the maximum working temperature does not exceed 200 °C.

(B) The grey iron castings may be used for pipe fittings except for blow-off valve in cases where the maximum working temperature and the design pressure do not exceed 220 °C and 1 MPa respectively.

(C) Special cast iron may be used in cases where the castings are made by the specifically approved manufacturers, and the maximum working temperature and the design pressure do not exceed 230 °C and 2.5 MPa respectively.

103. Type of joint

Longitudinal and circumferential joints of boilers are to be of the approved double welded butt joints. However, for cylindrical shells of small diameter, where the inside welding is considered difficult, the joints may be of the single welded butt joint subject to the approval by the Society.

104. Welding method for each part

The welding methods to be adopted for each part are to be as those shown in **Fig 5.5.1** or the equivalent. The definitions of representative symbols are stated at the end of the figures.(Unit : mm)

105. Efficiencies of joints

The values of efficiencies of joints for the shells of boilers are to be as follows in relation to their application and type of joints.

(1) For seamless shells : J = 1.00

(2) For welded shells :

(A) Double welded butt joints : J = 1.00

(B) Other cases : J = 0.90

106. Ligament efficiency

1. The efficiency of longitudinal ligament (hereinafter referred to as "**longitudinal efficiency**") along the row of tube holes of shell plate having a row parallel or nearly parallel to the shell axis, or of shell or tube plate having several parallel rows with sufficient distance to each other, is to be determined by the following formula.

(1) In case where the pitch of tube holes is uniform (See **Fig 5.5.2**(a))

$$J = \frac{P-d}{P}$$

where :

J = Efficiency of ligament

P = Pitch of tube holes (mm)

d = Diameter of tube holes (mm)

(2) In case where the pitch of tube holes is irregular (see **Fig 5.5.2**(b))

$$J = \frac{L-nd}{L}$$

where :

J, d = As specified in (1)

L = Total length between centres corresponding to n consecutive ligaments (mm)

n = Number of tube holes in length L

2. The efficiency of circumferential ligament (hereinafter referred to as "circumferential efficiency") at the part of tube holes drilled in the circumferential direction of the shell is to be calculated in a similar manner to that prescribed in **Par 1** and is to be at least 0.50 times the efficiency of longitudinal ligaments. In this case, the pitches of tube holes in the circumferential direction are to be measured either on the flat plate before rolling or along the median line of plate thickness after rolling.

3. The efficiency of ligament at the part of tube holes drilled in the diagonal direction of the shell is to be determined by the following formula.

(1) Where tube holes drilled in the diagonal direction of the shell as shown in **Figs 5.5.2** (c) and

(d) : The value calculated by the following formula or longitudinal efficiency, whichever is lower, is to be used as the lowest efficiency of ligaments. (see **Fig 5.5.3**)

$$J=\frac{2}{A+B+\sqrt{(A-B)^2+4C^2}}$$

$$A=\frac{\cos^2\alpha+1}{2\left(1-\frac{d\cos\alpha}{a}\right)}$$

$$B=\frac{1}{2}\left(1-\frac{d\cos\alpha}{a}\right)(\sin^2\alpha+1)$$

$$C=\frac{\sin\alpha\cdot\cos\alpha}{2\left(1-\frac{d\cos\alpha}{a}\right)}$$

$$\cos\alpha=\frac{a}{\sqrt{a^2+b^2}},\qquad \sin\alpha=\frac{b}{\sqrt{a^2+b^2}}$$

where :

J = Efficiency of ligament

α = As given in **Figs 5.5.2** (c), (d) and (e)

a, b = As given in **Figs 5.5.2** (c), (d) and (e) (mm)

d = Diameter of tube holes (mm)

(2) For the above requirements in (1), where the tube holes are arranged in a regular staggered spacing as shown in **Fig 5.5.2** (e) :
The value calculated by above formula, twice the circumferential efficiency or longitudinal efficiency, whichever is the lowest, is to be used as the lowest efficiency of ligament. (see **Fig 5.5.4**)

4. Where the efficiency of tube plate cannot be obtained by the above requirements due to the special pattern of tube holes, the manufacturer may submit to the Society for its approval an alternative method of calculating the efficiency.

Fig 5.5.1 Examples of Welded Joints

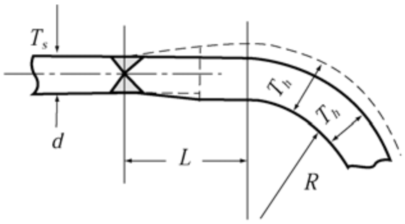
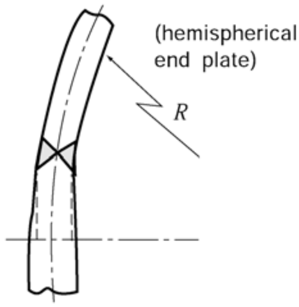
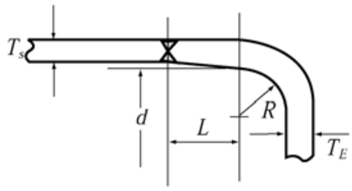
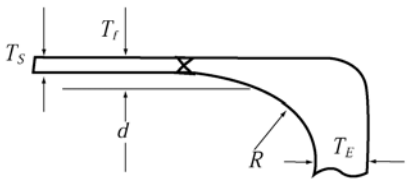
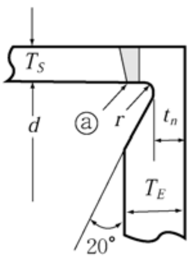
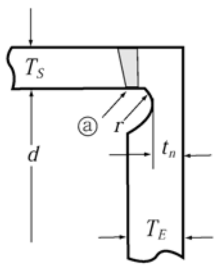
Welding part	Symbol	Welding mode	Remark
(1) Welding joint between formed end plate and shell plate	1 A		$L \geq 3T_h$ (but, need not be more than 38 mm.). Where $T_h \leq 1.25T_s$, the above mentioned value may be reduced.
	1 B		
(2) Welding joint between flat end plate or cover plate and shell plate	2 A		(1) L = see **Table 5.5.4** (2) $R \geq 3T_E$
	2 B		(1) $T_f \geq 2T_s$ (2) $R \geq 3T_f$
	2 C		(1) $r \geq 0.02T_E$ (but, not less than 5 mm) (2) $t_n \geq 1.25T_{ro}$ (3) In welding the part ⓐ, such welding process as should have a good penetration to the root is to be employed. (4) End plates or cover plates are to be made of forged steel.
	2 D		Same as above

Fig 5.5.1 Examples of Welded Joints (continued)

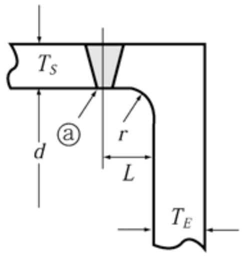
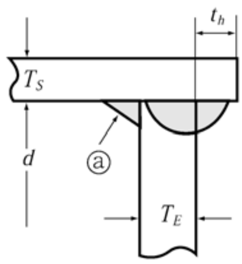
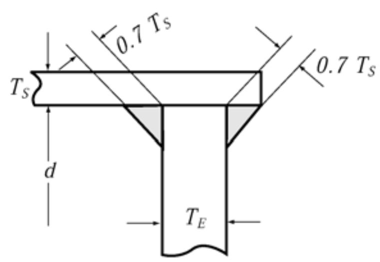
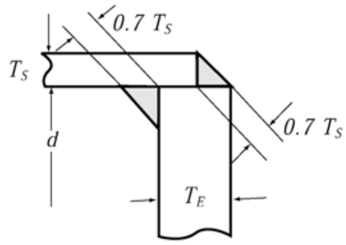
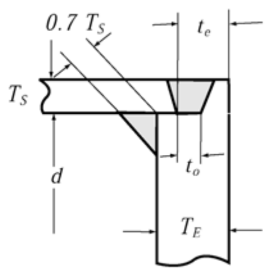
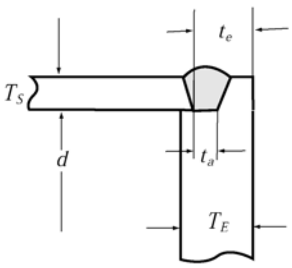
Welding part	Symbol	Welding mode	Remark
(2) Welding joint between flat end plate or cover plate and shell plate	2 E		(1) $r \geq 0.3T_E$ (2) $L \geq T_E$ (3) For the part ⓐ, the same is required as above. (4) End plates or cover plates are to be made of forged steel.
	2 F		(1) $T_s \geq 1.25T_{ro}$ (2) $t_h \geq T_s$ (3) Where the welding of part ⓐ is considered difficult, the backing strip is to be used or the welding process which should have a good penetration to the root is to be employed.
	2 G		$T_s \geq 1.25T_{ro}$
	2 H		
	2 I		(1) $T_s \geq 1.25T_{ro}$ (2) $t_o \geq T_s$ (but, need not be over 6.5 mm) (3) $t_e \geq 1.25T_s$
	2 J		(1) Tube headers only. (2) $T_s \geq 1.25T_{ro}$ (circular only) (3) t_e is not to be less than $2T_{ro}$ or 1.25 T_s, whichever is the larger. (4) $t_a \geq T_s$ (but, need not be over 6.5 mm)

Fig 5.5.1 Examples of Welded Joints (continued)

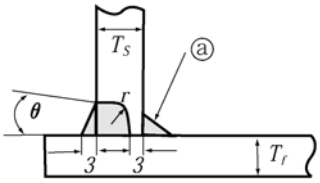
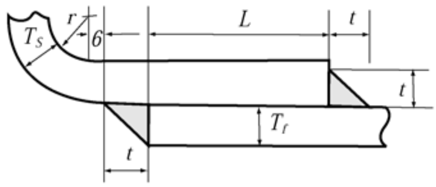
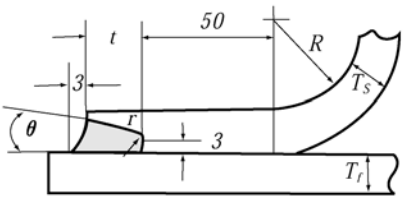
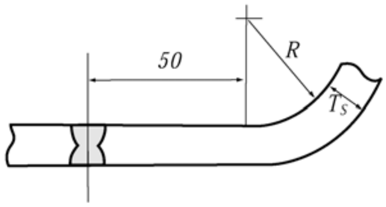
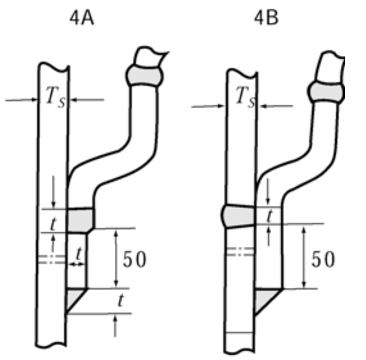
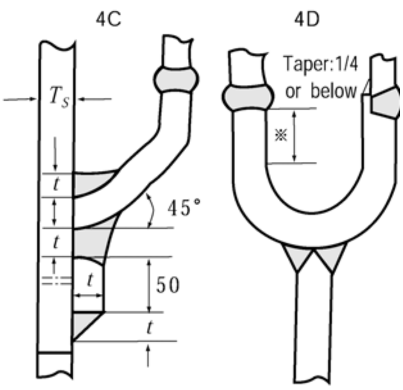
Welding part	Symbol	Welding mode	Remark
(3) Welding joint between flue or furnace and shell or end plate	3 A		(1) To be applied for welding of boiler front. (2) Light fillet welding is to be employed for part ⓐ, (throat depth 4~6 mm) (3) θ is to be 10°~20° (4) $5 \leqq r \leqq 10$
	3 B		(1) To be applied for welding of boiler front. (2) $t \geq T_f$ (3) $L \geq 2T_s$
	3 C		(1) To be applied for welding of boiler front. (2) $t \geq T_s - 3$ (3) θ is to be 10°~20° (4) $5 \leqq r \leqq 10$
	3 D		To be applied for welding of boiler rear.
(4) welding joint between furnace ogee ring and shell plate	4 A 4 B		(1) $t \geq T_s$ (2) The welded surface is not be lower than the plate surface.
	4 C 4 D		

Fig 5.5.1 Examples of Welded Joints (continued)

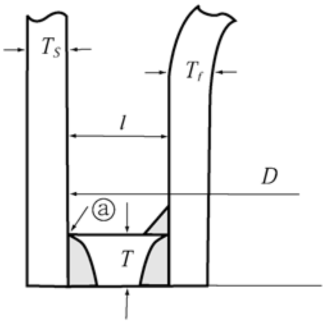
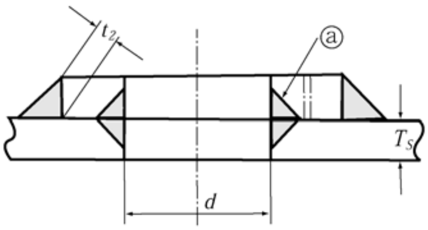
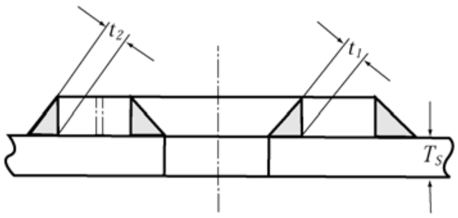
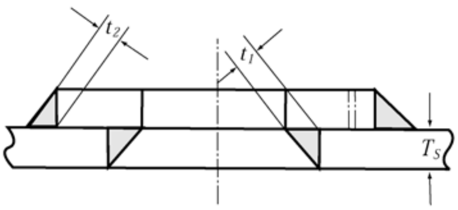
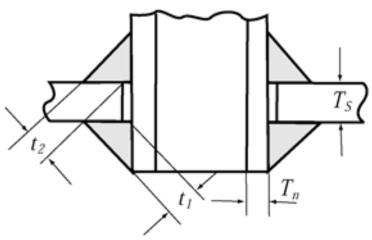
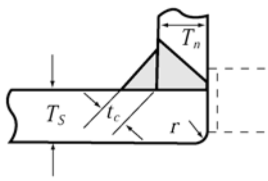
Welding part	Symbol	Welding mode	Remark
	4 E		(1) $T \geq 1.265\sqrt{DP}$ Where : D = Inside diameter of shell (mm) P = Design pressure (MPa) T = Thickness of foundation ring (mm) (2) Where $D \leqq 750$: $l \geqq 50$ Where $D > 750$: $l \geqq 60$ (3) In welding the part ⓐ, such welding process as should have a good penetration to the root is to be employed.
(5) Welding joint between washer or reinforcement ring and shell or end plate	5 A		(1) In case of $d < 60$, to be applied. (2) $t_2 \geq 0.7t_m$ (3) The seal welding is to be employed for part ⓐ.
	5 B		(1) $t_1 + t_2 \geq 1.25t_m$ (2) t_1 , $t_2 \geq \frac{1}{3}t_m$ (but, the minimum is 6.5 mm)
	5 C		
(6) Welding joint between nozzle and shell or end plate	6 A		(1) $t_c \geqq 6.5$ or $0.7t_m$, whichever is the smaller. (2) $t_1 + t_2 \geq 1.25t_m$ (3) t_1 , $t_2 \geq \frac{1}{3}t_m$ (but, the minimum is 6.5 mm) (4) $t_w \geq 0.7t_m$
	6 B		

Fig 5.5.1 Examples of Welded Joints (continued)

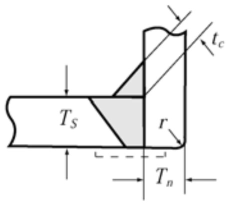
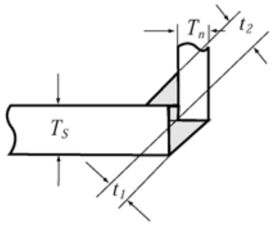
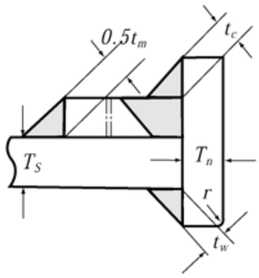
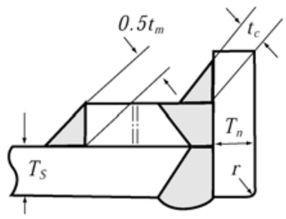
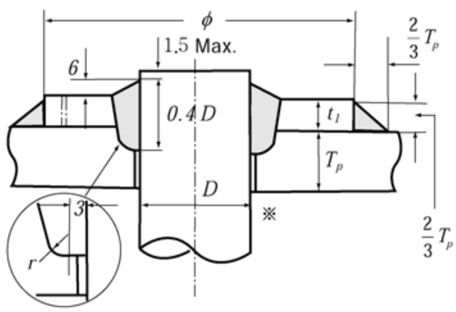
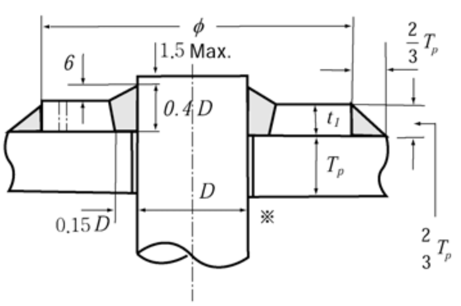
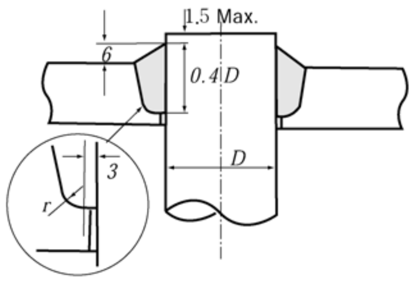
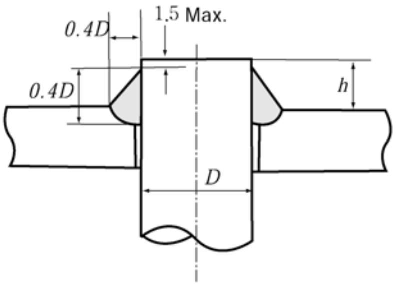
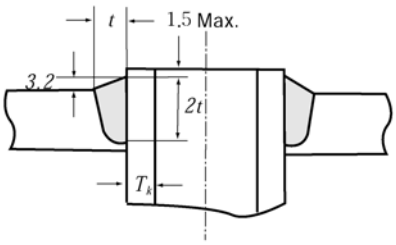
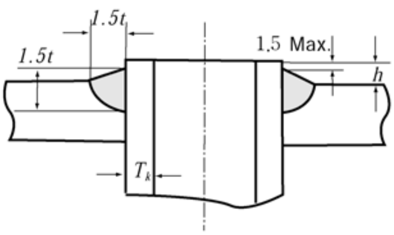
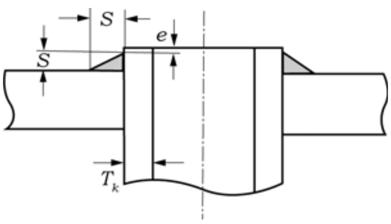
Welding part	Symbol	Welding mode	Remark
(6) Welding joint between nozzle and shell or end plate	6 C		(1) $t_c \geqq 6.5$ or $0.7t_m$, whichever is the smaller. (2) $t_1 + t_2 \geq 1.25t_m$ (3) t_1 , $t_2 \geq \frac{1}{3}t_m$ (but, the minimum is 6.5 mm) (4) $t_w \geq 0.7t_m$
	6 D		
	6 E		
	6 F		
(7) Welding joint between stay stay tube or tube and tube plate or end plate	7 A		(1) $\phi \geq \frac{2}{3}P$, P means the pitch of stay (same in the following) (2) $t_1 \geq \frac{2}{3}T_p$ (3) For the part marked ※, the light fillet welding (throat depth 4~6 mm) or caulking from the plate side is to be done to fill up the gap.
	7 B		(1) $\frac{2}{3}P > \phi \geq 3.5D$ (2) $t_1 \geq \frac{2}{3}T_p$ (3) The part marked with ※ is to be treated as mentioned above.

Fig 5.5.1 Examples of Welded Joints (continued)

Welding part	Symbol	Welding mode	Remark
(7) Welding joint between stay、 stay tube or tube and tube plate or end plat	7 C		
	7 D		On the side exposed to flame, $h \leqq 10.0$
	7 E		(1) $t \geq T_k$ (2) To be welded after expanding the tube, and after the welding the tube is to be further expanded slightly.
	7 F		(1) $t \geq T_k$ (2) To be welded after expanding the tube, and after the welding the tube is to be further expanded slightly. (3) On the side exposed to flame, $h \leqq 10$
	7 G		(1) $S \geq T_k + 3$ (2) On the side exposed to flame, $e \leq 1.5$ (3) To be welded after expanding the tube

NOTES :

T_s : Actual thickness of shell plate
T_h : Actual thickness of formed end plate
T_E: Actual thickness of flat end plate or cover plate
T_{ro} : Required thickness of seamless shell
T_p : Actual thickness of tube plate or flat end plate (formed end plate)
T_f : Actual thickness of flue or furnace plate, actual thickness of the flange on a forged head at the large end.
T_n : Actual thickness of nozzle
t_m : Smaller value of thickness of plates to be welded, however, the maximum value being 20 mm
T_k : Actual thickness of stay tube or tube.

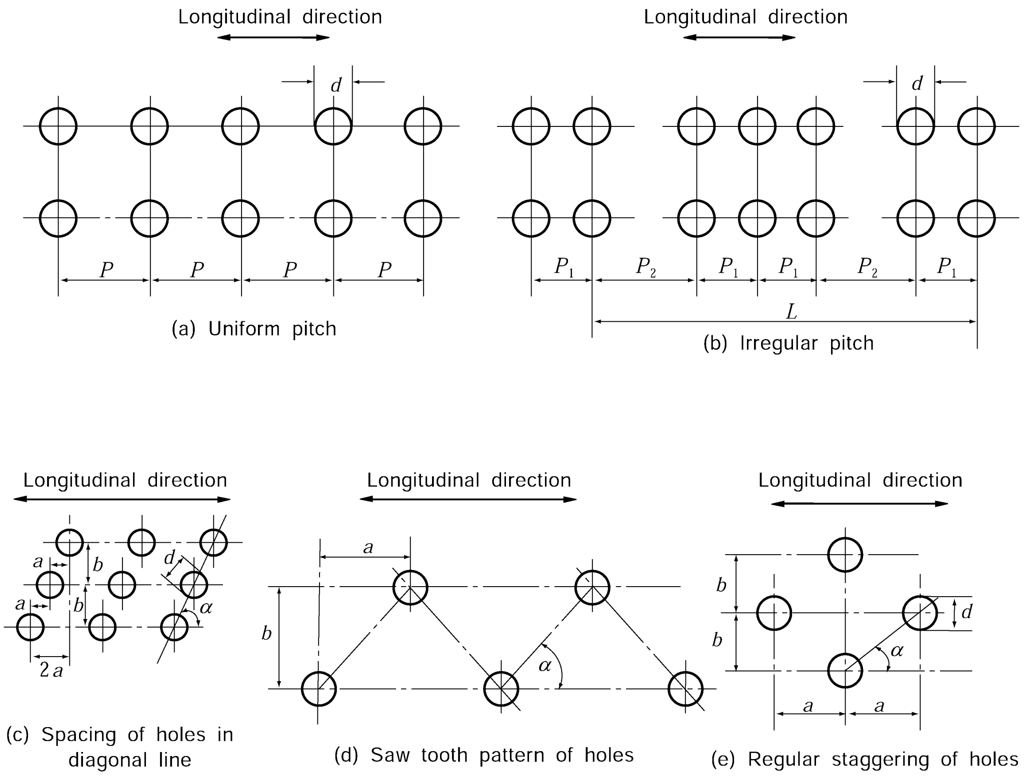


Fig. 5.5.2 Tube Holes

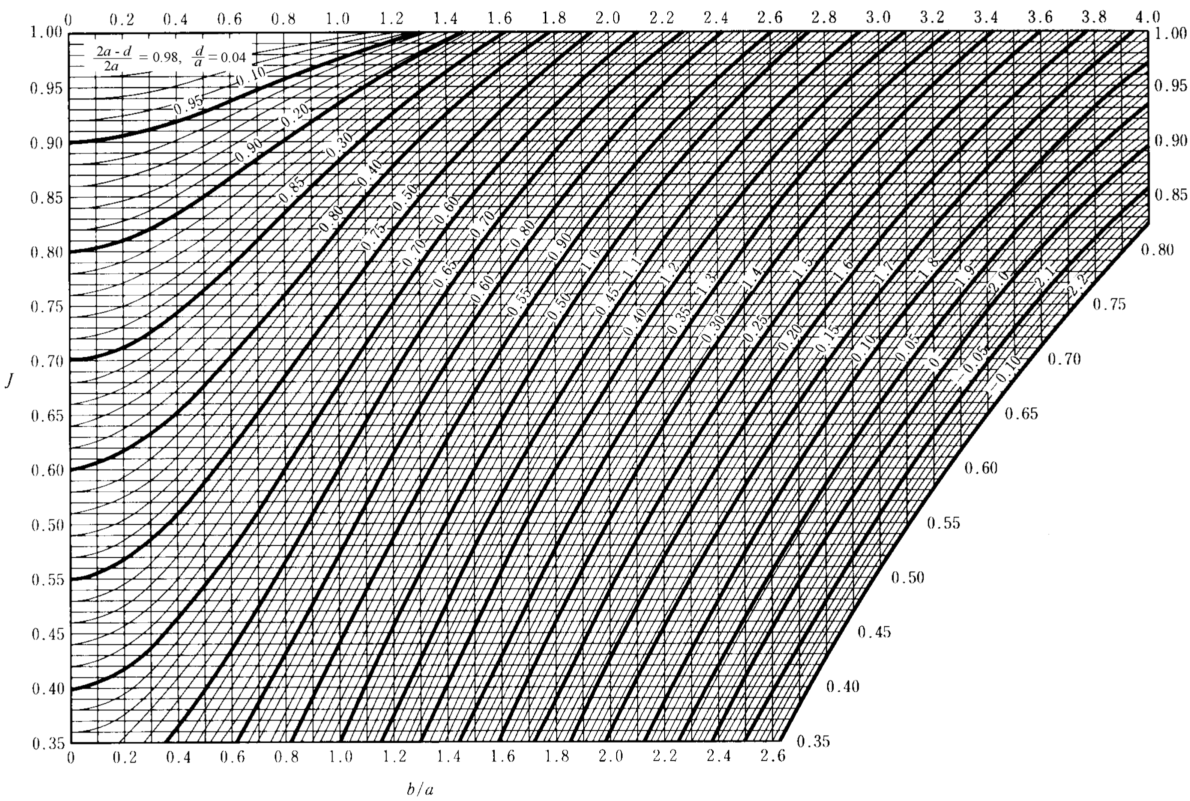
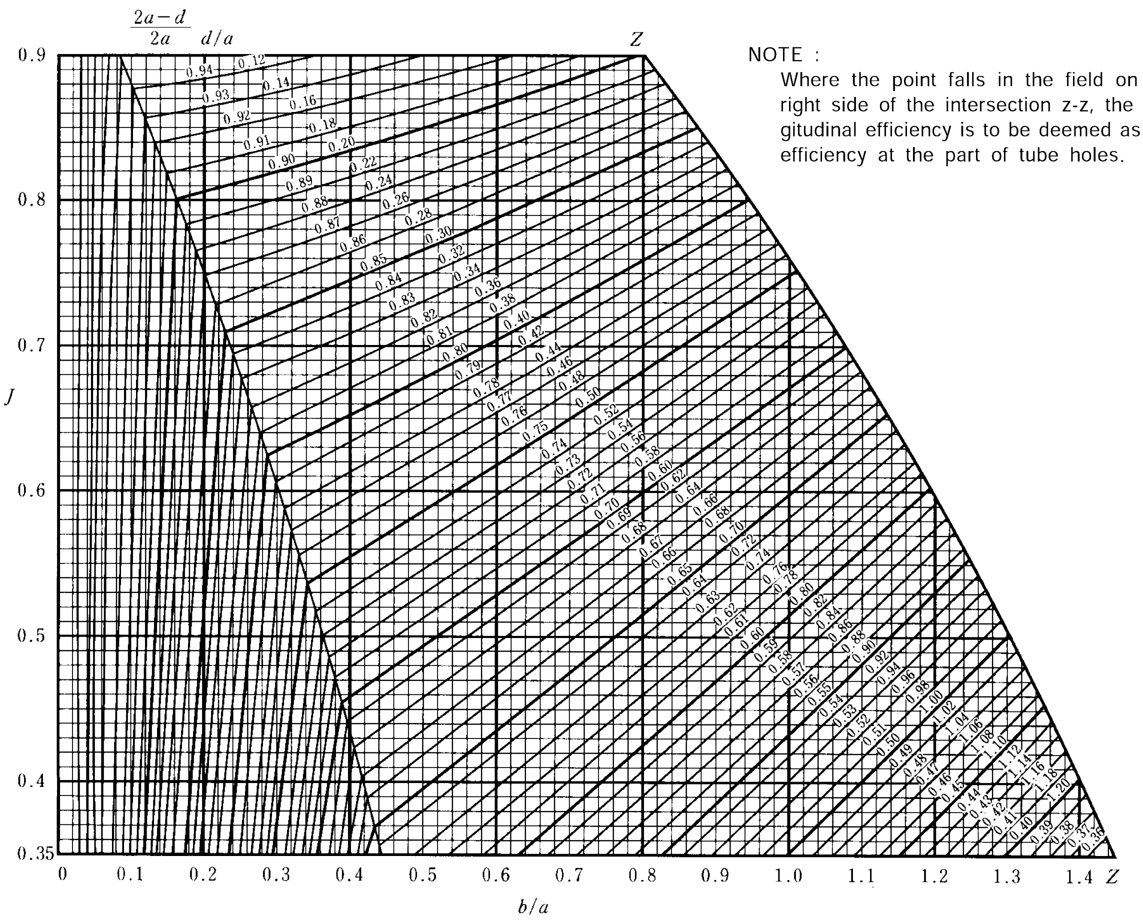


Fig. 5.5.3 The Efficiency of Ligament at the Part of Tube Holes Drilled in the Circumferential Direction



NOTE :
Where the point falls in the field on the right side of the intersection z-z, the longitudinal efficiency is to be deemed as the efficiency at the part of tube holes.

Fig. 5.5.4 The Efficiency of Ligament at the Part of Tube Holes Drilled in the Diagonal Direction

107. Allowable stress

1. The metal temperature at the heating surface, used to evaluate the allowable stress is to be taken as not less than the planned maximum temperature of the internal fluid increased by the temperature indicated in **Table 5.5.1.**

Table 5.5.1 Increase of Material Temperature

Heating surface in general	Heated by contact	25 °C
	Heated by radiation	50 °C
Heating surface of superheater	Heated by contact	35 °C
	Heated by radiation	50 °C
Heating surface of economizer	-	25 °C

2. The allowable stresses which are used for the calculation of strength in this Section are to be as follows.

(1) The allowable stress of carbon steel (including carbon manganese steel, hereinafter the same being referred in this Section) and low alloy steels excluding cast steels is not to be greater than obtained from the following formulae, whichever is the smallest. The allowable stress at each metal temperature may also be in accordance with the values given in **Table 5.5.2** instead of

the following formulae.

$$f = \frac{R_{20}}{2.7}, \quad f = \frac{f_R}{1.6}, \quad f = \frac{E_T}{1.6}, \quad f = \frac{S_C}{1.0}$$

where :

R_{20} = Specified minimum tensile strength at room temperature (N/mm^2)

f_R = Average stress to produce rupture in 100,000 hours at the design temperature (N/mm^2)

E_T = Specified minimum yield stress or 0.2 percent proof stress (N/mm^2)

S_C = Average stress to produce an elongation (creep) of 1 % in 100,000 hours at metal temperature (N/mm^2)

(2) The allowable stress of cast steels is to be 80 % of the value obtained by the formula in (1) or the value given in **Table 5.5.2.**

(3) The allowable stress of materials other than those specified in (1) and (2) will be considered in each case by the Society taking account of the mechanical properties of the materials.

Table 5.5.2 Allowable Stress (*f*)

Kind of materials		Allowable stress N/mm^2 (1)											
		250 °C and below	300 °C	350 °C	375 °C	400 °C	425 °C	450 °C	475 °C	500 °C	525 °C	550 °C	575 °C
Steel plates for boiler	*RSP* 42	110	104	103	96	88	76	57	39				
	RSP 46	122	117	113	106	95	80	58	39				
	RSP 49	124	122	121	114	102	84	58	39				
	RSP 46*A*	122	117	113	113	113	108	101	90	69	48		
	RSP 49*A*	124	122	121	121	121	117	106	91	69	48		
	RSP 56*A*	157	147	137	137	137	131	119	99	69	48		
Steels for header	*RBH*-1	105	104	103	97	88	76	57	39				
	RBH-2	117	115	113	106	95	80	58	39				
	RBH-3	102	99	96	96	96	93	91	87	67			
	RBH-4	106	104	103	103	103	102	98	92	74			
	RBH-5	106	104	103	103	103	102	98	92	81	64		
	RBH-6	106	104	103	103	103	102	98	92	81	64		
Steel tubes for boiler (2)	*RSTH* 33	86	84	81	78	74							
	RSTH 35	88	87	86	82	76	66	53					
	RSTH 42	113	104	103	97	88	76	57					
	RSTH 12	102	99	96	96	96	94	91	87	69			
	RSTH 22	106	104	103	103	103	102	98	92	81	64	44	
	RSTH 23	106	104	103	103	103	102	98	92	81	64	47	34
	RSTH 24	106	104	103	103	103	102	98	92	81	64	48	34
Forged Steel (3)		1/4 of specified minimum tensile strength of material (where 350 °C and below)											
Cast steel (3)		1/5 of specified minimum tensile strength of material (where 350 °C and below)											

NOTES :

(1) In case where the temperature of a material is between those indicated in the Table, the value of allowable stress is to be determined by interpolation.

(2) For the electric-resistance welded steel tubes, the values of f are to be 85 % of these values.

(3) Materials specified in **Pt 2, Ch 1.**

108. General construction and strength

1. Because the formulae of this Section do not take into account such additional stresses as load from boiler fittings, localized stress, repeated load, thermal stress and so on, some measures such as increasing the size, etc. are to be taken, in case those effects are considered to exist.

2. Economizer, exhaust-gas economizer and their accessories, and fittings on feed water pipes are to be designed to stand a pressure 1.25 times the design pressure of the boiler. Where, however, it is difficult to comply with the above, they may be designed basing upon the maximum working pressure of the feed water pump or the boiler water circulating pump concerned.

3. Where part of the boiler drum and tube header is of the construction exposed to flames or high temperature gas, the part is to be suitably insulated with non-combustible material and sheathed with steel or other non-combustive material. In case where a part of the flue gas duct is composed of the end plate at the vapour space of the cylindrical boiler, the exposure of that part of flame is to be avoided by preparing an intercepting plate.

4. The construction of shell type economizer is to be such that the inspection of welding part of the tube plate to shell plate can be easily carried out. And shell type economizer is to be provided with removable lagging at the welding part of the tube plate to shell plate to enable ultrasonic examination of the part even during subsequent surveys.

5. The fixed parts of the flue tube of the vertical boilers are to be so designed that deformation of the flue tube induced by the thermal expansion of the hemispherical furnace may not be extremely restricted.

6. Sufficient consideration is to be given to (1) and (2) to prevent overheat of the water tubes for the boilers having a high carolific capacity of combustion chamber :

(1) Boiler water is to sufficiently circulate to the water tubes
(2) Proper means such as water softner, etc. are to be provided, if necessary, to prevent attachment of scales.

7. Consideration is to be given to prevent exhaust gas boilers and exhaust gas economizers, from being damaged by a soot fire.

109. Shell plates and end plates

1. The thickness of shell plates or end plates is not to be less than the required thickness prescribed in **Table 5.5.3** and further is not to be less than 6 mm. The thickness of the formed end plate except for the full hemispherical end plate is not to be less than the thickness (calculated by using the efficiency equal to 1.00) of the shell to which the end plate is attached.

2. The required thickness of the end plate having openings for which reinforcement is required is to comply with the following :

(1) In case where the openings are reinforced in accordance with the requirements in **115. 2** the required thickness is to be calculated by the previous paragraph.
(2) Where an end plate has a flanged-in manhole or access opening with a maximum diameter exceeding 150 mm, and the flanged-in reinforcement complies with the requirements in **115. 6,** the thickness is to be calculated as follows :
(A) Dished or hemispherical end plates : The thickness is to be increased by not less than 15 % (if the calculated value is less than 3 mm, the value is to be taken to 3 mm) of the required thickness calculated by the formula in **Table 5.5.3.** In this case, where the inside crown radius of the end plate is smaller than 0.80 times the inside diameter of the shell, the value of the inside crown radius in the formula is to be 0.80 times the inside diameter of the shell. In calculating the thickness of the end plate having two manholes in accordance with this (A), the distance between the two manholes is not to be less than 1/4 of the outside diameter of the end plate.
(B) Semi-ellipsoidal end plates : The same requirements in **Table 5.5.3** are to be applied. However, in this case R_1 is to be 0.80 times the inside diameter of shell and E to be 1.77.

3. The required thickness of end plates subject to pressure on the convex sides is not to be less than that obtained from the formula for end plates subject to pressure on the concave sides provided that the value of design pressure P, in the formula is taken as 1.67 times P.

Table 5.5.3 Thickness of Shell Plates and End Plates

Shell plates and end plates		Thickness (mm)
Shell plates	Cylindrical	$T=\frac{PD_1}{2fJ-1.2P}+1.0$
	Spherical	$T=\frac{PR_1}{2fJ-0.2P}+1.0$
End plates	Dished(1)	$T=\frac{PR_2E}{2fJ-0.2P}+1.0$
	Semi-spherical	$T=\frac{PR_2}{2fJ-0.2P}+1.0$
	Semi-ellipsoidal(2)	$T=\frac{PD_2}{2fJ-0.2P}+1.0$

P = Design pressure (MPa)
J = Minimum value of the efficiencies prescribed in **105.** and **106.**
f = Allowable stress prescribed in **107. 2.** (N/mm^2)
D_1 = Inside diameter of shell (mm)
D_2 = Inside length of the major axis (mm)
R_1 = Inside radius of shell (mm)
R_2 = Inside crown radius (mm)

$$E=\frac{1}{4}\left(3+\sqrt{\frac{R_2}{r}}\right)$$

r = Inside knuckle radius (mm).

NOTES :
(1) The inside crown radius of dished end plate is not to be greater than the outside diameter of the flanged part of the end plate. The inside knuckle radius of end plate is not to be less than 6 % of the outside diameter of the flanged part of the end plate or 3 times the thickness of the end plate, whichever is greater.
(2) Half the minor axis inside the semi-ellipsoidal end plate is not to be less than 1/2 of half the inside major axis of the end plate.

110. Flat end plates or cover plates without stay or other supports

The required thickness of flat end plates and cover plates without stay or other supports is not to be less than that obtained by the following formula :

$$T=C_1C_2d\sqrt{\frac{P}{f}}+1.0 \quad (mm)$$

where :

P, f = As specified in **Table 5.5.3.**

d = Inside diameter of end plate at flange part in case of circular type (mm)
= Inside length of the shortest of the spans in case of non-circular type (mm)

C_2 = 1.00 for circular type

$C_2=\sqrt{3.4-\frac{2.4d}{b}}$ for non-circular type (but, need not exceed 1.6)

b = Inside length of the greatest of the spans perpendicular to d in case of noncircular end plates(mm)

C_1 = Constant determined by the fixing method and given in **Table 5.5.4.**

Table 5.5.4 Constant C_1

Fixing method	C_{11}
In case 2A in **Fig 5.5.1**	1) In case L is not restricted (circular or non-circular), C_1 = 0.50
	2) Where $L \geq (1.1 - 0.8 \times T_S^2/T_E^2)\sqrt{dT_E}$ (circular only), C_1 = 0.39
In case 2B in **Fig 5.5.1**	Circular or non-circular, C_1 = 0.50
In case 2C, 2D, 2E, 2G, 2H in **Fig 5.5.1**	Circular, C_1 = 0.55. Non-circular, C_1 = 0.70
In case 2F, 2J in **Fig 5.5.1**	Circular or non-circular, C_1 = 0.70
In case 2I in **Fig 5.5.1**	Circular only, C_1 = 0.55

111. Flat plates or tube plates with stay or other supports

1. The required thickness of tube plates and flat plates is not to be less than 10 mm for tube plates and 6 mm for flat plates, regardless of the following paragraphs.

2. The required thickness of flat plates supported by stays or stay tubes, arranged regularly is not to be less than that obtained by the following formula :

$$T = Cd\sqrt{\frac{P}{f}} + 1.0 \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

f = Allowable stress prescribed in **107. 2.** ($\mathrm{N/mm^2}$)

d = $\sqrt{a^2 + b^2}$

a = Horizontal pitch of stays or stay tubes (mm)

b = Vertical pitch of stays or stay tubes (mm)

C = Constant determined by the fixing methods of stays or stay tubes and given in **Table 5.5.5.** In case where various fixing methods are used, the value C is to be the mean of the constants for the respective methods.

Table 5.5.5 Constant C

Fixing method of stay or stay tube	C	
	In case the plates are exposed to flame	In case the plates are not exposed to flame
In case the stays are inserted into the plate as 7A in **Fig 5.5.1**	0.38	0.35
In case the stays are inserted into the plate as 7B in **Fig 5.5.1**	0.40	0.37
In case the stays are inserted into the plate as 7C in **Fig 5.5.1**	0.44	0.41
In case the stays are inserted into the plate as 7D in **Fig 5.5.1**	0.53	0.50
In case the stay tubes are inserted into the plate as 7E in **Fig 5.5.1**	0.45	0.42
In case the stay tubes are inserted into the plate as 7F in **Fig 5.5.1**	0.52	0.49
In case the stay tubes are inserted into the plate as 7G in **Fig 5.5.1**	0.52	0.49

3. At tube nests of tube plates supported by stay tubes arranged regularly, the required thickness of tube plates is not to be less than that obtained by the following formula :

$$T = Cd\sqrt{\frac{P}{f}} + 1.0 \quad (\mathrm{mm})$$

where :

P, f = As specified in **Par 2.**

d = Average length of four sides of the quadrilateral composed by four centre points of stay tubes at the corresponding parts (mm)

C = Constants determined by **Table 5.5.6.**

Table 5.5.6 Constant C

Fixing methods of stay tubes	C	
	In case the plates are exposed to flame	In case the plates are not exposed to flame
In case the stay tubes are inserted into the plate as 7 E in **Fig 5.5.1**	0.54	0.51
In case the stay tubes are inserted into the plate as 7 F in **Fig 5.5.1**	0.61	0.57
In case the stay tubes are inserted into the plate as 7 G in **Fig 5.5.1**	0.61	0.57

4. For the calculation of the required thickness of the flat plate in case where points of supports of stays or stay tubes are irregularly pitched, draw a maximum circle that passes through at least three points of supports with no point inside and the diameter d_1 of the circle is to be used as d in the formula in **Par 2,** or $\sqrt{a^2+b^2}$ is to be used as d in the formula in **Par 3.**

5. In case where the above formulae are applied, the commencement of curvature of the flange or the inside plain ends welded on shell or furnaces are to be regarded as points of supports, and the value of constant C in **Par 2** is determined by **Table 5.5.7.**

Table 5.5.7 Constant C

Item	C	
	In case exposed to flame	In case not exposed to flame
The commencement of curvature. However, when the inner radius of the curvature is greater than 2.5 times the thickness of the plate, the points located at a distance of 3.5 times the thickness of plate from outer surface of the flange may be considered as a commencement of the curvature.	0.39	0.36
The inside plain ends welded on shell or furnaces	0.47	0.43

112. Tube plates of vertical boiler

For vertical boilers where the smoke tubes are arranged horizontally, the required thickness of tube plate at the tube nests is not to be less than that obtained from the following formula or than that given by **111.3,** whichever is greater.

$$T = \frac{PD}{1.97fJ} + 1.0 \quad (\text{mm})$$

where :

P, f = As specified in **111. 2.**

D = Twice the distance between the axis of shell and the centre of the outer row of tube holes (mm)

$$J = \frac{P_i - d}{P_i}$$

P_i = Vertical pitch of smoke tubes (mm).

d = Diameter of tube holes (mm).

113. Tube plates of boilers with wet combustion chamber

The required thickness of rear tube plate in boiler with wet combustion chamber subjected to compression due to the pressure on the top plate is not to be less than that obtained by the following formula or than that obtained from **111. 3,** whichever is the greater.

$$T = \frac{PW}{183J} \quad (\text{mm})$$

where :

P = Design pressure (MPa)

W = Breadth at the top of combustion chamber (Inside distance between rear tube plate and back chamber plate) (mm)

$$J = \frac{P_i - d}{P_i}$$

P_i = Horizontal pitch of smoke tube (mm)

d = Inside diameter of ordinary smoke tube (mm)

114. Manholes, mud holes and peep holes

1. Manholes or mud holes are to be provided for boilers in a location where they do not come in the way on inspecting and cleaning of each portion of the boiler. The clear opening of manholes is to be not less than 300 mm by 400 mm. A mudhole opening in a boiler shell is not to be less than 60 mm by 90mm . Where, due to size or interior arrangement of a boiler, it is impractical to provide a manhole or other suitable opening for direct access, there are to be two or more suitable openings through which the interior can be inspected.

2. The manhole cover of internal type is to be provided with a spigot which has a clearance of not more than 1.5mm all round.

3. The minor axis of the oval opening to be provided on the shell plate is to be parallel to the longitudinal direction of the drum, except for the case where specially approved by the Society.

4. For the vertical boilers having cross tubes, a mud hole or some other proper attachment is to be provided for the purpose of cleaning the tube interior. Where, however, the diameter of the cross tubes is large, there are to be peep holes in the shell opposite to one end of each tube sufficiently large to permit the tube to be examined and cleaned in the easiest accessible position.

5. The caps of the peep holes of headers are to be rigid in construction, and the repetition of covering and uncovering is not to impair safety. In case where the cap is bolted, it is to be of such construction that the breakage of the bolts does not cause danger.

115. Reinforcement of openings

1. Openings in the shell are to be reinforced in accordance with the following Paragraph except single openings having a maximum diameter of not larger than 1/4 of the inside diameter of the shell and of not larger than 60 mm and the shell plate having margin in thickness for which no reinforcement is needed.

2. For openings in shell plates and formed end plates, reinforcement is to be provided in such a manner that the area of its cross section through the centre of the opening and normal to the surface of the opening is not less than that calculated by the following formula:

$$A = dT_r \quad (\mathrm{mm}^2)$$

where :

d = Maximum diameter of the finished opening in the longitudinal cross section for the shell plate or in the cross section for the end plate (mm)

T_r = Required thickness for a seamless shell or for a blank end plate (mm), except that, where the opening and its reinforcement are entirely within the spherical portion of a dished end plate, T_r is the thickness required for a seamless hemispherical end having the equal radius to the spherical portion of the head plate, and where the opening and its reinforcement are in semi-ellipsoidal end plate and are located entirely within a circle the centre of which coincides with the centre of the end plate and the diameter of which is equal to 80 % of the shell inside diameter, T_r is the thickness required for a seamless hemispherical head plate of a radius equal to 90 % of the shell inside diameter.

3. Where the flat head plates or cover plates prescribed in **110.** have openings with a diameter not exceeding one-half of the end plate diameter or the shortest span, the end plates are to have a total cross-sectional area of reinforcement not less than that given by the following formula :

$$A = 0.5dT_r \quad (\mathrm{mm}^2)$$

where :

d = Maximum diameter of holes (mm)

T_r = Required thickness calculated from the formula prescribed in **110.** (mm)

4. Effective limits of reinforcement

Reinforcement is to be provided within its effective limits. The limits of reinforcement are designated as the boundaries which are surrounded by two lines parallel to the centre line of the opening expressed by L and two lines vertical to inner and outer surfaces of the plate containing the centre of the opening expressed by H. The values of L and H may be taken as follows : (Also see **Fig 5.5.5**)

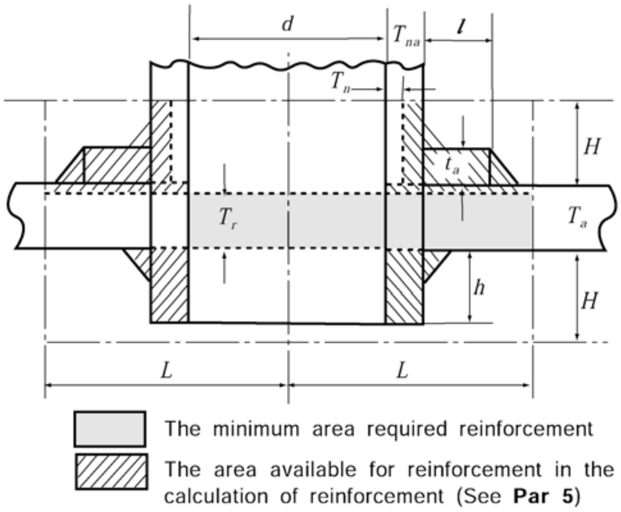


Fig. 5.5.5 Reinforcement of Holes

where :

L = d or $(d/2+T_a+T_{na})$, whichever is greater (mm)

H = $2.5T_a$ or $(2.5T_{na}+t_a)$, whichever is smaller (mm)

d = Diameter of opening in the cross section where reinforcement is intended (mm)

T_a = Actual thickness of the shell or end plate (mm)

T_{na} = Actual thickness of stand pipe (mm)

t_a = Actual thickness of reinforcement plate (mm)

5. The area available for reinforcement

The area available for reinforcement in the shell or end plate may be obtained as follows :

The total of these areas in each case is not to be less than the required sectional area A of reinforcement given in **Par 2** or **Par 3.** Where the opening requiring reinforcement passes through a joint in the shell or end plate, the actual area of the reinforcement is to be such that the efficiency of the joint is fully taken into account

$A_1 = (T_a - T_r)(2L-d)$ (mm²)

$A_2 = 2KH(T_{na} - T_n)$ (mm²)

$A_3 = 2KhT_{na}$ (mm²)

$A_4 = 2Kt_a l$ (mm²)

A_5 = Total section area of weld metal in one side (mm²)

$$A \le A_1 + A_2 + A_3 + A_4 + A_5$$

where :

T_a, T_{na}, t_a, d, L, H = As specified in **Par 4.**

T_r = As specified in **Par 2** or **3.**

T_n = Thickness of stand pipe provided as calculated from the formula in **Ch 6, 102. 6** minus corrosion allowance (mm)

h = Length of stand pipe within the effective limit where provided inside of the shell or end plate (mm)

l = Length of reinforcement in one side appearing in the cross section (mm)

$$K=\frac{Allowable\ stress\ of\ reinforcing\ material\ \text{or}\ stand\ pipe}{Allowable\ stress\ of\ shell\ \text{or}\ end\ plate}$$ (Provided that $K \leq 1.0$)

6. Where the end plate is bent around the manhole to form a flange, the depth of flange is not to be less than that obtained by the following formula :

Where the thickness of end plate is not more than 38 mm :

$$h = 3T_r \quad \text{(mm)}$$

Where the thickness of end plate exceeds 38 mm :

$$h = T_r + 76 \quad \text{(mm)}$$

where :

h = Depth of flange measured along the major axis of opening from the outer surface of end plate (mm)

T_r = The required thickness of end plate (mm)

116. Flues, furnaces, ogee rings and cross tubes

1. The thickness of flues is not to be less than that given by the following Paragraph and in no case is to be less than 5 mm and more than 22 mm.

2. The thickness of corrugated furnace plates is not to be less than that obtained by the following formula :

$$T = \frac{PD}{C} + 1.0 \quad \text{(mm)}$$

where :

P = Design pressure (MPa)

D = Minimum outside diameter measured at corrugated part of furnace (mm)

C = Constant determined by **Table 5.5.8.**

Table 5.5.8 Constant C

Furnaces	C
Morison, Deighton, Fox and similar furnaces	107
Leeds forge bulb furnaces	104

3. The required thickness of plain cylindrical furnace or cylindrical bottom of combustion chambers which are not reinforced by stays or other means is not to be less than that obtained by the following formulae, whichever is greater.

$$T_1 = \sqrt{\frac{PD(L+610)}{10,500}} + 1.0 \quad \text{(mm)}, \qquad T_2 = \frac{1}{325}\left(\frac{PD}{0.35} + L\right) + 1.0 \quad \text{(mm)}$$

where :

P = Design pressure (MPa)

D = External diameter of furnace or combustion chamber bottom (mm)

L = Length of furnace or depth of combustion chamber bottom (mm)

The length of furnace, however, is measured from commencement of curvature where the furnace plates are flanged and jointed to other plates, reinforcing rings, etc.

4. The required thickness of a hemispherical furnace without stays or other means is not to be less than that obtained by the following formula :

$$T = \frac{PR}{62} + 1.0 \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

R = Outside radius of hemispherical furnace (mm)

5. The required thickness of furnace supported by stays or other means or cylindrical steel plates exposed to flame is to be determined in accordance with the following requirements, choosing the value whichever is greater.

(1) The sum of the thickness calculated by the formula in **Par 3** and that given by the formula in **111. 2** using 0.50 times the design pressure specified.

(2) The sum of the thickness calculated by the formula in **111.2** and that given by the formula in **Par 3** using 0.50 times the design pressure specified, whichever is the greater.

6. Ogee rings

Where ogee rings are used to connect the furnace bottom of vertical boiler to shell and to sustain the whole load of the furnace, the required thickness of ogee rings is not to be less than that obtained by the following formula :

$$T = \frac{\sqrt{PD(D - D_0)}}{1010} + 1.0 \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

D = Inside diameter of boiler shell (mm)

D_0 = Outside diameter of the lower part of the furnace at the joint with ogee ring (mm)

7. Cross tubes

In cross tube boilers, the required thickness of cross tubes is not to be less than that obtained by the following formula. In no case, however, the thickness of cross tubes is to be less than 9.5 mm.

$$T = \frac{PD}{45} + 6.5 \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

D = Inside diameter of cross tubes (mm)

117. Stays, stay tubes and girders

1. The required diameter of stays or stay tubes is not to be less than that obtained by the following formula. However, the thickness of stay tube is not to be less than 6.0 mm for those in bounding rows of tube nests, nor 4.5 mm for others.

$$d = C_1 k \sqrt{PA} + C_2 \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

A = Area of plate supported by one stay or stay tube (mm^2)

$$k = \frac{1}{\sqrt{1-z^2}}$$

$z = \dfrac{Inside\ diameter}{Outside\ diameter}$, for stay tube

= 0, for stays

C_1, C_2 = Constants determined by **Table 5.5.9.**

Table 5.5.9 Constant C_1 and C_2

Description	C_1	C_2
Longitudinal stays without screws	0.127	3
Screwed stays	0.139	3
Stay tubes	0.158	0

2. Where stays are fitted diagonally, the required diameter of the stay is not to be less than that obtained from the formula in **Par 1** with the value of C_1 substituted by C_3 given in the following formula :

$$C_3 = C_1 \sqrt{\frac{L}{H}}$$

where :

L = Length of diagonal stay (mm)

H = Length of line, drawn perpendicular to boiler head or surface supported, to center of palm of diagonal stay (mm)

3. The required thickness of girders, or sum of the thickness in case of double plate construction supporting top plates of combustion chambers is not to be less than that obtained by the following formula :

$$T = \frac{PWP_i(W-a)}{CH^2S} \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

W = Width of combustion chamber at upper part (the inside distance between rear tube plate and back plate of combustion chamber) (mm)

P_i = Pitch of girders (mm)

a = Spacing of stay bolts supporting girder (mm). For the welding type, a is to be 0.

S = Specified minimum tensile strength of the girder material (N/mm^2)

H = Depth of girder at centre (mm)

C = Constants determined by **Table 5.5.10.**

Table 5.5.10 Constant C

Description		C
Bolt type	The number (n) of stay bolts in each girder is odd	$25\times\frac{n}{n+1}$
	The number (n) of stay bolts in each girder is even	$25\times\frac{n+1}{n+2}$
Welding type		31

4. For top and side plates of combustion chambers in boiler with wet combustion chamber, the distance between outer row of the nearest stay to tube plate or back plate and the commencement of curvature of tube plate or back plate is to be not more than the value of "a" calculated by substituting design pressure in the formula of **111. 2.**

5. Where the outer radius of curvature at the flange part joining the top and side plates of combustion chambers is less than one-half the allowable pitch, P_i, of the girder calculated by substituting design pressure in the formula in **Par 3,** the distance measured from the inside surface of side plate to the centre of girder adjacent to the side plate is not to be greater than the allowable pitch, P_i, of the girder. Where this radius is greater than one-half the value of P_i, the distance from the beginning point of the curvature at the flange part to the centre of the girder is not to be greater than one-half the value of P_i.

118. Headers

1. The required thickness of cylindrical headers is not to be less than that obtained by the formula in **Table 5.5.3.**

2. The required thickness of square headers is not to be less than that obtained by the following formula :

$$T=\frac{Pl_2}{4f}\left(1+\sqrt{1+\frac{8fl_1^2}{CPl_2^2}}\right)+1.0 \quad (\mathrm{mm})$$

where :

P = Design pressure (MPa)

f = Allowable stress prescribed in **107. 2** (N/mm^2)

l_1 = Inside breadth measured between supports of flat surface for the strength calculation (mm)

l_2 = Inside breadth of another side adjacent to l_1 (mm)

C = 2.0, where holes are not arranged in succession

= 1.0 + J, where holes are arranged in succession.

J = Longitudinal efficiency of openings arranged in succession choosing the least value obtained in accordance with **106.**

3. Where the shape and dimension of the openings provided on headers are irregular, the minimum shell thickness of headers is to be specially considered by the Society.

4. Thickness of part of peep holes of tube header

The peep holes of tube headers are to be well machined so that they may be effectively covered. In this case, the thickness of the tube headers may be 1.0 mm less than that calculated by the formula in **Par 2,** but is not to be less than 9 mm.

119. Stand pipes

The thickness of stand pipes welded to shell is not to be less than either the value of 1/25 of the outside diameter of the stand pipes plus 2.5 mm or the value calculated by the formula in **Ch 6, 102. 6.** However, it need not exceed the required thickness of the shell at the part where the stand pipe is attached.

120. Boiler tubes

1. The thickness of the boiler tubes is not to be less than that given by the formula in **Par 2,** and not to be less than 2mm for the tubes less than 30 mm in outside diameter and not to be less than 2.5 mm for the tubes more than 30 mm in outside diameter. For tubes to be expanded or bent, their thickness is to be increased to compensate for thickness reduction due to expansion or bending.

2. The required thickness of smoke tubes for boilers is to be calculated by the following formula (1). And, the required thickness of water tubes, evaporating tubes, and superheater tubes subjected to the internal pressure of boilers is to be calculated by the following formula (2).

(1) $T = \frac{Pd}{70} + 2.0 \quad (\text{mm})$

(2) $T = \frac{Pd}{2f + P} + 1.5 \quad (\text{mm})$

where :

P = Design pressure (MPa)

d = Outside diameter of tube (mm)

f = Allowable stress prescribed in **107. 2** (N/mm^2)

3. Tube holes

Tube holes in the tube plates of drums are to be formed in such a way that the tubes can be effectively tightened in them. Where the tubes are practically normal to the tube plates, the parallel seating of the holes is not to be less than 10 mm in depth. Where the tube ends are not normal to the tube plate, the depth of the holes perpendicular to the tube plate is not to be less than 10 mm for tubes not exceeding 60 mm in outside diameter, and not to be less than 13 mm for tubes exceeding 60 mm in outside diameter.

4. Fixing

All tubes are to be tightly attached to the tube plate by expanding or other suitable methods and the ends are to project through the tube plate not less than 6 mm, except where being attached by welding. Both ends of tubes are to be fixed to tube plates in such a manner that they will never fall off. When fixing them simply with the tube end expanded in a flare shape, the taper is to be 30° or more.

121. Bolting methods of cover plates

1. Bolting methods of attaching unstayed cover plates are to follow the examples in **Fig 5.5.6** or other methods with the equivalent effectiveness, and the required thickness of unstayed cover plates is not to be less than that obtained by the following formulae.

(1) In case where a full-face gasket is used : (**Fig 5.5.6 A**)

$$T = d\sqrt{\frac{C_1 P}{f}} + 1.0 \quad (\mathrm{mm})$$

(2) In case where it is necessary to consider a moment due to gasket reaction : (**Fig 5.5.6 B**)

For circular plate : $T = d\sqrt{\frac{C_1 P}{f} + \frac{1.78\,Wl}{fd^3}} + 1.0 \quad (\mathrm{mm})$

For non-circular plate : $T = d\sqrt{\frac{C_1 C_2 P}{f} + \frac{6\,Wl}{fLd^2}} + 1.0 \quad (\mathrm{mm})$

where :

P = Design pressure (MPa)

f = Allowable stress given in **107. 2** ($\mathrm{N/mm^2}$)

d = Diameter of circular plate or the shortest span of non-circular plate measured as indicated in **Fig 5.5.6** (mm)

b = Longest span of non-circular plate measured perpendicular to the shortest span d (mm)

C_1 = Constant depending on attaching methods given in **Fig 5.5.6.**

$C_2 = 3.4 - 2.4d/b$ (but, need not exceed 2.5)

W = Total bolt load (N)

L = Length of non-circular curve through the centres of bolts (mm)

l = Arm length due to gasket reaction, equal to radial distance from the centre line of bolts to the line of gasket reaction (mm)

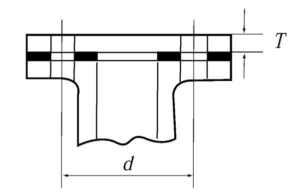
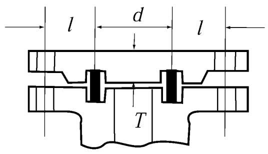
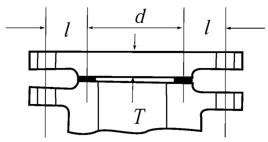
Symbol	Attaching method	Type and dimension	C_1	Remark
A	Bolted with full-face gasket		0.25 for circular and non-circular plates	—
B	Bolted	 	0.3 for circular and non-circular plates	W is mean value of the bolt load required for watertightness and the allowable bolt load in actual use.

Fig. 5.5.6 Examples of Bolting Methods of Cover Plates, etc.

122. Boiler mountings

1. The requirements in this Section apply to the fittings attached to boilers, such as valves, except where otherwise specified, and the requirements in **Ch 6** and **Pt 6, Ch 2** also apply respectively to the portions of boiler fittings that have close relation with piping systems and to the boilers that employ automatic and/or remote control.

2. Valves having nominal diameter not less than 50 A are to be of the outside-screw and yoke-rising-spindle type closing to the right hand with the bolted bonnet. Valves are to be fitted with an indicator to show whether the valve is opened or closed, except for the rising stem type.

3. All valves and cocks attached directly to a boiler are to be attached to the boiler with flange or by welding. Where stand pipes or distance pieces are used between the shell and mountings, they are to be as short as practicable. Where the thickness of boiler plate is 12 mm or above, or where a special stand for screwing is welded to the plate, the valves or cocks may be effectively attached to the boiler by pipe thread having a nominal diameter of 32 A and under. Where valves or cocks are attached to the boiler by stud bolts, the depth of threaded part inside the bolt holes is not to be less than diameter of bolt. The holes, however, are not to penetrate the whole thickness of the boiler plate.

123. The quantity and capacity of safety valves and relief valves

1. Boilers are to be fitted with not less than 2 spring loaded safety valves. However, only 1 safety valve may be accepted for the following boilers :

(1) Boilers with heating surface of less than 10 m^2

(2) Boilers with the design pressure of not more than 1 MPa, provided that they are equipped with a pressure controlling device and a device which cuts off fuel supply automatically at a pressure not exceeding the design pressure.

2. Safety valve with spring pilot valve may be used in lieu of spring loaded safety valve. The safety valve with spring pilot valve is to operate satisfactorily with the steam pressure.

3. In case where the boiler is provided with a superheater, at least one safety valve is to be fitted up at the outlet of the superheater.

4. Total area of safety valve seats

The total area of safety valve seats(for full bore valve, the required nozzle throat area) is not to be less than the required area given by the following formula. And, the seat diameter of safety valves is to be 25 mm or over, unless it is specially approved. For any boiler with an exhaust gas economizer which is so designed that it may be additionally heated while in use, the required area of the safety valves is to be calculated with the aggregated value of maximum evaporating capacity of boiler and evaporating capacity of exhaust gas economizer. But, the safety valves of the boiler having a superheater are to comply with **Par 6.**

(1) For saturated steam

$$A = \frac{KW}{10.5P + 1.0} \quad (\mathrm{mm}^2)$$

where :

A = Required area of safety valve seats (mm^2)

W = Designed maximum evaporating capacity (kg/hr)

P = Set pressure of safety valve (MPa)

K = Values given by **Table 5.5.11.**

Table 5.5.11 Values of K

Type of safety valves	K	Remarks
Ordinary type ($15 < D/L \leq 24$)	20.8	d_n : Diameter of throat (mm) L : Lift (mm) D : Inside diameter of valve seat (mm)
High lift type ($7 < D/L \leq 15$)	10.0	
Improved high lift type ($D/L \leq 7$)	5.0	
Full bore type ($D \geq 1.15\, d_n$)	3.34	

NOTES :
1. Where K is less than the above values, K is to be approved by the Society.

(2) For superheated steam
The area is to be the value calculated by the formula in (1), multiplied by

$$1 + \frac{Degree\ of\ superheat}{556}$$

5. Area of steam passages

(1) The required areas of steam passages of the ordinary type safety valve at the chest inlet and outlet are not to be less than 0.5 times and 1.1 times the required valve seat area respectively.
(2) The required areas of steam passages of the high lift type safety valve at the chest inlet and outlet are not to be less than the same and 2 times the required valve seat area respectively.
(3) The required areas of steam passages of the improved high lift type safety valve at the chest inlet and outlet are not to be less than 1.1 times and 2 times the steam passage area when the valve lift is 1/7 of the valve seat diameter respectively.
(4) The area of steam passage at the valve seat for the full bore safety valve is not to be less than 1.05 times the area at the throat, when the valve is open. Further, the areas of steam passages at the valve inlet and the nozzle are not to be less than 1.7 times the area at the throat, and the minimum steam passage area at the outlet is not to be less than 2 times the area at the valve seat when the valve is open.

6. Safety valve of superheater and reheater

(1) Where a superheater is considered as an integral part of a boiler with no intervening valve be-

tween the superheater and the boiler, the area of superheater safety valve seats may be included in determining the required total area of safety valve seats for the boiler as a whole, but is not to be credited of more than 25 % of the total capacity required in **Par 4.**

(2) The discharge capacity of the superheater safety valve is to be such that when main steam supply at normal load is shut down in an emergency, the superheater does not receive damages. In cases where this purpose cannot be achieved, the installation is to be provided so that a part of the fuel supply to the boiler is automatically shut down in emergency.

(3) One or more safety valves are to be fitted at the inlet and the outlet respectively of the independent reheater or the independent superheater, and the total discharge capacity is not to be less than the maximum passing steam quantity. The total discharge capacity of the safety valve provided at its outlet is not to be less than the quantity necessary to keep the steam temperature of the independent reheater or independent superheater not more than the designed point. However, for the independent superheater connected directly to the boiler which is designed with the same design pressure as that of the boiler, one or more safety valves are to be fitted at its outlet, and the total discharge capacity is not to be less than the quantity necessary to keep the steam temperature of the independent superheater not more than the designed point.

7. For the economizer and exhaust gas economizer equipped with a cutoff device from the boiler, one or more relief valves that are capable of discharging the quantity not lower than that calculated from the maximum absorbable energy are to be fitted. But, for shell type exhaust gas economizer having a total heating surface of 50 m^2 or more, two or more relief valves that are capable of discharging the quantity not lower than that calculated from the maximum absorbable energy are to be fitted.

124. Construction and tests of safety valves and relief valves

1. The safety valves and relief valves are to be so constructed that the springs and valves cannot be overloaded from outside and in case of fracture of the springs cannot spring out of their cages.

2. The valve springs are to be so set that the amount of contraction in length is not less than one-tenth the diameter of the valve seat, and the spring is to be such that the amount of permanent set will not exceed 1 % of the free length after it is fully compressed at cold state for 10 minutes.

3. The safety valves and relief valves are to be provided with easing gears which will surely open the valves in case of emergency and their handles are to be placed in a safe and easily accessible location.

4. The safety valves and relief valves are to be attached directly to boiler shells, headers, outlet connections of the superheater, or shells of shell type exhaust gas economizer by flanges or welded joints and the chests are to be of such type that they are not used in common with those of other valves. However, superheater safety valves may be fitted to the stand pipes or distance pieces attached at the outlet.

5. Relief valves for shell type exhaust gas economizers are to incorporate features that will ensure pressure relief even with solid matter deposits on the valve and guide, or features that will prevent the accumulation of solid matter in way of the valve and the in the clearance between the valve spindle and guide. Where no relief valves incorporating such features are fitted, a bursting disk discharging to suitable waste steam pipe is to be fitted in addition to the valve. The bursting disk is to function at a pressure not exceeding 1.25 times the economizer approved design pressure and is to have sufficient capacity to prevent damage to the economizer when operating at its design heat input level.

6. Waste steam pipe

(1) The waste steam pipe of the safety valve and relief valve is to be of such construction that back pressure does not interfere with operation of the valve. The inside diameter of the waste steam pipe is not to be less than the diameter of the valve outlet, and is to be designed at the pressure 1/4 or more of the setting pressure of the safety valve or relief valve.

(2) Where a common waste steam pipe is provided for two or more safety valves, the cross sectional area of the common pipe is not to be less than the aggregate area of required outlet area of each safety valve and where a common waste steam pipe is provided for two or more relief valves, the cross sectional area of the common pipe is not to be less than the aggregate area of

required outlet area of each relief valve. The waste steam pipes of boiler safety valves are to be separated from pipe lines containing drains such as waste steam pipes of relief valves for exhaust gas economizer or steam blow-out pipes to the atmosphere.

7. Drain

Draining hole having sufficient size is to be provided to the safety valve chest and the relief valve chest and the bursting disk specified in **Par 5** at the lowest part of the discharge side. Pipes for draining are to be led to a safety place clear of the boiler and exhaust gas economizer. No valves or cocks are to be fitted to these pipes.

8. Setting

The safety valve or relief valve is to be set in accordance with the following requirements at the completion of manufacturing at the factory and after the installation in the ship. And the valve is to operate satisfactorily while relieving at its setting pressure.

(1) The safety valve of the boiler drum is to be set to relieve steam automatically at a pressure not exceeding the design pressure. The range of pressure settings of all the drum safety valves is not to exceed 10 % of the highest pressure to which any safety valve is set. In no case is the relief pressure to be greater than the design pressure of the steam piping or that of the machinery connected to the boiler plus the pressure drop in the steam piping.

(2) Where a superheater is fitted, the superheater safety valve is to be set to relieve at a pressure no greater than the design pressure of the steam piping or the design pressure of the machinery connected to the superheater plus pressure drop in the steam piping. In no case is the superheater safety valve to be set at a pressure greater than the design pressure of the superheater. The superheater safety valve is to be set to relieve steam automatically at a pressure not greater than the value which is obtained by subtracting the setting pressure of the safety valve or valves at the boiler drum by the value of 0.035 MPa plus the steam pressure drop in the superheater at the rated load.

(3) The relieving pressure of the safety valve at the outlet of the superheater is to be set lower than that at the inlet.

(4) The relieving pressure of the relief valve provided to the economizer or exhaust gas economizer is to be set at a pressure not exceeding the design pressure.

9. Accumulation test

The accumulation test of the boiler is to be conducted in the methods specified below. However, in case the data on the evaporation of the boiler submitted to the Society has been approved, the accumulation test prescribed in (1) may be omitted.

(1) When the safety valve blows under the maximum firing condition of the boiler with the stop valves closed except for the valves for steam supply to the machinery necessary to the operation of the boiler, the accumulation of pressure in the boiler drum is not to exceed 110 % of the design pressure. In this case, however, the feed water necessary to maintain a safe water level may be supplied.

(2) For the oil burning boiler with superheater, where the accumulation test might endanger the superheater with possible overheating, the operation test of the installation by merely shutting down quickly the main steam supply under the maximum output of the boiler, as specified in **123. 6** (2).

10. In case the calculated discharge capacity of the safety valve does not comply with the requirement of **123. 4** on account of the reduction of the design pressure for the boiler, it may be accepted provided the accumulation test required by (1) of the preceding Paragraph has been carried out with satisfactory results.

125. Low water level safety device

Boiler is to be fitted with a low water level safety device which is capable of shutting off automatically the oil supply to the burners when the water level falls to a predetermined level higher than the critical level. The water level detector for this device is to be independent of water level detector for the feed water control system. For forced circulation boilers or once-through boilers, the safety device may be omitted, provided that the boiler is fitted with safety device specified in **129. 2.**

126. Steam stop valves

1. Main and auxiliary steam stop valves are to be fitted to the boiler shells at all steam outlets of boilers. Where a superheater is fitted as an integral part of a boiler, superheater steam stop valve is to be fitted at the superheater outlet side in order to prevent damage to the superheater.

2. Where the steam discharge pipes of two or more boilers are connected to each other, two stop valves are to be fitted between the boiler and the connecting part and the stop valve adjoining to the boiler is to be of the screw down check valve.

3. Where the diameter of steam stop valves exceeds 150 mm nominal diameter, by-pass valve is to be arranged as far as practicable for plant warm-up purpose.

127. Feed water connection and valves

1. A feed stop valve attached directly to the boiler is to be fitted to feed openings and a screw down check valve is to be provided as close to the stop valve as practicable. An approved feed water regulator may, however, be fitted between the check and stop valves.

2. Notwithstanding the requirement in **Par 1**, where the boiler has an economizer which is recognized as integral part of the boiler, the stop valves may be provided directly at the economizer inlet. In this case a screw-down check valve is to be provided as close to the stop valve as practicable.

3. Boilers fitted with economizers are to be provided with a check valve located in the feed water line between the economizer and the boiler drum. This check valve is to be located as close to the boiler drum feed water inlet openings as possible. When a by-pass is provided for the economizer, the check valve is to be of the stop-check type.

4. The part of the drum shell where feed water is discharged into the boiler is to be so arranged that a remarkable thermal stress may not occur due to direct contact of the feed water to the shell plate. This requirement is also to be applied to the parts of the boiler drum having desuperheater where the superheated steam pipes are penetrated through the drum.

5. Feed water discharge in the drum is to be distributed as far apart as practicable so that it may not impinge directly on the heating surfaces of the boiler at high temperature.

128. Blowoff valves and blowoff piping

1. Design

The design pressure of blowoff piping is not to be less than 1.25 times the design pressure of the boiler.

2. Blowoff valves

The boiler is to be provided with a blowoff valve mounted directly on its drum so that the boiler water may be discharged from the bottom of its water space ; its nominal diameter is not to be less than 25A but not more than 65A, except that for boilers with heating surface of 10 m^2 or less, the blowoff valve may be 20A in nominal diameter. Blowoff valves are to be of such construction that they are free from accumulation of scale and other sediments.

3. Blowoff pipe

(1) Where two or more boilers are installed and the blow off pipe of each boiler is connected to each other, screw-down check valves are to be fitted in each pipe line.
(2) Where the blowoff pipes are exposed to flame or high temperature gases, they are to be protected by thermal insulation materials.

129. Water level indicator

1. Each boiler is to be provided with at least two water level indicators independently, one of which is to be a glass water level gauge and the other is to comply with either of the following requirements. And, water level indicators other than glass water level gauge are to be type approved by the Society.

(1) Glass water level gauge located where the water level is easily read by the operator in his working area.
(2) Remote water level indicator, but, for the boiler whose design pressure is 1 MPa or under, this may be replaced with a level alarm device. In this case, remote water level indicator or detector for high and low water level alarm device is to be independent of the detector for the low water level safety device required in **125.**

2. For forced circulation or once-through boilers, where **Par 1** is not applicable for the indication of water level, a suitable level detector and the low water level safety device which are comprised of two detectors so designed to prevent the overheating of any part of the boiler by lack of water supply is to be provided.

3. In cases the water space in the boiler is long in the transverse direction of the ship, or an excessive difference in water level is feared to occur, the level indicators prescribed in **Par 1** are to be provided on both ends of the water space.

4. Construction of glass water level gauge is to be of the built-up rectangular-section box type(double-plate type) specified in the *Korean Industrial Standards or equivalent standards* or the equivalent approved by the Society.

5. The lowest visible part of the glass water gauge is to be at least 50 mm above the lowest permissible water level. The visible range of the remote level indicator is to be such that it covers all the possible water levels as related to the water level control in the boiler.

6. Each water gauge is to be fitted with shut-off valve or cock on the top and bottom, and drain valve at the bottom. Where top and bottom shut-offs of the watergauge are cocks, and where the water gauge or the water column is connected by the pipe to the boiler drum, the stop valves are to be fitted to the boiler drum.

7. The water column to which the water gauge is attached is to be strongly supported so that it may maintain its correct position. The inside diameter of the water column is to be 45 mm or over and the draining device with nominal diameter 20A or over is to be attached to the bottom of column. The connection pipes to the boiler drum are to be 15A or over for water gauge, and 25A or over for the water column in nominal diameter.

8. The connection pipes from the water column to the boiler are not to penetrate the flue, unless they are enclosed all through the flue and further the air passage of not less than 50 mm is provided around the pipes.

130. Pressure gauges and thermometers

1. The boiler drum, the superheater outlet and shell type exhaust gas economizer are to be provided with pressure gauges. These gauges are to be such that they have a scale 1.5 times and above the pressure at which the safety valves or relief valves are set and are to be placed where they can easily be observed. And they are also to be located such that the pressure can be easily read even from a position where the pressure can be controlled. In the scale of the pressure gauges, the approved working pressure and the working pressure at the superheater outlet are to be marked. A thermometer is to be provided at the outlet of superheater or reheater.

2. The pressure gauge is to be provided with a device to which a test pressure gauge for the indicator can be attached while the boiler is in operation, unless it is already equipped with a pressure gauge tester.

131. Monitoring of boiler water quality

1. Each boiler is to be provided with a boiler water takeout valve or cock in a convenient position of the body and the valve or cock is to be independent from a water gauge.

2. Boilers are to be provided with means such as water analyzer or other suitable device to supervise and control the quality of the feed water and boiler water.

132. Draught fans

The boilers are to be provided with draught fans with a capacity sufficient for the designed maximum steam evaporation of the boiler and for the stable combustion in the boiler within its service range. An alternative means which is available to ensure the normal navigation and cargo heating that is required continuously is to be provided, in the case of failure of the draught fan.

133. Safety devices and alarm devices

1. Fuel oil shut-off device

Each boiler is to be fitted with a safety device which is capable of shutting off automatically the fuel supply to all burners in the cases of the following :

(1) When automatic ignition fails.
(2) When the flame vanishes (in this case, the fuel oil supply is to be shut-off within 4 seconds after the extinguishing of flame).
(3) When the water level falls.
(4) When the combustion air supply stops.
(5) When the fuel oil supply pressure to the oil burners falls in the case of pressure atomizing, or when the steam pressure to the burners falls in steam atomizing.
(6) When considered necessary by the Society.

2. Alarm device

(1) Each boiler is to be provided with an alarm device which operates when the water level in the drum falls.
(2) In addition to the above, the main boilers are to be provided with alarm devices which operate in the following cases :
  (A) When combustion air supply reduces, or when the draught fan stops.
  (B) When the fuel oil supply pressure to the burner falls, in the case of pressure atomizing, or when the steam pressure to burner falls, in steam atomizing.
  (C) When the water level in boiler drum reaches to a high level.
  (D) When the steam temperature at the superheater outlet rises, if the superheater is provided.
  (E) When the exhaust gas temperature at the outlet of the gas type air preheater or economizer rises.
  Ff) When the flame vanishes
(3) For auxiliary boiler supplying steam to the turbines driving main generators, alarm devices which operate when the water level in the boiler drum reaches to a high level are to be provided in addition to those alarm devices given in (1).

134. Boiler installation

1. Boilers are to be efficiently insulated as far as possible and so arranged that all exterior parts, after lagging is removed, may be readily inspected or repaired. Boilers are to be so installed as to minimize the effect of the following loads or external forces.

(1) Ship motion or vibrations caused by machinery installations.
(2) External forces caused by the piping and supporting members fitted on the boiler.
(3) Thermal expansions due to temperature fluctuation.

2. Distance between boilers and fuel oil tanks

The distance between boilers and fuel oil tanks is to be 610 mm or more at the rear ends of the boilers and 457 mm or more at the other parts in order to prevent the oil temperature in the tanks from reaching the flash point of the oil. However, at the cylindrical part of a cylindrical boiler or the casing corners of a water tube boiler, the distance may be reduced down to 230 mm.

3. Water tube boilers

Water tube boilers are to be so arranged as to prevent the fuel oil from leaking into the bilge wells out of boiler bottom.

4. Dampers

In case dampers are installed in the funnels or uptakes of boilers, their openings are not to be reduced to more than 2/3 of the flue area when closed. They are to be capable of locking in any open position and the degree of the opening is to be clearly indicated.

5. Boiler casings

The boiler casings, the joints of funnels, and the covers of openings are to be so arranged as to prevent flue gas from leaking into the engines or boiler rooms.

6. Valves and cocks

All valve and cocks attached to boilers are to be so arranged as to have proper space around each of them in order to give facilities for their handling and repairing.

135. Drainage of superheaters and reheaters

Drain valves or cocks are to be arranged in the positions proper for draining water completely from the superheaters or reheaters.

136. Tests and Inspections

1. Hydraulic tests

Boilers, valves and cocks attached directly to a boiler, and water level indicators are to be tested by the hydraulic pressure specified in **Table 5.5.12** after construction in the presence of the Surveyor.

2. Tests and inspections of boiler

For the tests and inspections of the safety valves and accumulation tests of boilers, the requirements in **124. 8** and **9** are to be applied. Where boilers are automatically operated or remote-controlled, the requirements in **Pt 6, Ch 2, Sec 1** are to be applied.

Table 5.5.12 Test Pressure

Item	Test pressure
Boiler, superheater, reheater and the equivalent	1.5 times the design pressure
Economizer, exhaust gas economizer	1.5 times the design pressure in accordance with **108. 2.**
Valves and cocks attached directly to a boiler, superheater, reheater and the equivalent	2 times the design pressure of the boiler
Valves and cocks attached directly to a economizer and exhaust gas economizer	2 times the design pressure in accordance with **108. 2.**
Blow-off valves	2.5 times the design pressure of the boiler
Water level indicators	2 times the design pressure of the boiler

Section 2 Thermal Oil Heaters

201. Application

The thermal oil heaters heated by flame or combustion gas are to comply with the relevant requirements specified in **Sec 1** (in this case the term "boiler" is to be read as "thermal oil heater") as well as the requirements in this Section.

202. Safety devices for thermal oil heaters heated by flame

1. Temperature regulators are to be provided to control the temperature of the thermal oil within the predetermined range.

2. The master valve of the expansion tank is to be kept always open, and the burning system is to be interlocked in such a way that it does not start when the master valve is closed.

3. Safety valve or pressure relief pipe of sufficient capacity is to be provided.

4. The discharge pipes from the safety valve or the pressure relief pipe specified in **Par 3** are to have their open ends in the thermal oil tank with sufficient capacity.

5. The following safety devices are to be provided :

(1) Prepurging system for preventing explosion of the furnace gas.
(2) Fuel oil shut-off systems which operate in the following cases :
  (A) When the temperature of the thermal oil rises abnormally.
  (B) When the flow rate of the thermal oil falls or when the pressure difference of the thermal oil between the inlet and outlet of the heater falls.
  (C) When the level of the thermal oil in the expansion tank falls abnormally.

203. Safety devices for thermal oil heaters directly heated by the exhaust gas of engines

1. Safety devices etc., are to comply with the requirements in **202. 1, 3** and **4.**

2. The master valve of an expansion tank is to be kept normally open and, such a interlocking device that exhaust gas does not enter into the heater where the master valve is closed, is to be provided.

3. A by-pass damper is to be provided at the exhaust gas inlet of the thermal oil heater so that the engine can be operable even when the supply of the exhaust gas to the heater is shut-off.

4. Means are to be provided to prevent the leakage oil form thermal oil heaters or water used for fire fighting from flowing into the exhaust gas duct of the engine.

5. Stop valves are to be provided at the inlet and outlet of thermal oil of the thermal oil heater.

6. Audible-visible alarm is to be provided to warn on the following occasions and relayed to the monitoring station.

(1) When a fire breaks out in the thermal oil heater
(2) When abnormal high temperature of the thermal oil arises
(3) When the thermal oil leaks within the thermal oil heater
(4) When the flow rate of thermal oil falls, or when the pressure difference of the thermal oil between the inlet and outlet of the heater decreases
(5) When the liquid level in the expansion tank drops abnormally

7. A fixed fire extinguishing and cooling system as deemed appropriate by the Society is to be provided.

204. Thermal oil piping systems

Piping systems for thermal oil heaters are to comply with **Ch 6, Sec 10.**

Section 3 Pressure Vessels

301. Application

1. The requirements in this Section apply to pressure vessels and their fittings intended for marine service, provided that pressure vessels belong to Class 3 (PV-3) which are not used for important purposes are excluded.

2. In cases where pressure vessels are of unconventional construction and the requirements of this

Section are unsuitable to be applied, the manufacturer is to submit the detailed drawings, data and strength calculations for the construction to the Society for its approval.

3. The pressure vessels concerned in (1) to (3) are also to comply with the requirements in this Chapter except specially specified.

(1) Pressure vessels used for liquefied gas (**Pt 7, Ch 5**).
(2) Pressure vessels used for the refrigerating machinery (Requirements in **Ch 6, Sec 12** and **Pt 9, Ch 1**).
(3) Other pressure vessels used for inflammable gas or liquid are to comply with the separate requirements to the Society about the property and working condition of gas and liquid.

302. Classification

1. Class 1 pressure vessels (Symbol *PV*-1)

(1) Steam generators whose design pressure exceed 0.35 MPa.
(2) Pressure vessels in which inflammable high pressure gas having the vapour pressure not less than 0.2 MPa at 38 °C (hereinafter referred to as "inflammable high pressure gas") is contained. However, the requirements for "*PV*-2" may be applied to the pressure vessels with the capacity of 0.5 m^3 or under with respect to their materials, construction and welding.
(3) Pressure vessels whose shell plates exceed 38 mm in thickness, and/or whose design pressures exceed 4 MPa, and /or whose maximum working temperatures exceed 350 °C. However, the pressure vessels in which the shell plates exceed 38 mm in thickness and/or the design pressure exceed 4 MPa are classified as "*PV*-2", provided that they are subject to hydraulic pressure or water pressure at the atmospheric temperature.
(4) Pressure vessels contained ammonia or toxic gases.

2. Class 2 pressure vessels (Symbol *PV*-2**)**

(1) Steam generators whose design pressure do not exceed 0.35 MPa.
(2) Pressure vessels whose shell plate exceed 16 mm in thickness, and/or whose design pressure exceed 1 MPa, and/or whose maximum working temperature exceed 150 °C.

3. Class 3 pressure vessels (Symbol *PV*-3)

Pressure vessels not included in Class 1 and 2.

303. Materials

1. The materials used in the construction of the pressure parts of pressure vessels are to comply with following requirements.

(1) All materials used for Class 1 and Class 2 pressure vessels are to comply with the requirements in **Pt 2, Ch 1.** However, for the following Class 2 pressure vessels, the materials may be in accordance with the requirements in (2) below :
  (A) Vessels of which design pressure is less than 0.7 MPa.
  (B) Vessels whose design pressure and maximum working temperature are not more than 2 MPa and 150 °C respectively, and whose internal capacity is not more than 0.5 m^3.
(2) The materials used for Class 3 pressure vessels are to be materials specified in the *Korean Industrial Standards* in accordance with the usage, or equivalent thereto.
(3) The materials of fittings for a pressure vessel are to comply with the requirements in **Pt 2, Ch 1.** However, where deemed as appropriate by the Society, the Society may accept to use the materials which meet *Korean Industrial Standards* or equivalent.
(4) In case where the heat treatment, such as hot working or stress relieving, is carried out on steel plates during the manufacturing process of pressure vessels, the manufacturer is to inform of such intention with an order for the materials. What are expected of the manufacturer of steel plates in this case, are prescribed in **Pt 2, Ch 1, 303. 3.**
(5) Appropriate heat treatments are to be carried out on the cold-formed steel plates, where it is considered that the cold-forming affects the safety of pressure vessel.

2. Materials of cast steel and grey iron casting are to be used for the construction of pressure vessels, according to the following items.

(1) Cast steel may be used in pressure vessels.

(2) Grey iron castings may be used in the pressure vessels where the working temperature does not exceed 220 °C and the design pressure does not exceed 1 MPa. However, grey iron castings are not to be used for the pressure vessels which contain inflammable or toxic liquid or gas.
(3) Special cast iron such as nodular graphite cast iron etc. may be used for the pressure vessels with the maximum working temperature not exceeding 350 °C and the design pressure not exceeding 1.8 MPa where approved by the Society.

3. Electric resistance welded steel pipes for pressure piping may be used for shell of pressure vessels whose design pressure is 2 MPa or below and working temperature 150 °C or below, and which do not contain inflammable or toxic liquid or gas.

304. Type of joint

1. Class 1 pressure vessels

Longitudinal and circumferential joints of Class 1 pressure vessels are to be of the approved double welded butt joints. However, for cylindrical shells of small diameter, where the inside welding is considered difficult, the joints may be of the single welded butt joint subject to the approval by the Society.

2. Class 2 pressure vessels

(1) Longitudinal joints : They are to be the same as the case of Class 1 pressure vessels.
(2) Circumferential joints : They are to be of double welded butt joints or single welded butt joints with backing strip. However, for shell plates of 16mm or under in thickness, they may be of single welded butt joints.

3. Class 3 pressure vessels

(1) Longitudinal joints : Double welded butt joints or single welded butt joints with backing strip are to be applied. However, for plates of 9 mm or below in thickness, both sides welded full fillet lap joints may be accepted, and for plates of 6 mm or below in thickness, single welded butt joints may be accepted.
(2) Circumferential joints : Single welded butt joints or one side welded full fillet lap joints may be accepted.

305. Welding method for each part

The welding methods are to be in accordance with **104.**

306. Efficiencies of joints

The values of efficiencies of joints for pressure vessels are to be as follows in relation to their application and type of joints.
(1) For seamless shells : J = 1.00
(2) For welded shells : J is to be as given in **Table 5.5.13.**

Table 5.5.13 Efficiencies of Joints, J

Kind of radiographic testing / Type of joint	Full radiographic testing carried out	Spot radiographic testing carried out	No radiographic testing carried out
Double-welded butt joint or the butt welded joint considered equivalent by the Society	1.00	0.85	0.75
Single-welded butt joint where the backing strip is left unremoved or the single-welded butt joint considered equivalent by the Society	0.90	0.80	0.70
Single welded butt joint without backing strip	—	—	0.60
Double-welded full fillet lap joint	—	—	0.55
Single fillet welded lap joint	—	—	0.45

307. Allowable stress

1. The allowable stress of the materials used at room temperature is to be determined by the following items.

(1) The allowable stress of carbon steel (including carbon manganese steel) and low alloy steels excluding cast steels is not to be taken to be greater than obtained from the following formulae, whichever is the smaller. For pressure vessels used for liquefied gas, the values of denominator for f_1 and f_2 are to be 3.0 and 2.0, respectively.

$$f_1 = \frac{R_{20}}{2.7}, \quad f_2 = \frac{E_{20}}{1.6}$$

where :

R_{20} = Specified minimum tensile strength at room temperature $(\mathrm{N/mm^2})$

E_{20} = Specified minimum yield stress or 0.2% proof stress $(\mathrm{N/mm^2})$

(2) The allowable stress of the electric resistance welded steel tubes except where they are used for the shell of pressure vessels is to be taken to the value specified in (1) when subjected to the ultrasonic testing or any other compatible flaw detection approved by the Society for the entire length of the weld, and other cases 85 % of the value specified in (1).

(3) The allowable stress of cast steel is to be taken to the value obtained by (1) multiplied by the coefficients given in **Table 5.5.14.**

Table 5.5.14 Coefficients to be multiplied to Allowable Stress of Cast Steels

Type of test	Coefficient
When no radiographic test or any other alternative testing is carried out	0.7
When spot radiographic test or alternative testing is carried out	0.8
When the above tests are carried out on all parts	0.9

(4) The allowable stress of cast iron is to be taken to 1/8 of the specified minimum tensile strength. However, the allowable stress of special cast iron approved by the Society may be taken to 1/6 of the specified minimum tensile strength.

(5) The allowable stress of austenitic stainless steel is to be taken to the following f_1 or f_2, whichever is the smaller.

$$f_1 = \frac{R_{20}}{3.5}, \quad f_2 = \frac{E_{20}}{1.6}$$

where :

R_{20}, E_{20} = As specified in (1)

(6) The allowable stress of aluminium alloy is to be taken to the following f_1 or f_2 , whichever is the smaller.

$$f_1 = \frac{R_{20}}{4.0}, \quad f_2 = \frac{E_{20}}{1.5}$$

where :

R_{20}, E_{20} = As specified in (1)

2. For the allowable stress of materials used for pressure vessels for high temperature service, the requirements in **107.** or the value deemed appropriate by the Society apply.

3. The allowable tensile stress is to conform to the requirements in **Pars 1** and **2.** However, the allowable tensile stress of bolts is to comply with the following requirements :

(1) In case where bolts are used at room temperature, the value is to be taken to the following (A) or (B), whichever is the smaller. However, for bolts complying with the requirements in the recognized standards the value may be 1/3 of the proof load stress specified therein.

(A) $\frac{R_{20}}{5.0}$

(B) $\frac{E_{20}}{4.0}$

where :

R_{20}, E_{20} = As specified in (1)

(2) In case where bolts are used at high temperature, the value will be considered by the Society in each case.

4. The allowable bending stress is to comply with the following requirements :

(1) In case where the materials are used at room temperature, the requirements in **Par 1** are to be complied with. However, for cast iron or cast steel, the value is to be taken to 1.2 times thereof.

(2) In case where the materials are used at high temperature, the value will be considered by the Society in each case.

5. The allowable shearing stress for the mean primary shearing stress in the section subjected to shearing load is to be taken to 80 % of the allowable tensile stress.

6. The allowable compression stress in the cylindrical shell of pressure vessels used at room temperature subject to a load causing compression stress in longitudinal direction is to be taken to the following (1) or (2), whichever is the smaller :

(1) The value specified in **Par 1.**

(2) The allowable buckling stress by the following formula :

$$\sigma_z = \frac{0.3 E T_0}{D_m\left(1 + 0.004\frac{E}{E_{20}}\right)}$$

where :

σ_z = Allowable buckling stress (N/mm^2)

E = Modulus of longitudinal elastisity at room temperature (N/mm^2)

T_0 = Net thickness of shell plate excluding corrosion allowance from the actual shell plate (mm)

D_m = Average shell diameter (mm)

7. The allowable stress for various stresses of carbon steel or carbon manganese steel used for the shell of pressure vessels formed by rotating unit when detailed calculations are carried out, may be as follows :

$$P_m \le f$$

$$P_L \le 1.5f$$

$$P_b \le 1.5f$$

$$P_L + P_b \le 1.5f$$

$$P_m + P_b \le 1.5f$$

$P_L + P_b + Q \leq 3f$

where :

P_m = Equivalent primary general membrane stress (N/mm^2)

P_L = Equivalent primary local membrane stress (N/mm^2)

P_b = Equivalent primary bending stress (N/mm^2)

Q = Equivalent secondary stress (N/mm^2)

308. General construction and strength

1. Because the formulae of this Section do not take into account such additional stresses as load from fittings, localized stress, repeated load, thermal stress and so on, some measures such as increasing the size, etc. are to be taken, in case those effects are considered to exist.

2. In the provisions in this Section, the design pressure of the pressure vessels used for refrigerating machinery, inflammable high pressure gases or of those subjected to delivery pressure of the boiler feed pump is not to be less than the values given below ;

(1) For pressure vessels used for refrigerating machinery, **Pt 9, Ch 1, 102. 5** is to be applied depending on kinds of the refrigerants.

(2) Design pressure of pressure vessels used for liquefied gases, storaged under pressurized condition at atmospheric temperature or near it, is not to be less than the following, whichever is the greatest :

(A) Vapour pressure of the gas at 45 °C.

(B) Maximum working pressure to be expected.

(C) 0.7 MPa.

(3) For pressure vessels subjected to delivery pressure of boiler feed water pump, the allowable pressure is to be 1.25 times the design pressure of the boiler. Where, however, this is not applicable, the maximum working pressure of the feed water pump may be taken.

309. Shell plates and end plates

1. The thickness of shell plates or end plates is not to be less than the required thickness prescribed in **Table 5.5.15** and further is not to be less than 5 mm except where specially approved by the Society in consideration of the diameter, pressure, temperature, materials, etc.

2. The required thickness of the end plate having openings for which reinforcement is required is to comply with the following :

(1) In case where the openings are reinforced in accordance with the requirements in **115. 2** the required thickness is to be calculated by **Table 5.5.15.**

(2) Where an end plate has a flanged-in manhole or access opening with a maximum diameter of which exceeds 150mm and flanged-in reinforcement of which complies with the requirements in **115. 6,** the thickness is to be calculated as follows :

(A) Dished or hemi-spherical end plates : The thickness is to be increased by not less than 15 % of the required thickness by **Table 5.5.15** using the design pressure or 3 mm, whichever is greater. In this case, where the inside crown radius of the end plate is smaller than 0.80 times the inside diameter of the shell, the value of the inside crown radius in the formula is to be 0.80 times the inside diameter of the shell. In calculating the thickness of the end plate having two manholes in accordance with above paragraph, the distance between the two manholes is not to be less than 1/4 of the outside diameter of the head plate.

(B) Semi-ellipsoidal end plates : The requirements in **Table 5.5.15** are to be applied. However, in this case R_2 is to be 0.80 times the inside diameter of shell and E to be 1.77.

3. The required thickness of end plates subject to pressure on the convex sides is not to be less than that obtained from the formula for end plates subject to pressure on the concave sides provided that the value of design pressure P in the formula is taken as 1.67 times P.

Table 5.5.15 The Thickness of Shell Plates and End Plates

Shell plates and end plates		The required thickness (mm)
Shell plates	Cylindrical	$T=\frac{PD_1}{2fJ-1.2P}+1.0$
	Spherical	$T=\frac{PR_1}{2fJ-0.2P}+1.0$
End plates	Dished(1)	$T=\frac{PR_2E}{2fJ-0.2P}+1.0$
	Semi-spherical	$T=\frac{PR_2}{2fJ-0.2P}+1.0$
	Semi-ellipsoidal(2)	$T=\frac{PD_2}{2fJ-0.2P}+1.0$

P = Design pressure (MPa)
J = Minimum value of the efficiencies prescribed in **306.**
f = Allowable stress prescribed in **307.** (N/mm^2)
D_1 = Inside diameter of shell (mm)
D_2 = Inside length of the major axis (mm)
R_1 = Radius of shell (mm)
R_2 = Inside crown radius (mm).

$$E=\frac{1}{4}\left(3+\sqrt{\frac{R_2}{r}}\right)$$

r = Inside knuckle radius (mm).

NOTES :
(1) The inside crown radius of dished end plate is not to be greater than the outside diameter of the flanged part of the end plate. The inside knuckle radius of the plate is not to be less than 6 % of the outside diameter of the flanged part of the end plate or 3 times the thickness of the end plate, whichever is greater.
(2) Half the minor axis inside the semi-ellipsoidal end plate is not to be less than 1/2 of half the inside major axis of the end plate.

310. Flat end plates or cover plates without stay or other supports

The required thickness of flat end plates or cover plates without stay or other supports is to be in accordance with **110.**

311. Flat plates or tube plates with stay or other supports

The required thickness of flat plates or tube plates with stay or other supports is to be in accordance with **111.**

312. Bolting methods of cover plates

The required thickness of cover plates is to be in accordance with **121.**

313. Manholes, mud holes and peep holes

1. Pressure vessels are to be provided with manholes or mud holes on shell plates or end plates for inspection and cleaning as follows :

(1) Pressure vessels over 900 mm inside diameter of shell are to be provided with a manhole or at least two mud holes.
(2) The size of the manholes is not to be less than 300 mm by 400 mm.
(3) The size of the mud holes is not to be less than 75 mm by 100 mm, and 100mm by 150

mm where the internal diameter of shell exceeds 750 mm.

2. The construction of holes and covers is to be in accordance with **114. 2** and **3.**

314. Reinforcement of openings

Openings in the shell and end plate are to be reinforced in accordance with **115.**

315. Stand pipes

The thickness of stand pipes welded to shell is to be in accordance with **119.**

316. Required thickness of tubes for heat exchangers

The materials of the tubes for heat exchangers are to be suitable for their purposes, and the required thickness is to be calculated by the following formula.

$$t = \frac{PD_0}{2fJ} + a \quad (\mathrm{mm})$$

where ;

P = Design pressure (MPa)

f = Allowable stress. As given in **307. 1, Ch.6 Table 5.6.7.** or **Ch.6 Table 5.6.8.**

D_0 = Outside diameter of tube (mm)

a = Corrosion allowance mentioned below :

1.0 mm for steel tube

0.3 mm for copper or copper alloy tube

0 mm for austenite stainless steel and approved corrosion resistance materials

T : Actual thickness of tube (mm)

J = Efficiencies of joints mentioned below :

1.0 for seamless tubes

0.85 for electric resistance welded tubes.

317. Relief valves on pressure vessels

1. For pressure vessels in which pressure may exceed the design pressure under working condition and a pressure vessel where an additional hazard may be created by exposure of the pressure vessel to a fire or other unexpected source of external heat, a pressure relieving device is to be provided to prevent the pressure from exceeding the design pressure. However, if an air reservoir is provided with a fusible plug with melting point of approximately 100 °C to release the pressure automatically in the case of a fire, the pressure relieving device may be omitted.

2. A heat exchanger or other similar pressure vessels, where internal pressure may exceed the design pressure due to internal failure or other, is to be provided with a suitable relief valve.

3. A steam generator which comes under *PV*-1 is to be provided with a safety valve prescribed in **123.** and **124.**

4. There is to be no stop valve between a pressure vessel and a relief valve or other relieving devices, except where approved by the Society.

5. A rupture disc may be installed between a pressure vessel and a relief valve or at a discharge line of the relief valve. In this case, the bursting pressure of the rupture disc is not to exceed the setting pressure of the relief valve. In addition, the discharge capacity of the rupture disc is to be the same as the relief valve or larger.

318. Arrangement of pressure vessels

Pressure vessels and their fittings are to be arranged at places convenient for operation, repair and inspection.

319. Tests and inspections

1. Hydraulic tests

Pressure vessels and their fittings attached directly to a pressure vessel are to be subjected to hydraulic test according to **Table 5.5.16** after construction in the presence of the Surveyor.

Table 5.5.16 Hydraulic Test Pressure

Item	Test pressure
Class 1 and Class 2 pressure vessels(1)	1.5 times the design pressure
Heat exchangers and other special vessels not applicable to the above	To be determined in each case
Fittings attached directly to Class 1 and Class 2 pressure vessels	2 times the design pressure of the pressure vessel
NOTE : (1) Class 3 pressure vessels considered necessary by the Society are to be subjected to hydraulic test.	

Section 4 Welding for Boilers and Pressure Vessels

401. General

1. The manufacturers of welded boiler, Class 1 and Class 2 pressure vessels are to obtain the approval of manufacturing process and to submit to the Society for approval the detailed construction drawings and welding procedures as specified in **Ch 1, 208. 1** (7) (quality of materials, welding method, specification of welding materials, type of edge preparation, heat treatment, test methods are to be shown) before the commencement of the work. Unless specially specified otherwise, the following requirements are also to be applied to welded construction.

2. Welding procedure qualification test

The manufacturers are to submit the detailed data in connection with the welding work for examination of the Society and also conduct the welding procedure qualification tests specified by the Society if they plan to construct boilers or pressure vessels with welded structure for the first time, or if they adopt a new welding method, and if they change types of base metals, types of welding materials, or types of joints. But, for minor changes in the welding process, the test may be omitted if approved by the Surveyor.

3. General requisites for welded construction

General requisites for welded construction are as follows :

(1) Welding method and welding materials : Welding is to be carried out in accordance with the previously approved welding plans using approved electrodes, approved automatic welding materials or other equivalent materials.
(2) Welders : All important weldings are to be carried out by welders holding Society's qualification.
(3) Base materials: Unless specially approved otherwise, the base materials used are conform to the requirements of **Pt 2, Ch 1** and the carbon content is not to exceed 0.35 %.

402. Welding workmanship

1. V-out

The dimension and shape of the edges to be joined is to be such that the welding can be carried out without failure. The welded joint portion is to be designed so as not to be subjected to direct bending stress.

2. Plates of unequal thickness

Where plates of unequal thickness are to be jointed in a longitudinal butt weld of a shell, the thicker plate is as a rule to be reduced by machining both surfaces to the thickness of thinner plate with an inclination of not more than 1/4 so as to coincide the centre lines of both plates. Where the reduction in thickness is made on one surface, the distance between the centre line of weld and the commencement of the inclination is to be at least equal to the thickness of the thinner plate.

3. Joints

Details of welded joints of essential members are to be as required in **104.** or other equivalent methods with equal effectiveness.

4. Application

The details of welding workmanship are to conform to the requirements of **Pt 2, Ch 2, Sec 3** as far as practicable in addition to the requirements specified in the following Articles.

5. Misalignment

The butting edges of the plates are to be in line within a limit of the following misalignment:

(1) Longitudinal joints
 1 mm for plates of 20 mm and under in thickness.
 5 % of plate thickness for plates of over 20 mm but less than 60 mm in thickness.
 3 mm for plates of 60 mm and over in thickness.

(2) Circumferential joints
 1.5 mm for plates of 15 mm and under in thickness.
 10 % of the plate thickness for plates of over 15 mm but less than 60 mm in thickness.
 6 mm for plates of 60 mm and over in thickness.

6. Deformation

Deformation of all boilers and pressure vessels of cylindrical type is to be measured on completion of the welding or after heat treating if heat treatment is required. The difference between the maximum and minimum in inside diameter of any section of the shell is to be within a limit of 1 % of the designed diameter and there is to be no flat part on welded line.

403. Heat treatment

1. Boilers and Class 1 pressure vessels

Boilers and Class 1 pressure vessels are to be heat-treated after the joints of shells, end plates and all fitting such as stand pipes or reinforcements, are welded in place. But, for fusion-welded corrugated furnace, heat treatment may be dispensed with because the heating necessary for forming the corrugation after welding is considered to be sufficient stress relieving.

2. Class 2 pressure vessels

Class 2 pressure vessels corresponding to the following are to be subjected to stress relieving heat treatment.

(1) The thickness of shell plates exceeds 30 mm.

(2) The thickness of shell plates is not less than 16 mm and is greater than the value of T_n determined by the following formula :

$$T_n = \frac{D}{120} + 10$$

where:

D = The inside diameter of the shell (mm)

3. Omission of stress relief

In case corresponding to the following stress relieving may be omitted.

(1) In case where the material having a superior notch toughness is specially used and approved by the Society.

(2) Subsequent stress relieving is not necessary to the pressure vessels which have been carried out stress relieving, even if fillet weld is applied as described below:

(A) Seal welding not feared to induce a remarkable strain.

(B) Intermittent welding for attaching fittings provided that the welds do not exceed 6 mm in throat thickness and 50 mm in length, and have an interval of 50 mm or larger.

(3) The stress relieving for following parts may be omitted in case where the thickness of the welded part is not more than 19 mm for carbon steel or carbon manganese steel, or not more than 13mm for alloy steel.

(A) welded joint between tubes, tubes and tube flanges, and tubes and headers

(B) Circumferential joints of headers

(C) Welded parts specially approved by the Society

4. Furnace

Heat treatment is to be carried in a furnace capable of readily adjusting the temperature and of maintaining the adjusted temperature. At least 2 thermometers are to be provided to measure or record the temperature in the furnace.

5. Procedure of post weld heat treatment

The welds of boilers and Class 1 pressure vessels using carbon steel, carbon manganese steel and low alloy steel as the base metal are to be heated to a stress relieving temperature, maintained at that temperature for a period of at least one hour per 25mm of thickness and allowed to cool down slowly to a temperature of 400 °C or below in the furnace and thereafter in a still atmosphere. The stress relieving temperature is in general to be taken as 625 °C ± 25 °C but to be suitably adjusted to the material used.

6. Area of heat treatment

Where the heat treatment of a boiler and a pressure vessel cannot be accomplished at one time due to an insufficient size of the furnace, it may be carried out twice or more times, but in this case, care is to be taken to assure that sufficient area between each heat treated section is overlapped in the process of heat treatment. This provision may also be applied when a structure in sections heat-treated is welded together, in which case the joints between the sections are to be heat treated to an entire bend with width of at least six times the plate thickness on each side of the seams.

7. Local heat treatment

Stress-relieving heat treatment for reinforcements or other welded connections on heat treated boilers and pressure vessels may be carried out locally by heating a circular area around such connections provided that any part of the welded edge thereof is not less than 12 times the thickness of the plate from the nearest adjacent welded joint or other element that would tend to resist the free expansion of the heated area. The width of heat treatment area measured from the welded seam is to be at least 6 times the thickness of the plates. However, this width is not to be less than 125 mm.

8. Special heat treatment

Where the heat treatment is carried out on special materials and by special procedures, the requirements are to be specially considered by the Society according to the type of base metal and welding materials, and welding procedures. In case of need, another effectiveness test of heat treatment could be required by the Society.

404. Radiographic examination

1. Fully radiographed

For boilers and pressure vessels whose joint efficiency has been determined subject to a fully radiographic examination specified in **306.,** the entire length of both longitudinal and circumferential welded joints is to be subjected to radiographic examination (hereinafter referred to as "**fully radiographed**").

2. Spot radiographed

For pressure vessels whose joint efficiency has been determined subject to spot radiographic examination specified in **306.,** the radiographic examination is to be carried out in accordance with the following requirements (hereinafter referred to as "**spot radiographed**"):

(1) The length which is not less than 20 % of the longitudinal joints (minimum 300mm) and the intersecting part of the circumferential joints with the longitudinal joints which were welded by the same method and by the same welder, are to be spot radiographed.
(2) The locations to be spot radiographed are to be chosen by the Surveyor.

3. Reinforcement of welding

The reinforcement of the welding at the joints on which the radiographic examination is to be carried out is to be machined down to a plane surface to enable the examination. In this case, the height of reinforcement is not to exceed the following values:

(1) Double welded butt joints:

Thickness of base plate t (mm)	Height of reinforcement (mm)
$t \leq 12$	1.5
$12 < t \leq 25$	2.5
$t > 25$	3.0

(2) Single welded butt joints: 1.5 mm and under, regardless of the plate thickness.

4. Radiograph film

The radiographic technique employed is to be such as to detect as small as 2 % of the welding depth, and the thickness of the penetrameter corresponding to 2 % of the thickness of the base metal is to be clearly shown on the radiograph film. Each radiograph film is to be marked clearly as to the relative position of the weld seams to the radiograph position, and the following items are to be included in the report of radiographic examination:

(1) Thickness of material (flush or reinforced).
(2) Distance from radiation source to weld surface.
(3) Distance from film to weld surface.
(4) Type of penetrameter used.

5. Re-radiographed

The radiograph films are to be submitted to the Surveyor. There are to be no defects, such as crack, long cavity, slag inclusion, etc. If there are defects, the area is to be chipped off and to be rewelded and radiographed again. When spot radiographed is used, additional radiographic examination is to be carried out on both sides of the original spot in accordance with the indication of the Surveyor.

405. Welding workmanship approval tests for boilers and Class 1 pressure vessels

1. Test plates

Where the boilers and Class 1 pressure vessels are to be welded the approval test is to be in accordance with the following requirements, and test plates of sufficient size are to be prepared in order to make test specimens specified by the requirements in **Par 2.**

(1) The test plate is to be attached to the shell in such a manner that the centre of weld coincide with that of the longitudinal joint of the shell and that the welding is carried out continuously from the welding of the longitudinal joint of the shell. The test plates are to be adequately supported during welding in order to minimize any deformation.
(2) The test plate for the circumferential joints of shells are to be made separately under the same welding conditions as the circumferential joint. However, test plates for the circumferential joints are not required except where the shell has no longitudinal joints or welding procedure for the circumferential joints is very much different from that for the longitudinal joints.
(3) The material for the test plates is in general to be taken from a part of the structure.

2. Mechanical tests

Mechanical tests for test plate are to be in accordance with the following.

(1) The kind, number and dimension of test specimens are to be as shown in **Table 5.5.17.** However, the impact tests are to be carried out, where stress relieving was omitted in accordance with **403. 3** (1) or alloy steel was used.

(2) Face bend and root bend test are to be conducted for the test plate not more than 19 mm in thickness and side bend test is to be conducted for the test plate exceeds 19 mm.

Table 5.5.17 Test Specimen

Kind of test specimen	Number of test specimen	Dimension of test specimen
Tensile test for joint	1	As specified in **Table 2.2.1** of **Pt 2, Ch 2** (*R* 2*A* Type)
Guide bend test	1	As specified in **Table 2.2.2** of **Pt 2, Ch 2**
Charpy impact test	3	As specified in **Table 2.1.3** of **Pt 2, Ch 1**
Macro-etching test	1	—

3. Tensile test for welded joints

The tensile strength is not to be less than the minimum tensile strength specified for the base metal. However, if the test specimen breaks at the base metal but the specimen shows no sign of defect in the welded joint, and tensile strength is not less than 95 % of the specified minimum tensile strength for the base metal, the test may be considered to be satisfactory.

4. Guide bend test

The test specimen is to be put on the guide bend jig shown in **Fig 2.2.1** of **Pt 2, Ch 2,** so as to coincide with the centre line of the weld at the centre of the jig. For the side bend test, the test specimen is to be bent with one of both sides in tension, and for the root bend test, with the narrow side of the weld in tension. In all cases, the test specimens are to be bent in the jig through an angle of 180 *degrees* with internal radius of 20 mm. Cracks exceeding 3 mm in length or any other defect are not to be observed on the outer surface of the weld; however, any crack at corners of the test piece may not be considered as a failure.

5. Impact test

The impact test specimen is to be sampled from the welded joint portions such that its longitudinal axis is at right angle to the weld line and its surface is 5 mm inside from the surface of the plate. The notch on the test specimen is to coincide with the centre of the weld line and to be on the surface at right angle to the plate surface. The mean value of absorbed energy of three test specimens is not to be smaller than the standard value approved by the Society.

6. Macro-etching test

Cracks, lack of fusion, incomplete penetration or any other defect are not to be observed.

406. Welding workmanship approval tests for Class 2 pressure vessels

In case the important parts of Class 2 pressure vessels are welded, the workmanship tests prescribed for Class 1 pressure vessels are to be carried out. The guide bend test of the requirements in **405. 2,** however, are not necessary.

407. Retests and modification

1. Retest

If the result of any test does not conform to the requirements, two additional test specimens may be taken from the same test plate for each failure. In the case of retests, both of the test specimens are to conform to the requirements. Retest is allowed in the following cases :

(1) In case the results of tensile and impact tests are not less than 90 % of the value specified in the requirements.
(2) In case guide bend test fails to meet the requirements from the cause due to defects found in the part excepting the welded parts.

2. Modification of test

The workmanship tests for pressure vessels may be modified at the discretion of the Surveyor taking account of their past performances.⚓

CHAPTER 6 AUXILIARIES AND PIPING ARRANGEMENT

Section 1 General

101. General

1. Application

(1) The requirements in this Chapter apply to the materials, design, fabrication, tests and piping arrangement of auxiliaries and piping systems.
(2) The requirements in this Chapter may be modified for ships having special limitation for their service and usage and for small ships.

2. Related requirements

In addition to the requirements in this Chapter, the following relevant requirements are to be complied with.

(1) For piping systems of ships to be registered as those strengthened for navigation in ice, **Pt 3, Ch 20;** For piping systems of the ships for navigation in polar waters, **Pt 3, Ch 21;** For piping systems of the vessels for polar and ice breaking service, **Pt 3, Ch 22.**
(2) For steering gears, **Pt 5, Ch 7;** For windlasses and mooring winches, **Pt 5, Ch 8.**
(3) For automatic and remote control systems, **Pt 6, Ch 2.**
(4) For pumping arrangements of oil tankers, **Pt 7, Ch 1, Sec. 10;** For drainage of ore holds of ore carriers, **Pt 7, Ch 2 Sec. 2;** For water level detection & alarms and drainage & pumping systems for bulk carriers and single hold cargo ships, **Pt 7, Ch 3 Sec. 14;** For cargo handling facilities and piping systems of liquefied gas carriers and chemical carriers, **Pt 7, Ch 5** and **Ch 6.**

3. Definition

(1) Design pressure is the maximum working pressure of a medium inside pipes and is not to be less than the following pressures given in (A) to (H).
(A) For pipings fitted with a relief valve or other overpressure protective device, the pressure based on the set pressure of the relief valve or overpressure protective device. However, for steam pipings connected to the boiler or pipings fitted to pressure vessel, the design pressure of the boiler or the pressure vessel.
(B) For piping on the discharge side of the pumps, the pressure based on the delivery pressure of the pump with the valve on the discharge side closed running the pump at rated speed. However, for pumps having a relief valve or overpressure protective device, the pressure based on its set pressure.
(C) For feed water pipings on the discharge from the feed water pumps to feed water check valves, the pressure of the 1.25 times the design pressure of the boiler or the pump pressure against a shut valve, whichever is the greater.
(D) For pipings without relief valves on the low pressure side of pressure reducing valves, the pressure as the design pressure on the high-pressure side of the pressure reducing valve.
(E) For boiler blow-off pipings, the pressure of 1.25 times the design pressure of the boiler.
(F) For refrigerating machinery pipings, the pressure prescribed in **Pt 9, Ch 1, 102. 5.**
(G) For pipes containing fuel oil, the design pressure is to comply with the following requirements.
(a) Where the working pressure is not more than 0.7 MPa and the working temperature is not more than 60 °C : 0.3 MPa or max. working pressure, whichever is greater
(b) Where the working pressure is not more than 0.7 MPa and the working temperature exceeds 60 °C : 0.3 MPa or max. working pressure, whichever is greater
(c) Where the working pressure exceeds 0.7 MPa and the working temperature is not more than 60 °C : max. working pressure
(d) Where the working pressure exceeds 0.7 MPa and the working temperature exceeds 60 °C : 1.4 MPa or max. working pressure, whichever is greater
(H) Where it is impracticable to adopt the above values, the design pressure is to be specially considered by the Society in each case.
(2) The design temperature in this Chapter is the highest working temperature of the medium.

However, for piping systems intended for lower temperature services than the room temperature, the design temperature is the lowest working temperature of the medium.

4. Classes of piping systems

(1) For the purpose of testing, type of joint to be adopted, heat treatment and welding procedure, piping systems are subdivided into three classes as indicated in **Table 5.6.1** depending upon the service, design pressure and design temperature of the medium.

(2) Piping systems for other media than specified in **Table 5.6.1** are to be specially considered by the Society depending upon the nature of the mediums and their service conditions.

Table 5.6.1 Classes of Piping Systems

Service \ Class of piping	Class I	Class II	Class III
Steam	$P > 1.6$ or $T > 300$	Any pressure-temperature combination not belong to Class I or III	$P \le 0.7$ and $T \le 170$
Thermal oil			$P \le 0.7$ and $T \le 150$
Fuel oil Lubricating oil Flammable hydraulic oil	$P > 1.6$ or $T > 150$	Any pressure-temperature combination not belong to Class I or III	$P \le 0.7$ and $T \le 60$
Other media(3)	$P > 4.0$ or $T > 300$	Any pressure-temperature combination not belong to Class I or III	$P \le 1.6$ and $T \le 200$

NOTES;
1. Cargo oil pipes belong to Class Ⅲ.
2. P = Design Pressure (MPa), T = Design temperature (℃)
3. Including water, air, gases, non-flammable hydraulic oil.
4. Open ended pipes(drains, overflows, vents, exhaust gas lines, boiler escape pipes) belong to Class Ⅲ.
5. Piping systems for $R\,717\,(NH_3)$ used as a primary refrigerant belonging to Class Ⅰ, and for $R22$, $R\,134a$, $R\,404A$, $R\,407C$, $R\,410A$ and $R\,507A$ used as a primary refrigerant belonging to Class Ⅲ.

5. Structure, materials and strength for auxiliaries

(1) Materials for auxiliaries
(A) The shaft materials of essential auxiliaries driven by prime movers having output of 100 kW or more are to comply with the requirements in **Pt 2, Ch 1** of the Rules.
(B) The materials used for essential parts of auxiliary machinery are to be manufactured by the manufacturer approved by the Society and complied with *Korean Industrial Standards or equivalent*, unless the Society specially considers necessary.

(2) Strength of shafts for auxiliaries
Except crankshaft, the diameters of shafts for essential auxiliaries are not to be less than those obtained by the formula specified in **Ch 3, 203.** And for electric motor or hydraulic driving, P and F in this formula are to be as follows;

P : Output of prime mover driving essential auxiliaries (kW)
F : Factor, 95

(3) Power transmission systems which transmit power from prime movers driving essential auxiliaries for propulsion and safety of ships are to be complied with requirements specified in **Ch 3, Sec.4.**

6. Incinerators of waste oil and waste substance, gas bottles and piping systems of gas welding equipment are to be specially considered by the Society in each case.

102. Pipes

1. Materials

Materials for pipes are to be suitable for the medium and service for which the pipes are intended and are to be of the materials complying with the following requirements.

(1) The materials for pipes belonging to Class I or Class II are, as a rule, to be manufactured and tested in accordance with the appropriate requirements of **Pt 2, Ch 1.**

(2) The materials for pipes belonging to Class III piping systems are to be manufactured and tested in accordance with *Korean Industrial Standards or equivalent*.

2. Service limitations for steel pipes

(1) Grade 1 and Grade 2 specified in **Pt 2, Ch 1, 402.** are not to be used for pipes whose design temperature exceeds 350 °C. However, they may be used up to 400 °C if the value of the allowable stress is guaranteed.

(2) Grade 3, *RST* 338 and *RST* 342 are not to be used for the pipes whose design temperature exceeds 450 °C and Grade 3, *RST* 349 is not to be used for pipes whose design temperature exceeds 425 °C.

(3) Grade 4, *RST* 412 is not to be used for pipes whose design temperature exceeds 500 °C and Grade 4, *RST* 422, *RST* 423 and *RST* 424 are not to be used for pipes whose design temperature exceeds 550 °C.

(4) Carbon steel pipes for ordinary piping (*KS D* 3507, *SPP*) may be used for Class II and Class III piping systems having a design pressure up to 1 MPa with a design temperature up to 230 °C.

3. Service limitations for copper and copper alloy pipes

(1) Copper and copper alloy pipes are to be seamless drawn pipes or pipes fabricated by the procedure approved by the Society.

(2) Copper pipes for Class I and II are to be seamless.

(3) The design temperature of the pipes is not to exceed 200 °C for phosphorous-deoxidized copper and brass, and 300 °C for copper-nickel in **Table 5.6.7.**

(4) Copper and copper alloy pipes which are considered inappropriate by the Society are not to be used for piping system.

4. Service limitations for cast iron pipes

Spheroidal or nodular graphite iron castings according to **Pt 2, Ch 1** may be accepted for bilge, ballast and cargo oil piping.

5. Special material pipes, expansion pipes and flexible pipes

(1) Such special materials as rubber hoses, plastic pipes, vinyl pipes, aluminium alloys, etc, notwithstanding the provision in **Pars 2, 3** and **4** above, may be used where approved by the Society taking into account safety against fire and flooding as well as their service conditions.

(2) Expansion pipes and flexible pipes of metallic or non-metallic material may be installed between two points to provide flexibility for proper operation of the machinery, and they are to be as deemed appropriate by the Society.

6. Required wall thickness of pipes

(1) The minimum wall thickness of steel pipes is not to be less than the greater of the minimum wall thickness calculated by **Par 7** or the minimum wall thickness shown in **Table 5.6.2.** and **5.6.3.**

(2) The minimum wall thickness of copper and copper alloy pipes is not to be less than the greater of the minimum wall thickness calculated by **Par 7** or the minimum wall thickness shown in **Table 5.6.4.**

(3) The minimum wall thickness of austenitic stainless steel pipes is not to be less than the greater of the minimum wall thickness calculated by **Par 7** or the minimum wall thickness shown in **Table 5.6.5.**

7. Minimum calculated wall thickness of pipes

(1) The minimum calculated wall thickness of straight pipes subject to internal pressure is to be determined by the following formula:

$$t = (t_0 + c)\frac{100}{100 - a} \quad (\mathrm{mm})$$

where:

t_0 = Strength thickness specified in (3) (mm)

c = Corrosion allowance specified in **Tables 5.6.6** and **5.6.7** (mm)

a = Negative manufacturing tolerance (%)

Table 5.6.2 Minimum Wall Thickness for Steel Pipes (mm)

Nominal diameter (A)	Pipes in general	1. Air, overflow and sounding pipes for structural tanks 2. Over board scupper pipes	Bilge, ballast and sea water pipes	1. Bilge pipes, overflow pipes, air pipes, sounding pipes and fresh water pipes passing through ballast or fuel oil tanks 2. Ballast pipes passing through fuel oil tanks 3. Fuel oil pipes passing through ballast tank 4. Air pipes on exposed deck(position I or II)	Overboard scupper pipes to be omitted the nonreturn valve	1. Ballast piping passing through cargo tanks(1) 2. Cargo oil pipes passing through segregated ballast tanks(2)
6	1.6					
8	1.8					
10	1.8					
15	2.0		3.2			
20	2.0		3.2			
25	2.0		3.2			
32	2.0	4.5	3.6	6.3		
40	2.3	4.5	3.6	6.3		
50	2.3	4.5	4.0	6.3		6.3
65	2.6	4.5	4.5	6.3	7.0	6.3
80	2.9	4.5	4.5	7.1	7.6	7.1
90	2.9	4.5	4.5	7.1	8.0	7.1
100	3.2	4.5	4.5	8.0	8.6	8.6
125	3.6	4.5	4.5	8.0	8.8	9.5
150	4.0	4.5	4.5	8.8	10.0	11.0
175	4.5	5.3	5.3	8.8	10.0	11.8
200	4.5	5.8	5.8	8.8	12.5	12.5
225	5.0	6.2	6.2	8.8	12.5	12.5
250	5.0	6.3	6.3	8.8	12.5	12.5
300	5.6	6.3	6.3	8.8	12.5	12.5
350	5.6	6.3	6.3	8.8		12.5
400	6.3	6.3	6.3	8.8		12.5
450	6.3	6.3	6.3	8.8		12.5

NOTES:

1. Diameter and thickness according to other national or international standards recognized by the Society may be accepted.
2. Where pipes and any integral pipe joints are protected against corrosion by means of coating, lining etc., the thickness may be reduced by an amount up to not more than 1 mm.
3. For sounding pipes, except those for flammable cargoes, the minimum wall thickness in air, overflow and sounding pipes for structural tanks is intended to apply only to the part outside the tank.
4. The minimum thicknesses listed in this table are the nominal wall thickness. No allowance needs to be made for negative tolerance or for reduction in thickness due to bending.
5. For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.
6. (1) and (2) in this Table apply to the pipes passing through dangerous zone and the minimum wall thickness of following pipes is not to be less than 16 mm :
   (A) Overboard discharge pipes(bilge and ballast pipes) passing through cargo oil tanks.
   (B) In case where ballast pipes passing through cargo oil tanks are led to ballast tank located forward of the collision bulkhead.
7. The minimum wall thickness for pipes larger than 450 A nominal size is to be in accordance with a national or international standard recognized by the Society and in any case not less than the minimum wall thickness of the appropriate column indicated for 450 A pipe size.
8. The air pipes located within the forward 0.25 L are to be complied with the requirements of **Pt 4, Ch 9, 303. 1.**

Table 5.6.3 Minimum Wall Thickness for Steel Pipes for CO_2 fire extinguishing (mm)

Nominal diameter (A)	Fire extinguishing CO_2 pipes	
	From bottles to distribution station	From distribution station to nozzle
15	3.2	2.6
20	3.2	2.6
25	4.0	3.2
32	4.0	3.2
40	4.0	3.2
50	4.5	3.6
65	5.0	3.6
80	5.6	4.0
90	6.3	4.0
100	7.1	4.5
125	8.0	5.0
150	8.8	5.6

NOTES:
1. Pipes are to be galvanized at least inside, except those fitted in the engine room where galvanizing may not be required at the discretion of the Society.
2. For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.
3. The external diameters and thicknesses have been selected from ISO Recommendations *R* 336 for smooth welded and seamless steel pipes. Diameter and thickness according to other national or international standards may be accepted.
4. For larger diameters specified in this table, the minimum wall thickness will be subject to special consideration by the Society.
5. The minimum thicknesses listed in this table are the nominal wall thickness. No allowance needs to be made for negative tolerance or for reduction in thickness due to bending.

Table 5.6.4 Minimum Wall Thickness for Copper and Copper Alloy Pipes (mm)

External diameter (mm)	Copper pipes	Copper alloy pipes
8 ~ 10	1.0	0.8
12 ~ 22	1.2	1.0
25 ~ 44.5	1.5	1.2
50 ~ 76.1	2.0	1.5
88.9 ~ 108	2.5	2.0
133 ~ 159	3.0	2.5
193.7 ~ 267	3.5	3.0
273 ~ 457	4.0	3.5
(470)	4.0	3.5
508	4.5	4.0

NOTES:
Diameter and thickness according to national or international standards recognized by the Society may be accepted.

Table 5.6.5 Minimum wall thickness for austenitic stainless steel pipes (mm)

External diameter	Minimum wall thickness
10.2 ~ 17.2	1.0
21.3 ~ 48.3	1.6
60.3 ~ 88.9	2.0
114.3 ~ 168.3	2.3
219.1	2.6
273.0	2.9
323.9 ~ 406.4	3.6
over 406.4	4.0

NOTES:
Diameters and thicknesses according to national or international standards recognized by the Society may be accepted.

Table 5.6.6 Corrosion Allowance for Steel Pipes (mm)

Piping service	c
Superheated steam systems	0.3
Saturated steam systems	0.8
Steam coil systems in cargo tanks	2.0
Steam coil systems in fuel oil tanks	1.0
Feed water for boilers in open circuit systems	1.5
Feed water for boilers in closed circuit systems	0.5
Blow-off (for boilers) systems	1.5
Compressed air systems	1.0
Lubricating and hydraulic oil systems	0.3
Fuel oil systems	1.0
Cargo oil systems	2.0
Refrigerating plants	0.3
Fresh water systems	0.8
Sea water systems	3.0

NOTES:
1. For pipes passing through tanks, an additional corrosion allowance is to be considered according to the figures given in the Table, and depending on the external medium, in order to account for the external corrosion.
2. Where pipes and any integral pipe joints are protected against corrosion by means of coating, lining, etc., the corrosion allowance may be reduced by not more than 50 %.
3. In the case of use of special alloy steel with sufficient corrosion resistance, the corrosion allowance may be reduced to zero.
4. For other systems than specified in this Table, the corrosion allowance is to be specially considered by the Society in each case.
5. For sea water systems, steel pipes whose nominal diameter is 25 A or below, the corrosion allowance may be reduced to 1.5 mm.

Table 5.6.7 Corrosion Allowance for Copper and Copper Alloy Pipes (mm)

Pipe material	c
Phosphorus-deoxidized copper seamless pipes and brass seamless pipes specified in **Table 5.6.9**	0.8
Copper nickel seamless pipes specified in **Table 5.6.9**	0.5

NOTE:
For media without corrosive action in respect of the material employed, the corrosion allowance may be reduced to zero.

(2) Where pipes are bent, the minimum calculated wall thickness, t_b, before bending is to be determined by the following formula.

$$t_b = (t_0 + c + b)\frac{100}{100 - a} \quad \text{(mm)}$$

where:

b = Bending allowance specified in (4) (mm)

t_0, c, a = As defined in (1)

(3) The strength thickness is to be determined by the following formula:

$$t_0 = \frac{PD}{2fJ+P} \quad (\mathrm{mm})$$

where:

P = Design pressure (MPa)

D = Outer diameter of pipe (mm)

f = Allowable stress specified in (5) ($\mathrm{N/mm^2}$)

J = Efficiency factor

- Seamless pipes -------------------------- 1.00
- Electric resistance welded pipes ---- 0.85 (1.0 may be adopted for those which are considered as equivalent to seamless pipes.)
- For other welded pipes and forge butt welded pipes, the Society will consider an efficiency factor value depending upon the welding procedure.

(4) The bending allowance, b, is not be less than calculated by the following formula, except where it can be demonstrated that the minimum wall thickness at any point after bending is not to be less than the minimum calculated wall thickness of straight pipe:

$$b = \frac{1}{2.5} \times \frac{D}{R} t_0 \quad (\mathrm{mm})$$

where:

D = Outer diameter of pipe (mm)

R = Radius of curvature of a pipe bend at the centre line of the pipe (mm)
However, $R \geq 2D$

t_0 = Strength thickness specified in (3) (mm)

(5) Allowable stress

(A) The allowable stress for carbon steel and alloy steel pipes is in general to be chosen as the lowest of the following values:

$$f = \frac{E_T}{1.6}, \quad f = \frac{R_{20}}{2.7}, \quad f = \frac{f_R}{1.6}$$

where:

E_T = Specified minimum yield stress or 0.2 percent proof stress ($\mathrm{N/mm^2}$)

R_{20} = Specified minimum tensile strength at room temperature ($\mathrm{N/mm^2}$)

f_R = Average stress to produce rupture in 100,000 hours at the design temperature ($\mathrm{N/mm^2}$)

(B) For steel pipes for pressure piping prescribed in **Pt 2, Ch 1** the allowable stresses may be obtained from **Table 5.6.8.**

(C) The allowable stresses for copper and copper alloy pipes are to be obtained from **Table 5.6.9.**

Table 5.6.8 Allowable Stress of Steel Pipes for Pressure Piping (N/mm^2)

Kinds	Symbols \ Design Temperature °C	100 or less	150	200	250	300	350	375	400	425	450	475	500	525	550
Grade 1	*RST* 138	123	114	105	96	87	78								
	RST 142	138	129	118	107	96	90								
Grade 2	*RST* 238	123	114	105	96	87	78								
	RST 242	138	129	118	107	96	90								
	RST 249	156	145	133	122	117	113								
Grade 3	*RST* 338	123	114	105	96	87	78	75	70	63	56				
	RST 342	138	129	118	107	96	90	87	84	71	57				
	RST 349	156	145	133	122	117	113	105	96	77					
Grade 4	*RST* 412	119	112	105	97	89	85	83	80	77	73	70	65		
	RST 422	121	116	111	105	99	93	91	89	85	80	76	71	55	38
	RST 423	121	116	111	105	99	93	91	89	85	80	76	71	57	40
	RST 424	121	116	111	105	99	93	91	89	85	80	76	71	57	41

NOTES: Intermediate values are to be determined by interpolation.

Table 5.6.9 Allowable Stress of Copper and Copper Alloy Pipes (N/mm^2)

Kind of Materials \ Design Temp.°C		50 or below	75	100	125	150	175	200	225	250	275	300
Phosphorous-deoxidized copper seamless pipes	*C* 1201 *C* 1220	41	41	40	40	34	27.5	18.5				
Brass seamless pipes for condenser and heat exchanger	*C* 4430	68	68	68	68	68	67	24				
	C 6870 *C* 6871 *C* 6872	78	78	78	78	78	51	24.5				
Copper nickel seamless pipes for condenser and heat exchanger	*C* 7060	68	68	67	65.5	65	62	59	56	52	48	44
	C 7100	73	72	72	71	70	70	67	65	63	60	57
	C 7150	81	79	77	75	73	71	69	67	65.5	64	62

NOTES:
1. Intermediate values are to be determined by interpolation.
2. Kind of materials are to be in compliance with *KS D* 5301.
3. Allowable stress for materials not specified in the Table will be specially considered by the Society in each case.

103. Valves and fitting

1. Materials

Materials for valves and pipe fittings are to be suitable for the medium and service for which the pipes are intended and are to be of the materials complying with the following requirements.

(1) The materials of valves and fittings belonging to Class I and Class II piping systems, ship-side valves and fittings, and valves on the collision bulkhead are, as a rule, to comply with the relevant requirement of **Pt 2, Ch 1.** However, the Society may accept to use valves and fittings made of materials which meet *Korean Industrial Standards* or equivalent.

(2) The materials for valves and pipe fittings belonging to Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable *Korean Industrial Standards or equivalent*.

2. Service limitations for carbon and low alloy steel

Carbon steel castings and steel forgings are not to be used for valves and pipe fittings in the piping system whose design temperature exceeds 425 °C. Low alloy steel castings and low alloy steel forgings are not to be used for valves and pipe fittings in the piping system whose design temperature exceeds 550 °C.

3. Service limitations for copper alloy

Valves and pipe fittings made of copper alloy are not to be used for valves and pipe fittings with a design temperature over 200 °C. However, special bronze, when approved by the Society, can be used for valves and pipe fittings with a design temperature of 260 °C or less

4. Service limitations for cast iron for valves and pipe fittings

(1) Valves and pipe fittings made of cast iron with an elongation of 12 % or above can be used for valves and pipe fittings in the piping system with a design temperature of 350 °C or less, and they may be used only where deemed appropriate by the Society.

(2) Valves and pipe fittings made of cast iron with an elongation of less than 12 % are not to be used for the following piping system.
  (A) Ship-side valves and fittings.
  (B) Valves fitted on the collision bulkhead.
  (C) Valves fitted on the external wall of fuel tanks and subjected to the static head of internal fluid unless the valves are mechanically protected to the Society's satisfaction.
  (D) Valves and pipe fittings for boiler blow-off piping.
  (E) Valves fitted on shore connection for cargo pipings of inflammable liquid.
  (F) Valves and pipe fittings for piping liable to be subjected to water hammer, excessive strain or vibration.
  (G) Valves and pipe fittings whose design temperature exceeds 220 °C.
  (H) Valves and pipe fittings used for pipes of Class II (except steam pipes).
  (I) Valves and pipe fittings for clean ballast piping systems which penetrate cargo oil tanks and reach the forepeak tank.
  (J) Valves and pipe fittings used for cargo oil pipelines exceeding design pressure of 1.6 MPa.

(3) Cast iron products are not to be used for valves and pipe fittings in the piping system belonging to Class I, unless specially approved by the Society.

5. Construction of valves and pipe fittings

Valves, pipe fittings, gaskets and packings are to be suitable for the condition of use and to have a construction specified in *Korean Industrial Standards* or equivalent construction thereto. The dimensions of flanges and relative bolts are to be chosen in accordance with *Korean Industrial Standards* or equivalent. For special applications, when the temperature, the pressure and the size of the flange have values above certain limits, to be fixed, the complete calculation of bolts and flanges is to be carried out.

104. Type of connections

1. Direct connection of pipe lengths

Direct connection of pipe lengths is to be made by direct welding, flanges, threaded joints or mechanical joints, and is to be of a recognized standard or of a design proven to be suitable for the intended purpose and acceptable to the Society.

2. Welded connections

(1) Butt welded joints

(A) Butt welded joints are to be of full penetration type generally with or without special provision for a high quality of root side. The expression "special provision for a high quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by the Society.

(B) Butt welded joints with special provision for a high quality of root side may be used for piping of any Class, any outside diameter.

(C) Butt welded joints without special provision for a high quality of root side may be used for piping systems of Class II and III irrespective of outside diameter.

(2) Slip-on sleeve and socket welded joints

(A) Slip-on sleeve and socket welded joints are to have sleeves, sockets and weldments of adequate dimensions conforming to the Society Rules or recognized Standard.

(B) Slip-on sleeve and socket welded joints may be used in Class III systems, any outside diameter.

(C) In particular cases, slip-on sleeve and socket welded joints may be allowed by the Society for piping systems of Class I and II having nominal diameter 80 A and below (outside diameter ≤ 88.9 mm) except for piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

3. Flange connections

(1) The dimensions and configuration of flanges and bolts are to be chosen in accordance with recognized standards.

(2) Gaskets are to be suitable for the media being conveyed under design pressure and temperature conditions and their dimensions and configuration are to be in accordance with recognised standards.

(3) For non-standard flanges, the dimensions of flanges and bolts are to be subject to special consideration.

(4) Typical examples of flange attachments are shown in **Fig 5.6.1.** However, other types of flange attachments may be considered by the Society in each particular case.

(5) Flange attachments are to be in accordance with *Korean Industrial Standards or equivalent* that are applicable to the piping system and are to recognize the boundary fluids, design pressure and temperature conditions, external or cyclic loading and location.

4. Slip-on threaded joints

(1) Slip-on threaded joints having pipe threads where pressure-tight joints are made on the threads with parallel or tapered threads, are to comply with requirements of a recognized national or international standard.

(2) Slip-on threaded joints may be used for outside diameters as stated below except for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

(A) Threaded joints in CO_2 systems are to be allowed only inside protected spaces and in CO_2 cylinder rooms.

(B) Threaded joints for direct connectors of pipe lengths with tapered thread are to be allowed for:

(a) Class I, outside diameter not more than 33.7 mm.

(b) Class II and Class III, outside diameter not more than 60.3 mm.

(C) Threaded joints with parallel thread are to be allowed for Class III, outside diameter not more than 60.3 mm.

(D) In particular cases, sizes in excess of those mentioned above may be accepted by the Society if in compliance with *Korean Industrial Standards or equivalent.*

5. Mechanical joints

These requirements are applicable to pipe unions, compression couplings, slip-on joints as shown in **Fig 5.6.2.** Similar joints complying with these requirements may be acceptable.

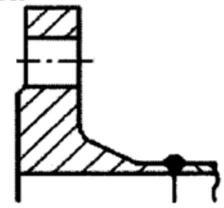
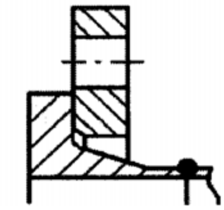
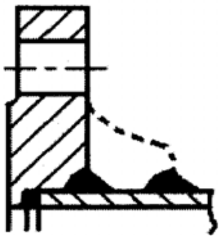
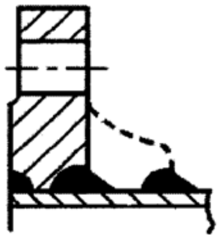
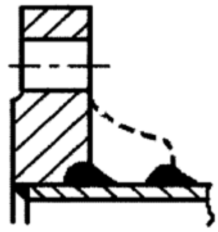
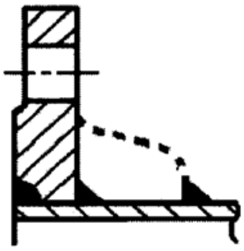
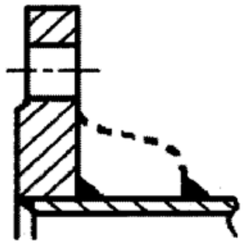
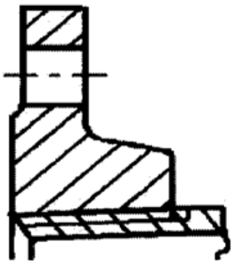
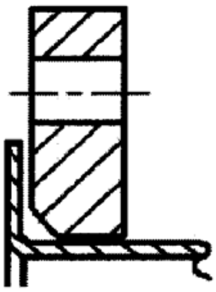
Type of flange	Example of attachments
Type A	A1  Welding neck flange A2  Loose flange with welding neck
Type B	B1  B2  B3  Slip-on welding flange-fully welded
Type C	C1  C2  C3  Slip-on welding flange
Type D	 Slip-on threaded flange-conical thread
Type E	 Lap joint flange-on flanged pipe
NOTE : For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. For certain types of thread, after the flange has been screwed hard home, the pipe is to be expanded into the flange.	

Fig 5.6.1 Examples of Flange Attachments

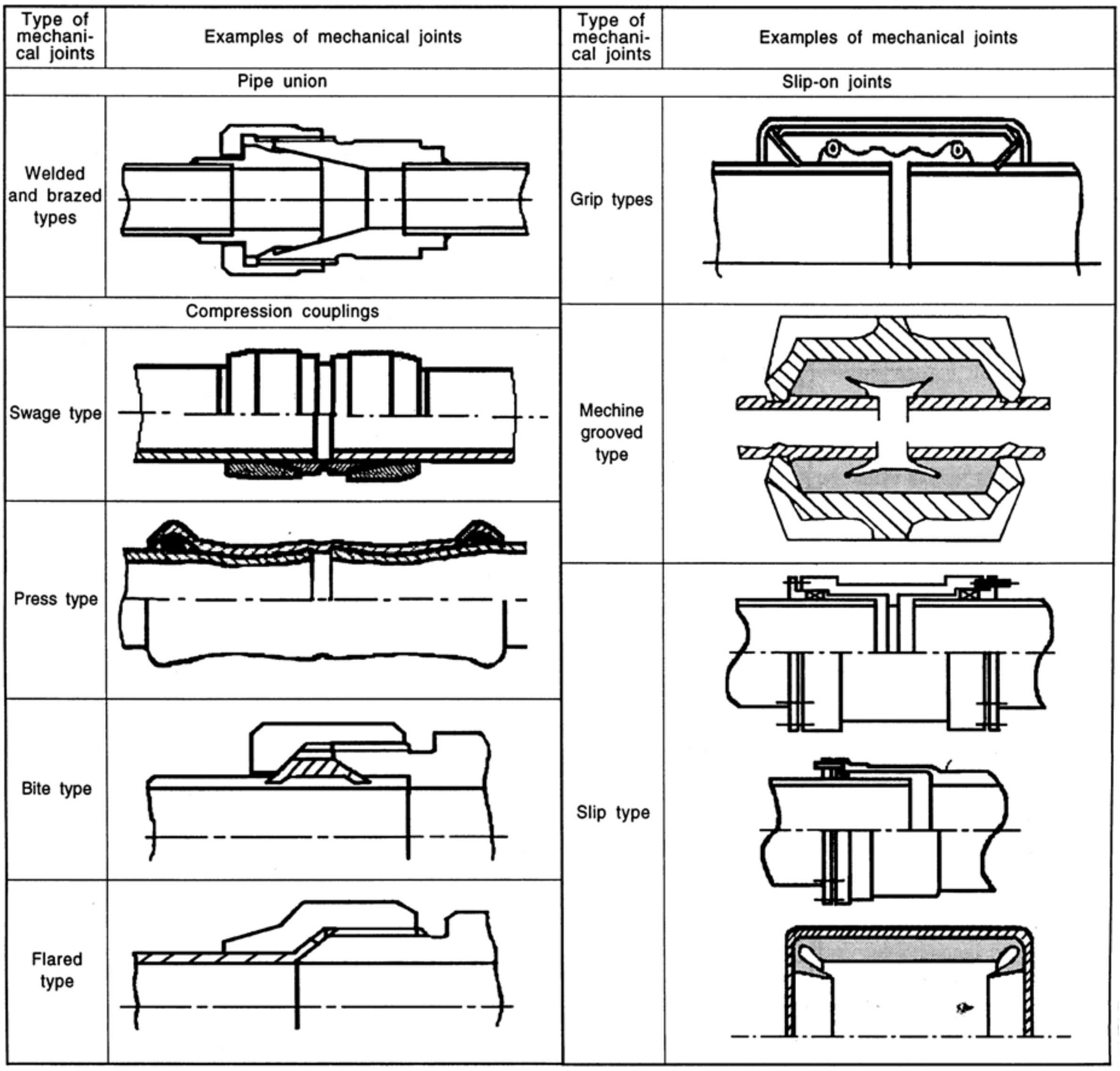


Fig 5.6.2 Examples of Mechanical Joints

(1) Mechanical joints including pipe unions, compression coupling, slip-on joints and similar joints are to be of approved type for service conditions and the intended application.
(2) Where the application of mechanical joints results in reduction in pipe wall thickness, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.
(3) Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.
(4) Material of mechanical joints is to be compatible with the piping material and internal and external media.
(5) Mechanical joints are to be tested where applicable, to a burst pressure of 4 times the design pressure. For design pressures above 20 MPa, the required burst pressure will be specially considered by the Society.
(6) Mechanical joints are to be of fire resistant type as required by **Table 5.6.10.**
(7) Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.
(8) The mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

(9) The number of mechanical joints in oil systems is to be kept to a minimum.

(10) Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

(11) Slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may be permitted only for the same media that is in the tanks. Unrestrained slip-on joints are to be used only in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

(12) Typical Application of mechanical joints and their acceptable use for each service is indicated in **Table 5.6.10;** dependence upon the Class of piping, pipe dimensions, working pressure and temperature is indicated in **Table 5.6.11.** In particular cases, sizes in excess of those mentioned above may be accepted by the Society if in compliance with a recognized national and/or international standard.

Table 5.6.10 Application of Mechanical Joints

The following table indicates systems where the various kinds of joints may be accepted. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

Systems		Kind of connections		
		Pipe Unions	Compression Couplings[6)]	Slip-on joints
Flammable fluids (Flash point ≤ 60 °C)				
1	Cargo oil lines	○	○	○[5)]
2	Crude oil washing lines	○	○	○[5)]
3	Vent lines	○	○	○[5)]
Inert gas				
4	Water seal effluent lines	○	○	○
5	Scrubber effluent lines	○	○	○
6	Main lines	○	○	○[2),5)]
7	Distributions lines	○	○	○[5)]
Flammable fluids (Flash point 〉 60 °C)				
8	Cargo oil lines	○	○	○[5)]
9	Fuel oil lines	○	○	○[2),3)]
10	Lubricating oil lines	○	○	○[2),3)]
11	Hydraulic oil	○	○	○[2),3)]
12	Thermal oil	○	○	○[2),3)]
Sea water				
13	Bilge lines	○	○	○[1)]
14	Fire main and water spray	○	○	○[3)]
15	Foam system	○	○	○[3)]
16	Sprinkler system	○	○	○[3)]
17	Ballast system	○	○	○[1)]
18	Cooling water system	○	○	○[1)]
19	Tank cleaning services	○	○	○
20	Non-essential systems	○	○	○
Fresh water				
21	Cooling water system	○	○	○[1)]
22	Condensate return	○	○	○[1)]
23	Non-essential system	○	○	○
Sanitary/Drains/Scuppers				
24	Deck drains (internal)	○	○	○[4)]
25	Sanitary drains	○	○	○
26	Scuppers and discharge (overboard)	○	○	-

Table 5.6.10 Application of Mechanical Joints (continued)

Systems		Kind of connections		
		Pipe Unions	Compression Couplings[6]	Slip-on joints
Sounding/Vent				
27	Water tanks/Dry spaces	○	○	○
28	Oil tanks (f.p. 〉 60 °C)	○	○	○[2),3)]
Miscellaneous				
29	Starting/Control air[1)]	○	○	-
30	Service air (non-essential)	○	○	○
31	Brine	○	○	○
32	CO_2 system[1)]	○	○	-
33	Steam	○	○	○[7)]

Abbreviations ○ : Application is allowed, - : Application is not allowed

NOTES:
1) Inside machinery spaces of category A - only approved fire resistant types
2) Excluding inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3) Approved fire resistant types
4) Above free board deck only
5) In pump rooms and open decks - only approved fire resistant types
6) If compression couplings include any components which readily deteriorate in case of fire, they are to be of approved fire resistant type as required for slip-on joints.
7) Slip type joints as shown in **Fig 5.6.2**, provided that they are restrained on the pipes, may be used for pipes on deck with a design pressure of 1 MPa or less.

Table 5.6.11 Application of mechanical joints depending upon the class of piping

Type of joints	Classes of piping systems		
	Class Ⅰ	Class Ⅱ	Class Ⅲ
Pipe Unions			
Welded and brazed type	○(OD≤60.3 mm)	○(OD≤60.3 mm)	○
Compression Couplings			
Swage type	○	○	○
Bite type	○(OD≤60.3 mm)	○(OD≤60.3 mm)	○
Flared type	○(OD≤60.3 mm)	○(OD≤60.3 mm)	○
Press type	-	-	○
Slip-on joints			
Machine grooved type	○	○	○
Grip type	-	○	○
Slip type	-	○	○

Abbreviations ○ : Application is allowed - : Application is not allowed

105. Welding of pipes and pipe fittings

1. Scope and documentation

(1) The following requirements apply to the fabrication of Class I and II piping systems operating at ambient or high temperature and made of steel of the types given below. At the discretion of the Society, these requirements may be applied also to the Class III piping systems and to repair welding pipelines.
   (A) carbon and carbon-manganese steels having minimum tensile strength 320, 360, 410, 460 and 490 N/mm^2.
   (B) low alloy carbon-molybdenum, chromium-molybdenum, chromium-molybdenum-vanadium steels having chemical composition 0.3 Mo; 1 Cr - 0.5 Mo; 2.25 Cr - 1 Mo; 0.5 Cr - 0.5 Mo - 0.25 V.

(2) The manufacturers are to submit to the Society for its approval the detailed construction drawings and welding procedures (quality of materials, welding method, specification of welding materials, type of edge preparation, heat treatment, test methods are to be shown) before the commencement of the work.

2. Welding workmanship

(1) Welding is to be carried out in accordance with the previously approved welding procedures using approved electrodes, approved automatic welding materials or other equivalent materials. Tack welds are to be made with an electrode suitable for the base metal; tack welds which form part of the finished weld are to be made using approved welding procedures. When welding materials requiring preheating, the same preheating is to be applied during tack welding.

(2) Welding is to be carried out at welding shops, in principle, and by the welders holding the Society's qualification specified in **Pt 2, Ch 2, Sec 5.**

(3) Base materials used in the welding work, unless otherwise specifically approved, are to conform to the requirements in **Pt 2, Ch 1,** and further the carbon content is not to exceed 0.35 %.

(4) Edge preparation is to be in accordance with recognized standards and/or approved drawings. The preparation of the edges is to be preferably carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching grinding or chipping back to sound metal.

3. Welded connections

(1) Welded butt joints are to be of the full penetration type. For Class I pipes, special provisions are to be taken to ensure a high quality of the root side.

(2) If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner of the butt joint with a slope not steeper than 1/4.

(3) Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thicknesses of pipe and branch are increased to maintain the strength of the pipe.

(4) Mis-alignment of joints
   The tolerances on the alignment of the pipes to be welded are to be as follows.
   (A) Where the pipes welded with backing ring: 0.5 mm
   (B) Where the pipes welded without backing ring:
      (a) In the case of the inside diameter less than 150 mm and up to 6 mm in thickness, 1 mm or 25 % of the thickness, whichever is less.
      (b) In the case of the inside diameter less than 300 mm and up to 9.5 mm in thickness, 1.5 mm or 25 % of the thickness, whichever is less.
      (c) In the case of the inside diameter 300 mm and over, or over 9.5 mm in thickness, 2 mm or 25 % of the thickness, whichever is less.

4. Preheating of welds

When pipes are welded, pipes are to be preheated adequately depending on the kinds and thickness of materials as specified in **Table 5.6.12.**

Table 5.6.12 Preheating of Welds

Kind of material		Thickness of welds t (mm)	Minimum preheating temperature(°C)
Grade 1 Grade 2 Grade 3	$C+\frac{Mn}{6} \leq 0.4$	$t \geq 20^{(1)}$	50
	$C+\frac{Mn}{6} > 0.4$	$t \geq 20^{(1)}$	100
Grade 4	*RST* 412	$t > 13^{(1)}$	100
	RST 422 *RST* 423	$t < 13$	100
		$t \geq 13$	150
	RST 424(2)	$t < 13$	150
		$t \geq 13$	200

NOTES:
1. Kind of materials are to be in accordance with the requirements in **Pt 2, Ch 1, 402.**
2. (1) and (2) marked in this Table are as follows :
(1) For welding in ambient temperature below 0 °C, the minimum preheating temperature is required independent of the thickness unless specifically approved by the Society.
(2) For these materials, preheating may be omitted for thicknesses up to 6 mm if the results of hardness test carried out on welding procedure qualification are considered acceptable by the Society.

5. Post weld heat treatment

(1) The heat treatments are not to impair the specified properties of the materials; verifications may be required to this effect as necessary. The heat treatments are preferably to be carried out in suitable furnaces provided with temperature recording equipment. However, localized heat treatments on a sufficient portion of the length way of the welded joint, carried out with approved procedures, also can be accepted.
(2) After the welding(excluding the oxy-acetylene welding process), the pipes specified in **Table 5.6.13** are to be subject to post weld heat treatment according to the kinds of materials for relieving the residual stress. The post weld heat treatment is to consist in heating the piping slowly and uniformly to a temperature within the range indicated in the **Table 5.6.13,** and soaking at this temperature for a suitable period(in general, one hour per 25 mm of thickness with minimum of half an hour), cooling slowly and uniformly in the furnace to a temperature not exceeding 400 °C and subsequently cooling in a still atmospheric temperature. In any case, the heat treatment temperature is not to be higher than $t_T - 20$ °C, where t_T is the temperature of the final tempering treatment of the material.
(3) After the oxy-acetylene welding, the pipes specified in **Table 5.6.14** are to be subject to post weld heat treatment according to the kinds of materials.
(4) Post weld heat treatment of pipes and pipe fittings made of materials other than those specified in (1), (2) and (3) above is to be made as deemed appropriate by the Society according to the kinds of base metals, welding materials, welding procedure and so on.

Table 5.6.13 Pipes Requiring Post Weld Heat Treatment

Kind of material		Thickness of welds t (mm)	Minimum preheating temperature (°C)
Grade 1 Grade 2 Grade 3		$t \geq 15^{(2),(3)}$	550 ~ 620
Grade 4	*RST* 412	$t \geq 15^{(2)}$	550 ~ 620
	RST 422 *RST* 423	$t > 8$	620 ~ 680
	RST 424	any (1)	650 ~ 720

NOTES:
1. Kind of materials is to be in accordance with the requirements in **Pt 2, Ch 1, 402.**
2. (1) ~ (3) in this Table are as following.
   (1) Post weld heat treatment may be omitted for pipes having thickness ≤ 8 mm, diameter ≤ 100 mm and design temperature ≤ 450 °C.
   (2) When steels with specified Charpy V notch impact properties at low temperature are used, the above thickness which post welded heat treatment is to be applied may be increased by special consideration of the Society.
   (3) For C and C-Mn steels, stress relieving heat treatment may be omitted up to 30 mm thickness by special consideration of the Society.

Table 5.6.14 Heat Treatment after Forming and Welding of Pipes

Kind of Material		Heat treatment and temperature (°C)
Grade 1, Grade 2, Grade 3		Normalizing 880 to 940
Grade 4	*RST* 412	Normalizing 900 to 940
	RST 422, *RST* 423	Normalizing 900 to 960, Tempering 640 to 720
	RST 424 (2.25 Cr - 1 Mo)	Normalizing 900 to 960, Tempering 650 to 780
	R*RST* 424 (0.5 Cr - 0.5 Mo - 0.25 V)	Normalizing 930 to 980, Tempering 670 to 720

106. Forming of pipes and heat treatment after forming

1. Hot forming of pipes of Class I and Class II is to be generally carried out in the temperature range of 1,000 °C ~ 850 °C. However, the temperature may decrease to 750 °C during the forming process. For steel pipes of Grade 4, the stress relieving heat treatment is to be carried out according to the requirements specified in **Table 5.6.13.**

(1) When the hot forming is carried out within this temperature range, a subsequent new heat treatment in accordance with is required for *RST* 422, *RST* 423 and *RST* 424. No subsequent heat treatment is required for Grade 1 through 3 and *RST* 412.

(2) When the hot forming is carried outside the above temperature range, a subsequent new heat treatment in accordance with **Table 5.6.14** is generally required for all grades.

2. When pipes of Class I and Class II are subjected to cold-forming, a stress relieving heat treatment in accordance with **Table 5.6.13** is required for all grades other than carbon and carbon-manganese steels with minimum tensile strength 320, 360 and 410 N/mm^2. After cold forming, when $r \leq 4D$ (where r is the mean bending radius and D is the outside diameter of pipe), consideration is to be given to a complete heat treatment in accordance with **Table 5.6.14.**

107. General requirements for piping arrangement

1. Installation

(1) Pipes are to be arranged in good and systematic order to facilitate the removal of pipes and fittings as well as the maintenance of machinery.

(2) Ample provision is to be made to take care of expansion or contraction stresses in pipes due to temperature changes or deflection of the hull.
(3) Piping arrangements are to be so made as not to give effects on the performance of machinery due to the stay of drain and air or the pressure loss in pipes.
(4) The support of the pipe system is to be such that detrimental vibrations do not arise in the system.
(5) Heavy pipes, valves and fittings are to be supported in such a way that their weight does not cause large additional stresses in adjacent piping and connected machinery.
(6) So far as practicable, pipes are not to be led in the vicinity of electrical equipment such as generators, motors, switchboards, control gears, etc. Where it is not practicable, all detachable pipe joints are to be at a safe distance from the electrical equipment, unless provision is made to prevent any leakage from pouring on the equipment.
(7) Oil pipes (fuel oil, lubricating oil, cargo oil and other oil) are not to be led upright the boiler, steam pipes, exhaust gas pipes, silencer and the other areas which are in a high temperature, and so far as practicable, to be isolated from the above systems.
(8) Hydraulic unit having working pressure above 1.5 MPa and having potential of oil leakage coming contact with hot surfaces, electrical installations or other sources of ignition, is to preferably be placed in separate spaces. If it is impracticable to locate such units in a separate space, adequate shielding is to be provided.

2. Protection of pipes and fittings

(1) All pipes, valves, cocks, pipe fittings, valve operating rods and handles are to be effectively secured and adequately protected for those liable to be damaged, and for those installed in cargo holds and chain lockers. Where a casing is provided for protection, it is to be so constructed as to be easily removed for inspection.
(2) All pipes including bilge, air and sounding pipes in refrigerating spaces are to be well insulated so that water in pipes may not freeze.
(3) For pipes arranged in the positions inaccessible for maintenance and inspection, due consideration such as corrosion protection is to be given to prevent corrosion.

3. Relief valves

All pipe lines which may be exposed to pressures greater than the design pressure are to be safeguarded by suitable relief valves or equivalent safety devices.

4. Pressure gauges and thermometers

(1) Pressure gauges and thermometers are to be provided on piping systems where deemed necessary.
(2) Cocks or valves are to be provided at the root of pressure measuring devices for isolating them from the pipes under a pressurized condition.
(3) Where thermometers are fitted in fuel oil, lubricating oil and other flammable oil piping or apparatuses, the thermometer is to be put in a safe protective pocket to prevent oil from spraying in case of fracture or removal of the thermometer.

5. Gaskets and packings for piping

Gaskets and packings used for flanges, pipe joints, valve covers, valves spindles, etc. in piping systems are to be selected carefully by taking account of the kinds of fluids, operating conditions and the type of flange contact surfaces.

6. Slip joints

Slip joints are not to be used in pipe lines in cargo holds, deep tanks and other spaces which are not easily accessible, unless otherwise specified.

7. Penetrations through bulkheads, decks, etc.

Where pipes are led through watertight bulkheads, decks, boundary plates of deep tanks and inner bottom plating, arrangements are to be made to ensure the integrity of the watertightness of the structure.

8. Watertight bulkheads

(1) Valves or cocks such as drain valves, which do not constitute a part of any pipe line are not

to be fitted on the collision bulkhead.

(2) Except as provided in para. (3), the collision bulkhead may be pierced below the bulkhead deck by not more than one(1) pipe for dealing with fluid in the forepeak tank in principle and the pipe is to be fitted with a screw-down valve capable of being operated from above the bulkhead deck, the valve chest being secured inside the forepeak to the collision bulkhead. The valve, however, may be fitted on the after side of the collision bulkhead provide that the valves are readily accessible under all service conditions and the space in which they are located is not a cargo space.

(3) If the fore peak is divided to hold two different kinds of liquids, the Society may allow the collision bulkhead to be pierced below the bulkhead deck by two pipes complying with para. (2), provided that the Society is satisfied that there is no practical alternative to the fitting of such a second pipe and that, having regard to the additional subdivision provided in the forepeak, the safety of the ship is maintained.

(4) Valves and cocks, such as drain valves, which do not constitute a part of any pipe lines may be fitted to watertight bulkheads other than the collision bulkhead, provided that they are readily accessible at any time for the inspection. Such valves and cocks are to be operable from above the bulkhead deck and to be provide with an indicator to show whether they are open or closed, except where the valves or cocks are secured at the fore or after bulkhead inside the engine room. In addition, the operation rod is to be so constructed that the weight of it is not supported by the valve or cock.

9. Prohibition of carriage of oil in forepeak tanks

In ships of 400 gross tonnage and above, compartments forward of the collision bulkhead are not to be arranged for the carriage of oil or other liquid substances which are flammable.

10. Marking

(1) The pipes located in the space where deemed necessary for safety are to be marked with distinctive colour.

(2) The valves for piping systems which are available for fire extinguishing aboard ship are to be marked with red paint.

11. Pipe cleaning

Piping systems are to be cleaned after fabrication or installation in ships where considered necessary.

12. Sea water and fresh water pipings

Sea water pipes are to be led separately as far as possible from fresh water pipes. Where such leading is not practicable, care is to be taken to prevent the accidental contamination of fresh water with sea water.

Section 2 Air Pipes, Overflow Pipes and Sounding Devices

201. Air pipes

1. General

(1) Air pipes are to be fitted to all tanks, cofferdams and tunnels.

(2) The air pipes are to be fitted at the fore and after portions of the tanks. Where the tanks are less than 7 m both in length and in width or having inclined top plates, one air pipe may be fitted at the highest part of the tanks.

(3) Where the tank top is of unusual or irregular profile, special consideration is to be given to the number and position of the air pipes.

(4) Air pipes are to be arranged to be self-draining under normal conditions of trim and to be clearly marked at the upper end.

(5) Air pipes for fuel oil service, settling and lubrication oil tanks are to be such that in the event of a broken air pipe this is not directly to lead to the risk of ingress of seawater splashes or rain water.

2. Termination of air pipe outlets

Air pipe to double bottom tank, deep tanks, cofferdams or tanks which can be run up from the sea are to be led to above the bulkhead deck. The position of open ends of air pipes are to be in accordance with the following requirements depending on the kinds of tanks.

(1) Air pipes to fuel oil and cargo oil tanks, cofferdams adjacent to their tanks and all tanks which can be pumped up are to be led to the open area.
(2) The open ends of air pipes to fuel oil and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled.
(3) Air pipes from lubricating oil tanks may terminate in the machinery space, provided that the open ends are so situated that issuing oil or gas cannot come into contact with electrical equipment or heated surfaces. However, air pipes from the heated lubricating oil tanks are to be led to the open area.
(4) Air pipes from fresh water tanks may terminate in the machinery space.

3. Protection of air pipe outlets

(1) All openings of air pipes extending above weather decks are to be provided with an automatic type closing devices. All automatic type closing devices are to be type approved by the Society.
(2) The open ends of air pipes to fuel oil and cargo oil tanks are to be furnished with the flame-screens which can be readily removed for cleaning or renewal and deemed appropriate by the Society. The clear area through the mesh of the flame-screens is not to be less than the required sectional area of the air pipe.

4. Size of air pipes

(1) The aggregated sectional area of air pipes to tanks which can be pumped up is not to be less than 1.25 times the aggregated sectional area of filling pipes. Where the tank is provided with an overflow pipe, the aggregated sectional area of air pipes is to be accordance with the requirements which the Society considers appropriate.
(2) The internal diameters of air pipes to cofferdams or tanks which form part of ship's structure are not to be less than 50 mm.

5. Height of air pipes

Where air pipes extend above the freeboard and superstructure decks, the exposed parts of the pipes are to be of substantial construction; the height from the upper surface of the deck to the point where water may have access below is to be at least as given in the following table: Where these height may interfere with the working of the ship, a lower height may be accepted, provided that the Society is satisfied that the closing arrangement and other circumstances justify the lower height.

Location	Height of coaming
On the freeboard deck	760 mm
On the superstructure deck	450 mm

202. Overflow pipes

1. General

(1) Where tanks which can be pumped up come under either one of the following categories, overflow pipes of steel are to be fitted:
 (A) Where the cross-sectional area of the air pipes does not comply with the requirements in **201. 4** (1).
 (B) Where there is any opening below the open ends of air pipes fitted to tanks.
 (C) Fuel oil settling tank and fuel oil service tank.
(2) Overflow pipes are to be arranged to be readily visible and self-draining under normal conditions of trim and to be clearly marked at the upper end.

2. Termination of overflow pipes

(1) In case of fuel oil and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

(2) A sight glass is to be provided in the overflow pipe at a readily visible position or, alternatively, an alarm device is to be provided to give warning either when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.
(3) Overflow pipes from tanks, other than fuel oil, cargo oil and lubricating oil tanks, are to be led to the open air or to suitable tanks where the overflows can be disposed of.

3. Size of overflow pipes

The total cross-sectional area of the overflow pipes is not to be less than 1.25 times the effective area of the filling pipes. In any case, the minimum internal diameter for overflow pipes is not to be less than 50 mm.

4. Prevention of counter-flow of overflow lines

(1) The overflow system is to be so arranged that water from the sea cannot enter through the overflow main line into tanks located in other watertight compartments in the event of any tank being damaged.
(2) Where overflows from tanks which are used for the alternative carriage of oil, ballast water, general cargo, etc., are connected to an overflow system, arrangements are to be made to prevent the entering of liquid or vapour from other tanks into the tank carrying general cargo, or to prevent the entering of oil different quality or ballast water from other tanks into the tank carrying oil.
(3) Overflow pipes discharging through the ship's sides are to extend above the load line and are to be provided with non-return valves fitted on the ship's sides.
Where the overflow pipes do not extend above the freeboard deck, the opening at the shell is to be protected against sea water ingress in accordance with the same provisions as that for overboard gravity drain from watertight spaces described in **302. 4.** In this connection, the vertical distance of the 'inboard end' from the summer load water line may be taken as the height from the summer load water line to the level that the sea water has to rise to find its way inboard through the overboard pipe.
Where, in accordance with **302. 4**, a non-return valve with positive means of closing is required, means is to be provided to prevent unauthorized operation of this valve. This may be a notice posted at the valve operator warning that it may be shut by authorized personnel only.

203. Sounding devices

1. General

(1) All tanks, cofferdams and other compartments which are not at all times readily accessible are to be provided with sounding pipes.
(2) In cargo holds, sounding pipes are to be fitted to the bilges on each side and as near the suction pipe rose boxes as practicable.
(3) All sounding pipes are to be clearly marked at the upper end.
(4) In addition to this requirements, the relevant requirements in **Pt 8, Ch 2, 101.** are to be complied with.

2. Termination of sounding pipes

(1) Sounding pipes are to be led to positions above the bulkhead deck which are at all times readily accessible and are to be provided with effective closing means at the upper end.
(2) In machinery spaces and shaft tunnels where it is not always practicable to extend the sounding pipes above the bulkhead deck, short sounding pipes extending to readily accessible positions above the platform may be fitted. In this case, the following closing means are to be fitted to the upper end of the pipes according to the kinds of tanks:
(A) Sounding pipes to fuel oil tank, lubricating oil tank and other flammable oil storage tank are to comply with relevant requirements in **Pt 8, Ch 2, 101.**
(B) Sounding pipes to other tanks mentioned in (A) and cofferdams are to be fitted with sluice valves, cocks or screw caps attached to the pipes by chains.

3. Construction of sounding pipes

(1) Sounding pipes are to be arranged as straight as practicable, and if curved, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.
(2) Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

Where sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

(3) The inside diameter of sounding pipes is not to be less than 32 mm. But the inside diameter of sounding pipes passing through a refrigerated chamber cooled down 0 °C or below is not to be less than 65 mm.

4. Sounding devices other than sounding pipes

(1) Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks.
(2) These devices are to be tested at the working condition on completion of the installation.
(3) Glass gauges used for tanks carrying fuel oils, lubricating oils and other flammable oils are to comply with the requirements specified in **Pt 8, Ch 2, 101. 2** (3) (E) (b) and (c).

Section 3 Ship-side Valves and Overboard Discharge

301. Ship-side valves and fittings

1. Installation

(1) All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating or to the plating of fabricated steel water boxes attached to the shell plating.
(2) These valves or cocks are to be fitted up to the doublings which are welded to shell plating or sea chest by using stud bolts not piercing the shell plating, or to the distance pieces attached to shell plating by using bolts.

2. Construction of distance pieces

Distance pieces attached to the shell plating are to be of rigid construction and as short as practicable.

3. Construction of sea chests

(1) Sea chests forming part of the ship's structure are to be as compact as possible and of rigid construction with no air to stay inside.
(2) Gratings are to be fitted at all openings in the ship's side for sea inlet valves or sea chest. The net area through the gratings is to be not less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air.

4. Sea inlet and overboard discharge valves

(1) Sea inlet and overboard discharge valves or cocks are in all cases to be fitted in easily accessible position. Indicators are to be provided local to the valves or cocks showing whether they are open or shut.
(2) Sea inlet valves are to be so located as to minimize the possibility of blanking off the suction and the valve spindles are to be extended above the lower platform. Power operated sea inlet valves are to be arranged for manual operation in the event of failure of the power supply.
(3) Discharge valves or cocks are to have spigots extending through the shell plating unless they are provided with distance pieces or doublings having spigots.

5. Blow-off valves of boilers and evaporators

(1) Blow-off valves or cocks of boiler and evaporators are to be fitted on the accessible ship's side and are to be provided with indicators showing whether they are open or shut, Cock handles are not to be capable of being removed unless the cocks are shut and if valves are fitted, the hand wheels are to be suitably retained on the spindle.
(2) These blow-off valves or cocks are to have spigots extending through the shell plating and protecting rings.

6. Location of overboard discharges

The location of overboard discharges is not to be such that water can be discharged into life boats when launched. Where such location is unavoidable, special consideration is to be given to prevent the discharge water from entering into the life boats.

302. Scuppers and sanitary discharge

1. General

Scuppers, sanitary discharges or similar openings led through the ship's side are to have, as far as possible, one common discharge; if this is impracticable, it is recommended to minimize the number of discharge openings by other means. In general, however, different systems of overboard discharges are not to be connected to each other unless specially approved by the Society.

2. Scupper

(1) Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.
(2) Where scuppers penetrate shell plating or superstructure side plating, suitable reinforcement is to be made at the penetrating parts.

3. Scuppers of exposed decks

Scuppers draining weather decks and spaces within superstructures or deck houses not fitted with efficient weathertight doors are to be led overboard.

4. Non-return valves of scuppers and sanitary pipes

Scuppers and sanitary pipes from spaces below the freeboard deck or from spaces within enclosed superstructures or enclosed deckhouses on the freeboard deck are to be led to the bilges or to suitable sanitary tanks. Alternatively, they may be led to overboard where they are provided with valves in accordance with the following requirements.
(1) Each separate discharge is to have one automatic non-return valve with a positive means of closing it from a position above the freeboard deck or, alternatively, one automatic non-return valve having no positive closing means and one stop valve controlled from above the freeboard deck. However, where the scuppers lead overboard through the shell plating in way of manned engine room, the fitting to the shell plating of a locally operated positive closing valve, together with a non-return valve inboard, will also be accepted. The means for operating the positive action valve from above the freeboard deck are to be readily accessible and provided with an indicator showing whether the valve is open or closed.
(2) Where, however, the vertical distance from the load line to the inboard end of the scupper pipe exceeds $0.01L_f$ (L_f : length for freeboard specified in **Pt 3, Ch 1** of the Rules), the scupper pipe may have two automatic non-return valves without positive means of closing in lieu of valves prescribed in (1). In this case, the inboard valve is to be located above the level of the tropical load line and always accessible for inspection under service condition. If this is not practicable, the inboard valve need not be located above the tropical load line, provided that a locally controlled stop valve is fitted between the two automatic non-return valves.
(3) Where the vertical distance from the summer load water line to the inboard end of the discharge pipe exceeds $0.02\ L_f$, a single automatic non-return valve without positive means of closing may be fitted.

5. Scupper pipes from the enclosed cargo spaces on the freeboard deck

Notwithstanding the requirements in above **Par 4.**, scupper pipes from the enclosed cargo spaces on the freeboard deck are to be in accordance with the following requirements.
(1) Where the freeboard to the freeboard deck is such that the deck edge is immersed when the ship heels more than 5°, scupper pipes are to be led directly overboard, fitted in accordance with the requirement specified in above **Par 4**.
(2) Where the freeboard to the freeboard deck is such that the deck edge is immersed when the ship heels 5° or less, scupper pipes are to be in accordance with the following requirements.
  (A) Scupper pipes are to be led directly to inboard bilge wells.
  (B) High water level alarm is to be provided in the bilge wells to where scupper pipes are led.
  (C) Where the enclosed cargo space is protected by a carbon dioxide fire-extinguishing system, the deck scuppers are to be fitted with means to prevent the escape of the smothering gas.

6. Overboard scuppers

Scuppers and discharge pipes originating at any level and penetrating the shell plating either more than 450 mm below the freeboard deck or less than 600 mm above the summer load waterline, are to be provided with an automatic non-return valve at the shell plating. This valve, unless required by **Par 4,** may be omitted provided that the pipe thickness is in accordance with the **Table 5.6.2.**

7. Deck wash and sanitary pipes

Sea water pipes for deck wash and sanitary pipes are not to be led through cargo holds except where specially approved for unavoidable cases.

8. Garbage chute

(1) For garbage chute, two gate valves instead of the non-return valve with a positive means of closing from a position above the freeboard deck which comply with the following requirements are acceptable.
  (A) Two gate valves are to be controlled from the working deck of the chute.
  (B) The lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.
  (C) The inboard end is to be located above the waterline formed by an 8.5° heel to port or starboard at a draft corresponding to the assigned summer freeboard, but not less than 1,000 mm above the summer waterline. Where the inboard end exceeds 0.01 L_f above the summer waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

(2) A hinged weathertight cover at the inboard end of the chute together with a discharge flap may be acceptable in lieu of the upper and lower gate valves complying with the requirements in (1). In this case, the cover and flap are to be arranged with an interlock so that the discharge flap cannot be operated until the hopper cover is closed.

(3) The entire chute, including the cover, is to be constructed of material of substantial thickness.

(4) The controls for the gate valves and/or hinged covers are to be clearly marked: **"Keep closed when not in use"**.

(5) For ships applied to damage stability requirements, following requirements are to be satisfied where the inboard end of the chute is below the freeboard deck.
  (A) The inboard end hinged cover/valve is to be watertight.
  (B) The screw-down non-return valve is to be fitted in an easily accessible position above the deepest load line and is to be controlled from a position above the bulkhead deck and provided with open/closed indicators. The valve control is to be clearly marked: **"Keep closed when not in use"**.

Section 4 Bilge and Ballast System

401. General

1. Application

(1) The requirements of this Section apply to the bilge and ballast system on the ship not less than 50 m in length.

(2) Bilge and ballast system of passenger ship, special ship and the ship less than 50 m in length are to be in accordance with the discretion of the Society.

2. Piping arrangement

(1) An efficient bilge pumping system is to be provided, capable of pumping from and draining any watertight compartment other than a space permanently appropriate for the carriage of liquid and for which other efficient means of pumping are provided, under all practical conditions and these suctions are, except where otherwise stated, to be branch bilge suctions connected to a main bilge line.

(2) An efficient ballast piping system is to be provided, capable of pumping ballast water into and from any tanks for carriage of ballast water under all practical conditions.

(3) In addition to the requirements in this chapter, following requirements for the drainage system

are to comply with:
(A) Where means of cooling the under deck cargo space for dangerous goods by an arrangement of fixed spraying nozzles etc. are installed, **Pt 8, Ch 5, 202. 1** (3);
(B) Where a fixed pressure water-spraying system is installed in the ro-ro space for dangerous goods, **Pt 8, Ch 5, 202. 9**;
(C) Where a fixed pressure water-spraying system is installed in the vehicle, special category and ro-ro spaces, **Pt 8, Ch 5, 305. 1** (4) and (5).

402. Drainage of compartment other than machinery spaces

1. Cargo holds

(1) In ships having only one hold, and this over 33 m in length, bilge suctions are to be fitted in suitable positions in the fore and after suctions of the hold.
(2) Where the inner bottom plating extends to the ship's side, the bilge suctions are to be led to wells placed at the wings and also at the center line if the top plating has inverse camber. But in the case of fishing vessels, a single well may be accepted.
(3) Where close ceiling or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.
(4) Bilge pipe arrangement in refrigerating chambers of ships except those to be registered according to **Pt 1, Ch 1, Sec 13,** is to be in accordance with the requirements in **Pt 9, Ch 1, Sec 5.**

2. Tanks

(1) All tanks including double bottom tanks are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank. Where fore and after peak tanks are used as fresh water tanks and small capacity, a hand pump may be substituted.
(2) All ballast tanks are to be connected to at least two(2) power driven ballast pumps. One of which may be driven by the propulsion unit. Bilge, sanitary and general service pumps driven by independent power may be accepted as independent power ballast pumps, provided that they are connected properly to the line. However, gravity discharge from top side tanks are to be complied with **302. 2** (1) (B) of **the Guidance**. And, where cargo pump is arranged for de-ballasting in emergency as **Pt 7, Ch 1, 1003. 2** (2), the cargo pump may be accepted as one(1) independent power ballast pumps,

3. Dry compartment other than cargo holds

(1) Bilge of chain lockers, fore and after peaks not used as tanks or deck forming the top of these tanks may be drained by eductors or hand pumps. These eductors or hand pumps are to be capable of being operated at any time from accessible position above the summer load water line.
(2) If steering gear compartments or other small enclosed spaces situated in the after peak compartment are adequately isolated from the adjacent decks and are capable of draining by gravity, they may be drained to the shaft tunnel or the machinery space by scuppers. In this cases, these pipes are not to be more than 65 A in nominal diameter and are to be provided with a quick-acting self-closing valve located in an accessible position.

4. Maintenance of integrity of bulkheads

(1) The intactness of the machinery space bulkhead, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck. These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but closed to these spaces and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.
(2) The air pipe of scupper drain tank is to be led above the bulkhead deck, and provision is to be made for ascertaining the level of water in the tank.
(3) Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

403. Drainage of machinery spaces

1. Machinery space with double bottom

(1) Where the double bottom extends to the full length of the machinery space and the bilge ways

are to be formed at both wings, one branch bilge suction and one direct bilge suction are to be provided at each side.

(2) Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

2. Machinery space without double bottom

(1) Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near the centerline as practicable.

(2) In ships where the rise of floor is less than 5°, additional bilge suctions are to be provided at the wings.

3. Additional bilge suctions

Additional bilge suctions are to be provided where considered necessary in connection with the arrangement of machinery room, ship's bottom structure or machinery layout.

4. Separate machinery spaces

Where the machinery space if divided by a watertight bulkhead to separate the boiler room or the auxiliary engine room from the main engine room, the bilge pipe arrangements in the boiler room and the auxiliary engine room are to be in accordance with the requirements of **Par 1** or **2.** However, only one direct bilge suction is enough though there is a double bottom.

5. Direct bilge suction

(1) The direct bilge suctions provided in machinery rooms are to be connected directly to the pumps driven by independent power specified in **405. 1** and their arrangements are to be such that they can be used independently of all other piping lines.

(2) The inside diameter of direct bilge suction pipes is not to be less than the inside diameter of main bilge pipes required. Where direct bilge suction is provided on each side of the machinery room with double bottom and also the emergency bilge suction is provided, the inside diameter of the direct bilge suction pipe at the side where the emergency bilge suction is provided, may be reduced to the required inside diameter of bilge suction branch pipe.

(3) Where the separate machinery spaces are of small dimensions, the sizes of the direct bilge suctions to these spaces will be specially considered.

6. Emergency bilge suction

(1) In addition to the bilge branch suctions and direct bilge suctions, an emergency bilge suction is to be provided in each main machinery space.

(2) This suction with a screw-down non-return valve having a hand wheel which is easily operable from above the platform in the machinery space is to be led to the main cooling water pump or main circulating pump and the suction is to be led to a suitable level in the machinery space.

(3) Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

(4) In ships with steam propelling machinery, the internal diameter of suction pipe is not to be less than two-thirds of the diameter of that of the main circulating pump suction. In other ships, the suction is to be the same size as the diameter of the main cooling pump suction.

(5) Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump as specified in **405. 1.** This pump is to have a capacity not less than that required for a bilge pump specified in **405. 2,** and the bilge suction is to be the same size as that of the pump suction branch.

(6) Where the pump to which the emergency bilge suction is connected is of self-priming type, the direct bilge suction arranged on the same side of the ship as the emergency bilge suction may be omitted.

404. Size of bilge suction pipes.

1. Main bilge line

The internal diameter d_m of the main bilge line is to be not less than that required by the following formula, to the nearest standard pipes, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1.68\sqrt{L(B+D)} + 25 \quad (\mathrm{mm})$$

where:

L, B, D = Length, breadth and depth of ship, respectively (m), defined in **Pt 3, Ch 1.**

2. Branch bilge suction

The internal diameter d_b of the branch bilge suction pipes is not to be less than that required by the following formula, to the nearest standard pipes, but in no case is the diameter to be less than 50 mm except that for drainage of a small compartment, it may be reduced to 40 mm, where considered acceptable by the Society.

$$d_b = 2.15\sqrt{l(B+D)} + 25 \quad (\mathrm{mm})$$

where:

l = Length of the compartment which shall be drained by branch pipe (m)

B, D = Breadth and depth of ship, respectively (m), defined in **Pt 3, Ch 1.**

3. Main bilge line of tanker and similar ships

In oil tankers, where bilge pumps in the machinery space are exclusively used for the bilge drainage of the machinery space, the internal diameter of main bilge suction pipes may be reduced to the value obtained from the following formula.

$$d_{m0} = \sqrt{2}\,(2.15\sqrt{l_m(B+D)} + 25) \quad (\mathrm{mm})$$

where:

l_m = Length of engine room (m)

B, D = Breadth and Depth of ship, respectively (m), defined in **Pt 3, Ch 1**.

4. Common bilge suction pipes

(1) The internal sectional area of common bilge suction pipes connecting two or more branch bilge suction pipes to the main bilge line is not to be less than the sum of internal sectional areas of the largest two branch bilge suction pipes, but need not be greater than the internal sectional area of the main bilge line.

(2) Where permitted, common-main type bilge system is to have the fore-and-after piping installed inboard of 20 % of the molded beam of the vessel. The control valves required in the branches from the bilge main are to be accessible at all times and are to be of the stopcheck type with an approved type of remote operator. Remote operators may be located in a manned machinery space, or from an accessible position above the freeboard deck, or from underdeck walkways. Remote operators may be of the hydraulic, pneumatic or reach-rod type.

5. Peak tanks and shaft tunnels

The internal diameter of bilge pipes in peak tanks and shaft tunnels is not to be less than 65 mm. However, in ships of 60 m or less in length, the internal diameter may be reduced to 50 mm.

6. Where bilge suctions are provided at the fore and after part of cargo hold in accordance with the requirements in **402. 1** (1), the internal diameter of the branch bilge suction pipe at the fore part may be reduced to 0.7 times that obtained from the formula in **Par 2.**

405. Bilge pumps

1. Number of pumps

(1) All ships are to be provided in their machinery rooms with at least two sets or two groups of independent power bilge pumps connected to the bilge main. In ships of 90 m in length and under, one of these pumps may be driven by the main engines.
(2) Ballast, sanitary and general service pumps driven by independent power may be accepted as independent power bilge pumps, provided that they are connected properly to the main bilge line.
(3) One of the independent power bilge pumps prescribed in (1) may be substituted by an eductor in connection with a sea water pump other than bilge pump where considered acceptable by the Society. In this case, the capacity of the eductor is to comply with the requirement in **Par 2.**

2. Capacity of pumps

(1) The capacity, Q, of each bilge pumping unit or bilge pump is not to be less than that required by the following formula.

$$Q = 5.66 d_m^2 10^{-3} \quad (\mathrm{m^3/hr})$$

where:

d_m = Required internal diameter of main bilge line (mm)

(2) Where one bilge pump or pumping unit is of slightly less than the required capacity, the deficiency may be made good by an excess capacity of the other unit. But in any cases the capacity of this pump is to be more than 70 % of the required capacity.

3. Self-priming type

All power pumps required in **Par 1** are to be of the self-priming or the equivalent type and are to be so arranged that they are immediately operable when in use.

4. Connection of bilge pumps and suction pipes

All of the power pumps prescribed in **Par 1** are to be arranged for discharging bilge from all holds, engine room and shaft tunnel. Where, however, an eductor is used exclusively for bilge drainage in a hold, the bilge suction pipe of this hold need not be connected to the bilge pumps prescribed in **Par 1**. In this case, the eductor is to be so arranged as to be driven by two or more pumps. Capacity of the sea water pump for sending driving water to the eductor, capacity of the eductor, internal diameter of the suction pipe are to be considered appropriate by the Society.

5. Pump connections

(1) The bilge pumps may be used for ballast, fire or general service duties of an intermittent nature.
(2) The connections at the bilge pumps are to be such that one unit may continue in operation when the other pump is being opened up for overhaul.
(3) Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any of the pumps so connected is unaffected by the other pumps being in operation at the same time.

406. Pipe systems and their fittings

1. Isolation of bilge system

Bilge suction pipes used for draining cargo holds, machinery room and shaft tunnels are to be entirely separate from pipes other than the bilge suction pipes.

2. Prevention of communication between compartments

The arrangement of bilge system is to be such as to prevent the ingress of water or oil inadvertently from the sea or the tanks to machinery spaces, dry cargo spaces or other similar compartments, or of bilge passing from one watertight compartment to another. For this purpose, screw-down non-return valves or cocks are to be provided as follow.

(1) Screw-down non-return valves or cocks which bilge and water or oil are not to be communicated at same time, are to be provided at the bilge pipes connected to the pump drawing water or oil.
(2) Screw-down non-return valves are to be provided between each branch bilge suction and distribution chests.

3. Bilge pipes in way of double bottom tanks

Bilge pipes passing through double bottom tanks are to be led through oiltight or watertight pipe tunnel or alternatively, are to be of sufficient thickness complying with the requirements in **Table 5.6.2.**

4. Bilge pipes or ballast pipes in way of deep tanks

Bilge pipes passing through deep tanks and ballast pipes passing through deep tanks except for ballast tanks are to be led through an oiltight or watertight pipe tunnel or alternately, are to be of sufficient thickness complying with the requirements in **Table 5.6.2** and all joint of them are to be welded, and they are to be properly installed taking sufficient care of leakage, expansion and contraction.

5. Valves and valve boxes

(1) All valves, valve boxes or cocks which are fitted to the bilge piping are to be provided at easily accessible locations in any condition of the ship.
(2) Bilge pipes passing through double bottoms, side tanks, bilge hopper tanks or void spaces, where there is a possibility of damage of these pipes due to grounding or collision, are to be provided with non-return valves near the bilge suctions or stop valves capable of being closed from readily accessible positions.

6. Pipes in various purpose deep tanks

(1) Where a hold is intended for carrying ballast water and cargo alternately, adequate provisions such as blank flange or spool piece are to be made in the ballast piping system to prevent inadvertent ingress of sea water through ballast pipes when carrying cargo and in the bilge piping system to prevent inadvertent discharge of ballast water through bilge pipes when carrying ballast water.
(2) Where a tank is intended to be used both for fuel oil and ballast water, adequate provisions such as blank flange or spool piece are to be made to prevent mixing of fuel oil and ballast water in the ballast pipe when carrying fuel oil and in the fuel oil pipe when carrying ballast water.

7. Ballast piping system

(1) Ballast piping system is to be provided with a suitable provision such as a non-return valve or a stop valve which can be kept closed at all times excluding the time of ballasting and de-ballasting and which is provided with an indicator to show whether it is open or closed, in order to prevent the possibility of water inadvertently passing from the sea to the ballast tanks or of ballast passing from one ballast tank to another.
Where butterfly valves(except remote control valves) are used, they are to be of type with positive holding arrangements, or equivalents, that will prevent movement of the valve position due to vibration or flow of fluids.
(2) Remote control valves, where fitted, are to be arranged so that they will close and remain closed in the event of loss of control power. Alternatively, the remote control valves may remain in the last ordered position upon loss of power, provided that there is a readily accessible manual means to the valves upon loss of power.
Remote control valves are to be clearly identified as to the tanks they serve and are to be provided with position indicators at the ballast control station.

8. Mud boxes

All bilge suction pipes in the machinery room are to be provided with mud boxes, having straight tail pipes to bilges and fitted with covers which can be readily opened or closed and placed at easily accessible positions above the floor level of the machinery room. For emergency bilge suction pipes these requirements may not be complied with.

9. Rose boxes

All bilge suction branch pipes of such cargo holds and spaces other than machinery compartment are to be fitted at their open ends with rose boxes which can be cleaned without disconnecting the flanges of the suction pipes. The diameter of suction holes on the rose boxes is not to be greater than 10mm and the total open area of perforation is not to be less than three times that of the suction pipe.

10. Bilge wells

(1) Bilge wells are to be constructed of steel and not less in capacity than 0.17 m^3. However, where the spaces to be drained are of small dimensions, steel bilge hats of reasonable capacity may be fitted.
(2) The depth of bilge wells constructed in double bottom and the vertical distance between the bottom shell plating and the bottom plate of bilge wells are to comply with the requirements in **Pt 3, Ch 7, 103.**

11. Manhole

Where accessible manholes to the bilge well of cargo holds are necessary, they are to be fitted as near bilge suctions as practicable. It is to be avoided to provide the above manholes in the fore and after bulkheads and tank top plating of the machinery space. Where, however, this arrangement is necessary, a manhole cover of the hinged type is to be fitted and notice plate indicating "**To be kept shut except when access is required**", is to be posted up in well observable position near the manholes.

Section 5 Feed Water and Condensate System for Boiler

501. Feed water pumps

1. Ships equipped with main boiler for steam propulsion and essential auxiliary boiler for driving of essential auxiliaries are to be provided with at least two independent power driven feed water pumps. One feed pump may, however, be accepted in case of auxiliary boiler other than the essential auxiliary boiler.

2. Each pump is to be of the capacity sufficient to supply water to the boilers under designed full load conditions.

3. The feed pumps are to be driven by independent prime movers.

4. The feed pumps are to be used exclusively for feed purposes.

502. Feed water piping

1. For all main and auxiliary boilers which are required for essential services, at least two separate means of feed are to be provided between the pumps and each boiler. However, a single penetration in the steam drum is acceptable. In this case, the screw down check valve in **Ch 5, 127.** is to be installed in each of the two feed lines.

2. One feed water system may be accepted in case of auxiliary boilers other than the essential auxiliary boilers. In this case, feed water regulator, feed water heater and de-oiler installed on discharge piping of feed water pumps are to be provided with a by-pass valve.

3. A feed water regulator capable of automatically controlling the feed rate is to be provided on the feed water system of main boiler or essential auxiliary boiler.

4. Where auxiliary boiler other than essential auxiliary boiler is controlled automatically, a feed water regulator capable of automatically controlling the feed rate is to be provided on the feed water piping.

503. Condensate pumps

1. At least two independent condensate pumps are to be provided for dealing with condensate from the main condenser.

2. Each of these condensate pumps is to have a capacity to deal with the maximum designed rate of condensate from the condenser.

504. Piping

1. Where two feed pumps or two condensate pumps are required, these pumps are to be installed such that one pump may continue in operation when the other pump is being opened up for overhaul.

2. The pipe lines connected to boiler feed water or drinking fresh water tanks are to be entirely separate from oil pipe lines or pipe lines for oily water.

3. Boiler feed water pipes are not to be led through tanks which contain oil, nor are oil pipes to be led through boiler feed water tanks.

505. Distilling plant and feed water tank

1. In ships with main boilers, at least one distilling plant with a sufficient capacity is to be provided.

2. All ships with boilers are to be provided with feed water tanks of sufficient capacity.

Section 6 Steam and Exhaust Gas Piping

601. Steam piping

1. Piping

(1) In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.
(2) Water pockets in the steam flow lines are to be avoided as far as practicable in order to prevent water hammer in the system. If this cannot be avoided, drain cocks or valves are to be fitted in such places that the pipes may be efficiently drained while in operation.
(3) Steam pipes are not to be led through cargo spaces without special approval.
(4) If a steam pipe or fitting may receive steam from any source at a higher pressure than that for which it is designed a suitable reducting valve, relief valve and pressure gauge are to be fitted.

2. Steam supply to auxiliary machinery

In ships with two or more boilers, the arrangement of steam piping for auxiliaries is to be such that it is possible to supply steam from at least two boilers to the essential auxiliaries, prime movers thereof and steam whistle.

3. Oil heating pipes

Where steam is used for heating of fuel oil or lubricating oil, the steam drain pipes are to be led to observation tanks in a well-lighted and accessible position in machinery spaces.

602. Exhaust gas piping

1. Exhaust gas pipes for internal combustion engines

(1) Exhaust gas pipes and silencers are to be water cooled or effectively insulated against heat. Silencers are to be so arranged that they may be easily cleaned.
(2) In principle, exhaust gas pipes of two or more engines are not to be connected together. But if the pipes have to be led to a common silencer, effective means are to be arranged to prevent the return of exhaust gases to the cylinders of non-operating engines.
(3) Boiler uptakes and engine exhaust lines are not to be connected, except when specially approved as in the case where the boilers are arranged to utilize the waste heat from the engines.
(4) Exhaust gas lines led overboard near the water line are to be provided with suitable device to prevent water from being siphoned back to the cylinders.

2. Exhaust gas pipes for boilers

Exhaust gas pipes for boilers are to be complied with **Ch 5, 134. 4.**

Section 7 Cooling System

701. Main cooling pumps

1. Cooling system for the main engines, essential auxiliary engines and various attached coolers are to be provided with main cooling water pump to have sufficient capacity for supplying the cooling water under working condition at the maximum continuous output.

2. In steam turbine ships, adequately installed scoop arrangement may be accepted in place of main cooling water pumps.

3. Main cooling pumps may be driven either directly by main or auxiliary engines or by independent prime movers.

702. Stand-by cooling water pumps

1. Cooling system for the main engines, essential auxiliary engines and various attached coolers are to be provided with stand-by cooling water pump in addition to the main cooling pump to have sufficient capacity for supplying the cooling water under normal service condition.

2. Stand-by cooling pumps are to be driven by independent prime movers.

3. In ships having steam turbines as their main engines and provided with the scoop arrangement in place of main cooling pumps, their main condensers are to be so arranged as to be sufficiently cooled with other cooling systems while ships run at low speed, in addition to the cooling system by stand-by cooling pumps.

4. Where duplicate essential auxiliary engines are provided with exclusive cooling pump respectively, stand-by cooling pump need not be provided.

5. Where any suitable independent power driven pump for other purposes is available as a stand-by cooling pump, this pump may be regarded as a stand-by cooling pump.

6. Where fresh water is employed for the cooling, the stand-by fresh water cooling pump need not be fitted if there is suitable connections with sea water cooling system.

7. Where two or more main engines are provided, each of them having a built-in main cooling pump, and where it is possible to give a navigable speed even if one of the pumps is out of use, the stand-by cooling pumps may be dispensed with on condition that one complete spare pump is carried on board.

8. Where engines with a built-in main cooling pump in a small ship, a stand-by cooling pump may be omitted.

703. Sea inlets

Sea water cooling systems for the main engine and prime mover driving the essential auxiliaries needed to propel the ship, are to be connected to at least two sea inlets, on opposite sides and close to the ships bottom.

704. Strainer

Where sea water is used for the direct cooling of the main engine and essential auxiliary engine, strainers which are arranged to be capable of being cleaned without stopping the supply of filtered cooling water to the respective engines are to be provided between the sea suction valve and the cooling sea water pump. In small ships. however, these strainers may be omitted with approval of the Society.

705. Using lubricating oil or fuel oil

Where lubricating oil or fuel oil is used for cooling the machinery, the lubricating oil system or fuel oil systems are to be complied with **Sec 8** or **9** respectively.

Section 8 Lubricating Oil System

801. General

In addition to the requirements in this section, the relevant requirements in **Pt 8, Ch 2, 101.** are to be complied with.

802. Lubricating oil pumps

1. Main engines, propulsion shaftings and their power transmission systems, and auxiliary machinery essential for the propulsion and their prime movers are to be provided with main lubricating oil pumps of sufficient capacity to maintain the supply of oil at the maximum continuous output and stand-by lubricating oil pumps of sufficient capacity to supply oil under normal service condition.

2. The main lubricating oil pumps may be driven either directly by main engines or by independent prime movers. Stand-by lubricating oil pump, however, are to be driven by independent prime movers.

3. Where two or more main engines, propulsion shaftings and their power transmission systems are provided, and where each of them has a built-in main lubricating oil pump and when it is possible to give a navigable speed even if one of them is out of use, the stand-by lubricating oil pumps may be dispensed with on condition that one complete spare pump is carried on board.

4. Where duplicate essential auxiliary engines are provided with exclusive lubricating oil pump respectively stand-by pump may be omitted.

5. Where any suitable independent power driven pump for other purposes is available as a stand-by lubricating oil pump, this pump may be regarded as a stand-by lubricating oil pump.

6. For engines having maximum continuous output not exceeding 257 kW with a built-in main lubricating oil pump, a stand-by lubricating oil pump may be omitted with the approval of the Society.

7. Main lubricating oil pumps and their corresponding stand-by lubricating oil pumps are to be easily changed over each other.

803. Piping

1. Lubricating oil pipings are to be entirely separate from other piping system except where specially approved by the Society.

2. For ships of 100 m and above in length where a double bottom is used as a lubricating oil sump tank, a stop valve is to be provided between the engine and the lubricating oil sump tank and is to be so arranged as to facilitate its operation from the engine room floor.

804. Lubricating oil filters and purifiers

1. Where forced lubrication system (including gravity supply from head tank) is adopted for lubrication of engines, lubrication oil filters are to be provided.

2. The filters used for the lubricating oil systems of main engine, power transmission of propeller shafting and controllable pitch propeller system are to be capable of being cleaned without stopping the supply of filtered lubricating oil.

3. Lubricating oil purifiers or equally effective filters are to be provided in ships which have internal combustion engines or steam turbines as their main engines.

805. Lubricating oil drain

Metallic drip trays with sufficiently deep coaming are to be provided under lubricating oil pumps, lubricating oil filters, lubricating oil tanks and other lubricating oil appliances which are often opened up for cleaning or adjustment, and leaked oil and/or discharged drain are to be led to lubricating oil drain tanks. If it is impossible to lead them from each drip tray to a lubricating oil drain tank, coaming of each drip tray is to be made deep and every possible means is to be taken to ensure that no drain is left behind at any time.

Section 9 Fuel Oil System

901. General

1. In addition to the requirements in this section, the relevant requirements in **Pt 8, Ch 2, 101.** are to be complied with.

2. Arrangement of fuel oil systems

(1) The compartments in which fuel oil burning systems, fuel oil settling and service tanks, fuel oil purifiers, etc. are located, are to be readily accessible and well ventilated.
(2) Fuel oil tanks, fuel oil pumps, fuel oil filters, etc. are not to be located right above or near units of high temperature including boilers, steam pipe lines, exhaust pipe lines, silencers, etc.
(3) The distance of separation between fuel oil tanks and boilers is to be complied with the requirements **Ch 5, 134. 2.**
(4) As far as practicable, fuel oil pipes are to be located far from hot surfaces and electrical equipments, but where this is impracticable, the pipe joints are not to be located above nor near such ignition sources. The pipes are to be led in well lighted and readily visible positions.
(5) Valves, cocks and other fittings fitted on fuel oil tanks are to be located in safe positions so as to protect them from the external damage.
(6) All valves or cocks connected to fuel oil system in machinery spaces or boiler spaces are to be capable of being operated from the floor.

3. Fuel oil pipes and their fittings

(1) Fuel oil pipes are to be of steel. Fuel oil pipes intended for the design temperature above 60 °C and the design pressure above 1 MPa are to be seamless steel pipes or pipes fabricated with the approved procedure.
(2) The valves and fittings used for the fuel oil system with a design temperature above 60 °C and a design pressure above 1 MPa are to be of not to be less than 1.6 MPa in nominal pressure of Korean Industry Standard or national industry standard. The valves and fittings used for fuel oil transfer piping lines, fuel oil suction piping lines and other low pressure fuel oil piping lines are not to be less than 0.5 MPa in nominal pressure.
(3) Packings for pipe joints are to be both heat and oil resisting and to be as thin as practicable.
(4) Where union joints are used for short pipes connecting fuel oil injection pipes for internal combustion engines or boiler burners, they are to be of specially robust construction and to have

metal contact of conical or spherical shape.

(5) Oil fuel lines are to be screened or otherwise suitably protected to avoid as far as practicable oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition. The number of joints in such piping systems are to be kept to a minimum.

4. Drainage system

(1) Metallic drip trays with sufficiently deep coaming are to be provided under burners, fuel oil pumps, fuel oil filters, fuel oil tanks such as fuel oil settling and service tanks, and other fuel oil appliances which are opened up for cleaning or maintenance.
(2) Fuel oil settling tanks and service tanks are to be provided with drain valves or cocks on their bottoms.
(3) Where drain valves or cocks are fitted to fuel oil tanks, the valves or cocks are to be of self-closing type.
(4) Oil in the drip trays and from drain valves is to be led to suitable oil drain tanks not forming part of an overflow system.
(5) Suitable appliances are to be provided for disposing fuel oil drains stored in the drain tanks.

5. Construction of fuel tanks

Fuel oil tanks which do not form part of ship's structure are to be so constructed that they can be readily inspected and cleaned, and the thickness of plating of the tank is not to be less than 5 mm, but in case of small tanks may be reduced to 3 mm.

6. Tank filling pipes

(1) Filling pipes of fuel oil tanks from outboard are to be of exclusive use and to be led above decks as far as possible, and to be provided with strong covers at their open ends.
(2) Where fuel oil filling pipes are fitted not on nor near the top of fuel oil tanks, non-return valves are to be directly fitted to the tanks, or alternatively, valves or cocks having remote closing means specified in **Pt 8, Ch 2, 101. 2** (3) (D) are to be provided.
(3) Notwithstanding the requirements in (1), where fuel oil filling pipes are connected to suction pipes, stop valves are to be provided on the filling pipes. And additional non-return valves are to be provided where the tanks are situated on a higher position than the double bottom and fuel oil may flow to other fuel oil tanks through the filling pipes thereto and overflow from the openings of sounding pipes, etc.

7. Valves for tank suction pipe

(1) All suction pipes from double bottom fuel oil tanks are to be provided with stop valves or cocks which are capable of controlling in engine room.
(2) The relevant requirements in **Pt 8, Ch 2, 101. 2** (3) (D) are to be complied with.
(3) Pneumatic remote shut-down devices (of the type that requires compressed air only at the time of closing) of main suction valves of fuel oil tanks are to comply with the following requirements:
  (A) an exclusive air bottle for remote shut-down is to be provided in an easily accessible position outside the compartment in which fuel oil tanks are situated.
  (B) The capacity of air bottle is to be sufficient for closing all the main suction valves of fuel oil tanks at least 2 times.
  (C) The air bottle is to be provided with a pressure measuring device at a position which can be easily seen from the position where the remote shut-down device is operated.
  (D) Air pipes from the air bottle to the main suction valve's actuators are not to be provided with valves except for valves for remote control and blow-off valves for these pipes.
  (E) Air pipes from the air bottle to the main suction valve's actuators are to be steel or copper pipes.
  (F) Air charging pipes to the air bottle are to be provided with non-return valves.

8. Fuel oil pumps

(1) Stop valves or cocks are to be fitted on both the suction and delivery sides of fuel oil pumps to overhaul these pumps.
(2) All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves arranged discharge back to the suction side of the pump. However, pressure relief valves may not be fitted when the system is served only by centrifugal pumps, so designed that the pressure delivered can not exceed that for which the

piping is designed.

(3) The power supply to the fuel oil transfer pump, fuel oil burning pump, fuel valve cooling oil pump, other similar fuel oil pumps and fuel oil purifiers is to be capable of being stopped from a remote position which will always be accessible in the event of fire taking place in the compartment in which they are situated or its neighbourhood, as well as from the compartment itself.

9. Fuel oil transfer pumps

(1) In ships where a power pump is used for pumping up to the settling and service tanks, at least, two independent power fuel oil pumps are to be provided, and these pumps are to be connected ready for use. In case of small ships, however, a manual pump of proper capacity may be used in lieu of power pump.

(2) Where any suitable fuel oil pump being driven by an independent prime mover for other purposes is available as one of the transfer pumps, this pump may be regarded as a fuel oil transfer pump.

10. Fuel oil piping

(1) Fuel oil piping systems are to be entirely separated from other piping systems as far as practicable. Should it be unavoidable to interconnect to other systems, effective means are to be provided to prevent the accidental contamination with other liquids.

(2) Where it is intended to carry fuel oil and ballast water in the same compartment alternately, the pipes are to be so arranged that the fuel oil can be pumped from any one compartment at the same time as the ballast water is being discharged from any other compartment. Where settling or service tanks are provided, each having a capacity sufficient to permit 12 hours normal service without replenishment, the above requirement may be modified.

(3) Pipelines intended for serving the oil fuel tanks are not to pass through the cargo and slop tanks and are to have no connection with pipelines serving the cargo and sloptanks.

11. Fuel oil heating systems

(1) Heating arrangements in tanks

(A) Flash point

Fuel oil in storage tanks is not to be heated within 10 °C below its flash point. Where fuel oil in service tanks, settling tanks and any other tanks in the supply system is heated, the arrangements are to comply with the following :

(a) The temperature at the open ends of the air pipes from the tanks is to be below flash point of fuel oil, or the outlet of the air pipes is to located at least 3 m away from a source of ignition.

(b) Air pipes are to be fitted with the flame-screens.

(c) There are no openings from the vapor space of the fuel tanks leading into machinery spaces, except for bolted manholes.

(e) Enclosed spaces, such as workshops, accommodation spaces, etc., are not to be located directly over the fuel tanks, except for vented cofferdams.

(B) Fuel oil temperature control

All heated fuel oil tanks located within machinery spaces are to be fitted with a temperature indicator. Means of temperature control are to be provided to prevent overheating of fuel oil, in accordance with (A) above. However, electric heaters are to be provided with automatic temperature controlling devices.

(C) Temperature of heating media

Where heating is by means of fluid heating medium(steam, thermal oil, etc.), a high temperature alarm is to be fitted to warn of any high medium temperature. This alarm may be omitted if the maximum temperature of the heating medium can, in no case, exceed 220 °C.

(D) Steam heating

To guard against possible contamination of boiler feed water, where fuel oil tanks are heated by steam heating coils, steam condensate returns are to be led to an observation tank, or other approved means, to enable detection of oil leaking into the steam system.

(E) Electric heating

(a) Where electric heating is installed, the heating elements are to be arranged to be submerged at all times during operation, and are to be fitted with an safety temperature switch of preventing the surface temperature of the heating element from exceeding 220 °C. This safety temperature switch is to be independent of the fuel oil temperature control specified in (B) above. Additionally, this safety temperature switch is to cut off the electrical power supply in the event of excessive temperature and is to be provided with manual reset.

(b) Double bottom tanks and deep tanks are not to be provided with electric heaters, unless approved by the Society.

(F) UMA and CMA ships

Fuel oil tanks provided with heating arrangements are to be fitted with the following alarms at the centralized control station.

(a) High temperature alarm and temperature display for the heated fuel oil in the settling and service tanks.

(b) High temperature alarm for the fluid heating medium (steam, thermal oil, etc.) for fuel oil tanks, where the maximum temperature of the heating medium would exceed 220 °C .

(2) Heaters

(A) Fuel oil temperature control

All heaters are to be fitted with a fuel oil temperature indicator and a means of temperature control.

(B) Heating media and electric heating

The requirements specified in (1) (C), (D) and (E) (a)are also applicable to fuel oil heaters.

(C) Relief valve

Relief valves are to be fitted on the fuel oil side of the heaters. The discharge from the relief valve is to be led to a safe location.

(D) UMA and CMA ships

Fuel oil heaters are to be fitted with the following alarms at the centralized control station.

(a) Fuel oil high temperature (or low viscosity) alarm

(b) High temperature alarm for the fluid heating medium (steam, thermal oil, etc.) for fuel oil heater, where the maximum temperature of the heating medium would exceed 220℃.

12. Oil tanks for galleys

Oil tanks provided for galleys are not to be installed in the galley space and are to be fitted with filling and air pipes of approved construction. Stop valve is to be fitted on the fuel oil supply line at an easily accessible location so that the valve can be readily shut in case of fire in the galley.

13. Fuel oil service tanks

Two fuel oil service tanks for each type of fuel used on board necessary for propulsion and vital systems or equivalent arrangements are to be provided with a capacity of at least 8 hours at maximum continuous rating of the propulsion plant and normal operating load at sea of the generating plant.

902. Burning systems for boiler

1. Burning system

(1) Where the main boiler is provided with the combustion system of pressurized fuel injection type, at least two oil burning units, each unit comprising a burning pump, a suction filter, a discharge filter and a heater, are to be provided, and each unit is to be capable of supplying oil for generating steam of required quality even in the case of failure of one unit.

(2) As for essential auxiliary boiler and other boilers to supply steam for fuel oil heating necessary for the operation of the main engine or cargo heating that is required continuously, the burning systems are to be provided in accordance with the requirements in (1) above. However, where the alternative means, such as exhaust gas economizer, heating equipments, etc., are available to ensure the normal navigation and cargo heating with the burning system being out of operation only one unit of burning system will be accepted.

2. Oil feeding by gravity

Where in main boiler or essential auxiliary boiler oil is fed to the burners by gravity, the fuel oil filters are to be capable of being cleaned without stopping the supply of fuel oil.

3. Cold starting

In main or essential auxiliary boiler, a suitable cold starting device which does not require power from the shore is to be provided.

4. Burners

(1) Boiler burners are to be so arranged that they cannot be removed unless the fuel supply is cut off and also that the fuel oil cannot be supplied unless the burners are set correctly.
(2) Boilers designed to use both exhaust gas and fuel oil, are to be provided with devices which will not allow the supply of fuel oil unless the gas in the exhaust gas pipe is cut off.

5. Piping arrangement for fuel oil burning pumps

Fuel oil pipings of burning pumps are not to be connected with other piping lines than those for fuel oil.

6. Automatic combustion systems

Where the automatic control and/or remote control are used with boilers, the burning systems are to be in accordance with the requirements in **Pt 6, Ch 2** in addition to the requirements in this Chapter.

903. Fuel oil supply system of internal combustion engines

1. Fuel oil supply pumps

(1) For main engines and essential auxiliary engines, one stand-by fuel oil supply pump driven by independent power having a sufficient capacity to maintain the supply of fuel under normal service condition is to be provided in addition to the main fuel oil supply pump which has a sufficient capacity for suppling the fuel oil under working condition at the maximum continuous output.
(2) Where any fuel oil pump driven by independent power source intended for other purposes is available as a stand-by fuel oil supply pump, this pump may be regarded as a stand-by fuel oil supply pump.
(3) As for the internal combustion engines driving the auxiliary machinery for important use requiring main and stand-by and where each engine is provided with a fuel oil supply pump, the stand-by fuel oil supply pump may be omitted.
(4) For engines having maximum continuous output not exceeding 370 kW with a built-in main fuel oil supply pump, a stand-by fuel oil supply pump may be omitted subject to the approval by the Society.
(5) Main fuel oil supply pumps may be driven by engines or independent power, but stand-by fuel oil supply pumps are to be driven by independent power sources.
(6) Where two or more main propulsion machinery is provided, and where each of them has a built-in main fuel oil supply pump and when it is possible to give a navigable speed even if one of them is out of use, stand-by fuel oil supply pump may be dispensed with on condition that one complete spare pump is carried on board.

2. Fuel oil filters

(1) Fuel oil filters are to be provided on fuel oil supply piping lines for internal combustion engines. These fuel oil filters under pressure for diesel engines are to be located such that, in the event of oil leakage, they can not be sprayed onto the exhaust manifold.
(2) The filters for internal combustion engines for propulsion are to be capable of being cleaned without stopping the supply of filtered fuel oil.

3. Fuel oil heating devices and fuel oil purifying devices

Where low grade oil is used as fuel oil, suitable fuel oil heating devices and fuel oil purifying devices are to be provided.

Section 10 Thermal Oil System

1001. Application

1. Thermal oil piping systems are to be complied with the requirements specified in **201., 901. 2, 4, 6** (2), **7** and **8** (1).

2. In addition to the requirements of this Section, these systems are to comply with the requirements in **Pt 8, Ch 2, 101. 4** of the Rules.

1002. Thermal oil piping system

1. Expansion tanks are to be provided with liquid level indicator.

2. Circulating pumps are to be provided with a pressure measuring device at a suitable position on the delivery and suction sides.

3. The inlet and outlet valves on thermal oil heaters are to be controllable from outside the compartment where they are installed. As an alternative, an arrangement for quick gravity drainage of the thermal oil contained in the system into a collecting tank is acceptable.

1003. Pumps for thermal oil system

1. The thermal oil system for important use is to be provided with two thermal oil circulating pumps and two fuel oil burning pumps. However, only one fuel oil burning pump will be accepted, where alternative means are available to ensure the normal navigation and cargo heating in case of failure of the pump.

2. Circulating pumps are to be capable of being stopped from a suitable position other than a space in which thermal oil heaters are situated.

1004. Heating of liquid cargoes with flash points below 60 ℃

1. Heating of liquid cargoes with flash points below 60 °C is to be arranged by means of a separate secondary system, located completely within the cargo area. However, a single circuit system may be accepted, where the thermal oil systems are satisfied with the following whole conditions:

(1) The system is to be arranged so that a positive pressure in the coil is at least 3 m water column above the static head of the cargo when circulating pump is not in operation.
(2) The thermal oil system expansion tank is to be fitted with high and low level alarms.
(3) Means is to be provided in the thermal oil system expansion tank for detection of flammable cargo vapours. Portable equipment may be accepted.
(4) Valves for the individual heating coils are to be provided with locking arrangement to ensure that the coils are under static pressure from thermal oils at all times.

Section 11 Compressed Air System

1101. Compressed air starting devices

1. Number and capacity of main air reservoirs

(1) Where the main engines are arranged for starting by compressed air, at least two starting air reservoirs of about equal capacity are to be fitted. These reservoirs are to be connected ready for use.
(2) The total capacity of air reservoirs is to be sufficient to provide, without their being replenished, not less than 12 consecutive starts altering between Ahead and Astern of each main engine of the reversible type, and not less than 6 consecutive starts of each main non-reversible type engine. The number of starts refers to engine in cold and ready to start conditions.

(3) Where the auxiliary engines are designed for starting by compressed air, two separate auxiliary air reservoirs which are to be sufficient for at least three starts for each auxiliary engine when in cold and ready to start conditions are to be fitted, or starting air for auxiliary engines is to be supplied by separate piping from main air reservoirs. In case where only one auxiliary reservoir is fitted, starting air pipes are to be connected with main air reservoir.

(4) Where the auxiliary engines are designed for starting by the main air reservoirs, the capacity of the main air reservoirs is to be more than sum of the capacity required in (2) and (3) above, and the amount consumed for engine control systems, whistle, etc.

(5) For multi-engine installations, the number of starts required for each engine is to be determined as deemed appropriate by the Society.

2. Number and total capacity of air compressors

(1) Where the main engines are designed for starting by compressed air, at least two starting air compressors are to be provided and arranged so as to be able to charge each reservoir.

(2) At least one of them is to be driven by a prime mover other than main engines. Where cylinders are provided with air charging valves by the small engine, the charging valves may be considered as equivalent to an air compressor driven by the main engine.

(3) The total capacity of air compressors is to be sufficient to supply air in the reservoirs from atmospheric pressure to the pressure required for the consecutive starts prescribed in **Par 1** within one hour.

3. Emergency air compressors

(1) Where prime movers driving air compressors specified in **Par 2** are arranged for air starting, an independent power driven emergency air compressor is to be provided.

(2) The prime movers driving the emergency air compressor are to be capable of starting without compressed air.

(3) The capacity of the emergency air compressor is to be sufficient to start the prime movers of the air compressor prescribed in **Par 2.** For this purpose, a small air reservoir for emergency air compressor may be provided.

(4) In case of a small installation, a manual air compressor of adequate capacity may be accepted as an emergency air compressor.

4. Arrangement of starting air piping

(1) All discharge pipes from starting air compressors are to be led directly to starting air reservoirs.

(2) All starting pipes from the air reservoirs to main or auxiliary engines are to be entirely separate from the said compressor discharge system.

1102. Construction and safety devices

1. Construction, materials, strength and safety device of air compressors

(1) Provision is to be made to the arrangement of air compressor to reduce the entry of oil into compressed air to a minimum.

(2) Air coolers of air compressors are to be so constructed and arranged that they can be easily overhauled for inspection.

(3) Materials used for shafts and essential parts of air compressor are to be in accordance with **101. 5** (1).

(4) The strength of crankshafts of air compressors is to be in accordance with **1102. of the Guidance** and the strength of shafts other than crankshafts is to be in accordance with **101. 5** (2).

(5) Each air compressor is to be provided with a relief valve to prevent that the pressure of cylinder exceeds the design pressure.

2. Construction and safety device of air reservoirs.

(1) Relief devices and other fittings for air reservoirs are to comply with the requirements in **Ch 5, 317.**

(2) Air reservoirs are to be so constructed and arranged that they can be readily opened up for cleaning and inspection, and to be provided with drainage arrangement at a suitable position permitting drain to be effectively blown out under extreme condition of trim.

(3) All air reservoirs are to be provided with pressure gauges at the position where it can be easily seen.

Section 12 Refrigerating Machinery

1201. General

1. Application

(1) The requirements in this Section apply to the refrigerating machinery of refrigerating chamber using the primary refrigerants listed below and forming the refrigerating cycle used for refrigeration, etc.. However, the refrigerating machinery with compressors of 7.5 kW or less and the refrigerating machinery using primary refrigerants other than those listed below are to be as deemed appropriate by the Society.

$R\ 22$: $CHClF2$
$R\ 134a$: $CH2FCF3$
$R\ 404A$: $R\ 125/R\ 143a/R\ 134a$ (44/52/4 $wt\%$)
$CHF2CF3/CH3CF3/CH2FCF3$
$R\ 407C$: $R\ 32/R\ 125/R\ 134a$(23/25/52 $wt\%$)
$CH2F2/CHF2CF3/CH2FCF3$
$R\ 410A$: $R\ 32/R\ 125$ (50/50 $wt\%$) $CH2F2/CHF2CF3$
$R\ 507A$: $R\ 125/R\ 143a$(50/50 $wt\%$)
$CHF2CF3/CH3CF3$

(2) For items especially provided in this Section, the requirements in this Section are applied in lieu of the requirements in **Ch 5** and **6**.

1202. Design of refrigerating machinery

1. General

The design pressure of pressure vessels and piping systems and the class of pipes used for refrigerating machinery are as follows :

(1) The design pressure of the pressure vessels and piping systems used for the refrigerating machinery and exposed to a pressure of the refrigerant is not to be less than the pressure in **Table 5.6.15** depending on the kind of the refrigerants.
(2) Pipes for the refrigerants specified in **Table 5.6.15** are to be classified into Class III.

2. Locations

Refrigerating machinery compartments are to be provided with efficient arrangements of drainage and ventilation, and separated by gastight bulkheads from the adjacent refrigerated chambers.

Table 5.6.15 Design pressure of pressure vessels and piping systems for refrigerating machinery

Refrigerants	High Pressure side (MPa)(1)	Low Pressure side (MPa)(2)
$R\ 22$	1.9	1.5
$R\ 134a$	1.4	1.1
$R\ 404A$	2.5	2.0
$R\ 407C$	2.4	1.9
$R\ 410A$	3.3	2.6
$R\ 507A$	2.5	2.0

NOTES:
(1) High Pressure side : The pressure part from the compressor delivery side to the expansion valve.
(2) Low Pressure side : The pressure part from the expansion valve to the compressor suction valve. In case where a multistage compression system is adopted, the pressure part from the lower-stage delivery side to the higher-stage suction side is to be included.

3. Materials

(1) Materials used for the refrigerating machinery are to be suitable for the refrigerant used, the design pressure, the minimum working temperature, etc.
(2) Materials used for the primary refrigerant pipes, valves and their fittings are to comply with the requirements in **102. 1.** to **5.** and **103. 1.** to **5.** according to the classes of pipes specified in **1202. 1** (2).
(3) Materials used for the pressure vessels exposed to the refrigerant pressure(condensers, receivers and other pressure vessels) are to comply with the requirements in **Ch 5, 303.** to **307.** according to the classes of pressure vessels specified in **Ch 5, 302.**
(4) Materials used for essential parts of refrigerating compressor are to be in accordance with **101. 5** (1).
(5) The following materials are not to be used for the parts of refrigerating machinery.
  (A) Aluminium alloy containing magnesium over 2 % for parts to be contacted with primary refrigerants.
  (B) Pure aluminium less than 99.7 % for parts to be usually contacted with water without corrosion protection.
(6) The service limitations of valves made of iron castings are shown in **Table 5.6.16.** Although utilizing of iron castings is permitted by the Table, they are not to be used for valves in pipings having a design temperature below 0 °C or exceeding 220 °C. However, where the normal working pressure of the piping is not exceeding 1/2.5 times the design pressure, the temperature limitations may be lowered to -50 °C.

Table 5.6.16 Service limitation of Valves made of Iron Casting

Kind of valves	Materials	Application
Stop valves	Gray iron castings with specified tensile strength not exceeding 200 N/mm^2 or equivalent thereto	Not to be used
	Gray iron castings other than those specified in above, Spheroidal graphite iron castings, Malleable iron castings or equivalent thereto	1) May be used for design pressure not exceeding 1.6 MPa 2) May be used for design pressure exceeding 1.6 MPa but not exceeding 2.6 MPa, provided nominal diameter does not exceed 100 mm and design temperature is 150 ℃ or below.
Relief Valve	Any iron casting	Not to be used
Automatic control valve	Gray iron castings with specified tensile strength not exceeding 200 N/mm^2 or equivalent thereto	Not to be used
	Gray iron castings other than those specified in above or equivalent thereto	1) May be used for design pressure not exceeding 1.6 MPa 2) May be used for design pressure exceeding 1.6 MPa but not exceeding 2.6 MPa, provided nominal diameter does not exceed 100 mm and design temperature is 150 ℃ or below.
	Spheroidal graphite iron castings, Malleable iron castings or equivalent thereto	Not to be used for design pressure exceeding 3.2 MPa

4. Pressure relief devices

(1) A relief valve is to be provided between compressor cylinder and gas delivery stop valve, and then the discharge is to be led to suction side of the compressor. However, compressors of 11 kW or less for the refrigerating installation may be provided with a pressure control switch in lieu of the above safety device.

(2) Relief valves are to be fitted to the pressure vessels which may be isolated and store the primary refrigerants in a liquid condition. The discharged gases from the relief valves are to be led to the atmosphere in a safe place above the weather deck or to the low pressure parts of the equipment.
(3) Where the discharged gases from relief valves on high pressure parts of primary refrigerants are led to low pressure parts before being relieved to the atmosphere, the operation of the relief valves are not to be interrupted by back pressure accumulation.
(4) Relief valves are to be provided to the cooling liquid side of condenser and brine side of evaporator except where the pump connected is so constructed that the pressure does not exceed the design pressure.

1203. Test

1. Shop test

Refrigerating machinery is, to be tested according to the following :
(1) Pressure vessels exposed to a pressure of the primary refrigerant are to be subjected to a hydraulic test at the pressure of 1.5 times the design pressure and a tightness test at a pressure equal to the design pressure.
(2) Cylinders and crankcases of the compressors of the refrigerator are to be subjected to a hydraulic test at the pressure of 1.5 times the design pressure and a tightness test at a pressure equal to the design pressure.

2. Test after installation on board

The piping systems which are exposed to a pressure of the primary refrigerant are, after installed on board, to be subjected to a leak test at the pressure of 90 % of the design pressure.

Section 13 Tests and Inspections

1301. Hydrostatic Tests of auxiliary machinery

1. The pressure receiving portions of the essential auxiliary are to be tested to a hydrostatic pressure of 1.5 times the design pressure after having been machine-finished, except where otherwise specified. The test pressure, however, is not to be less than 0.2 MPa.

2. The compressor cylinders and crankcases of the refrigerating machinery subject to the requirements in **Sec 12** are to be tested to hydrostatic pressure of 1.5 times the pressure specified in **Pt 9, Ch 1, 102. 5,** respectively and additionally be subjected to tightness tests for the pressure respectively stipulated in the same Article.

1302. Hydrostatic tests of valves and pipe fittings

1. Valves and pipe fittings belonging to Class I and Class II piping are to be subjected to a hydrostatic test at the pressure of 1.5 times the design pressure. However, the hydrostatic test may be omitted according to the discretion of the Society.

2. Ship-side valves and cocks fitted at the ship side below the load waterline are to be subjected to a hydrostatic test at the pressure of 0.5 MPa.

1303. Hydrostatic tests of fuel tanks

Fuel oil tanks with their fittings which do not form part of ship's structure are, after having been constructed, to be tested to a hydrostatic pressure corresponding to a head of water not less than 2.5 m above the top plates. Hydrostatic tests may be replaced by gastight tests at the discretion of the Society.

1304. Tests on workmanship of pipes

1. Welding procedure qualification tests

The manufacturers are to submit the detailed data in connection with the welding work for examination by the Society and also to conduct the welding procedure qualification test specified by the Society where they plan to joint pipes to pipes, pipes to valves or pipes to fittings belonging to Class I and Class II piping system by welding for the first time, or where they adopt a new welding method, and where they change quality of base metals, grade of welding materials or type of joint. But, for minor changes in the welding process, the test may be omitted where approved by the Society.

2. Non-destructive tests

(1) For butt welded joints of Class I pipes with a nominal diameter exceeding 65A, fully radiographic examination is to be carried out.
(2) For butt welded joints of Class I pipes with a nominal diameter not exceeding 65A and of Class II pipes with a nominal diameter exceeding 90A, at least 10 % spot radiography examination is to be carried out.
(3) More stringent requirements may be applied at the Society's discretion depending on the kinds of materials, welding procedure and controls during the fabrication. An approved ultrasonic testing procedure may be accepted, at the Society's discretion, in lieu of radiography testing when the conditions are such that a comparable level of weld quality is assured.
(4) Fillet welds of flange pipe connections are to be examined by the magnetic particle method or by other appropriate non-destructive methods, in case of Class I pipes. In other cases, magnetic particle examination or equivalent non-destructive testing may be required at the discretion of the Surveyor.
(5) The Society may require other particular testing considering welding procedures or properties of welding consumables.
(6) Radiographic examination methods are to comply with the requirements in **Ch 5, 404. 3** to **5.**
(7) Radiographic and ultrasonic examination are to be performed with an appropriate technique by trained operators. At the request of the Society, complete details of the radiographic and ultrasonic technique are to be submitted for approval.
(8) Magnetic particle examination is to be performed with suitable equipment and procedures, and with a magnetic flux output sufficient for defect detection. The equipment is to be required to be checked using standard samples.

3. Hydrostatic tests

(1) All Class I and II pipes and all steam pipes, feed water pipes, compressed air pipes and fuel oil pipes having a design pressure greater than 0.35 MPa are to be subjected to hydrostatic tests together with the welded fittings, after completion of manufacture but before insulation or coating, at a pressure of 1.5 times the design pressure. However, where joints between pipes and valves are welded on board, the hydrostatic test may be omitted provided non-destructive tests deemed appropriate by the Society are carried out.
(2) For steel pipes and intergral fittings having a design temperatures above 300 °C, the test pressure(P_h) is to be determined by the following formula but need not exceed 2 times the design pressure.

$$P_h = 1.5\frac{\sigma_{100}}{\sigma}P \quad (\mathrm{MPa})$$

where:

σ_{100} = Allowable stress at 100 °C (N/mm^2)

σ = Allowable stress at the design temperature (N/mm^2)

P = Design pressure (MPa)

The test pressure may be reduced to 1.5 times the design pressure, in order to avoid excessive stress in way of bends, T-pieces, etc.
(3) In any case the membrane stress is not to exceed 90 % of the specified yield stress at the test-

ing temperature.

(4) When, for technical reasons, it is not possible to carry out complete hydro-testing before assembly on board, for all sections of piping, proposals are to be submitted for approval to the Society for testing the closing lengths of piping, particularly in respect to the closing seams.

(5) The hydrostatic test of piping referred in (1) may be carried out after installation on board. In this case, the test is to be carried out together with the welded fittings at a pressure described in (1) or (2) after completion of manufacture but before insulation or coating and this test may be carried out in conjunction with the test required under **1305.**

(6) Pressure testing of small bore pipes (outside diameter less than 15 mm) may be waived at the discretion of the Society depending on the application.

1305. Tests of piping systems on board

1. Piping systems are, after installation on board, to be tested in accordance with the following requirements.

(1) All piping systems specified in this Chapter are to be tested for effectiveness together with machinery under the working conditions and checked for leakage.

(2) Fuel oil piping systems and heating coil in tanks are to be tested by hydrostatic pressure not less than 1.5 times the design pressure but in no case less than 0.4 MPa. ⚓

CHAPTER 7 STEERING GEARS

Section 1 General

101. Application

1. The requirements in this Chapter apply to powerdriven steering gears. For small ships, however, the requirements in **102., 103., 105., 301. 3** and **410.** may be modified.

2. Manual steering gears are to be of the construction approved by the Society, and to be tested and examined to the satisfaction of the Society.

102. Terminology

1. The terms used in this Chapter are defined as follows:

(1) **Main steering gear** is the machinery such as rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

(2) **Auxiliary steering gear** is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller or components serving the same purpose (hereinafter referred to as "tiller, etc.").

(3) **Steering gear power unit** (hereinafter referred to as "power unit") is:
   (A) in the case of electric gear, an electric motor and its associated electrical equipment;
   (B) in the case of electro-hydraulic steering gear, a hydraulic pump, electric motor and its associated electrical equipment; and
   (C) in the case of hydraulic steering gear other than those in (B), a hydraulic pump and its driving engine.

(4) **Power actuating system** is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a power unit or units, together with the associated hydraulic pipes and fittings, and a rudder actuator. The power actuating system may share common mechanical components, i.e., tiller, etc.

(5) **Rudder actuator** is the component which converts directly hydraulic pressure into mechanical action to move the rudder.

(6) **Control system** is the equipment by which orders are transmitted from the navigating bridge to the power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

103. Plans and documents

1. Plans and documents to be submitted are as follows:

(1) Plans
   (A) General arrangements of steering gear
   (B) Details of tiller, etc.
   (C) Assembly and details of power units
   (D) Assembly and details of rudder actuators
   (E) Piping diagram of hydraulic pipes; Arrangements of control systems
   (F) Diagram of hydraulic and electrical systems (including alarm devices and automatic steering gear)
   (G) Arrangements and diagram of an alternative source of power
   (H) Diagram of a rudder angle indicator

(2) Documents
   (A) Particulars
   (B) Calculation sheet of the strength of essential parts
   (C) Operating instructions (including plans showing the change-over procedure for power units and control systems, plans showing the sequence of automatic supply of power from an alternative source of power; and the type, particulars and an assembly of the power source in

the case that the alternative source of power is an independent source of power)
(D) Manuals for countermeasures to be taken at the time of a single failure of the power actuating system.

104. Display of operating instructions

1. Simple operating instructions with a block diagram showing the change-over procedures for power units and control systems are to be displayed on the navigating bridge and in the steering gear compartment of a ship equipped with power-operated steering gears.

2. Where the system failure alarms according to **301. 4** are provided, instructions for emergency procedures when the alarm is activated, are to be displayed on the navigating bridge.

105. Related requirements

1. The strength of the pressure vessels such as accumulators, etc. used in power actuating systems is to comply with the relevant requirements in **Ch 5** in addition to this Chapter.

2. Hydraulic piping systems used in the power actuating systems are to comply with the relevant requirements in **Ch 6** in addition to this Chapter.

3. Electrical equipment for steering gear are to comply with the relevant requirements in **Pt 6, Ch 1** in addition to this Chapter.

Section 2 Performance and Arrangement

201. Number of steering gears

1. Unless expressly provided otherwise, every ship is to be provided with a main steering gear and an auxiliary steering gear. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

2. Where the main steering gear comprises two or more identical power units, the auxiliary steering gear need not be fitted provided that:

(1) The main steering gear is capable of operating the rudder as required **202.** (1) while operating with all power units. In a passenger ship, the main steering gear is capable of operating the rudder as required by **202.** (1) while any one of the power units is out of operation;

(2) The main steering gear is so arranged that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained. Steering gears other than of the hydraulic type will be considered by the Society in each case.

202. Performance of main steering gear

1. The main steering gear is to be capable of putting the rudder over from 35 degrees on one side to 35 degrees on the other side with the ship at its load draught and running ahead at the speed specified in **Pt 3, Ch 1, 120**. and, under the same conditions, from 35 degrees on either side to 30 degrees on the other side in not more than 28 seconds.

2. The main steering gear is to be operated by power where necessary to meet the requirements in **1.** and in any case when the diameter of upper rudder stock is required in **Pt 4, Ch 1** to be over 120 mm (excluding the additional for strengthening for navigation in ice, the same being referred hereinafter).

3. The main steering gear is to be so designed that they will not be damaged at maximum astern speed. However, this design requirement need not be provided by trials at maximum astern speed and maximum rudder angle.

203. Performance of auxiliary steering gear

1. The auxiliary steering gear is to be capable of putting the rudder over from 15 degrees on one side to 15 degrees on the other side in not more than 60 seconds with the ship at its load draught and running ahead at one half of the speed specified in **Pt 3, Ch 1, 120.** or 7 knots, whichever is the greater, and capable of being brought speedily into action in an emergency.

2. The auxiliary steering gear is to be operated by power where necessary to meet the requirement in **1.** and in any case when the diameter of upper rudder stock is required in **Pt 4, Ch 1** to be over 230 mm.

204. Piping

1. The hydraulic piping system is to be arranged so that transfer between power units can be readily effected.

2. Suitable arrangements to maintain the cleanliness of the hydraulic fluid are to be provided taking into consideration the type and design of the power actuating system.

3. Arrangements for bleeding air from the power actuating system are to be provided where necessary.

4. Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting pressure of the relief valves is not to be less than 1.25 times the maximum working pressure. The minimum discharge capacity of the relief valves are not to be less than total capacity of pumps which provide power for the actuator, increased by 10 %. Under such conditions the rise in pressure is not to exceed 10 % of the setting pressure. In this regard, due consideration is to be given to the extreme foreseen ambient conditions in respect of oil viscosity.

5. A low level alarm is to be provided for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. This alarm is to be audible and visual and to be given on the navigating bridge and at a position from which the main engine is manually controlled.

6. A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir is to be provided, where the main steering gear is operated by hydraulic power. The storage tank is to be permanently connected by piping in such a manner that the hydraulic system, can be readily recharged from a position within the steering gear compartment and is to be provided with a contents gauge.

7. Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

205. Re-start and power-failure alarm of power units

1. Main and auxiliary steering gear power units are to be :

(1) arranged to re-start automatically when power is restored after a power failure and
(2) capable of being brought into operation on the navigation bridge. In the event of a power failure to any one of the power units, an audible and visual alarm is to be given on the navigating bridge.

206. Alternative source of power

1. Where the diameter of upper rudder stock is required in **Pt 4, Ch. 1** to be over 230 mm, an alternative source of power supply to steering gears is to be provided in accordance with the following:

(1) The alternative source of power is to be either:
  (A) emergency source of electric power; or
  (B) independent source of power located in the steering gear compartment and used only for this purpose.
(2) The alternative source of power is to be capable of automatically supplying, within 45 seconds, alternative power to the power unit and its associated control system and the rudder angle indicator. In every ship of 10,000 gross tonnage and upwards, the alternative source of power is

to have a capacity for at least 30 minutes of continuous operation of the steering gear and in any other ship for at least 10 minutes.

(3) Steering gears operated by the alternative power supply are to be capable of operating the rudder as required by **203.**

(4) The automatic starting arrangement for the generator or the prime mover of the pump used as the independent source of power specified in (1) (B) is to comply with the requirements for starting device and performance in **Pt 6, Ch 1, 1406.**

207. Electrical installations for electric and electro-hydraulic steering gear

1. Cables used in power circuits required to be installed in duplicate by this Chapter are to be separated as far as practicable throughout the length.

2. Means for indicating that the power units are running are to be installed on the navigating bridge and at the position from which the main engine is normally controlled.

3. Each electric or electro-hydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuit fed directly from the main switchboard. However, one of the circuits may be supplied through the emergency switchboard.

4. An auxiliary electric or electro-hydraulic steering gear associated with a main electric or electro-hydraulic steering gear may be connected to one of the circuits supplying this main steering gear. The circuits are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

5. Short circuit protection and overload alarm are to be provided for such circuits and motors. The overload alarm is to be both audible and visual and to be situated in a conspicuous position in the place from which the main engine is normally controlled.

6. Protection against excess current including starting current, if provided, is to be for not less than twice the load current of the motor or circuit so protected, and to be arranged to permit the passage of the appropriate starting currents.

7. Where a three-phase supply is used an alarm is to be provided that will indicate failure of any one of the supply phases. The alarm is to be both audible and visual and to be situated in a conspicuous position in the place from which the main engine is normally controlled.

8. When in a ship of less than 1,600 gross tonnage an auxiliary steering gear which is required by **203.** to be operated by power is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Where such an electric motor primarily intended for other services is arranged to power such an auxiliary steering gear, the requirements in **Pars 5** to **7** may be waived by the Society if satisfied with the protection arrangement together with the requirements in **205.** and **301. 1** (3) applicable to auxiliary steering gear.

208. Position of steering gears

1. The steering gear is to be installed in an enclosed compartment readily accessible and, as far as possible, separated from machinery spaces.

2. The steering gear compartment is to be provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

209. Means of communication

A means of communication is to be provided between the navigating bridge and the steering gear compartment.

210. Rudder angle indicator

1. The angular position of rudder is to be indicated in the navigating bridge. The rudder angle indicator is to be independent of the control system.

2. The angular position of rudder is to be recognizable in the steering gear compartment.

Section 3 Controls

301. General

1. Steering gear control is to be provided:

(1) for the main steering gear, both on the navigating bridge and in the steering gear compartment;
(2) where the main steering gear is arranged in accordance with the requirements in **201. 2.** by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.
(3) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it is also to be operable from the navigating bridge and to be independent of the control system for main steering gear.

2. Any main and auxiliary steering gear control system operable from the navigating bridge is to comply with the following:

(1) If electric, it is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit.
(2) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.
(3) The system is to be capable of being brought into operation from a position on the navigating bridge.
(4) In the event of a failure of electrical power supply to the control system, an audible and visual alarm is to be given on the navigating bridge.
(5) Short circuit protection only is to be provided for steering gear control supply circuits.

3. Cables and pipes of control systems required to be in duplicate by this Chapter are to be separated as far as practicable throughout their length.

4. For the steering gears which are so arranged that more than one system (either power or control) can be simultaneously operated, where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided on navigation bridge.

302. Change-over from automatic to manual steering

The steering gears of a ship provided with an automatic pilot are to be capable of immediate change-over from automatic to manual steering.

Section 4 Materials, Constructions and Strength

401. Materials

1. Materials used in the steering gears are to be sound, flawless and adequate for their service conditions.

2. Materials used for cylinders and housings of rudder actuators, pipings subjected to a hydraulic pressure and all components transmitting mechanical forces to the rudder stock are to be of steel or other approved ductile material, comply with the requirements in **Pt 2, Ch 1.** In general such materials are not to have a minimum elongation of less than 12 % nor a specified minimum tensile strength in excess of 650 N/mm^2. This does not apply to the materials for valves and bolts where approved by the Society.

3. Materials used for bolts for assembling split type tillers and bolts for securing the vanes to the bosses of rotary vane type rudder actuators are to be forged steels or rolled steels comply with the requirements in **Pt 2, Ch 1.**

4. Materials used for major parts other than those mentioned in **Pars 2** to **3** are to comply with the requirements in recognized standards.

5. Materials other than those mentioned in **Pars 2** to **4** may be used where approved by the Society.

402. Welds

1. All welded joints of the parts of power actuating systems are to be such that there are no incomplete penetration and other injurious defects.

2. Welded joints in parts subjected to the internal pressure of the power actuating system are to have sufficient strength.

403. General construction of steering gear

1. The steering gears are to be of sufficient strength and reliability.

2. Configurations of major parts of the steering gear are to be determined to avoid local concentration of stress.

3. The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure is to be at least 1.25 times the maximum working pressure to be expected under the operational conditions specified in **202. 1** taking into account any pressure which may exist in the low pressure side of the system. The design pressure is not to be less than the relief valve setting pressure.

4. Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component is, where appropriate, to utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which are to be permanently lubricated or provided with lubrication fittings.

5. Where considered necessary, fatigue analysis is to be carried out to the piping and components, taking into account pulsating pressure due to dynamic loads. Both the cases of high cycle and cumulative fatigue are to be considered.

404. Strength of rudder actuators

1. Strength of all components of rudder actuators subjected to an internal pressure, except for the allowable stress specified in this Chapter, is to comply with relevant requirements in **Ch 5.**

2. In the strength calculations specified in **Par 1,** the allowable stress for the equivalent primary general membrane stress is not to be greater than the following values (1) or (2), whichever is the smaller:

(1) $\frac{\sigma_B}{A}$

(2) $\frac{\sigma_Y}{B}$

where:

σ_B = Specified minimum tensile strength of the material (N/mm^2)

σ_Y = Specified minimum yield stress or 0.2 proof stress of the material (N/mm^2)

A, B = As given in the following **Table 5.7.1.**

Table 5.7.1 Constants of A and B

	Steel	Cast steel	Nodular cast iron
A	3.5	4	5
B	1.7	2	3

405. Oil seals in rudder actuators

1. Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

2. Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage will be accepted where approved by the Society.

406. Flexible pipes

Flexible hose assemblies specified in **Ch 6, 102. 5** are to be used in piping systems where flexibility is required.

407. Tillers etc.

1. The scantlings of tillers of forged steels are to comply with the requirements in the following. The scantlings of those of cast steels and ductile material will be considered by the Society in each case.

(1) The scantlings of tillers are to comply with the requirements in the following:

(A) The sectional area of each side of the tiller boss about the vertical section at centre of rudder stock is not to be less than that obtained from the following formula:

$$A = 0.4 d_u^2 \quad (\mathrm{cm}^2)$$

where:

d_u = The diameter of upper stock required in **Pt 4, Ch 1** taken as having been calculated for upper rudder stock of mild steel with a yield strength of 235 $\mathrm{N/mm^2}$(i.e. with a material factor K_S = 1)

(B) The section modulus, Z, of arm about the vertical axis is not to be less than that obtained from the following formula:

$$Z = 0.163\left(1 - \frac{r_0}{R}\right) d_u^3 \quad (\mathrm{cm}^3)$$

where:

r_0 = Distance from the centre of rudder stock to the section (cm)

R = Length of tiller arm measured from the centre of rudder stock to the point of application of the driving force (cm). In case where the length varies in accordance with rudder angle, R is the maximum length within 35 degrees of rudder angle.

(C) The standard sectional area of arm at its outer end is obtained from the following formula:

$$A = 0.22 d_u^2 \quad (\mathrm{cm}^2)$$

(D) In case of tiller having two arms, where power units are connected to each arm and these two power units are driven simultaneously, the scantlings of arms may be suitably modified.

(2) Tillers are to be of shrinkage fit or bolted to the stock in addition to being secured by a key in any case.

(3) Where tillers are bolted on both sides of rudder stock, there are to be at least two bolts on each side of the head. Diameter of the bolts at the bottom of threads is not to be less than that obtained from the following formula. In such a case, the thickness of coupling flange is not to be less than three-fourths of the diameter of the bolts.

$$d = 0.5\sqrt{\frac{d_u^3}{nb}} \quad (\mathrm{cm})$$

where:

n = Number of bolts on each side of the head

b = Distance from the centre of rudder stock to the centre of bolts (cm)

(4) The scantlings of tillers of exclusive auxiliary steering gear system are to have the strength 0.5 times those specified in (1).

408. Stoppers

1. Tillers are to be provided with the suitable stopping arrangement to restrict the rudder movement. This arrangement may be an integral part of the rudder actuator.

2. Steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control. These arrangements, however, may be operated through a mechanical links such as a floating levers.

3. Suitable brake arrangements are to be provided to tillers to keep the rudder steady in the event of an emergency. In the case of hydraulic steering gear, where the rudder can be stopped safely by closing the oil pressure valves, this brake arrangement will not be required.

409. Buffers

Steering gears other than of hydraulic type are to be provided with spring buffers or other suitable buffer arrangements to relieve the gear from shocks given by the rudder.

Section 5 Testing

501. Shop tests

1. Pressure vessels and piping systems are to be subjected to tests in accordance with the requirements in **Chs 5** and **6,** in addition to the tests specified in this Section.

2. All pressure parts are to be subjected to pressure tests with a pressure equal to 1.5 times the design pressure.

3. Each type of pumps used as a power unit is to be subjected to a running test for a duration of not less than 100 hours. The test arrangements are to be such that the pump may run in idle condition, and at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be disassembled to ascertain that there is no abnormality. The test may be waived for a power unit which has been proved to be reliable in marine service.

502. Testing after installation

1. Hydraulic piping systems are after installed on board to be subjected to a leak test at a pressure at least equal to the maximum working pressure.

2. The steering gear is after installed on board to be subjected to the running test.

503. Sea trials

1. The steering gears are to be subjected to the following tests during sea trials. However, the tests required in (4), (7) and (8) may be carried out at the time when a vessel is being anchored or at dockside.

(1) Tests on the steering capabilities specified in **202.** and **203.** For controllable pitch propellers, the propeller pitch is to be at the maximum design pitch approved for number of maximum continuous ahead revolution at the main steering gear trial. If the ship cannot be tested at the load draught, alternative trial draught conditions will be specially considered. In this case for the main steering gear trial, the speed of ship corresponding to the number of maximum continuous revolution of main engine is to apply.
(2) Running tests of the power units, including transfer between power units.
(3) Tests on the isolation of one power actuating system, checking the time for regaining steering capability.
(4) Tests on the hydraulic fluid recharging system.
(5) Tests on the emergency power supply required by **206.**
(6) the steering gear controls, including transfer of control and local control
(7) Tests on the means of communication between the navigating bridge and the steering gear compartment.
(8) Tests on the functioning of indicators for the alarms, rudder angle indicator and power units.
(9) Where the steering gear is designed to avoid hydraulic locking, this feature is to be demonstrated.

Section 6 Additional Requirements Concerning Tankers of 10,000 Gross Tonnage and Upwards and Other Ships of 70,000 Gross Tonnage and Upwards

601. Main steering gears

1. In every oil tanker, ships carrying liquefied gases or dangerous chemicals in bulk (hereinafter referred to as "**tankers**" in this Section) of 10,000 gross tonnage and upwards and in every other ship of 70,000 gross tonnage and upwards, the main steering gear is to comprise two or more equivalent power units complying with the requirements in **201. 2.**

2. The steering gear in every tanker of 10,000 gross tonnage and upwards is to comply with the following:

(1) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating system of the main steering gear, excluding failure in the tiller, etc. and seizure in the rudder actuator, steering capability is to be regained in not more than 45 seconds after the loss of one power actuating system.
(2) The main steering gear is to comprise either:
(A) Two independent and separate power actuating systems, each capable of meeting the requirements in **202. 1;** or
(B) at least two equivalent power actuating systems which, acting simultaneously in normal operation, are to be capable of meeting the requirements in **202. 1.** In this case, the following requirements of (a) and (b) are also to be met:
(a) Loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems are to remain fully operational.
(b) Where necessary to obtain steering capability, interconnection of hydraulic power actuating systems is to be provided.

(3) Steering gears other than of the hydraulic type will be considered by the Society in each case.

602. Controls

In the case of tankers of 10,000 gross tonnage or upwards, the modification for the hydraulic telemotor permitted in **301. 1** (2) is not to be applied.

603. Number and strength of rudder actuators

1. For tankers of 10,000 gross tonnage and upwards, but of less than 100,000 tons deadweight, a single rudder actuator may be permitted provided that:

(1) Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is to be regained within 45 seconds;

(2) Special consideration is to be given to stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, to the material used, to the installation of sealing arrangements and to testing and inspection and to the provision of effective maintenance. In this case, the high cycle fatigue and cumulative fatigue are to be considered.

(3) Isolating valves are to be directly mounted on the rudder actuator so as to isolate the rudder actuator from the hydraulic oil in the piping systems; and

(4) Relief valves for protecting the rudder actuator against overpressure as required in **204. 4** are to be provided.

2. For tankers of 10,000 gross tonnage and upwards, but less than 100,000 tons deadweight and equipped with a single rudder actuator, the strength of the rudder actuator is to comply with the following requirements in addition to those of **404.**

(1) A detailed calculation of the major parts of the rudder actuator is to be carried out to confirm their strength.

(2) A detailed stress analysis of the parts of rudder actuators subject to hydraulic pressure is to be carried out to confirm the strength sufficient to withstand the design pressure.

(3) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis are to be carried out. In this case, the high cycle fatigue and cumulative fatigue are to be considered. In connection with these analyses, all foreseen dynamic loads are to be taken into account. Where considered necessary by the Society, experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations.

(4) For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses are to comply with:

$$\sigma_m \leq f$$
$$\sigma_l \leq 1.5f$$
$$\sigma_b \leq 1.5f$$
$$\sigma_l + \sigma_b \leq 1.5f$$
$$\sigma_m + \sigma_b \leq 1.5f$$

where:

σ_m = Equivalent primary general membrane stress ($\mathrm{N/mm^2}$)

σ_l = Equivalent primary local membrane stress ($\mathrm{N/mm^2}$)

σ_b = Equivalent primary bending stress ($\mathrm{N/mm^2}$)

f = Lesser of σ_B/A or σ_Y/B

σ_B = Specified minimum tensile strength of material ($\mathrm{N/mm^2}$)

σ_Y = Specified minimum yield stress of 0.2 % proof stress of material ($\mathrm{N/mm^2}$)

A, B = As given in the following Table

	Rolled or forged steel	Cast steel	Nodular cast iron
A	4	4.6	5.8
B	2	2.3	3.5

(5) Where the parts of rudder actuators subject to hydraulic pressure are subjected to a burst test at the minimum bursting pressure specified below and they are confirmed to withstand this test, the detailed stress analysis required by (2) may be omitted. Where, however, considered necessary because of the design complexity or manufacturing procedures, the detailed stress analysis required by (2) is to be carried out notwithstanding the above.

$$P_b = P \times A \frac{\sigma_{Ba}}{\sigma_B} \quad (\text{MPa})$$

where:

P_b = Minimum bursting pressure (MPa)

P = Design pressure (MPa)

A = As given in (4)

σ_{Ba} = Actual tensile strength of the material (N/mm^2)

σ_B = Specified minimum tensile strength of the material (N/mm^2)

604. Non-destructive tests

For tankers of 10,000 gross tonnage and upwards, but less than 100,000 tons deadweight and equipped with a single rudder actuator, the rudder actuator is to be subjected to suitable and complete non-destructive testing to detect both surface flaw and volumetric flaws. The procedure and acceptance criteria for the non-destructive testing will be considered by the Society in each case. Where considered necessary, fracture mechanics analysis is to be used for determining maximum allowable flaw size.⚓

CHAPTER 8 WINDLASSES AND MOORING WINCHES

Section 1 General

101. Application

1. The requirements in this Chapter apply to electric driven, steam reciprocating engine driven or hydraulic driven windlasses and mooring winches. The requirements of windlasses and mooring winches manually operated as the main driving power are to be to the satisfaction of the Society.

2. In addition to complying with the requirements in this Chapter, those are to be applied with appropriate modifications respectively such as follows: For power transmission gears, **Ch 3;** For pressure vessels and hydraulic pumps, **Ch 5;** For piping arrangements, **Ch 6.**

102. Materials

Materials used in the major parts are to be of steel forgings, steel castings or equivalent thereto.

Section 2 Windlasses

201. Definitions

1. The working load, derived from the nominal diameter and the grade of anchor chain cables, is the tensile force exerted upon the cable lifter in the tangential direction when the anchor and anchor chain cable are being hoisted.

2. The overload pull is the necessary temporary overload capacity of the windlass, and to be not less than 1.5 times the working load.

3. The holding load is the maximum static load on the anchor chain cables which the cable lifter brake should withstand.

4. Nominal speed is the average speed of recovery of 55 m (two lengths) of anchor chain cables when 82.5 m (three lengths) of the cables are submerged and freely suspended at commencement of lifting.

5. The breaking test load of the anchor chain cables is the minimum breaking test load specified in **Pt 4, Table 4.8.8.**

202. Plans and documents

1. Plans and documents to be submitted are as follows:

(1) Plans
- (A) General arrangement
- (B) Sectional drawings
- (C) Diagram of steam and hydraulic systems
- (D) Diagram of electric systems and arrangement of control systems
- (E) Detail drawings of gears and driving shafts of power transmission gears

(2) Documents
- (A) Particulars for major parts
- (B) Particulars for material of power transmission parts
- (C) Calculation sheet for the strength of major parts

203. Design, construction and equipment

1. Type of drive

The drive of windlasses with two cable lifters is to be of the type capable of hauling up both anchors simultaneously.

2. Strength

(1) The parts for the windlass proper such as the bedplate, cable lifter, cable lifter shaft, bearing frame, brake gear, holding down bolt, etc. are to have such strength that the stress on these parts is below the yield points of the materials when sustaining the holding load on the cable lifter specified in **Table 5.8.1.**

(2) The driving section of windlass is to have such strength that the stress on each part is below 40 % of the yield points of the materials used when the working load specified **204. 1**. is applied.

Table 5.8.1

Division of chain cable stopper	Holding load
with chain cable stopper	B.T.L×0.45
without chain cable stopper	B.T.L×0.8
NOTES: B.T.L. : Breaking test load of anchor chain cable	

3. Construction and equipment

(1) Construction

(A) The windlasses are to be so designed as to ensure smooth operation of the components in consideration of impact such as waves. The closed portions of the windlass installed on exposed decks are to have suitable watertight construction.

(B) The cable lifters are to be provided with 5 teeth at minimum, and the revolution speed of the anchor chain cable lifter is to be controllable.

(2) Equipment

(A) Protective devices and safety devices

Prime movers and gearing are to be provided with protective devices and safety devices against excessive torque and shock as follows;

(a) Overpressure preventive devices for hydraulic equipment
(b) Slipping clutches between electric motor and reduction gear
(c) Protective devices for the electric motor against overload
(d) Covers for open gear

(B) Clutches

Windlasses are to be fitted with clutches between the cable lifter and the driving shaft. Power operated clutches are to be declutchable by hand.

(C) Brake systems

(a) Electric windlasses are to be provided with an automatic control brake system which operates when the control handle is in the "Off" position or when the power supply is cut off. The automatic breaking system is to be capable of sustaining 130 % of the working load.

(b) Each cable lifter is to be fitted with a hand-brake system, which may be remotely controlled, capable of applying a brake torque sufficient to maintain a load equal to the holding load specified in **201. 3.**

(D) Emergency stop mechanism

Each remotely controlled windlass is to be fitted with a quick acting local emergency stop mechanism.

204. Performance

1. Windlasses are to be capable of lifting anchor and anchor chain at a nominal speed of at least 0.15 m/s.

2. The windlasses are to be capable of continuous operation for a period of 30 minutes under the working load specified in **Table 5.8.2** and be capable of operating under the overload for a period of 2 minutes at a correspondingly reduced lifting speed.

Table 5.8.2 Working Load

Kind of chain cable	Working load (N)
Grade 1 chain	$37.5d^2$
Grade 2 chain	$42.5d^2$
Grade 3 chain	$47.5d^2$

NOTES :
1. d is the diameter of chain cable (mm).
2. Studless chain cables are to be to the satisfaction of the Society.

205. Tests and Inspections

1. Windlasses are to be carried out following tests after construction, which are in accordance with the procedures as deemed appropriate by the Society.

(1) No load test
(2) Load test
(3) Brake test

Section 3 Mooring Winches

301. Relevant requirements

1. The relevant requirements such as the design, etc. for mooring winch are to comply with ISO 3730(KS V ISO 3730) or other recognized standards which deemed appropriate by the Society.

302. Test and inspections

1. Mooring winches are to be subjected to the following tests after their installation on board :

(1) Running test
The winch is to be run for 10 minutes at no load speed, 5 minutes continuously in each direction.

(2) Bearings
Bearing temperature rises shall be checked. ⚓

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 5

Machinery Installations

GA-05-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 5 "MACHINERY INSTALLATIONS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date : 1 Jan. 2011 (regardless of the contract date for construction)

CHAPTER 1 GENERAL

Section 1 General
- 103. 1 has been deleted.

Effective Date : 1 July 2011 (based on the contract date for construction)

CHAPTER 2 MAIN AND AUXILIARY ENGINES

Section 1 Generals
- 101. 1 has been amended.

Section 2 Internal Combustion Engines
- 203. 4 has been deleted.

CHAPTER 6 AUXILIARIES AND PIPING ARRANGEMENT

Section 2 Air Pipes, Overflow Pipes and Sounding Devices
- 203. 2 and 3 have been deleted.

Section 3 Ship−side Valves and Overboard Discharge
- 302. 3 has been amended. .

Section 12 Refrigerating Machinery
- 1201. 1 has been amended.

CHAPTER 7 STEERING GEARS

Section 2 Performance and Arrangement
- 201 has been amended.

Section 3 Controls
- 301. 2 has been amended.
- 301. 3 has been newly added.

Section 4 Materials, Constructions and Strength
- 401 has been amended.

- 407 has been amended.
- Article No. 410 has been modified to 409 and pars.2 has been deleted.

Section 5 Testing

- 503. 1 has been newly added.

CHAPTER 8 WINLASSES AND MOORING WINCHES

Section 1 General

- 101. 1 (2) and (4) have been amended.

CONTENTS

<ANNEX>

CHAPTER 1 GENERAL

Section 1 General

101. Application

In application to **101. 3** of the Rules, the thrusters may be in accordance with the following;

1. Thrusters

(1) Application
These requirements apply to the thrusters and their control units (hereinafter called "**thrusters**").
(2) Plans and documents
Before the work is commenced, the manufacturers are to submit the following plans and documents in triplicate to the Society for approval.
(A) General arrangement of thruster
(B) Sectional assembly (including materials of principal component)
(C) Controlling diagrams
(D) Shaft arrangement and sealing devices
(E) Propeller
(F) Power transmission gear arrangement
(G) Piping arrangement
(H) Main particulars (kind of prime mover, output, number of revolution, capacity, etc. are to be stated)
(I) Plans and documents considered necessary by the Society
(3) Materials
The materials used in the principal component, in principle, are to be complied with the requirements of **Pt 2, Ch 1** of the Rules. However, the Society may accept to be used of the materials which comply with *Korean Industrial Standard* or standard considered as equivalent thereto.
(4) Shop tests
(A) The test requirements of shafting, propellers and power transmission gears are to be applied appropriate modifications respectively such as follows;
For shafting, **Ch 3, Sec 2** of the Rules; For propellers, **Ch 3, Sec 3** of the Rules;
For power transmission gears **Ch 3, Sec 4** of the Rules.
(B) The hydraulic tests for hydraulically pressurised parts of equipment and piping systems are to be in accordance with the requirements of **Ch 6** of the Rules. However, theses shop tests may be substituted for the tests carried out by the manufacturer.
(C) The test requirements of piping system are to be applied appropriate modifications of **Ch 6** of the Rules.
(D) The requirements of electrical installations are to be applied appropriate modifications of **Pt 6, Ch 1** of the Rules.
(5) On board tests
The performance test and the safety device test for thruster are to be carried out.

102. Definitions

1. The essential auxiliaries given in **102. 5** of the Rules are as follows;

(1) Auxiliary machinery essential for main propulsion
(A) For ships equipped with an internal combustion engine as main engine
(a) For cooling water system
Jacket cooling water pumps, piston cooling water (oil) pumps, fuel valve cooling water (oil) pumps, turbo-charger cooling water pumps, cooler cooling water pumps, generator engine cooling water (oil) pumps, air compressor cooling water pumps
(b) For fuel oil system
Fuel oil supply (booster) pumps, fuel oil transfer pumps
(c) For lubricating oil system
Lubricating oil pumps, cam shaft lubricating oil pumps, turbo-charger lubricating oil pumps, reduction gear lubricating oil pumps
(d) Hydraulic oil pumps (a pump to supply hydraulic oil to the hydraulic circuit for driving

or controlling the equipment having relevance to main propulsion)
ex) a controllable pitch propeller hydraulic oil pump
(e) Air compressors (excluding air compressor for emergency use)
(f) For auxiliary boilers
Feed water pumps, boiler water circulating pumps, exhaust gas economizer feed water pumps, draught fans for boiler, burner units
(g) Other
Auxiliary blowers for main engine
(h) Other auxiliary machinery as deemed essential by the Society
(B) For ships equipped with a steam turbine as main engine
(a) For feed water, condensed water and drain system
Feed water pumps, condensate water pumps and drain pumps
(b) For cooling water system
Circulating water pumps
(c) For fuel oil system
Burning pumps, fuel oil transfer pumps, fuel oil service pumps
(d) For lubricating oil system
Lubricating oil pumps
(e) Hydraulic oil pumps (a pump to supply hydraulic oil to the hydraulic circuit for driving or controlling the equipment having relevance to main propulsion)
ex) a controllable pitch propeller oil pump
(f) Others
Vacuum pumps for condenser, gland steam exhaust fans, boiler draught fans, fresh water generators, control air compressors
(g) Other auxiliary machinery as deemed essential by the Society
(2) Auxiliary machinery for the safety of life and ship
(A) Pumps
Bilge pumps, ballast pumps, fire pumps (including fire pump for emergency use), eductors provided instead of bilge pump
(B) For the maneuvering of ship
Steering gears, thrusters, stabilizers
(C) Deck machinery
Windlasses
(D) Ventilating fans (installed in hazardous area due to flammable gases or gases harmful to the health such as cargo oil pump room of oil tanker, etc.), ventilating fans for cargo oil tank of oil tankers, machinery for gas free and machinery for inert gas system
(E) Other auxiliary machineries as deemed essential by the Society
(3) Auxiliary machinery having relevance to specific service of ships
(A) Cargo handling machinery subject to **Pt 9, Ch 2** of the Rules
Hydraulic pump for cargo handling machinery
(B) Auxiliary machineries for oil tankers, ships carrying liquefied gases in bulk, ships carrying dangerous chemicals in bulk
Cargo pumps, stripping pumps, tank cleaning pumps, gas compressors, pumps for gas cooling system, gas refrigerating compressors
(C) Refrigerating machinery
Compressors, liquid pump and condenser cooling pumps used for cargo refrigerating machinery (including items subject to **Pt 9, Ch 1** of the Rules)
(D) Other auxiliary machineries as deemed essential by the Society

2. Pipe fittings given in **102. 22** of the Rules mean the following;
(1) Pipe connection units
(A) Pipe flanges and pipe pieces(elbow, reducer, tee, bend, socket, etc.), etc.
(B) Mechanical joints, expansion joints and flexible joints
(2) Fittings installed on a piping arrangement (strainers, separators, flow meters, viscosity meters, etc.)

103. Construction, materials and installation

In application to **103. 7** of the Rules, where insulation for surfaces of machinery installations e.g. turbo blowers, etc, is difficult, consideration will be given to the discretion of the Society.

106. Communication between Navigating Bridge and Machinery Space

The telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of the fact that the engine room is attended or not.

109. Protection against noise

In application to **109.** of the Rules, the allowable noise levels are as follow;
(1) Where there are noise level criteria specified by the Administration, the levels are to comply with the requirements of the Administration.
(2) Where there are no noise level criteria specified by the Administration, IMO Res. A.468(XII). may be referred.

Section 2 Plans and Documents

202. Plans and documents to be submitted by the shipyard

1. Plans for approval

(1) The following are to be stated in the various piping diagrams for the purpose of reviewing to be satisfied with the requirements of **Pt 5, Ch 6** of the Rules.
(A) Material, nominal diameter or outside diameter, thickness and design pressure of pipes
(B) Kind, material and nominal diameter or outside diameter of valves, cocks and pipe fittings
(C) Kind, particular, capacity, etc. of auxiliaries and their prime mover
(D) Total capacity of tanks
(E) Design temperature of superheaters, if provided
(2) Type, capacity, kind, and output of essential auxiliaries and their prime mover and related equipment are to be stated in the machinery particulars.
(3) The following are to be stated on drawings of scupper piping arrangement;
(A) Designed load line
(B) Line of 0.01 L_f and 0.02 L_f above the designed load line
(C) Line of 600 mm above the designed load line
(D) Line of 450 mm below the free-board deck
(4) In application to **202. 1** (5) of the Rules, following may be applied.
(A) In case of fuel oil tanks not more than 1 m^3 (0.5 m^3 in case of ships subject to SOLAS), submission of the plans for the tanks may be omitted.
(B) Where the shipyards are submitted the manufacturing practice for tanks and the manufacturing practice are approved by the Society, the manufacturing practice may be considered as the details of the tanks.

2. In application to **202. 2** (5) of the Rules, where considered necessary by the Society is the following (1), and shaft alignment calculations are to comply with the following (2) and (3).
(1) Shaft alignment calculations for the following alignment-sensitive types of installations are to be submitted for reference :
(A) Propulsion shafting of the actual propeller shaft diameter greater than 400 mm.
(B) Propulsion shafting with reduction gears where the gear wheel is driven by two or more ahead pinions.
(C) Propulsion shafting for which the propeller shaft bearings are to be slope-boring.
(D) Propulsion shafting for which the bearings in shafting are to be slope-alignment
(2) The alignment calculations are to include bearing reactions, shear forces and bending moments along the shafting, slope boring details (if applicable) and detailed description of alignment procedure.
(3) The alignment calculations are to take account of thermal effects, and to be performed for cold and hot conditions of the shafting.

203. Plans and documents to be submitted by the manufacturers of internal combustion engines

1. In application to **203. Table 5.1.4**, the plans and documents to be submitted for reference of all type of engines intended to be installed for the first time on the ship which is going to be registered by the Society, are as follows ;

(1) Plans
. General arrangement (the length, width, height and weight are to be entered)
. Cylinder cover, cylinder liner, cylinder block, piston crown, piston skirt, guide ring
. Piston pin
. Frame and intermediate frame
. Scavenging air chamber installed below cylinder block
. Camshaft drive
. Cam and cam shaft assembly
. Fuel oil pump
. Valve driving mechanism
. Diagram of engine control
. Tie rod (including coupling and set-screw)
. Main bearing bolt and cylinder cover fixing bolt (including valve box fixing bolt)
. Construction and arrangement of relief valve for cylinder
. Construction and arrangement of bracing of the engine
. Construction and arrangement of damper and detuner
. Construction and arrangement of balancer or compensator
. Flywheel (in case of a power transmission component)
. Other construction and arrangement as deemed necessary by the Society

(2) Documents
. Operation and service manual of engine (including inspection and maintenance instruction)
. Review sheets on bracing, balancing and prevention of vibration of the engine (including calculation sheets)
. Data for vibration of engine (construction and arrangement of dampers, detuners, balancers or compensators, and data regarding calculations for torsional(see **Ch 4, Sec 1** of the Rules) and axial vibration of shafting)

(A) Whenever the manufacturers propose modification of construction, particulars or materials, the reasons of modification, and the associated plans and documents are to be submitted by the manufacturer.

(B) Where the particulars, list and application for omission of plans and document for approval are submitted, the submission of plans and documents same as the approved engine type may be omitted. The list is to include the subject of approved plans and documents relation to the components and units specified in **203. Table 5.1.4** of the Rules, and **203.** of the Guidance, engine serial number, name of shipyard and hull number.

2. In application to **203. Table 5.1.4 of the Rules**, the special sheet of the Society is as the following **Table 5.1.1**.

204. Plans and documents to be submitted by the manufacturers of steam turbines

1. The various piping diagrams given in **204. 2** of the Rules are to include the piping diagrams of steam, lubricating oil, drain, and are to be stated materials, dimension and working pressure for pipes belonging to Class I or II according to requirements of **Pt 5, Ch 6** of the Rules.

2. Whenever the manufacturers propose modification of construction, particulars or materials, the reasons of modification and the associated plans and documents are to be submitted by the manufacturer.

3. The plans and documents to be submitted for reference of all type of steam turbine intended to be installed for the first time on the ship which is going to be registered by the Society, are as follows;

(1) Plans given in **204. 1** of the Rules

(2) Documents given in **204. 2** of the Rules, steam condition at every stage at the continuous maximum output, natural frequencies of blade and nozzle (whichever calculated values or measured values), and operation and service manual of stem turbine

4. Where the application for omission of plans and document for approval are submitted according to the requirements of **203. 1** (2) (B) of the Guidance, the submission of those same as the plans and documents for approved type of steam turbine may be omitted.

208. Plans and documents to be submitted by the manufacturers of boilers, Class 1 and 2 pressure vessels

1. The submission of plans and documents for approval of air inter-cooler of internal combustion engines may be waived.

2. Operation instructions specified in **208. 2.** (3) of the Rules is to be include following items.

(1) Feed water treatment and sampling arrangements
(2) Operating temperatures(exhaust gas and feed water temperatures)
(3) Operating pressure
(4) Inspection and cleaning procedures
(5) Records of maintenance and inspection
(6) The need to maintain adequate water flow through the economizer under all operating conditions
(7) Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly
(8) Procedures for using the exhaust gas economizer in the dry condition
(9) Procedures for maintenance and overhaul of safety valves

210. Plans and documents to be submitted by the manufacturers of essential auxiliaries

1. In application to **210.** of the Rules, the essential auxiliaries required approval of the Society are following;

(1) Air compressors (except air compressor for emergency use)
(2) Fresh water generators (in case of ships equipped with main boiler)
(3) Pumps (in case where the output of prime mover is not less than 100 kW)
(4) Draught fans for boiler and auxiliary blowers for main engine (in case where the output of prime mover is not less than 100 kW)
(5) Draught fans installed in cargo oil pump room and cargo space of tankers intended to carry oils having a flash point not exceeding 60 °C.
(6) Auxiliaries for maneuvering (steering gears, side thrusters, stabilizers, etc.)
(7) Deck auxiliaries (windlasses)
(8) Cargo handling machinery subject to **Pt 9, Ch 2** of the Rules
(9) Auxiliary machinery for oil tankers, ships carrying liquefied gases in bulk, and ships carrying dangerous chemicals in bulk (Cargo pumps, stripping pumps, tank cleaning pumps, gas compressors, pumps for gas cooling system, gas refrigerating compressors)
(10) Refrigerating machinery (excluding refrigerating machinery having both *R* 22, *R* 134*a*, *R* 404*A*, *R* 407*C*, *R* 410*A* and *R* 507*A* as primary refrigerant and prime mover with output of 7.5 kW or less)

Table 5.1.1 Data sheet for calculation of crankshafts for internal combustion engines

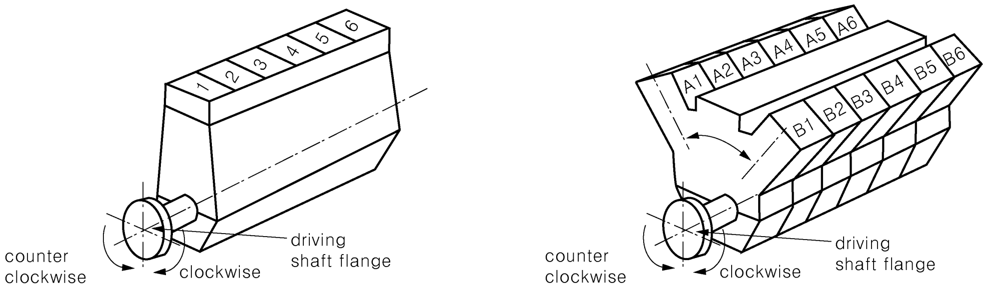
1	Engine builder		
2	Engine type designation		
3	Stroke-cycle	☐ 2 SCSA ☐ 4 SCSA	
4	Kind of engine	☐ In-line engine ☐ V-type engine with adjacent connecting rods ☐ V-type engine with articulated-type connecting rods ☐ V-type engine with forked/inner connecting rods ☐ Crosshead engine ☐ Trunk piston engine	
5	Combustion method	☐ Direct injection ☐ Precombustion chamber ☐ Others :	
6	 Designation of the cylinders		
7	Sense of rotation(corresponding to item 6)	☐ Clockwise ☐ Counter clockwise	
8	Firing order(corresponding to item 7)		
9	Firing intervals[deg](corresponding to item 8)		
10	Rated power		kW
11	Rated engine speed		rpm
12	Mean effective pressure		N/mm^2
13	Mean indicated pressure		N/mm^2
14	Maximum cylinder pressure(gauge)		N/mm^2
15	Charge air pressure(gauge)(before inlet valves or scavenge ports)		N/mm^2
16	Nominal compression ratio		-
17	Number of cylinder		-
18	Diameter of cylinder		mm
19	Length of piston stroke		mm
20	Length of connecting rod(between bearing center)		mm
21	Oscillating mass of one cylinder(mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod)		kg
22	Digitalized gas pressure curve(gauge)-presented at equidistant intervals[N/mm^2-crank angle]-(intervals not more than 5° CA) ☐ given in the appendix		

Table 5.1.1 Data sheet for calculation of crankshafts for internal combustion engines (continued)

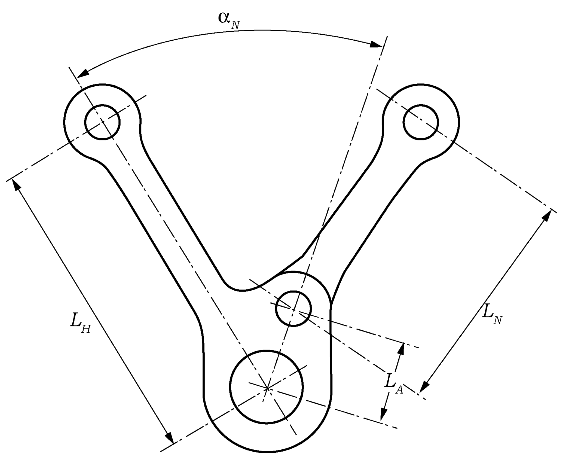
additional data of V-type engines			
23	V-angle(a_V)(corresponding to item 6)		deg
For the cylinder bank with articulated-type connecting rod (dimensions corresponding to item 27)			
24	Maximum cylinder pressure(gauge)		N/mm^2
25	Charging air pressure(gauge)(before inlet valves or scavenge ports)		N/mm^2
26	Nominal compression ratio		-
27	 Articulated-type connecting rod		
28	Distance to link point(L_A)		mm
29	Link angle(a_N)		deg
30	Length of connecting rod(L_N)		mm
31	Oscillating mass of one cylinder(mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod)		kg
32	Digitalized gas pressure curve(gauge)-presented at equidistant intervals[N/mm^2-crank angle]-(intervals not more than 5° CA) ☐ given in the appendix		
For the cylinder bank with inner connecting rod			
33	Oscillating mass of one cylinder(mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod)		kg
Data of crankshafts(dimensions corresponding to item 39) Note : For asymmetric cranks the dimensions are to be entered both for the left and light part of crank throw			
34	Drawing No.		
35	Kind of crankshaft(e.g. solid-forged crankshaft, semi-built crankshaft, etc.)		
36	Method of manufacture(e.g. free form forged, cast steel, etc.) ☐ Description of the forging process - if c.g.f forged or drop forged-given in the appendix		
37	Heat treatment(e.g. tempered)		
38	Surface treatment of fillets, journals and pins(e.g. induction hardened, nitrided, rolled, etc.) ☐ Full details given in the appendix		

Table 5.1.1 Data sheet for calculation of crankshafts for internal combustion engines (continued)

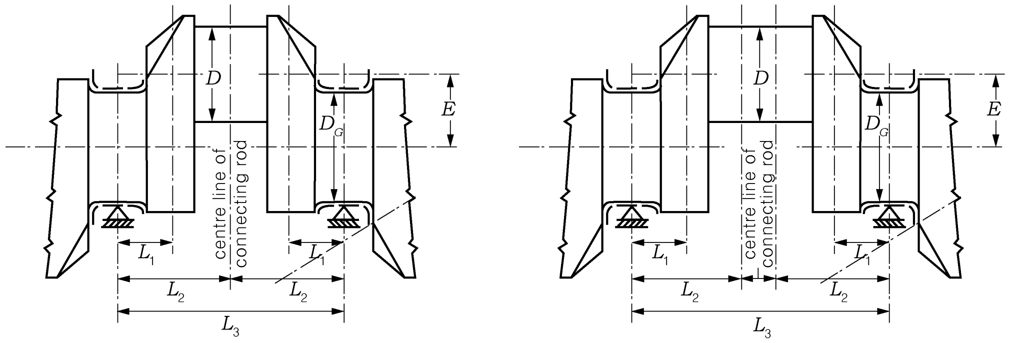
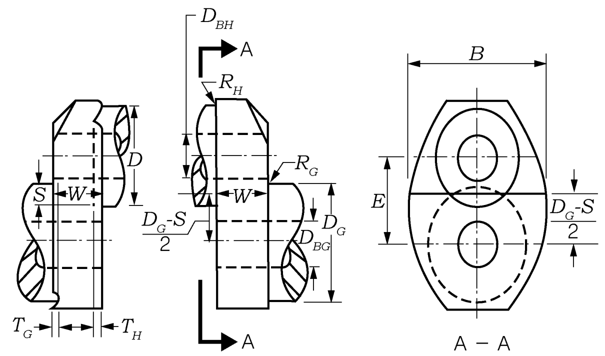
<table>
<tr><td>39</td><td colspan="3">
Crank throw for in−line engine
Crank throw for engine with 2 adjacent connecting rods

Crank dimensions necessary for the calculation of stress concentration factors</td></tr>
<tr><td>40</td><td>Crankpin diameter(D)</td><td></td><td>mm</td></tr>
<tr><td>41</td><td>Diameter of bore in crankpin(D_{BH})</td><td></td><td>mm</td></tr>
<tr><td>42</td><td>Fillet radius of crankpin(R_H)</td><td></td><td>mm</td></tr>
<tr><td>43</td><td>Recess of crankpin(T_H)</td><td></td><td>mm</td></tr>
<tr><td>44</td><td>Journal Diameter(D_G)</td><td></td><td>mm</td></tr>
<tr><td>45</td><td>diameter of bore in journal(D_{BG})</td><td></td><td>mm</td></tr>
<tr><td>46</td><td>Fillet radius of journal(R_g)</td><td></td><td>mm</td></tr>
<tr><td>47</td><td>Recess of journal(T_G)</td><td></td><td>mm</td></tr>
<tr><td>48</td><td>Web thickness(W)</td><td></td><td>mm</td></tr>
<tr><td>49</td><td>Web width(B)</td><td></td><td>mm</td></tr>
<tr><td>50</td><td>bending length(L_1)</td><td></td><td>mm</td></tr>
<tr><td>51</td><td>bending length(L_2)</td><td></td><td>mm</td></tr>
<tr><td>52</td><td>bending length(L_3)</td><td></td><td>mm</td></tr>
<tr><td>53</td><td colspan="3">Oil bore design
☐ Safety margin against fatigue at the oil bores is not less than acceptable in the fillets</td></tr>
<tr><td>54</td><td>Diameter of oil bore</td><td></td><td>mm</td></tr>
<tr><td>55</td><td>Smallest edge radius of oil bore</td><td></td><td>mm</td></tr>
<tr><td>56</td><td>Surface roughness of oil bore fillet</td><td></td><td>μm</td></tr>
<tr><td>57</td><td>Inclination of oil bore axis related to shaft axis</td><td></td><td>°</td></tr>
</table>

Table 5.1.1 Data sheet for calculation of crankshafts for internal combustion engines (continued)

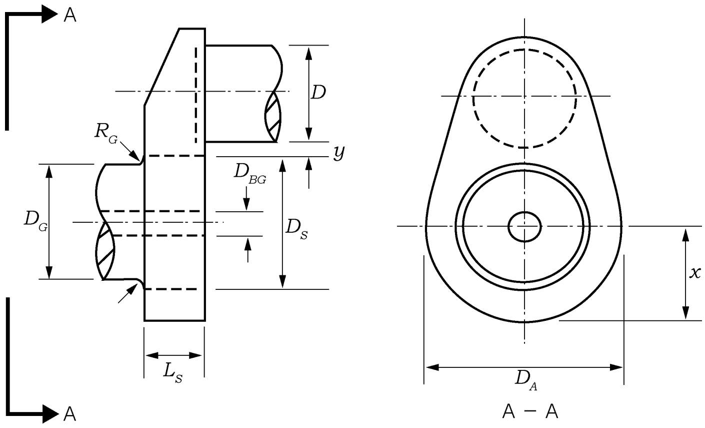
	Additional data for shrink-fits of semi-built crankshafts (dimensions corresponding to item 58)		
58	Crank throw of semi-built crankshaft		
59	Shrink diameter(D_S)		mm
60	Length of shrink-fit(L_S)		mm
61	Outside diameter of web(D_A) or twice the minimum distance(x) (the smaller value is to be entered)		mm
62	Amount of shrink-fit(upper and lower tolerances)		mm
			%
63	Maximum torque(ascertained according to **Annex 5-3**, **2**. (2), (A) of the Guidance)		Nm
	Data of crankshaft material Note : Minimum values of mechanical properties of material obtained from longitudinal test specifications		
64	Material designation(according to the standard which deemed appropriate by the Society(DIN, AISI, etc.))		
65	Method of material melting process(e.g. open-hearth furnance, electric furnance, etc.		
66	Tensile strength		N/mm^2
67	Yield strength		N/mm^2
68	Reduction in area at break		%
69	Elongation(A_5)		%
70	Impact energy-KV		J
71	Young's modulus		N/mm^2
	Additional data for journals of semi-built crankshafts		
72	Material designation(according to the standard which deemed appropriate by the Society(DIN, AISI, etc.))		
73	Tensile strength		N/mm^2
74	Yield strength		N/mm^2
	Data according to calculation of torsional stresses		
75	Maximum nominal alternating torsional stress(ascertained by means of a harmonic synthesis according to **Annex 5-3**, **2**. (2), (A) of the Guidance and related to cross-sectional area of bored crank pin) — crankpin		N/mm^2
	journal		N/mm^2
76	Engine speed(at which the max. nominal alternating torsional stress occurs)		rpm
77	Minimum engine speed(for which the harmonic synthesis was carried out)		rpm

Table 5.1.1 Data sheet for calculation of crankshafts for internal combustion engines (continued)

<table>
<tr><td colspan="5">Data of stress concentration factors(S.C.F.) and/or fatigue strength furnished by reliable measurements
Note : to be filled in only when data for stress concentration factors and/or fatigue are furnished by the engine manufacturer on the basis of measurements. Full supporting details are to be enclosed</td></tr>
<tr><td>78</td><td colspan="2">S.C.F. for bending in crankpin fillet(α_B)</td><td></td><td>-</td></tr>
<tr><td>79</td><td colspan="2">S.C.F. for torsion in crankpin fillet(α_T)</td><td></td><td>-</td></tr>
<tr><td>80</td><td colspan="2">S.C.F. for bending in journal fillet(β_B)</td><td></td><td>-</td></tr>
<tr><td>81</td><td colspan="2">S.C.F. for shearing in journal fillet(β_Q)</td><td></td><td>-</td></tr>
<tr><td>82</td><td colspan="2">S.C.F. for torsion in journal fillet(β_T)</td><td></td><td>-</td></tr>
<tr><td rowspan="2">83</td><td rowspan="2">Allowable fatigue strength of crankshaft(σ_{DW})</td><td>crankpin</td><td></td><td>N/mm^2</td></tr>
<tr><td>journal</td><td></td><td>N/mm^2</td></tr>
<tr><td colspan="5">Remarks</td></tr>
<tr><td>84</td><td colspan="4"></td></tr>
</table>

Section 3 Tests and Inspections

301. Shop trials

1. The programme for shop trials of diesel engine is to be in accordance with the following;

(1) During all stages being tested, the engine manufacturers are to measure and record data pertaining to operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine.

(2) All data measured at the various load points are to be measured at steady operating conditions.

(3) When no-load operating is carried out for adjusting the engine maneuvering conditions, the fuel delivery system, maneuvering system and safety devices are to be properly adjusted before operating.

(4) The programme shown in **Table 5.1.2** of the Guidance is to be used as a standard for shop trial of diesel engines. In this case, the details for the programme are to be referred to specified below. Additional test items may be requested according to the discretion of the Society.

(A) For main engines of diesel ships and electric propulsion ships;
KS V 4314 (Shop Test Code for Marine Internal Combustion Engine for Propelling Use) or standards considered as equivalent thereto

(B) For diesel engines driving main generators or essential auxiliaries;
KS V 4316 (Water-Cooled Four Cycle Marine Diesel Engines for Electrical Generator) or standards considered as equivalent thereto

(5) For electronically controlled diesel engines, integration tests are to be carried out to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be selected based on the FMEA required in **Table 5.1.4** Note 2. (5) of the Rules and confirmed by the Society.

2. *KS V* 4211 (Shop Test Code of Marine Steam Engine for Propelling Use) or standards considered as equivalent thereto are to be used as a standard for the programme of shop trial for steam turbines, and the performance test for safety devices is to be included in the details of programme.

3. The manufacturers of gas turbine are to submit the details of the programme to the Society, and the shop tests are to be carried out according to the details of the programme approved by the Society.

4. In application to **301.** of the Rules, auxiliary to be inspected means only the essential auxiliaries. For the items of tests and inspections not specified in the Rules or Guidance, consideration will be given to the discretion of the Society.

Table 5.1.2 Programme for Shop Trials

<table>
<tr><th colspan="2">Use of engines / Test items</th><th>Main engines of diesel ships(1)</th><th>Main engines of electric propulsion ships(2)</th><th>Diesel engines driving generators or essential auxiliaries(2)</th></tr>
<tr><td colspan="2">110 % power run(3)</td><td>30~45 minutes at the speed of 1.032 times of the rated engine speed</td><td>30 minutes of the rated engine speed</td><td rowspan="7">The same as the left</td></tr>
<tr><td rowspan="6">Load tests</td><td>100 % power run(4)</td><td>60 minutes of the rated engine speed</td><td>50 minutes of the rated engine speed</td></tr>
<tr><td>Nominal continuous cruise power run(5)</td><td rowspan="4">20 minutes at the engine speed in accordance with characteristics of propeller</td><td>—</td></tr>
<tr><td>75 % power run</td><td rowspan="2">20 minutes of the rated engine speed</td></tr>
<tr><td>50 % power run</td></tr>
<tr><td>25 % power run</td><td>20 minutes of the rated engine speed</td></tr>
<tr><td colspan="2">Starting maneuvering test</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Reverse maneuvering test(6)</td><td>0</td><td>—</td><td>—</td></tr>
<tr><td colspan="2">Governor characteristics test</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Performance test of alarm and safety devices</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Overhaul inspection(7)</td><td>0</td><td>0</td><td>0</td></tr>
</table>

NOTES :

1. For electronically controlled diesel engines, integration tests are to be carried out in accordance with **301. 1** (5) of the Guidance.
2. (1) through (7) in this Table are subject to the following;
   (1) After the trials, the fuel delivery system is to be blocked so as to limit the engines to run at not more than 100 % power.
   (2) After the trials, the fuel delivery system is to be adjusted such that overload (110 % power) can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.
   (3) The testing time may be shorten to 20 minutes for engines having a cylinder bore 400 mm or less when deemed appropriate by the Society in consideration of the conditions of quality assurance, production records, etc. of the manufacturer.
   (4) The readings are to be taken twice at an interval of at least 30 minutes.
   (5) The test item may be dispensed with when deemed appropriate by the Society.
   (6) The test item applies only to direct reversible engines.
   (7) The overhaul inspection for one cylinder assembly is to be carried out, but the scope of overhaul inspection may be extended according to the discretion of the attending Surveyor.

302. On-board tests

In application to **302.** of the Rules, the programme for on-board tests or sea trials is to be in accordance with the following, and only the essential auxiliary machinery is to be inspected;

1. The **Table 5.1.3** of the Guidance is to be used as a standard for the details of on-board test programme or sea trial programme for diesel engines. Additional tests may be carried out according to *KS V* 0811 (Sea Trials Code for Machinery Department) where considered necessary by the Society. The details of the programme are referred to *KS V* 0811 or standards considered as equivalent thereto, and the overhaul inspection for cylinder assembly may be carried out where considered necessary by the Society.

Table 5.1.3 Programme for Sea Trials (on-board tests)

<table>
<tr><th colspan="2">Use of engines / Test items</th><th>Main engines of diesel ships(1)</th><th>Single Main engines of electric propulsion ships(2)</th><th>Diesel engines driving generators or essential auxiliaries(3)</th></tr>
<tr><td colspan="2">110 % power run(4)</td><td>30 minutes at the speed of 1.032 times of the rated engine speed</td><td>30 minutes at the 110 % rated propulsion power</td><td>to be verified</td></tr>
<tr><td rowspan="5">Load tests</td><td>100 % power run(5)</td><td>4 hours at the rated engine speed</td><td>4 hours of the 100 % power (rated propulsion power)</td><td rowspan="5">4 hours at the rated engine speed including 100 % power run(5)(6)</td></tr>
<tr><td>Nominal continuous cruise power run(5)</td><td>2 hours at engine speed corresponding to nominal continuous cruise power</td><td>2 hours at the nominal continuous cruise propulsion power</td></tr>
<tr><td>75 % power run</td><td rowspan="3">reasonable hours at the rated engine speed for 1 or 2 kind of power run</td><td rowspan="3">reasonable hours at the rated engine speed for 1 or 2 kind of propulsion power run</td></tr>
<tr><td>50 % power run</td></tr>
<tr><td>25 % power run</td></tr>
<tr><td colspan="2">Minimum engine speed test</td><td>0</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Starting maneuvering test(7)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Reverse maneuvering test</td><td>10 minutes at the minimum engine speed of 70 % of the rated engine speed</td><td>10 minutes at the minimum engine speed of 70 % of the nominal propeller speed</td><td></td></tr>
<tr><td colspan="2">UMA test(8)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Alarms and safety devices test</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Test for fitness of fuel oil(9)</td><td>0</td><td>0</td><td>0</td></tr>
</table>

NOTES: (1) through (9) in this Table are subject to the following;
(1) For controllable pitch propellers, the tests are to be carried out at the various pitches.
(2) The governor is to be adjusted constantly, the rated electrical powers of electric propulsion motors is to be used as the standard.
(3) The governor is to be adjusted constantly, the rated output of driving generator is to be used as the standard.
(4) The test may be dispensed with when deemed appropriate by the Society in consideration of the result of the shop trials.
(5) The testing time may be shorten appropriately when deemed appropriate by the Society in consideration of the result of the shop trials (for main engines of diesel ships or electric propulsion ships, 1 hour or more).
(6) In case that it is difficult to give the demanded load, the load may be reduced appropriately.
(7) The direct reversible engines are to be carried out ahead and astern starting repeatedly without replenishment, and the other engines are to be carried out starting and stop repeatedly without replenishment.
(8) The test is to be carried out for ships which are going to be registered as ships provided with unattended machinery automatic systems.
(9) The test is to be carried out for the engines used residue oil or equivalent thereto. However, the test may be dispense with when deemed appropriate by the Society or in the case of that the fitness was certified at the shop trial.

2. *KS V* 0811 (Sea Trials Code for Machinery Department) or standards considered as equivalent thereto are to be used as a standard for the details of on-board test programme or sea trial programme for steam turbines. The steam turbines are to be sufficiently able to ensure their function and reliable under all service conditions, and are not to be set up any abnormal vibration at the engine working speed. However, for the steam turbines certified and carried out the shop tests in accordance with **301.** of the Guidance, the on-board tests may be considered appropriately at the discretion of the Society.

3. The details of sea trial programme for gas turbines are to be approved by the Society. The gas turbines are to be sufficiently able to ensure their function and reliable under all service condition, and are not to be set up any abnormal vibration at the engine working speed. However, for the gas turbines certified and carried out the shop tests in accordance with **301.** of the Guidance, the on-board tests may be considered appropriately at the discretion of the Society.

Section 4 Spare Parts and Tools

401. Application

1. For the kind and number of spare parts, each table in **Ch 1, Sec 4** of the Rules is to be applied in general and the Regulations and Instructions regarding Machinery Installations of Ship's of the Korean Government is to be applied for ships with smooth water service or coastal service or fishing vessel. However, the requirements of this section are for general guidance purpose and in general are not mandatory for retention of class. Kind and number of spare parts specified in this section may be added or reduced when deemed appropriate by the Society in consideration of the design, recommendations of the manufacturer, the discussion with owner, production records of the same type machinery and maintenance method.

2. The prime movers for auxiliaries to be furnished spare parts in accordance with **Ch 1, Sec 4** of the Rules are those essential for main propulsion specified in **102.** of the Guidance.

402. Internal combustion engines

In application to **402.** of the Rules, at the request of the Owners, the spare parts of camshaft driving gears, chains and bearings may be omitted according to the discretion of the Society.

405. Boiler

Description and number of spare parts for steam heating type steam generator are to be applied appropriate modifications of **Ch 1, Table 5.1.8** of the Rules except oil burner complete.

406. Essential auxiliary

1. In the case that a scoop is provided instead of a circulating pump at the ships equipped with a main steam turbine, the spare parts for reserve circulating pump are to be furnished.

2. The spare parts for exhaust gas economizer circulating water pump and independent ballast pump may not be furnished.

407. Tools and instruments

Indicators and bridge gauges or equivalent thereto are included in the special tools and instruments for maintenance or repair work of the machinery. ⚓

CHAPTER 2 MAIN AND AUXILIARY ENGINES

Section 1 General

101. Application

1. In application to **101. 1** of the Rules, "the small auxiliary engines and auxiliary engines driving emergency generators" may apply to the following;

(1) For auxiliary engines having output of 100 kW or less driving generators or essential auxiliaries, or for auxiliary engines driving emergency generators

(A) Where a auxiliary engine is not for driving generators and where an auxiliary engine is for driving emergency generators, the submission of plans and documents may be omitted. However, plans or documents to confirm that the engines are comply with requirements in **Ch 1, 103. 1** and **Ch 2, 203. 9** of the Rules, are to be submitted to attending Surveyor.

(B) Materials used in the main components may comply with *Korean Industrial Standards or equivalent.*

(C) The attending Surveyor may admit of the hydraulic test results carried out by manufacturer.

(2) For auxiliary engines for cargo handling machinery having output of 100 kW or over, but less than 375 kW, the plans and documents are to be submitted, however, (1) (B) and (C) may apply to materials and tests.

2. Welding In application to **101. 5** of the Rules, the general requirements for principal component with welded construction are to be comply with **Ch 5, Sec 4** of the Rules.

3. Electronically controlled diesel engines In application to **101. 7** of the Rules, the additional requirements specified otherwise by the Society are to be in accordance with **Annex 5-8** of the Guidance.

Section 2 Internal Combustion Engines

201. Materials

In application to **Table 5.2.1** of the Rules, necessary actions for prohibition of arc strike are to be taken at magnetic particle test by prod method.

203. Safety devices

1. Control and safety systems for dual fuel diesel engines are to comply with the requirements given in **Annex 5-7.**

2. In application to **203. 2** of the Rules, other acceptable means may includes methods to prevent over pressure by tension of cylinder head bolts.

3. In application to **203. 4** of the Rules, manual and name plate for relief valves of crankcase are to be in accordance with the following.

(1) A copy manufacturer's installation and maintenance manual that is pertinent to the size and type of relief valve being supplied for installation on a particular engine is to be provided on board ship. The manual is to contain the following information.

(A) Description of valve with details of function and design limits
(B) Installation instructions
(C) Maintenance in service instructions to include testing and renewal of any sealing arrangements
(D) Actions required after a crankcase explosion

(2) Relief valves are to be provided with suitable markings that include the following information.

(A) Name and address of manufacturer
(B) Designation and size
(C) Month/Year of manufacture
(D) Approved installation orientation

4. In application to **203. 10** (1) of the Rules, bearing temperature monitors or equivalent devices are to be in accordance with the following.

(1) Bearing temperature monitors of low speed diesel engines(crosshead type) are to be capable of monitoring temperature(or oil outlet temp.) of main bearing, crank bearing and crosshead bearing.
(2) Bearing temperature monitors of medium and high speed diesel engines(trunk piston type) are to be capable of monitoring temperature(or oil outlet temp.) of main bearing and crank bearing.
(3) An equivalent device could be interpreted as measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.

5. In application to **203. 10** (1) of the Rules, where an overriding for automatic shutoff arrangements is installed, the documents on the consequences are to be submitted to this Society for approval.

6. In application to **203. 10** (2) of the Rules, the engine designer's and oil mist manufacturer's instructions are to be included the following particulars.

(1) Schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector.
(2) Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.
(3) The manufacturer's maintenance and test manual.(A copy of the manual is to be provided on board ship.)
(4) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

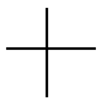
7. In application to **203. 10** (8) of the Rules, the details are to be submitted for consideration are to be in accordance with the following.

(1) Engine particulars (type, power, speed, stroke, bore and crankcase volume, etc.)
(2) Details of arrangements prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements.
(3) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(4) Operating instructions and the maintenance and test instructions.

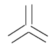
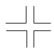
204. Crank shafts

1. Minimum diameter In application to **Table 5.2.2,** coefficients A and B for engines having unequal firing intervals are to be in accordance with the following;

(1) 4-stroke cycle in-line engines

Number of cylinders	Arrangement of crank	*A*	*B*
4		1.25	4.7

(2) 2-stroke cycle vee engines

Number of cylinders	Minimum firing interval between two clyinders on one crankpin	Arrangement of crank	A	B
12	60°		1.00	21.6
				15.0
16				26.3

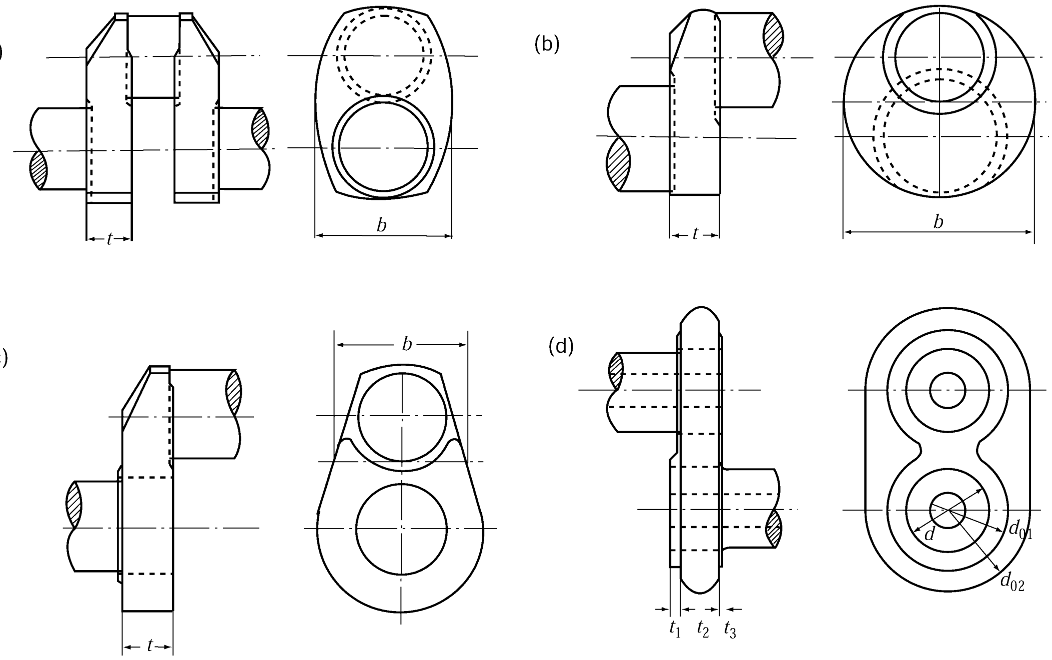
205. Dimensions of crank arms

The dimensions of the crank arms breadth b, crank arms thickness t and radius in fillet r are to be in accordance with the following;

1. Solid crankshaft

(1) In application to **205. 1** of the Rules, as for b, the breadth on the perpendicular bisector of the line between the crankpin center and journal center is to be used. As for t, the thickness at the same section as b is to be used, and the recess need not be accounted in the thickness even when it is provided. As for r, the radius connecting to the crankpin or journal is to be used when a composite radius is provided.

(2) When the diameters of crankpin and journal are different each other, their t/d and b/d are to be in accordance with **205. 1** or **Fig 5.2.1** of the Rules.



(Note)
$A_{s1}=d_{01}/d$, $A_{s2}=d_{02}/d, \cdots$ (values divided out-diameters of crankarm in way of crankarm splited up t_1, $t_2 \cdots$ into hole diameter in way of the shrinkage fit) are to apply to the formula given in **205. 3** of the Guidances.

Fig. 5.2.1 Measuring Method of b and t

2. Semi-built-up crankshaft

In application to **205. 3** of the Rules as for b, the breath on the line perpendicularly interested to the line between the crankpin center and journal center and tangent to the crankpin is to be used. As for t, the thickness at the same section as b is to be used, and the recess need not be accounted in the thickness even when it is provided, and the ring around the shringkage hole is not to be included in the thickness. As for r, the radius connecting to the crankpin or journal is to be used when a composite radius is provided. b and t are given in **Fig 5.2.1** of the Guidance.

3. In application to **205. 3** and **4** of the Rules the thickness of crankarm in way of the shrinkage fit as **Fig 5.2.1** (d) of the Guidance is to comply with the following formula instead of **205. 3** of the Rules;

$$t_1\left(1-\frac{1}{A_{s_1}^2}\right)+t_2\left(1-\frac{1}{A_{s_2}^2}\right)+\cdots\cdots \geq \frac{C_1 TD^2}{C_2 d_h^2}$$

$$t_2 \geq 0.525 d_c$$

206. Material consideration

In the application **206.** of the Rules, in case where the semi-built-up crankshaft made of the materials having a specified tensile strength less than 440 $\mathrm{N/mm^2}$, the coefficient K_m may be 1.

208. Special consideration

1. The requirements of **208.** of the Rules are in accordance with the following;

(1) The definition and approval test for “manufacturing process of the different manufacturing methods of forged crankshaft” are to be in accordance with **Ch 2, Sec 5** of the "**Guidance for Approval of Manufacturing Process and Type Approval, Etc.**"

(2) The diameter of crankshaft manufactured by the different manufacturing methods mentioned previous (1) may be reduced by multiplying d_c by the less coefficient between k_r and k_p.

(A) In case where the crankshaft are manufacturers by such a special method approved by the Society that the forging grain-flow is continuous, and the product quality is stable, and the fatigue strength is considered to be improved by 20 % or more compared with that in free forging process;

$$k_r = \sqrt[3]{\frac{1}{1.15}}$$

(B) In case where the crankshaft are manufactured by such a special method approved by the Society that a surface hardening is provided and the product quality is stable, and a superiority is considered in the fatigue strength;

$$k_\rho = \sqrt[3]{\frac{1}{1+\rho/100}}$$

ρ : Degree of improvement in strength approved by the Society relative to the surface hardening (%)

(3) In case **205. 3** and **210. 1** of the Rules, the previous (2) is not to be applied.

2. In case where the diameter of crankshaft, dimension of crankarm and radius in fillet are less than the valves required in **204.** and **205.** of the Rules, the requirements of **208.** of the Rules are in accordance with the following (refer to **Fig 5.2.2** of the Guidance).

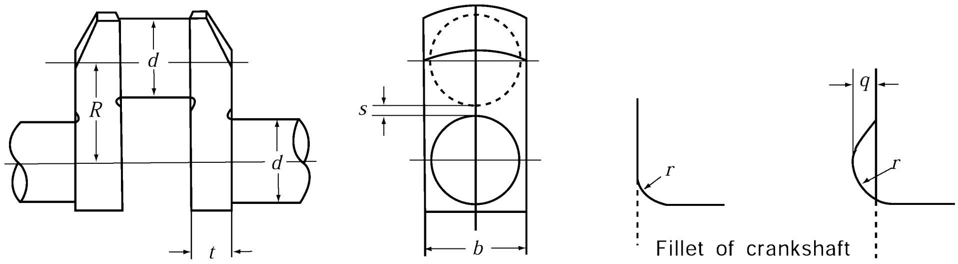


Fig. 5.2.2 Dimensions for Crankshaft

(1) When it is not satisfied with **204. 2** of the Rules;
In case where the diameter of crankpins or journals is less than the required diameter d_c given in **204. 2** of the Rules and considered according to **206., 207.** of the Rules and **208. 1** (2) of the Guidance, consideration will be given in each case on basis of the stress levels in fillets, the torsional stress levels in parallel parts, friction force of shrinkage fitted parts, material, etc. In this connection, the stress levels in fillets are to be in accordance with the following (A) or (B).

(A) In case where the torsional stress in crankpins and journals are evaluated without carrying out a forced vibration calculation including the stern shaftings;
The diameter of pin may be acceptable where the value of equivalent stress amplitude de calculated by the **Annex 5-2** (Guidance for calculation of crankshaft stress(1)) is not more than the allowable stress s obtained from the formula below with the coefficient shown in **Table 5.2.1** of the Guidance.

$$\sigma = \sigma_a \cdot f_m \cdot f_s + a (\mathrm{N/mm^2})$$

Table 5.2.1 Coefficient of Allowable Stress at Fillet

σ_a N/㎟	Cycle		2 cycle		4 cycle
	Type of crankshaft		Semi-built-up	Solid	Solid
	Solid Shaft Diameter(d)	$d \geq 200$	53.9	53.9(※)	83.3
		$200 > d \geq 100$	—	132.3 - d/4	
		$100 > d$	—	107.8	
	NOTES : d is the actual diameter of crankpin or journal whichever is larger. (※) In case engine bed other than welded type, σ_a may be applied 83.3.				
f_m	$1 + \frac{2}{3}\left(\frac{T_s}{440} - 1\right)$				
	NOTES : T_s is the minimum specified tensile strength ($\mathrm{N/mm^2}$) of crankshaft materials.				
f_s	Manufacturing method				
	Ordinary method	Method meeting (A) for K_r specified in **208. 1.** (2) of the Guidance		Method meeting (B) for K_ρ specified in **208. 1.** (2) of the Guidance	
	1	1.15		1 + ρ/100	
	NOTES : ρ signifies the degree of strength improvement(%) approved by the Society relative to surface hardening.				
α N/mm^2	Main bearing material				
	White metal		Tri-metal or kelmet		
	0		9.8		

(B) In case where the torsional stress in crankpins and journals are evaluated by carrying out a forced vibration calculation in including the stern shafting:
The diameter may be acceptable where the value of the acceptability factor Q calculated by the **Annex 5-3** (Guidance for calculation of crankshaft stress(2)) is comply with the following formula.

$$Q \geq 1.15$$

(2) In case where the dimensions of crankarms fail to meet the requirements **205.** of the Rules;
(A) The dimension of crankarms may be acceptable where the actual diameters d of crankpins and journals are not less than the required diameter d_c calculated by **204.** of the Guidance by replacing M and T with those specified below. In this case, the dimensions are to be within the following ranges. And, b, t and r are specified in **205.** of the Guidance.

$$M = 10^{-2} APL \times \frac{\alpha_{KB}}{5}$$

$$T = 10^{-2} BP_i S \times \frac{\alpha_{KT}}{1.8}$$

Where :

$$0 \leq \frac{q}{r} \leq 1,\ -0.3 \leq \frac{s}{d} \leq 0.4,\ 8 \leq \frac{d}{r} \leq 27$$

$$1.1 \leq \frac{b}{d} \leq 2.1,\ 0.2 \leq \frac{t}{d} \leq 0.56$$

$_{KB\,r}$= 4.84f1Å f2Å f3Å f4Å f5 (Stress concentration factor for bending)

$$f_1 = 0.42 + 0.16\sqrt{\frac{d}{r} - 6.864}$$

$$f_2 = 1 + 81\left\{0.769 - \left(0.407 - \frac{s}{d}\right)^2\right\}\left(\frac{q}{r}\right)\left(\frac{r}{d}\right)^2$$

$$f_3 = 0.285\left(2.2 - \frac{b}{d}\right)^2 + 0.785$$

$$f_4 = 0.444\left(\frac{d}{t}\right)^{1.4}$$

$$f_5 = 1 - \left\{\left(\frac{s}{d} + 0.1\right)^2 / \left(4\frac{t}{d} - 0.7\right)\right\} \cdot \cdot \cdot \cdot \cdot \left(\frac{t}{d} \geq 0.36\right)$$

$$= 1 - 1.35\left(\frac{s}{d} + 0.1\right)^2 \cdot \cdot \cdot \cdot \cdot \left(\frac{t}{d} < 0.36 \text{ and } \frac{s}{d} > -0.1\right)$$

$$= 1 \cdot \cdot \cdot \cdot \cdot \left(\frac{t}{d} < 0.36 \text{ and } \frac{s}{d} \leq -0.1\right)$$

$_{KT\,r}$= 1.75g1Å g2Å g3 (Stress concentration factor for torsion)

$$g_1 = 31.6\left(0.152 - \frac{r}{d}\right)^2 + 0.67$$

$$g_2 = 1.04 + 0.317\frac{s}{d}$$

$$g_3 = 1.31 - 0.233\frac{b}{d}$$

d : actual diameter of crankpin or journal (mm)

r : radius in fillet (mm)

q : recess (mm)

s : Offset between crankpin and journal (mm)

$$s = \frac{Diameter\,of\,pin + Diameter\,of\,journal - Length\,of\,stroke}{2}$$

(B) In case where the dimensions of the crankarms fail to meet the requirements even after applying (A) above, **208. 2** (1) (A) and (B) of the Guidance may be applied.

(C) In case where the thickness or outside diameter of crankarms of built-up crankshaft fail to meet the requirements, they may be acceptable provided that the following is satisfied.

$$d^2 \times t \times p_m \geq CTD^2$$

where :

C : 103 for 2-stroke cycle in-line engines
165 for 4-stroke cycle in-line engines

d : Diameter of the hole at shrinkage fit (mm)

t : Thickness of crankarm measured parallel to the axis (mm)

T : Same as **204.** of the Rules

D : Cylinder bore (mm)

P_m : Surface pressure at shrinkage fit (N/mm^2), as given by the following formula;

$$p_m = Y\left[\log_e K + \frac{1}{2}\left\{1 - \frac{K^2}{A_s^2}\right\}\right] \times (1 - R^2)$$

Y : Yield strength of crank web material (N/mm^2)

$$A_s = \frac{External\,diameter\,of\,web\,(mm)}{d}$$

$$K = 0.9\sqrt{\frac{206\,\alpha}{Y} + 0.25}$$

$$\alpha = \frac{Shringkage\,all\,lowance\,(mm)}{d} \times 10^3$$

R : Quotient obtained by dividing the inside diameter of hollow shaft by its outside diameter

211. Tests and inspections

1. In the application **211. 3** of the Rules, "the procedure as deemed appropriate by the Society" means the procedure specified in **Ch 3, Sec 8-1** or 8-**2** of the "**Guidance for Approval of Manufacturing Process and Type Approval, Etc.**"

2. In the application **Table 5.2.3** NOTES 2 of the Rules, for piston crowns and cylinder covers, test methods other than hydraulic testing may be accepted. e.g. suitable non-destructive examination and dimension measurement and surface inspection.

3. In the application **Table 5.2.3** of the Rules, where the cooling space of piston crowns is sealed by piston rod or by piston rod and skirt, hydraulic test is to be carried out after assembly.

Section 3 Steam Turbines

304. Safety devices

It is recommended that the main turbines are provided with a quick acting device which automatically shut off the steam supply in case of unacceptable axial displacement of the turbine rotor in addition to the devices mentioned in **304. 2** and **3** of the Rules.

306. Strength and sectional area of turbine blades

When the calculations for vibration stress for the blade or the specified 0.01 % proof-stress of the blade material are submitted to the Society and are deemed appropriate by the Society, the values of 2 times the specified 0.01 % proof-stress for the blade material may be applied instead of S in the formula given in **306.** of the Rules. ⚓

CHAPTER 3 PROPULSION SHAFTING AND POWER TRANSMISSION SYSTEMS

Section 1 General

101. Welded structure component

In application to **101.** of the Rules, the general requirements for major parts with welded construction are to apply appropriate modifications of **Ch 5, Sec 4** of the Rules.

102. Other propulsion and maneuvering machinery

In application to **102.** of the Rules, water-jet propulsion systems and azimuth or rotatable thrusters may be complied with the following ;

1. Water-jet propulsion systems and azimuth or rotatable thrusters water-jet propulsion systems or azimuth or rotatable thrusters are to comply with the requirements given in **Annex 5-1.**

Section 2 Shafting

201. Application

1. In application to **201. 2.** of the Rules, the alternative calculation methods are considered appropriate by the Society are to be in accordance with the following.

(1) Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions.
(2) Consideration is to be given to the dimensions and arrangements of all shaft connections.
(3) An alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength).
(4) The fatigue strength analysis may be carried out separately for different load assumptions as follows.
(A) Low cycle fatigue criterion (typically $< 10^4$)
(B) High cycle fatigue criterion (typically $>> 10^7$)
(C) The accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition

203. Intermediate shaft and thrust shaft

1. In case the ships engaged in smooth water service area, the values of F in formula given in **203.** of the Rules may be taken as 95.

2. The diameter of shafts may be reduced on the basis of the application to **204. 2** of the Rules.

204. Propeller shaft and stern tube shaft

1. In application to **Table 5.3.2** NOTE (3) of the Rules, the required diameters of Kind 1 shaft made of approved corrosion-resistant materials and kind 2 shaft are to be determined by the following formula;

$$d_p = K_4 \times \sqrt[3]{\frac{P}{n}} \quad (\mathrm{mm})$$

P : Maximum continuous output of main propulsion machinery (kW)

n : Number of shaft revolution at maximum continuous output (rpm)

K_4 : Factor concerning shaft design, given in **Table 5.3.1** of the Guidance

Table 5.3.1 Values of $K4$

Application \ Shaft Material		Propeller shaft kind 1		Propeller shaft kind 2
		Precipitation hardened stainless(KS STS 630 series or equivalent)approved by the Society	Austenitic stainless steels with the diameter not exceeding 200 mm (KS STS 316 series or equivalent)	Austenitic stainless steels (KS STS 304 or equivalent series)
1	The portion from the big end of the tapered part of propeller shaft(in case of flange connected propeller, the fwd end of flange) to the fwd end of the after most stern tube bearing or to 2.5 d_p(4.0 d_p in sea-water-lubricated) whichever is larger	105	128	128
2	The portion in the direction toward the bow side up to the fwd end of fwd stern tube sealing assembly and excluding the portion shown in 1 above	$94^{(1)}$	$116^{(1)}$	$116^{(1)}$
3	The portion between the fwd end of the fwd stern tube sealing assembly and the intermediate shaft coupling	$94^{(2)}$	$116^{(2)}$	$116^{(2)}$
4	Stern tube shaft	94	116	116

NOTES : (1) and (2) in the Table are as follows;
(1) The diameter of boundary portion is to be tapered down smoothly.
(2) The diameter may be tapered down to the diameter calculated by the formula given in **203.** of the Rules assumed as T = 410 N/mm^2

2. Reducing diameter

In case where the diameter of shafts fails to meet the requirements specified in **203.** and **204.** of the Rules, the criteria specified in below may be used.

(1) In case of ships engaged in smooth water service area, the diameters of propeller shaft and stern shaft may be taken as the values not less than 92 % of the value calculated in accordance with **204. 1** of the Rules or prescribed **1.**

(2) The diameter of shafts may be reduced to those having the torsional stress satisfying following formula.

$$\gamma_m \cdot \tau_m + \gamma_t \cdot \tau_D \le \frac{\tau_y}{S_y}$$

$$\gamma_t \cdot \tau_D \le \frac{\tau_f}{S_f}$$

τ_m : Average torsional stress on the shaft. However, in case where the average bending stress acts on the shaft, it is to be accordance with the following formula.

$$\tau_{me} = \sqrt{\tau_m^2 + \frac{1}{3}\sigma_m^2}$$

τ_{me} : Equivalent average torsional stress (N/mm^2)
σ_m : Average bending stress (N/mm^2)

β_m : Notch parameter for static stress

τ_D : Variable torsional stress on shaft. However, where the variable bending stress acts on the shaft, it is to be accordance with the following formula.

$$\tau_{De} = \sqrt{\tau_D^2 + \frac{1}{3}\left(\frac{\beta_b}{\beta_t}\sigma_D\right)^2}$$

τ_{De} : Equivalent variable torsional stress (N/mm^2)

σ_D : Variable bending stress (N/mm^2)

β_b : Notch parameter for bending stress

β_t : Notch parameter for torsional stress

τ_y : Torsional yield strength of shaft material (N/mm^2)

S_y : Safety factor for yield strength

τ_f : Torsional fatigue strength of shaft material when average stress τ_m (or τ_{me}) is loaded on (N/mm^2)

S_f : Safety factor for fatigue strength

(3) In above (2), the torsional fatigue strength and torsional yield strength of shaft are determinated by the Society through considering the materials, heat-treatment and surface treatment and reviewing the submitted documents. The safety factors for fatigue and yield are determinated by the Society through considering the using purpose and conditions of shaft.

206. Stern tube bearing and sealing devices

In application to **206. 1.** (3) of the Rules, where the length of oil lubricated bearings is less than 2 times the required calculation diameter of the propeller shaft in way of the bearing, the following are to be satisfied with.

(1) Improvement in condition of bearing loads
The relative contact condition between propeller shaft and its bearing in the longitudinal direction is to be improved by employing the slope alignment (including the slope boring) and uniform distribution of bearing loads are to be ensured. For approval of the above, an slop alignment calculation sheet (bending moment, bending stress bearing pressure, bearing load, amount of deflection, angle of inclination, etc.) satisfying the following, and installation instruction is to be submitted.
(A) Alignment calculation only dealing with the static external force may be accepted (the review for shaft alignment variation due to dynamic force such as variation of bending moment, bending stress and etc. is not accepted).
(B) At any position on the propeller shaft static bending moment (absolute value) is not to exceed the value at the aft end of the stern tube bearing.

(2) Improvement in lubricating oil and condition of lubricating
For improving the lubricating condition of stern tube bearing, the following measures are to be taken;
(A) The lubricating oil inlet is to be provided at the aft end of the bearing for ensuring the forced circulation of the lubricating oil.
(B) To be use lubricating oil with superior resistance against burning out bearing and characteristic being easy to emulsify (being difficult to separate). However, additaments for lubricating oil are to be considered the fitness with sealing materials for stern tube sealing device such as rubber.
(C) Damage found of bearings at early stage
For finding of bearings burned out at early stage and preventing of extension of the damage, at least one(1) temperature sensor in bearing shell and high temperature alarm (Set point 60 °c or below) are to be provided.
(D) Low level alarm is to be provided in the lubricating oil tank.

Section 3 Propellers

301. Application

1. For the propellers such as following, the Society may request the submission of calculation sheets for stress of blades.

(1) Propellers having special type blade such as nozzle propeller, jacket propeller, etc.
(2) Propellers for special purpose ships such as tug boat, stern trawler, pusher, etc.
(3) Propellers having pitch ratio of more than 0.8 at the radius 0.25 R.
(4) Specially designed propellers for improving propelling efficiency.

302. Materials

1. The major parts of propeller (an oblique line part in **Fig 5.3.1** of the Guidance) are to be carried out liquid penetrant test or other effective non-destructive test.

303. Thickness of blades

1. The thickness of skewed propeller blades more than 25° of skew angle is to comply with the following requirements depending on skew angle (the angle, on the expanded blade drawing, between the line connecting the center of the propeller shaft with the point at the blade tip on the center line of blade width and the tangential line drawn from the center of the propeller shaft to center line of blade width(See **Fig 5.3.2**)

(1) In case where the skew angle exceeds 25° but is 60° or less

(A) The blade thicknesses at a radius of 0.25 R (0.35 R for controllable pitch propellers) and 0.6 R are not to be less than the values obtained by multiplying the values (t_x) calculated by the formula in **303.** of the Rules, by the coefficient A given in the formula below;

$$A = \left(1 + B\frac{\theta - 25^\circ}{60^\circ}\right)$$

θ : Skew angle (°)

B : 0.2 at 0.25 R (0.35 R for controllable pitch propeller)

0.6 at 0.6 R

(B) Blade thickness t_x at any radius between 0.6 R and 0.9 R is not to be less than the value determined by the following formula.

$$t_x = 0.003D + \frac{(1-x)(t_{0.6} - 0.003D)}{0.4} \quad (\mathrm{mm})$$

D : Diameter of propeller (mm)

x : Radius position having no dimension

$t_{0.6}$: blade thickness at 0.6 R as required in (A) above

(2) In case where the skew angle exceeds 60°
On the basis of the precise calculation sheet on propeller strength submitted by the manufacturer or designer, the blade thickness is to be determined under the satisfaction of the Society.

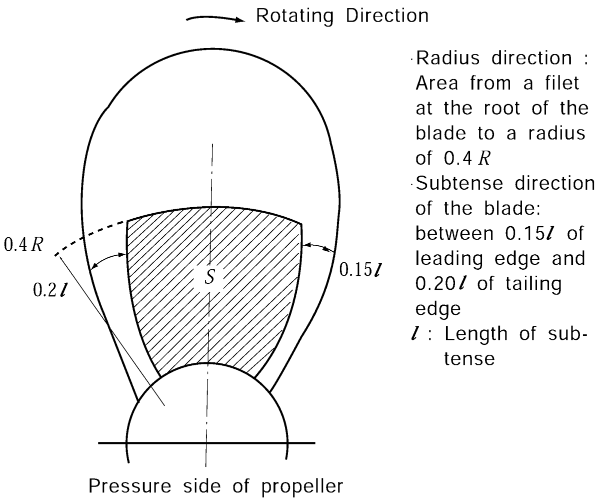


Fig 5.3.1 Non-destructive Testing Area

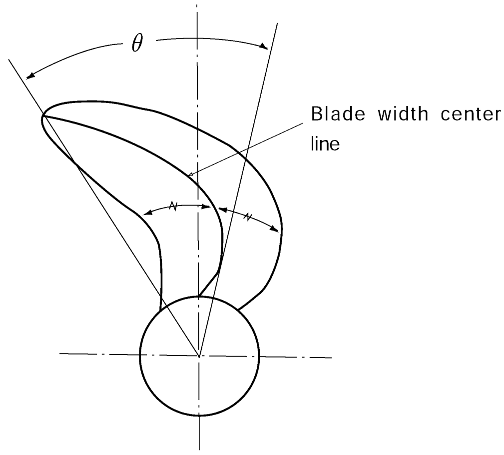


Fig 5.3.2 Skew Angle

304. Fixing of blades

In **304. 1** of the Rules, the blade fixing bolts are in accordance with the following.

(1) The diameter of blade fixing bolts of controllable pitch propellers is not to be less than the value calculated by the following formula. In this case, the value of K_3 may be taken as the values specified in **Fig 5.3.3** of the Guidance.

$$d = 0.55\sqrt{\frac{1}{\sigma_a} \cdot \frac{1}{n}\left(\frac{A \cdot K_3}{L} + F_c\right)}$$

where;

d : Required diameter of blade fixing bolt (mm)

A : Value given by the following formula.

$$A = 3.0 \times 10^4 \frac{H}{NZ}$$

H : Maximum continuous output of main propulsion machinery (kW)

Z : Number of blades

N : Number of maximum continuos revolution per minute divided by 100 (rpm/100)

K_3 : Values given by the following formula

$$K_3 = \sqrt{(D/P)^2(0.622 - 0.9x_0)^2 + (0.318 - 0.499x_0)^2}$$

x_0 : Ratio of the radius at the boundary between blade flange and pitch control gear to propeller radius (see **Fig 5.3.3** of the Guidance). Where $x_0 >$ 0.3, the ratio is to be taken as 0.3.

D : Diameter of propeller (m)

P : Pitch at radius of 0.7 R (m), (R = Radius of propeller)

L : Mean value of L_1 and L_2 (cm)

L_1 and L_2 show the length of the perpendicular lines constructed to the line which passes through the rotating center of blade flange and has an inclination compatible with the pitch angle β at 0.7 R, from the center of bolts located on each edge side in face side when the pitch angle is β. (see **Fig 5.3.4** of the Guidance)

F_C : Centrifugal force (N) of propeller blade given by the following formula:

$$F_C = 1.10 \times mR'N^2$$

m : Mass of one blade (kg)

R' : Distance between center of gravity of blade and propeller shaft center line (cm)

n : Number of bolts on the face side of blade

σ_a : Allowable stress of bolt material given by the following formula (N/mm²)

$$\sigma_a = 34.7 \times \left(\frac{\sigma_B + 160}{600}\right)$$

σ_B : Specified tensile strength of bolt material (N/mm²). Where σ_B > 800 N/mm², it is to be taken as 800 N/mm².

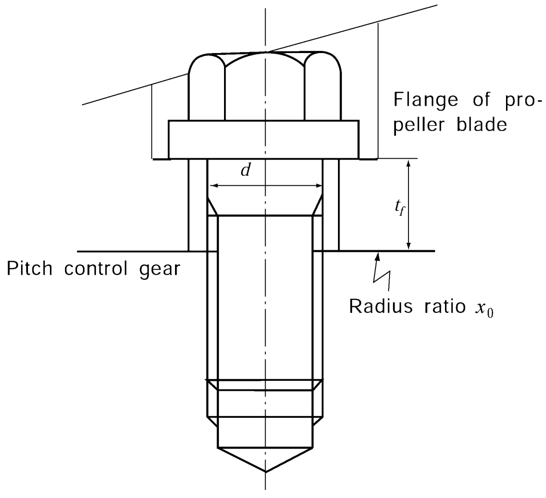


Fig 5.3.3 Measuring Method of Blade Fixing Bolt Dimension

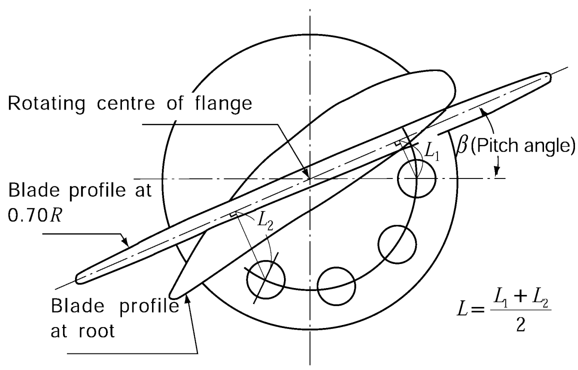


Fig 5.3.4 Determination of *L*

(2) The thickness of flange for fixing the blade to the pitch control gear (the thickness as measured from the seat of fixing bolt or nut to the boundary face between the flange and the pitch control gear) is to be not less than the value calculated by the following formula:

$$t_f = 0.9d$$

Where;

t_f : Thickness of flange (mm) (see **Fig 5.3.3** of the Guidance)

d : Required diameter of bolt calculated by the formula specified in (1) (mm)

(3) The blades are to be fixed securely to the pitch control gears by giving the fixing bolts the ad-

equate initial fixing force. It is to be regarded as the standard practice that the initial fixing force complies with the following condition;

$$\frac{1.3}{n}\left(\frac{A \cdot K_3}{L}+F_C\right)< T_0 < 0.55\,\sigma_0 \cdot d^2$$

where

T_0 : Initial fixing force (N)

σ_0 : Yield strength or 0.2 % proof strength of bolt material (N/mm^2)

Other symbols are the same as in the formula shown in (1).

305. Fitting of propeller

1. In **305. 1** of the Rules, the heating temperature of propeller boss at drawing out is to be not more than 100 °C.

2. In application **305. 2** of the Rules, keyless forced fitting propellers are to satisfy the following.

(A) General

(a) The formula, etc., given herein are not applicable for propellers where a sleeve is introduced between propeller shaft (hereinafter referred to as "**shaft**") and propeller boss (hereinafter referred to as "**boss**").

(b) The taper of the shaft cone is not to exceed 1/15.

(c) Prior to final pull-up, the contact area between the mating surface is to be checked and is not to be less than 70 % of the theoretical contact area. Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable.

(d) After final pull-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

(e) The factor of safety against friction slip at 35 °C is not to be less than 2.8 under the action of rated torque at corresponding power and speed plus pulsating torque due to torsional.

(f) For the oil injection method the coefficient of friction is to be 0.13 for bosses made of bronze and steel.

(g) The maximum equivalent uniaxial stress (N/mm^2) in the boss at 0 °C based on the Mises-Hencky criterion should not exceed 70 % of the yield point or 0.2 % proof-stress (0.2 % offset yield strength) for the propeller. For cast iron the value should not exceed 30 % of the nominal tensile strength.

(B) Materials

Modulus of elasticity, Poisson's ratio and coefficient of linear expansion of materials are in accordance with the **Table 5.3.2** of the Guidance.

Table 5.3.2 Modulus of Elasticity, Poisson's Ratio and Coefficient of Linear Expansion

Kind of material	Modulus of elasticity (N/mm^2)	Poisson's ratio	Coefficient of linear expansion (mm/mm °C)
Steel castings and steel forgings	20.6×10^{4}	0.29	12.0×10^{-6}
Cast iron	9.8×10^{4}	0.26	12.0×10^{-6}
High strength brass casting, CU1, CU2	10.8×10^{4}	0.33	17.5×10^{-6}
Aluminium bronze casting, CU3, CU4	11.8×10^{4}	0.33	17.5×10^{-6}

(C) Calculations for pull-up length and pull-up load

(a) The formulae are applicable for solid shafts only.

(b) Pull-up length

(i) Corresponding minimum pull-up length at 35 °C (mm) :

$${}_{35} = P_{35}\frac{D_s}{2\text{¤}}\left[\frac{1}{E_b}\left(\frac{K^2+1}{K^2-1}+v_b\right)+\frac{1}{E_s}(1-v_s)\right]$$

(ii) Minimum pull-up length at temperature t (t < 35 °C) (mm)

$$_{t} = {}_{35} + \frac{D_{s}}{2¤}({}_{b} - {}_{s})(35 - t)$$

(iii) Corresponding maximum permissible pull-up length at 0 °C (mm)

$$_{max} = \frac{P_{max}}{P_{35}}{}_{35}$$

Where

P_{35} : Minimum required surface pressure at 35 °C (N/mm²)

$$P_{35} = \frac{ST}{AB}\left[-S\theta + \sqrt{\mu^2 + B\left(\frac{F_V}{T}\right)^2}\right]$$

S : Factor of safety against friction slip at 35 °C

T : Thrust(N) (if not given, calculate P35 with the value calculated by the following formulas and take the value which make P35 grater)

$$T = 1{,}762\frac{H}{V_s} \text{ or } T = 57.4 \times 10^6\frac{H}{PN}$$

H : Maximum continuous output (kW)

V_s : Ship speed at maximum continuous output (Knots)

P : Mean propeller pitch (mm)

N : Number of revolution at maximum continuous output (rpm)

A : 100 % theoretical contact area between boss and shaft, as read from drawings and disregarding oil grooves (mm²)

B : Values according to the following formula

$$B = \mu^2 - S^2\theta^2$$

μ : Coefficient of friction between mating surfaces

θ : Half taper of tail-shaft (e.g. taper = 1/15, θ = 1/30)

F_V : Shear force at interface (N)

$$F_V = \frac{2cQ}{D_s}$$

c : Constant,

1 : for turbines, geared diesel drives, electric drives and for direct diesel drives with a hydraulic or an electromagnetic or high elasticity coupling

1.2 : for a direct diesel drive

Q : Troque transmitted according to maximum continuous output (N/mm)

D_s : Diameter of tail-shaft at the midpoint of the taper in the axial direction (mm)

K : Values according to the following formula

$$K = \frac{D_b}{D_s}$$

D_b : Mean outer diameter of propeller boss at the axial position corresponding to D_s (mm)

E_b : Modulus of elasticity of boss material (N/mm^2)

V_b : Poisson s ratio for boss material

E_s : Modulus of elasticity of shaft material (N/mm^2)

V_s : Poisson s ratio for shaft material

a_b : Coefficient of linear expansion of boss material (mm/mm °C)

a_s : Coefficient of linear expansion of shaft material (mm/mm °C)

P_{max} : Maximum permissible surface pressure at 0 °C (N/mm^2)

$$P_{max} = 0.7\frac{\sigma_y(K^2-1)}{\sqrt{3K^4+1}}$$

σ_y : Yield point or 0.2 % proof stress (0.2 % offset yield strength) boss material (N/mm^2)

(c) Minimum pull-up load at temperature t °C (N)

$$W_t = AP_t(\mu+\theta)$$

where

P_t : Corresponding minimum surface pressure at temperature t °C (N/mm^2)

$$P_t = P_{35}\frac{\delta_t}{\delta_{35}}$$

3. When the propeller is forced fitted to the propeller shaft by hydraulic force, the confirmation of the pull-up length specified in **307. 3** of the Rules is to be made assuming that the true relative start point is the point where the pull-up load equal zero on the approximate line drawn in the measured points plotted on the chart of the relation between pull-up length and load. And when the propeller is forced fitted to the propeller shaft after second times, the pull-up length is to be confirmed by the calculations and the records drawn up at the previous time.

307. Tests and inspections

1. Static balancing test for propellers The unbalanced mass at a static balancing test of propeller is not to exceed the value determined by the following formula;

$$P = C\frac{m}{R \cdot n^2} \text{ or } P = K \cdot m$$

where

P : Unbalanced mass referred to the circumference of the propeller (kg)

m : Mass of propeller (kg)

R : Radius of propeller (m)

n : Number of propeller revolution at the maximum continuos output (rpm)

C and K : Given in the following table

Class*	S	I	II	III
C K	15 0.0005	25 0.001	40 0.001	75 0.001
NOTE: * Refer to ISO 484/1-1981				

2. Where it is not possible to confirm the unbalanced mass and torque by the static balancing tests, dynamic balancing tests may be carried out where deemed appropriate by the Surveyor.

Section 4 Power Transmission Systems

401. General

1. "Small ships" given in **401. 3** of the Rules means ships having length not more than 50 m.

2. The for small transmitted power specified in **401. 5** of the Rules means the transmitted power less than 257 kW .

402. General construction of gearing

The general requirements for the major parts with welded construction are to apply **Pt 2, Ch 2** of the Rules.

403. Allowable tangential load for gears

1. In gearing for main propulsion internal combustion engines having maximum continuos output not more than 257 kW and maximum continuos revolution not less than 1,300 rpm, where the coupling complied with the following (1) or (2) is provided between engines and gearing, and the gearing and coupling are of type having actual examples used on ships, the value of K_1 given in **403. 2** of the Rules may be taken as 1.0.

(1) High elasticity couplings

(2) Elasticity coupling not existed resonance rpm occurring critical fluctuation at revolution ratio 0.4 through 1.15

2. In application **403. 4** of the Rules, the strength calculation for gears of power transmission systems may be in accordance with **Annex 5-4** of the Guidance. ⚓

CHAPTER 4 TORSIONAL VIBRATION OF SHAFTING

Section 2 Allowable Limit of Vibration Stresses

201. Crankshafts

1. In application to **201.** of the Rules, the strength calculation for crankshafts is carried out according to the special requirements given by the Society means **Annex 5-3**. For the allowable limit of vibration stresses, the nominal alternating torsional stresses(τ_N) specified in **Annex 5-3**, **2**. (2) (A) are to be applied in the operational speed range of the engine. Where barred speed ranges are imposed, the allowable torsional vibration stresses in the ranges may be specially considered.

2. In application to **201. 4** of the Rules, in case where the specified minimum tensile strength of the crankshaft exceeds 590 $\mathrm{N/mm^2}$ for carbon steel forging, or 835 $\mathrm{N/mm^2}$ for low alloy steel forging, the value of T_s given in formula for f_m is to be in accordance with the following.

(1) The value of T_s is to be taken as 590 $\mathrm{N/mm^2}$ for carbon steel forging, and 835 $\mathrm{N/mm^2}$ for low alloy steel forging. However (2) below is to be excepted.

(2) Where the crankshaft approved by **Ch 2, Sec 5, 503. 2** of the "**Guidance for Approval of Manufacturing Process and Type Approval, etc.**" for torsional fatigue strength of crankshaft, the value of T_s is to be taken as the value added the fatigue strength improved.

202. Intermediate shafts, thrust shafts, propeller shafts and stern tube shafts

1. The allowable limit of torsional vibration stress for propeller shafts made of the approved corrosion resistance materials is to be calculated by the following formula in place of the formula for τ_1 shown in **202. 1** of the Rules.

$$\tau_1 = A - B\lambda^2 \quad (\lambda \le 0.9)$$
$$\tau_1 = C \quad (0.9 < \lambda)$$

τ_1 : Allowable limit of torsional vibration stress at the continuos operation ($\mathrm{N/mm^2}$)
λ : Ratio of the number of revolution to the number of maximum continuos revolution
A, B, C : Constant dependent on shaft materials given in **Table 5.4.1** of the Guidance

Table 5.4.1 Values of A, B and C

	Precipitation hardened stainless steel	Austenitic stainless steel(*KS STS* 304 or equivalent)
A	61.1	40.7
B	47.3	30.5
C	22.8	16.0
NOTES : For material other than above, the values are to be determined on each case.		

2. For ships powered by steam turbines, gas turbines, diesel engines having slip couplings such as electro-magnetic couplings or fluid couplings or electric propulsion systems with reduction gear, the allowable limits of torsional vibration stress on the intermediate shafts, thrust shafts, propeller shafts and stern tube shafts are to be calculated by applying the values of C_K given in the **Table 5.4.2** of the Guidance to the formula specified in **202. 1** of the Rules.

Table 5.4.2 Values of C_K

Intermediate shaft	Integral flange couplings	0.75
	Shrink fit couplings	0.75
	Keyways	0.45
Thrust shaft	On both sides of the thrust collar	0.65
	In way of axial bearings where a roller bearing is used as a thrust bearing	0.65
Propeller shaft and stern tube shaft	-	0.35
NOTE : The value of C_K other than above is to be determined by the Society in each case.		

3. In application to **Table 5.4.1** NOTE (5) of the Rules, if the slot dimensions are outside of the limitations, or if the use of another C_K is desired, C_K is to be in accordance with the following.

$$C_K = 1.45/scf$$

scf : stress concentration factor at the end of slots defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress determined for the hollow shaft without slots.

$$scf = \alpha_{t(hole)} + 0.57 \cdot \frac{(l-e)/d_o}{\sqrt{1-\left(\frac{d_i}{d_o}\right) \cdot \frac{e}{d_o}}}$$

l : slot length (mm)
e : slot width (mm)
d_i : inside diameter of the hollow shaft at the slot (mm)
d_o : outside diameter of the hollow shaft (mm)
$\alpha_{t(hole)}$: stress concentration factor of radial holes(in this context e = hole diameter) determined by the following formula

$$\alpha_{t(hole)} = 2.3 - 3 \cdot \frac{e}{d_o} + 15 \cdot \left(\frac{e}{d_o}\right)^2 + 10 \cdot \left(\frac{e}{d_o}\right)^2 \cdot \left(\frac{d_i}{d_o}\right)^2$$

or simplied to $\alpha_{t(hole)} = 2.3$

However, this formula for above stress concentrate factor applies to the following slots.
(A) Slots at 120 or 180 or 360 degrees apart
(B) Slots with semicircular ends (A multi-radii slot end is not included in this empirical formula)
(C) Slots with no edge rounding(except chamfering)

203. Shafting system of generators

1. In application to **203.** of the Rules, the strength calculation for crankshafts is carried out according to the special requirements given by the Society means **Annex 5-3**. For the allowable limit of vibration stresses, the nominal alternating torsional stresses(τ_N) specified in **Annex 5-3**, **2**. (2) (A) are to be applied in the operational speed range of the engine. Where barred speed ranges are imposed, the allowable torsional vibration stresses in the ranges may be specially considered.

205. Detailed evaluation for strength

Where the torsional vibration stress acted on shaft is satisfied with requirements of **Ch 3, 204. 3** of the Guidance, τ_D according to the requirements of **Ch 3, 204. 3** of the Guidance may be taken instead of τ_1 given in **Pt 5, Ch 4** of the Rules at the calculation for allowable limit of torsional vibration stress. ⚓

CHAPTER 5 BOILERS AND PRESSURE VESSELS

Section 1 Boilers

101. Applications

1. In application to **101. 2** of the Rules, small boilers having design pressure less than 0.35 MPa (hereinafter referred to as "**small boiler**") may be in accordance with the following regardless of requirements in **Ch 5, Sec 1** of the Rules.

(1) Materials, construction, strength and accessories of small boilers
  (A) Materials, construction, strength and accessories of small boilers are to be complied with *Korean Industrial Standards or equivalent.*
  (B) Safety valve or pressure relief pipe having sufficient capacity is to be fitted.
  (C) Safety devices for the following are to be fitted.
    (a) Draught fan for pre-purging to prevent the gas explosion in furnace
    (b) Fuel oil shut-off device in the case of flame vanishes, automatic ignition fails or combustion air supply stops
    (c) Fuel oil shut-off device when the fuel oil supply pressure to the oil burners falls in case of pressure atomizing
    (d) Fuel oil shut-off device for preventing from overheating of boilers when the water level falls

(2) Tests
  (A) The pressure receiving portions are to be tested to a hydrostatic pressure of 2 times the design pressure. However, the test pressure is not to be less than 0.2 MPa
  (B) Performance test for the safety devices mentioned above (1) (C) are to be carried out.

102. Materials

1. In application to **102. 1** (2) of the Rules, "where deemed appropriate by the Society" means the fittings having design pressure less than 3 MPa and nominal diameter less than 100 A.

2. In application to **102. 2** of the Rules, the cast steels used for body of the boilers are to be ensured that the materials have not any harmful defect through radiographic examination and magnetic particle test. Test methods and judgement standards are to be in accordance with the following.

(1) The radiographic examination is to be carried out according to "*KS D* 0227 (method of radiographic examination for cast steels and classification of grade for radiograph film)", and if there is crack, the cast steel is to be rejected. The defects specified in *KS D* 0227 such as blow holes, sand spots, inclusions and concavity are to be accepted only defects of Grade 1.
(2) The magnetic particle test is to be carried out according to "*KS D* 0213 (method of magnetic particle test for steels and classification of grade for defect shape of magnetic particle)", the defects specified in *KS D* 0213 are to be accepted only defects of Grade 1 or Grade 2.
(3) The cast steels rejected by above (1) and (2) may be repaired. Repairing method by welding is to comply with **Pt 2, Ch 1, 501. 11** of the Rules.

111. Flat plates or tube plates with stay or other supports

1. Where the required thickness at the portion including water tube holes of the tube plates of a dry combustion cylindrical boiler is calculated by the formula specified in **111. 3** of the Rules, the value of C in the formula for the supports adjacent to water tube holes is to be divided by the square of the rate of strength reduction obtained by the following formula.

$$\eta = \frac{p - 0.5d}{p}$$

where

η : Rate of strength reduction

p : Pitch of water tube holes (mm)

d : Diameter of water tube holes (mm)

114. Manholes, mud holes and peep holes

1. The required thickness of manhole covers is to be determined by the formula below. However, the thickness at the center is not to be made 14 mm or less. In case where a groove is provided at the periphery of a manhole cover, the thickness of such a part may be reduced to 2/3 of that of the central area.

$$T = \frac{b}{2c}\sqrt{\frac{100P}{f}}$$

where

T : Required thickness of manhole cover (mm)

P : Design pressure (MPa)

f : Allowable stress specified in the Rules (N/mm^2)

b : Length of minor axis of manhole (mm)

c : Value given in **Fig 5.5.1** of the Guidance. In **Fig 5.5.1** of the Guidance, a stands for the length of major axis of manhole (mm), and when b/a is 1, c is to be 9. In the case of the corrugated manhole cover, a and b are to be taken as shown in **Fig 5.5.2** of the Guidance.

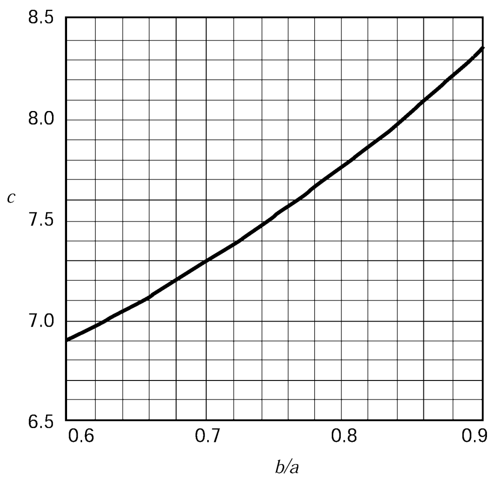


Fig 5.5.1 Values of *c*

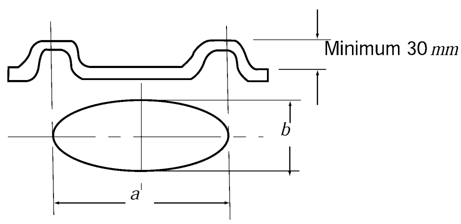


Fig 5.5.2 a and b of Corrugated Manhole Cover

116. Flues, furnaces, ogee rings and cross tubes

1. The required thickness of plain cylindrical furnaces supported with stays or other members is to be calculated by the formula in **116. 3** of the Rules by regarding the effective length between the stays as L in the formula.

117. Stays, stay tubes and girders

1. The required diameter (d) of stays or stay tubes specified in **117. 1** of the Rules is to be determined as follows.

(1) When the adjacent support is a stay or stay tube, the boundary is considered as the perpendicu-

lar bisector of the line connecting the both support points.
(2) When the adjacent support is curved flange or welded joint, the boundary is considered as the locus of the center of inscribed circle to the support point in question and the commencement line of curvature or the inside plain ends welded on shell or furnaces specified in **111. 5** of the Rules.
(3) At the corner part of smoke tube nests, the calculation may be carried out by regarding the half of the sum of two area supported by stays or stay tubes adjacent each other.
(4) The areas of stay, stay tube and smoke tube included in the concerned area are to exclude from the area specified in above (1) through (3).

124. Construction and tests of safety valves

1. In application to **124. 8** of the Rules, the duration of accumulation test is to be in accordance with the following.
(1) For water tube boilers : 7 minutes
(2) For smoke tube boilers : 15 minutes

129. Water level indicator

1. In application to **129. 2** of the Rules, exhaust gas boilers are to be provided with a glass water level gauge, and a remote water level indicator or a high/low water level alarm device.

136. Tests and inspections

1. Hydraulic test
(1) The hydraulic test of desuperheaters installed within water drum or steam drum of boiler is to be carried out at 1.5 times or more the design pressure of the boiler when a steam stop valve is provided at the inlet of desuperheater, and 1.5 times or more the assumed pressure difference when a stop valve is provided only at the outlet of the desuperheater. However, test pressure is not to be less than 2 MPa.
(2) In the hydraulic tests for boilers the test pressure for the hydraulic test of boiler tubes and connecting pipes after completion of welding and assembly may be modified to 1.25 times the design pressure, in case where parts or members such as drums, headers, and others are subjected to hydraulic test individually at a test pressure of 1.5 times the design pressure.

Section 2 Thermal Oil Heaters

203. Safety devices for thermal oil heaters directly heated by the exhaust gas of engines

In application to **203. 7** of the Rules, “Fixed fire extinguishing and cooling system as deemed appropriate by the Society” means the combination of fixed gas fire-extinguishing systems and the systems for cooling the heating coil, header, casing, etc., and the heater itself such as water-spray. The fixed fire extinguishing cooling system can be a water-drenching system able to discharge copious amounts of water. In this case, the suitable means for collection and drainage, to prevent the water from flowing into the diesel engines, are to be provided on exhaust ducting below the heater, and the drainage is to be led to suitable places.

Section 3 Pressure Vessels

302. Classification

1. The low pressure steam generators belong to Class 1 are to be provided with the following accessories.
(1) Water level indicators : 1 set of glass water level gauge
(2) Safety valves : To be applied with appropriate modifications of the requirements of the boilers.

(3) Peep holes : To be applied with appropriate modifications of the requirements of the boilers.
(4) Boiler water blow-off valves : To be applied with appropriate modifications of the requirements of the boilers.
(5) Relief valve : To be applied with appropriate modifications of the requirements of the boilers.
(6) Pressure gauges : To be applied with appropriate modifications of the requirements of the boilers.
(7) Thermometers : To be applied with appropriate modifications of the requirements of the boilers.

303. Materials

1. In application to **303. 2** of the Rules, body of pressure vessels used for noxious substances is not to be used special iron castings.

2. When the steel castings are used for the body of Class 1 or Class 2 pressure vessels, non-destructive test methods and judgement standards are to be in accordance with the following.

(1) The radiographic examination is to be carried out according to "*KS D* 0227 (method of radiographic examination for steel castings and classification of grade for radiograph film)" and if there is crack, to be rejected. The defects specified in *KS D* 0227 such as blowholes, sand spots, inclusions and concavity are to be accepted only defects of Grade 1. However, in the case of Class 2 pressure vessels, the defects specified in *KS D* 0227 such as blowholes, sand spots and inclusions found on test portions of thickness more than 25 mm may be accepted defects of Grade 1 and Grade 2.
(2) The magnetic particle test is to be carried out according to "*KS D* 0213 (method of magnetic particle test for steels and classification of grade for defect shape of magnetic particle)", the defects specified in *KS D* 0213 are to be accepted only defects of Grade 1 or Grade 2.
(3) The penetration inspection is to be carried out according to "*KS D* 0816 (method of penetration inspection and classification of grade for defect shape)", the judgement standards of defects are to be applied with appropriate modifications the above (2).
(4) The steel castings rejected by above (1) through (3) may be repaired. Repairing method by welding is to comply with **Pt 2, Ch 1, 501. 11** of the Rules.

3. The materials used for fitting are restricted to the following;

(1) The gray iron castings are not for fitting of pressure vessels intended for containing inflammable or toxic substances.
(2) The special iron castings are not used for fittings for pressure vessels intended for containing toxic substances.

4. In application to **303. 1** (3) of the Rules, "where deemed as appropriate by the Society" means the fittings having design pressure less than 3 MPa and nominal diameter less than 100 A.

308. General construction and strength

1. Construction of fitting is to comply with the following.

(1) Fittings such as valves, flanges, and bolts, nuts, gaskets, etc. are to have the construction and dimension conforming to the recognized standards and they are to conform to the service conditions specified in such standards.
(2) Fittings are to be attached to shells of Class 1 and Class 2 pressure vessels by flanged joint or by welding. However, in case where the thickness of the shell is over 12 mm or in case where a seat for screwing is fitted to the shell, the fittings of not more than 32 *A* in nominal diameter may be attached to the shell by screwing.

310. Flat end plates or tube plates without stay or other supports

1. The thickness of tube plates for heat exchangers without tube stays is to comply with the following requirements:

(1) Except for floating head, the required thickness of flat tube plates without tube stays for the heat exchangers and the like is to be either of the values calculated by the following formula, whichever is the greater;

$$T_1 = \frac{CD}{2}\sqrt{\frac{P}{f}} + a$$
$$T_2 = \frac{PA}{\tau L} + a$$

where

P : Design pressure (MPa)

f : Allowable bending stress of material (N/mm^2)

τ : Allowable shearing stress of material (N/mm^2)

C : Factor determined by the supporting method of tube end plate. Where the tube plates are not integral with the shell, this value is to be taken to 1.0 when straight tubes are used and 1.25 when U-tubes are used. Where the tube plates are integral with the shell, the values are shown in **Fig 5.5.3** of the Guidance.

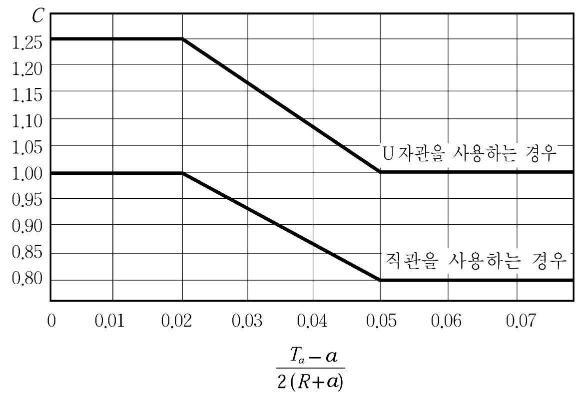
D : Diameter of outer circle of tube end plate (mm), i.e., in case where the tube end plate is bolted to flange, D is the diameter of a circle passing through the position to which gasket reaction is acted; where tube end plate is fixed to the shell, D is the inside diameter of the shell (corrosion allowance is to be deducted)

A : Area of a polygon obtained by connecting the center of outermost tube holes (mm^2) (see **Fig 5.5.4** of the Guidance)

L : Length obtained by deducting the sum of tube hole diameters of the outermost tubes from the length of the outer periphery of the forementioned polygon (mm)

a : 1.0 mm as corrosion allowance. In case where corrosion resistance materials are used, where effective corrosion control measures are taken or when there is no possibility of corrosion, a may be taken as 0.

(2) In obtaining the thickness in (1), calculations are to be carried out on both sides by using respective P, C and D. However, in case where differential pressure calculation is carried out, consideration will be given by the Society in each case.



(비고) T_a : 동판의 실제 두께 R : 동체의 안쪽반지름

Fig 5.5.3 Value of C

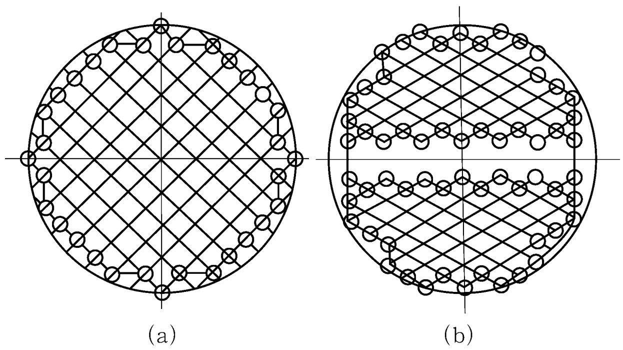


Fig 5.5.4 Polygon Used for Tube Plate Calculation

313. Manholes, mud holes and peep holes

In application to **313.** of the Rules, manholes, mud holes or peep holes of pressure vessels with inside-diameter 900 mm or less may be applied with *Korean Industrial Standards* or standards considered as equivalent thereto according to the discretion of the Society.

319. Tests and inspections

In application to **319. 1. Table 5.5.16** of the Rules, the Class 3 pressure vessels which deemed necessary by the Society mean vessels satisfied with the following (1) or (2).

(1) Design pressure (MPa) × Capacity (m^3) ≥ 1

(2) Heat exchangers (fresh water coolers, lubricating oil coolers, hydraulic oil coolers, lubricating oil heater, fuel oil heaters, condensors, feed water heaters, air coolers, etc.) and air tanks (control air tank, etc.) for operating the following; and other essential pressure vessels :

(A) Main propulsion engines, essential auxiliary engines and propulsion shafting systems

(B) Boilers and thermal oil installations (main boilers, essential auxiliary boilers, boilers and thermal oil heaters for main propulsion engine fuel oil heating and for heating of cargo to be usually heated)

Section 4 Welding for Boilers and Pressure Vessels

401. General

1. Welding procedure qualification tests In application to **401. 2** of the Rules, the welding procedure qualification tests are to comply with **Pt 2, Ch 2, Sec 4** of the Guidance.

2. In application to **401. 3** (3) of the Rules, the requirements of base metals for welding are to be in accordance with the following.

(1) Base metals used in the welding work are to be those suitable for welding. And the carbon content is not to exceed 0.23 % for carbon steel and low alloy steel castings and forging, or 0.35 % for other materials. When approved by the Society in consideration of the welding conditions, the carbon content may be increased to the value approved.

(2) The upper limit of the carbon equivalent for high tensile steels as base material is to be as deemed appropriate by the Society.

403. Heat treatment

1. Omission of stress relief In application to **403. 3** (1) of the Rules, the required conditions for omitting stress relieving in case where the material having superior notch toughness is used, are to be as specified below:

(1) The base metal is to be of steel plate with the specified impact value of 47.1 J or more by the use of test specimens R 4 at a temperature of 0 °C.

(2) The plate thickness of the material is to be 40 mm or less.

(3) Regardless above (1) and (2), in case of the pressure vessels specially designed or used for special condition, the necessity of stress relieving is to be determined at every time of test.

404. Radiographic examination

1. In application to **404.** of the Rules, ultrasonic examination may be substituted for radiographic examination subject to the approval by the Society.

405. Welding workmanship approval tests for boilers and Class 1 pressure vessels

1. In application to **405. 3** of the Rules, when the capacity of tensile test equipment is insufficient, the thickness of tensile test specimens may be reduced to thickness which can be carried out the test. However, when the distribution of strength is identified by the welding procedure qualification test and etc., the tensile test for representative specimens may be substituted for the tensile tests.

2. In application to **405. 5** of the Rules, "the standard value approved by the Society" means the impact test values specified in **Pt 2, Ch 2, Table 2.2.7** and **2.2.8** of the Rules, and in case when materials are not specified in the Tables, that means the impact values of base metal. However, in case where the impact values for base metals are not specified, impact test may be omitted subject to the approval by the Society. ⚓

CHAPTER 6 AUXILIARIES AND PIPING ARRANGEMENT

Section 1 General

101. General

1. Application In application to **101. 1** of the Rules, the construction of auxiliaries is accordance with the following.

(1) The auxiliaries are to have the sufficient strength and adapt to purpose of service, and they are to be maintained and checked easily and made of materials adequate for service.
(2) Bearing bolt of auxiliaries, bolts and nuts of moving parts are to be well secured by effective means to prevent from slaking such as split pin or equivalent.
(3) The auxiliaries and piping systems, as practicable as, are not to leak gases harmful to operators or inflammable gases.
(4) The auxiliaries are installed in the space where the gases mentioned in (3) can be discharged rapidly.
(5) The rotating parts, reciprocating parts and high temperature parts are to be arranged with suitable protection means for the safety of watchmen, operators or men neighbouring to these parts.

2. Definitions The definitions are in accordance with the following and **101. 3** of the Rules;

(1) The planned discharge pressure of 1.1 times is to be used as the standard for design pressure of piping systems on the discharge side for positive displacement pumps.
(2) The range for applying to design pressure specified in **101. 3** (1) (A) and (B) of the Rules is in accordance with the following;
  (A) For piping systems on the discharge side of ballast pumps or cargo oil pumps, from piping systems on the discharge side of pumps to inlet valves of ballast tanks or cargo oil tanks and joints of shore connection. However, where the ships discharge ballast water through sea chests, piping systems to sea chests are to be included.
  (B) For piping systems for operating oil, from hydraulic winches and hydraulic operating valves to the nearest stop valves.
(3) The design pressure of piping systems on the discharge side of circulating water pumps for exhaust gas economizer is applied appropriate modifications of the definitions for design pressure of feed water pump specified in **101. 3** (1) (C) of the Rules.

3. Structure, materials and strength for auxiliaries

In application to **101. 5** (1) of the Rules, "the Society specially considers necessary" is to be in accordance with the following;

(1) For the special auxiliaries specially considered necessary by the Society, the materials are to be determined case by case by the Society.

102. Pipes

1. Materials

(1) The carbon steel pipes for ordinary piping marked *KS* as pipes produced at the manufacturing process approval factory of the Society may be used for Class II on the assumption that the requirement specified in **102. 2.** (4) of the Rules.

2. Service limitations for copper and copper alloy pipes In application to **102. 3** of the Rules, service limitations for copper and copper alloy pipes are to be in accordance with the following;

(1) Copper pipes are not to be used for the following;
  (A) Pipes of which design temperature exceeds 200 °C (excluding pipes for gauging)
  (B) Fuel oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes, air purge pipes, and short pipes from fuel oil burning pumps to combustion units)
  (C) Lubricating oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes, air purge pipes, and pipes arranged in spaces except machinery spaces)
  (D) Hydraulic oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes and air purge pipes)
  (E) Thermal oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes and air purge pipes)

(F) Cargo oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes and air purge pipes)
(G) Bilge pipes (excluding pipes for gauging, drain pipes and air purge pipes)
(H) Ballast water pipes (excluding pipes for gauging and air purge pipes)
(I) Pipes for fire extinguishing (excluding pipes for gauging)
(J) Pipes which directly affect water ingress by damage when fire(application range is cooling sea water pipes installed below the load water line in machinery space category A excluding pipes for gauging, drain pipes and air purge pipes).
(K) Air pipes (including starting air pipes)
(L) Overflow pipes
(M) Sounding pipes (excluding pipes in the sounded compartments)
(N) Pipes considered necessary by the Society

(2) Copper alloy pipes are not to be used for the following;
(A) Pipes of which design temperature exceeds 200 °C (excluding pipes for gauging), white copper pipes of which design temperature exceeds 300 °C (excluding pipes for gauging)
(B) Fuel oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes and air purge pipes)
(C) Lubricating oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes, air purge pipes, and pipes arranged in spaces except machinery spaces)
(D) Hydraulic oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes, air purge pipes and pipes arranged in spaces exept machinery spaces)
(E) Control oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes and air purge pipes)
(F) Thermal oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes, and air purge pipes and pipes arranged in spaces except machinery spaces)
(G) Cargo oil pipes (excluding pipes arranged in tanks, pipes for gauging, drain pipes and air purge pipes)
(H) Pipes for fire extinguishing (excluding pipes for gauging)
(I) Pipes which directly affect water ingress by damage when fire(application range is cooling sea water pipes installed below the load water line in machinery space category A excluding pipes for gauging, drain pipes and air purge pipes)
(J) Control air pipes of auxiliaries and valves being used for fire extinguishing (excluding drain pipes)
(K) Any pipe penetrating either A class division or B class division
(L) Pipes specified in above (1) (G), (H), (K) through (N)

(3) Copper and copper alloy pipes for gauging are to be of short only.

3. Use of special materials and flexible pipes In application to **102. 5** of the Rules, the following are to apply.

(1) In case where plastic pipes are used, plastic pipes are to comply with the requirements given in the **Annex 5-6.**

(2) When aluminium alloy pipes are used, the following requirements are to be complied with;
(A) Aluminium alloy pipes are, as a rule, to be in accordance with the requirements of the standards deemed appropriate by the Society, and are to be of seamless drawn pipes or seamless extruded pipes.
(B) The pipes for the following are not to be of aluminium alloy;
(a) As a rule, pipes with a design temperature exceeding 150 °C
(b) Pipes specified in above **2.** (2) (B) through (L)
(C) The required wall thickness of aluminium alloy pipes subject to internal pressure are to be in accordance with the following;
The wall thickness of pipes is to be determined by the formula in **102. 6** of the Rules. In this case, the allowable stress f is to be of the minimum value of the following values. However, when the design temperature is not in the creep region of the material, no consideration may be required for the value of f_3.

$$f_1 = \frac{R_{20}}{4.0}, \quad f_2 = \frac{E_T}{1.5}, \quad f_3 = \frac{S_R}{1.6}$$

Where

R_{20} : Specified minimum tensile strength (N/mm^2) of the material at room temperature (less than 50 °C)

E_T : 0.2 % proof strength (N/mm^2) of the material at the design temperature

S_R : Mean value of creep breaking stress (N/mm^2) of the material after 100,000 hours at the design temperature

(3) Expansion pipes(including end connection parts) and flexible pipes(including end connection parts) of metallic or non-metallic material, used for the pipes of Class 1 or class 2 or used for pipes likely to cause fire or flooding in case of their fracture, are to be of approved type. And flexible pipes(including end connection parts) are to be in accordance with the requirements given in the **Annex 5-9.**

4. Required wall thickness of pipes

(1) The column "Overboard scupper pipes" in **Table 5.6.2** of the Rules is applied to ships having length of 24 m or over, and international service area.
(2) The requirement of "threaded pipes" in **Table 5.6.3** NOTES 2. of the Rules is not applied to pipes from distribution stations to nozzles on CO_2 piping for fire fighting.
(3) The minimum wall thickness of exposed parts of air pipes opened on free-board deck or superstructure of ships having length of 24 m or over, and international service area is to be in accordance with the following;
(A) For the air pipes installed on position I or position II of exposed deck openings defined in **Pt 4, Ch 2, 102.** of the Rules, and induced to compartments under freeboard deck, enclosed super-structure or enclosed deck house, the relevant column of "Air pipes on exposed deck" in **Table 5.6.2** of the Rules is applied.
(B) For the pipes other than above (A), the relevant column of "Air, overflow and sounding pipes for hull structural tanks" in **Table 5.6.2** of the Rules is applied.
(4) The corrosion allowance for CO_2 pipes used for fire fighting may be reduced to zero.

103. Valves and fittings

1. In application to **103. 1.** (1) and **4.** (1) of the Rules, "the Society may accept to use valves and fittings made of materials which meet Korean Industrial Standards or Equivalent." means the following valves and fittings.

Materials	Design Temperature (°C)	Nominal diameter (D) : A Design pressure (P) : MPa
Carbon and low alloy steel, cast iron with an elongation of 12 % or above	< 300 and	$D \leq 50$ or $P \times D \leq 250$
Copper alloy	< 200 and	$D \leq 50$ or $P \times D \leq 150$

2. The materials for pipes, valves, cocks and fittings of piping systems used for ships having length less than 30 m may be manufactured and tested in accordance with *Korean Industrial Standards* or standards considered as equivalent thereto.

3. Service limitations for cast iron for valves and pipe fittings In application to **103. 4** (3) of the Rules, the gray cast iron may be used for the following piping system.

(1) The valves and pipe fittings used in cargo oil lines within cargo tanks of tankers.
(2) The valves and pipe fittings used in piping systems on open deck for flammable liquid cargo which has not any other risks.

4. Rubber seat butterfly valves are to be dealt with under the following requirements ;

(1) Application
Rubber seat butterfly valves (hereinafter referred to as the butterfly valve) may not to be used for the applications below. However, they may be used according to the discretion of the Society.

(A) Outlet valves fitted to the tank carrying flammable or combustible liquid (e.g., fuel oil, crude oil, etc.) and subjected to the liquid head, installed in the engine room or area susceptible to fire. However, they may be as those installed within the cargo oil tanks or outlet valves leading to the pump room of oil tankers.
(B) Valves in piping system with a design pressure exceeding 1.6 MPa
(C) Valves in piping system with a design temperature exceeding 70 °C
(D) Valves in piping system handling special liquids other than water and oil
(E) Valves in the fuel oil piping system within the engine room in case they have such a construction that the internal lining rubber is extended to the abutting face of flange for using as a gasket.

(2) Construction and marking of product
The construction of butterfly valves is to conform to the following requirements ;
(A) Stopper can be engaged at the designed "Open" and "Shut" positions.
(B) Valves serving at intermediate valve disc position can be kept the position with the locking system not to be loosened between "Open" and "Shut" by vibration, mechanical impact or liquid flow, etc..
(C) The valve can be one-man-operated.
(D) Means are to be provided to indicate the valve disc position.
(E) The valve stem is to have a sufficient strength and the valve disc is to be fitted to the valve stem in such a way of hardly loosening.
(F) The materials of the main parts of the valve are to have sufficient corrosion resistance and wear resistance in consideration of its intended use.
(G) Butterfly valves used as seawater suction valves or overboard discharge valves are, in principle, to be of the flange type.
(H) Marking of product
The butterfly valve is to be marked with the following items at a conspicuous place of the product:
(a) Kind of liquid
(b) Design pressure
(c) Material of valve box
(d) Nominal diameter
(e) Name of manufacturer

(3) Tests and Inspections
The butterfly valve is to be tested and inspected in accordance with the following. However, where the attendance of the surveyor is required by the Rules, tests and inspections are to be in accordance with the relevant requirements.
(A) Material test
Material test is to comply with the requirement given in **103. 1.**
(B) Hydrostatic test for valves
Valves are to be subjected to a hydrostatic test at the pressure not less than 1.5 times the design pressure. However, the ship-side valves are to be subjected to a hydrostatic test at the pressure of 0.5 MPa. (in way of valves with rubber lining, to be tested after lining)
(C) Leak test for valves
Valves are to be subjected to a leak test by 1.1 times the design pressure at each sides. Valves with special seat construction are to be subjected to tests according to the construction. However, leak test of pressure side only may be accepted where deemed necessary by the Society.
(D) Operating test
Operating tests are to be carried out appropriate times.
(E) Visual inspection
Visual inspections for valve seat and valve disc are to be carried out after tests specified in (B) and (C).
(F) The attending surveyor may request documents relating to inspections for rubber materials used for seat and lining.

5. Construction and standard of pipe fittings

(1) Standards for pipe flanges
Standards for pipe flanges are to be in accordance with the following;
(A) In **103. 5** of the Rules, "construction specified in *Korean Industrial Standards*" means those

complying with the requirements of "*KS B* 1501-1503, 1506, 1507, 1509-1511, 1519, 1521 and *KS B* 1540"

(B) Where pipe flanges complying with "*B* 16-150~2500 *Lb*" specified in *ANSI* are used, the material, size and type of weld joints may be taken as equivalent to those complying with the Rules.

(2) Nominal diameter (The following applies same-wise to "nominal diameter of pipes" used in **Pt 5, Ch 6** of the Rules)
Nominal diameters of pipes are to be in accordance with the following;

(A) For the pipes having their nominal diameter specified in *KS*, the pipes having the nominal diameter specified in the Rules or the Guidance are to be taken for those having same nominal diameter in *KS*.

(B) For the pipes having their nominal diameter not specified in *KS*, the pipes having "nominal diameter 00 mm" specified in the Rules or the Guidance are to be taken for those having corresponding "out-diameter xx mm" in *KS*, being replaced by the relation between the nominal diameters and the outside diameters of pipes in *KS*.

(3) Pipe flanges
Flanges specified in "*KS B* 1503, 1511 and *KS B* 1521" may be used at the pressure specified in "*KS B* 1501".

104. Type of connection

1. Flange connections

(1) The type of pipe joint with a bell-mouthed pipe end as shown in **Fig 5.6.1** of the Guidance may be used for pipes in pipes in Class Ⅲ and pipes in Class I or II with a design pressure of 1 MPa or less and with a nominal diameter of 50 A or less.

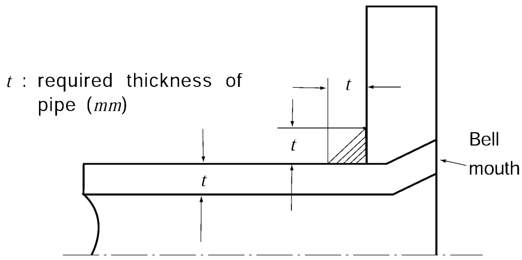


Fig 5.6.1

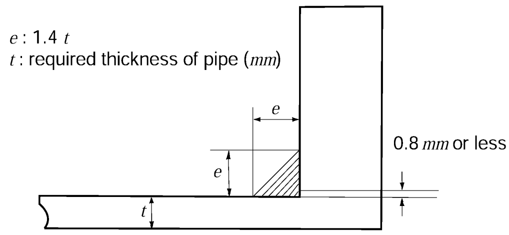


Fig 5.6.2

(2) The one side welded flange joint shown in **Fig 5.6.2** of the Guidance may be used for drinking water piping, scupper piping and sanitary piping located above the load line, drain piping, overflow piping, air vent piping, exhaust gas piping, gas vent piping of crank chambers, exhaust steam piping and foam fire extinguishing agent discharge piping having an open end. For pipes in Class Ⅲ used for pipes other than above, they may be used for pipes with a nominal diameter of 40 A or less other than for flammable oils.

(3) In application to **104. 3.** (5) of the Rules, application of flange connections is to comply with Guidance **Table 5.6.1**.

2. Slip-on threaded joints

In application to **104. 1** of the Rules, threaded pipe joints may be used in pipes having small diameter for gauging devices.

3. Solder

In application to **104.** 1 of the Rules, non-ferrous metal valves and fittings may be soldered to non-ferrous metal pipes. Where design pressure 0.7 MPa or below and the design temperature does not exceed 93 °C, ordinary solder may be used. When pipe flanges are soldered to copper pipes, the procedure for soldering is to comply with the following.

(1) The portion to be soldered is to be provided with a suitable molten pool and the pipe end is to be bell mouthed.

(2) Fillet welding is not recommendable for connecting a copper pipe with pipe flange. However, this recommendation may be waived when special soldering method such as silver soldering or TIG welding is applied.
(3) Copper pipes connected by soldering may be used for applications when the design temperature is 200 °C or below.

Table 5.6.1 Typical Application of Flange Connections

Class of piping \ Service	Steam[(1)] and thermal oil	Fuel and lubricating oil	Air[(1)], Water[(1)], Hydraulic oil[(1)] and gas[(1)]
I	A, B[(2)]	A, B	A, B
II	A, B, C, D[(3)]	A, B, C	A, B, C, D[(3)]
III	A, B, C, D	A, B, C	A, B, C, D, E[(4)]

NOTES:
1. (1) to (5) marked in this Table are as follows.
   (1) Type A joints are to be used for pipes whose design temperature exceeds 400°C.
   (2) Type B joints may be used for pipes having a nominal diameter not exceeding 150A only.
   (3) Types D and E joints are not to be used for pipes whose design temperature exceeds 250°C.
   (4) Type E joints may be used for water pipes or pipes with an open end.
2. Type A, B or C joints may be used for refrigerant piping of ammonia.

106. Post weld heat treatment

1. Nevertheless the requirements of **106. 1** of the Rules, for pipes for pressure gauge equipped with pipe systems belonging to Class I or Class II, the post weld heat treatment may be omitted after considering temperature of fluid.

107. General requirements for piping arrangement

1. Installation In application to **107. 1** (6) of the Rules, where pipes are inevitably led in the vicinity of electrical equipment, it is to be also complied with requirements of **Part 6, 301. 1** of the Guidance.

2. Protection of pipes and fittings In application to **107. 2** (2) of the Rules, drain traps are to be provided on the scuppers from refrigerating spaces.

3. Pressure gauges and temperature gauges In application to **107. 4** of the Rules, pressure gauges and temperature gauges, as a general rule, are to be installed in accordance with "*KS V* 7013 and *KS V* 7014".

4. Gaskets and packings In application to **107. 5** of the Rules, packings for flanges, pipe fittings, valve covers and valve stems, as a general rule, are to be installed in accordance with "*KS V* 7112".

5. Slip joints In application to **107. 6** of the Rules, the slip joints are to be complied with the following.

(1) The joints of bilge suction piping and ballast piping led to cargo hold are to be flanged connections or welding type joints. However, slip joints may be used where deemed appropriate by the Society.
(2) For the pipes within the tanks containing the same liquid as that drawn through the piping, slip joints may be used.
(3) Slip joints may be used for the cargo oil pipes, but are not to be used within the ballast tanks through which the pipes are passing.

6. Penetration of pipes In application to **107. 7** of the Rules, valve stems of various valves are, in principle, not to penetrate through the part subjected to liquid head such as the bottom plate of wing tanks and top plate of double bottom used for tanks. In case where such penetrations are unavoidable, considerations are to be taken by providing such means as protection pipe to prevent liquid head from imposing on the stuffing box.

7. Watertight Bulkhead In application to **107. 8** of the Rules, suction pipes of the stern tank are to be fitted with stop valves at the fore side of the bulkhead.

8. Sea water and fresh water piping In application to **107. 12** of the Rules, Where the piping are unavoidably used both as sea water service and fresh water service, the stop valve is to be provided on each suctions, with a notice plate suitably put so as to prevent from mishandling.

9. When equipment for gas welding are provided on-board, it is to comply with **Annex 5-5** of the Guidance.

10. Marking In application to **107. 10** (1) of the Rules, markings for identification of pipes, as a general rule, are to be in accordance with "*KS V* 7015 (Identification of Pipes for Vessels)".

Section 2 Air Pipes, Overflow Pipes and Sounding Devices

201. Air pipes

1. General

In application to **201. 1** (5) of the Rules, the examples of the construction preventing direct ingress of seawater splashes or rain water are as shown in **Fig 5.6.3** of the Guidance. This requirement applies only to ships subject to the requirements of the SOLAS. However, where air pipes are located in higher position than the upper deck and are considered not to be damaged by wave or other external force such as fuel oil tank and lubricating oil tank for emergency generator, this may be omitted.

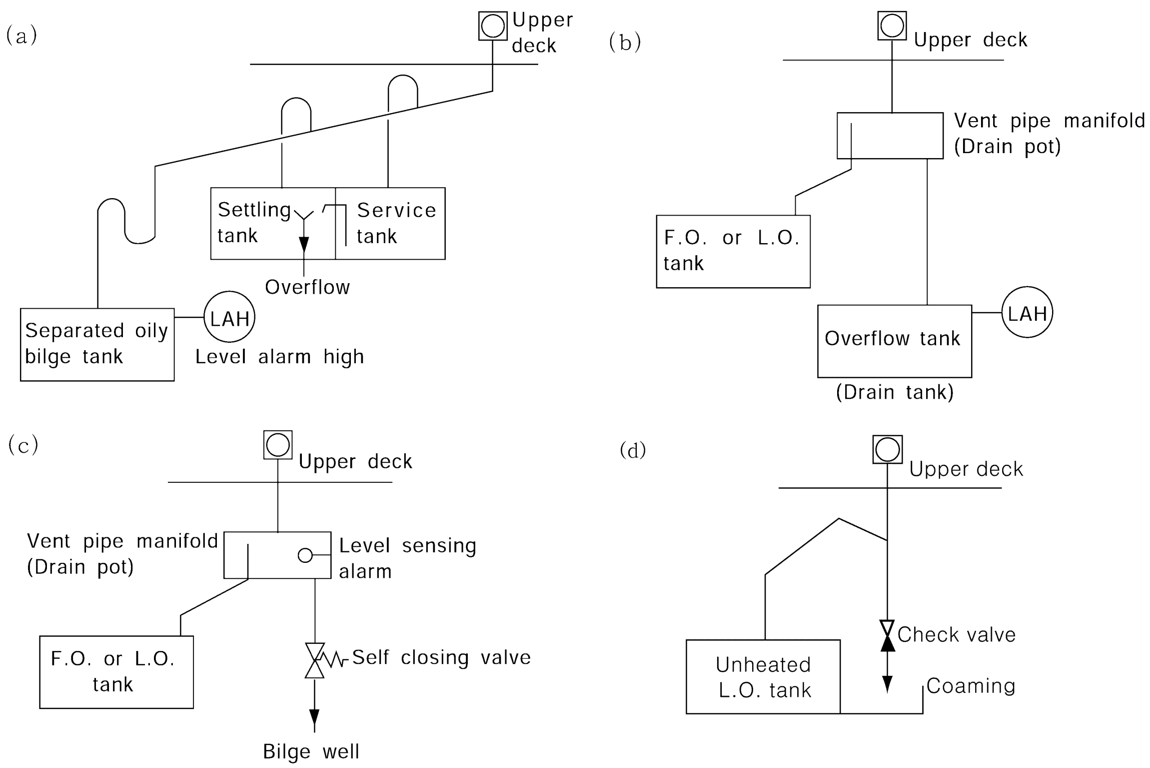


Fig 5.6.3 The Example of Construction Preventing Direct Ingress of Seawater Splashes or Rain Water

2. Protection of air pipe outlets

(1) In application to **201. 3** (2) of the Rules, the wording "the flame-screens which deemed appropriate by the Society" is to comply with the following.

(A) to be made of corrosion resisting material
(B) to comprise two fitted screens of at least 20 × 20 mesh spaced 25.4 ± 12.7 mm apart or single fitted screen of at least 30 × 30 mesh, or to have a performance equivalent thereto.

3. Size of air pipes

In application to **201. 4.** (1) of the Rules, the air pipes for the tank is provided with an overflow pipe are to comply with the following.

(1) Where the aggregated sectional area of overflow pipes in the tank is greater than 1.25 times the effective area of the filling pipes, the air pipes may be omitted. In this time, the sectional area of air pipes in the overflow tank is not less than the aggregated sectional area of overflow pipes.

(2) For the tanks which are provided with common overflow pipes, the air pipes in each tank may be omitted where the sectional area of overflow pipes from each tank is greater than 1.25 times the effective area of filling pipes from each tank, and the sectional area of common overflow pipes and the sectional area of air pipes of the overflow tank are greater than 1.25 times the aggregated sectional area of the filling pipe of each tank which filled simultaneously. However, the sectional area of common overflow pipes and the sectional area of air pipes of the overflow tank are need not to exceed 1.25 times the sectional area of common filling pipes.

(3) In application to (1) and (2) above, where overflows from the tanks such as fuel oil settling tank, fuel oil service tank, etc. are led to other tank with air pipes, suitable means are to be provided so that the air in the highest portion of these tanks is vented to other tank with air pipes. (refer to **Fig 5.6.4** of the Guidance).

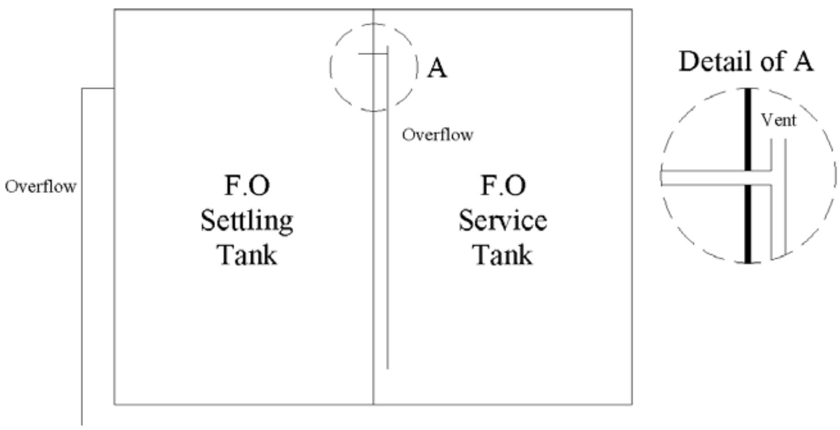


Fig 5.6.4 Example of Details of Overflow Pipe

4. Height of air pipes

(1) In application to **201. 5** of the Rules, the height of air pipes above deck is to be measured as shown in **Fig 5.6.5** of the Guidance.

(2) In application of **201. 5** of the Rules, where these height interfere with the working of the ships, such as ships not engaging on international voyages, tug boat, barge, etc., a lower height may be accepted, provided that the automatic closing device approved by the Society is fitted. In such cases, the minimum height may be reduced to 450 mm on the freeboard deck and 300 mm on the superstructure deck.

203. Sounding devices

1. Construction of sounding pipes In application to **203. 3** of the Rules, construction of sounding pipes is to be complied with the following.

(1) In case where elbow type sounding pipe is unavoidable to use, sufficient support is to be provided for the arm of the pipe. The standard thickness value of striking plate is approximately 10 mm for ships having length less than 30 m and 12 mm for ships having length 30 m or over. (refer to **Fig 5.6.6** of the Guidance)

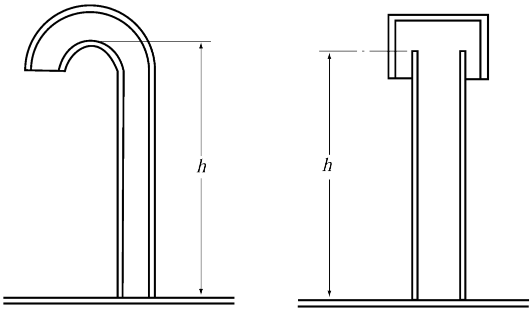


Fig 5.6.5 The Height of Air Pipe

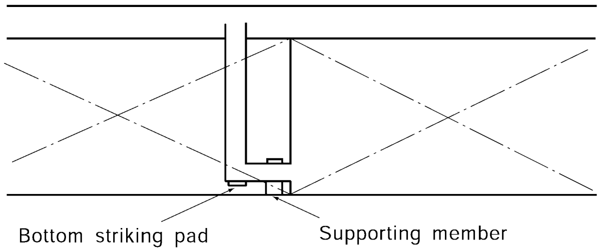


Fig 5.6.6 Example of Elbow Type Sounding Pipe Arrangement

Section 3 Ship-side Valves and Overboard Discharge

301. Ship-side valves and fittings

1. Construction of distance pieces In application to **301. 2** of the Rules, distance pieces are to be complied with "*KS V* 7141 (ship-side distance pieces)" or equivalent.

2. Location of overboard discharges In application to **301. 6** of the Rules, location of overboard discharges is to be complied with the following.

(1) The wording "overboard discharges" specified in **301. 6** of the Rules, means the discharge opening subjected to pressure by the pump and not including those for natural gravitational discharge.

(2) The wording "such location" specified in **301. 6** of the Rules, means the area other than that hatched in **Fig 5.6.7** of the Guidance.

(3) Where the location of overboard discharges is to be such that water can be discharged into life boats when launched, either of the following means is to be provided.

(A) Means to guide the water flow to the shell plating.

(B) Means to stop water discharge which is able to be operated from the weather deck and in the vicinity of the installed place of the lifeboat.

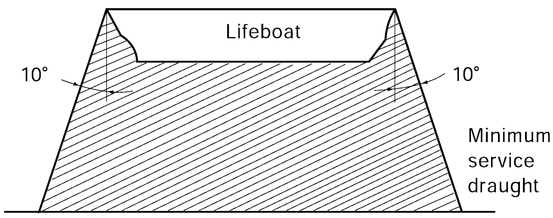


Fig 5.6.7

302. Scuppers and sanitary discharge

1. Scuppers of exposed decks In application to **302. 3** of the Rules, scuppers piping within superstructures are not to be connected to the scupper piping of exposed decks.

2. Non-return valves of scuppers and sanitary pipes In application to **302. 4** of the Rules, discharge from spaces under the freeboard deck is to comply with the following.

(1) Discharge from under the freeboard deck

(A) Inboard open end of scuppers

(a) Where discharge of bilge from the small compartments at fore and stern (steering gear room, boatswain's store, chain locker, etc.) is carried out by hand pumps or ejectors, "the vertical distance to the inboard opening end of scupper" means the vertical distance to the position located highest in the system of such discharge pipes.

(b) Inboard open end of scupper pipes in case where timber load lines are marked, the vertical distance to the inboard open end is to be measured from the timber summer load line.

(B) Overboard discharge pipes which are always closed during navigation.
Requirements of **302. 4** of the Rules are to be applied to normally opened discharge pipes during a voyage, but, in case normally closed discharge pipes, except when discharging, during a voyage such as gravity discharge of top side tank, a screw down stop valve with opened/close indicator being operable from a position easily accessible on the freeboard deck may be used.

(C) Overboard discharge pipes
Discharge pipes passing through cargo hold are to be of steel pipe with SCH.160 or 16 mm of wall thickness and above, or are to be protected appropriately.

3. Scupper pipes from the enclosed cargo spaces on the freeboard deck

In application to **302. 5** (1) of the rules, where the freeboard to the freeboard deck is such that the deck edge is immersed when the ship heels more than 5°, the drainage of the enclosed cargo spaces on the freeboard deck to suitable spaces below deck is also permitted, provided such drainage is arranged in accordance with the requirements in **302. 5** (2) of the Rules.

Section 4 Bilge and Ballast System

401. General

1. Application Bilge piping of ships having length less than 50 m is to comply with the following. However, requirements not specified in the following are to be in accordance with the Rules.

(1) Number of bilge pumps
Number of bilge pumps are to be in accordance with **Table 5.6.2** of the Guidance.

(2) Capacity of bilge pump
The independent power bilge pump specified **Table 5.6.2** of the Guidance, is to have capacity not less than that obtained from the formula in **405. 2** of the Rules. However, it may be added to the capacity of a independent power bilge pump given in (1) above.

(3) Internal-diameter of bilge suction pipes
Main bilge suction pipes, direct bilge suction pipes and bilge suction branch pipes are to be of internal diameters not less than the diameter obtained from the following formula (A) through (C).

(A) Main bilge suction pipes or direct bilge suction pipes

(a) For ships having length less than 25 m

$$d = 1.22 \times (L - 10) + 10 \quad (\mathrm{mm})$$

(b) For ships having length 25 m or over, but less than 35 m

$$d = 2.67 \times (L - 20) + 15 \quad (\mathrm{mm})$$

(c) For ships having length 35 m or over

$$d = 1.68\sqrt{L(B+D)} + 25 \quad (\mathrm{mm})$$

(However, d is not to be less than 50 mm.)

(B) Bilge suction branch pipes

(a) For ships having length 35 m or over

$$d' = 2.15\sqrt{l(B+D)} + 25 \quad (\mathrm{mm})$$

(b) In ships having international service area, internal diameter of bilge suction branch pipes is not to be less than 50 mm, but, internal diameter of bilge suction pipe for small compartments may be 40 mm according to the discretion of the Society.
(c) Internal diameter of bilge suction branch pipes for bow and stern tanks and shaft tunnel may be reduced to 50 mm in ships having length 35 m or over, and to internal diameter approved by the Society in ships having length less than 35 m.

(C) In ships having length 35 m or over, internal diameter of main bilge suction pipes is not to be less than the largest value for bilge suction branch pipe obtained from the formula specified in (B).

(4) Direct bilge suction pipe
Nevertheless above (A), the internal diameter of direct bilge suction pipes may be reduced appropriately according to the discretion of the Society.

(5) Emergency bilge suction pipe
Emergency bilge suction pipes are to comply with the following.
(A) Ships provided with steam turbine as main engine are to be provided with emergency bilge suction pipes complied with the Rules.
(B) Ships provided with diesel engine as main engine may be omitted according to the discretion of the Society.

(6) Bilge pipe in engine room
Bilge pipes made of copper may be used.

Table 5.6.2 Number of Bilge Pumps

Length of ship(L)	Power bilge pump		Manual pump	Remarks
	Main engine driven pump	Independent power pump		
$L < 25$ m	1 set	—	1 set	The main engine driven pump may be omitted according to the discretion of the Society. In case ships less than 10 m, a bucket may be provided instead of a pump.(※)
25 m ≤ L < 30 m	1 set	1 set	—	2 sets of manual pumps may be provided instead of the main engine driven pump. Where ships is difficult to be provided with the independent power pump, the independent power pump may be omitted by considering piping system and capacity of other pumps.(※)
30 m ≤ L < 50 m	1 set	1 set	—	2 sets of manual pumps may be provided instead of the main engine driven pump.

(Note)
1. The requirement with mark (※) is to be applied to ships other than passenger ship.
2. In this Table, power pump may be provided instead of manual pump, and independent power pump may be provided instead of main engine driven pump.
3. In ships having length 25 m or over, but less than 30 m, the requirement for omission of independent power pump is to be applied to ships difficult to be provided with the independent power pump, provided with main engine driven pump having capacity more than suction capacity required by independent power pump, and arranged bilge piping in all compartment required bilge discharge. Where the hand pump is substituted for main engine driven pump, the independent power pump may be omitted.
4. In ships having coastal service area, the bilge pump for oil filtering equipment may be recognized as a manual bilge pump.
5. All power pumps and manual pumps are to discharge bilge from cargo hold, engine room and shaft tunnel.

2. In application to **401. 2** (1) of the Rules, where void spaces and cofferdams do not affect to ship's stability and are located above the load water line, the spaces may be drained by installation of a separate bilge pump(a portable pump may be accepted) or by gravity, instead of fixed bilge piping system connected to main bilge line. However, where draining by gravity, this pipe is to be provide with a quick-acting self-closing valve located in a readily accessible position.

402. Drainage of compartment other than machinery spaces

1. Omission of bilge suction pipes For small compartment such as echo sounder recess, the provision of bilge suction pipes may be omitted under the approval of the Society.

2. Bilge scuppers in special case In case where hold bilges are drained to the engine room or shaft tunnel adjacent thereto through the watertight construction as specified in **Fig 5.6.8** of the guidance, the bilge drainage piping is to be led to spaces readily accessible and self-closing valve or cock is to be provided. Where such bilge is led to the watertight bilge tanks, the above mentioned valve or cock may be omitted, but where the hold is located under the load line, non-return valve is to be provided. In case where hold bilges are led to the shaft tunnel, no sounding pipe may be provided, but the diameter of the drainage pipe is not to be less than the value specified for bilge suction pipe.

3. Bilge well high water level alarms For ships being within the application limits of regulation XII/4.2 of SOLAS, which have been constructed with an insufficient number of transverse watertight bulkheads to satisfy the regulation, it is provided with bilge well high water level alarms in all cargo holds, or in cargo conveyor tunnels, as appropriate, giving an audible and visual alarm on the navigation bridge.

404. Size of bilge suction pipes

1. Main bilge pipes

(1) Internal diameter of main bilge pipes is not to be less than 60 mm in ship engaged in international service area, and not to be less than 50 mm in ships having length 35m or over.
(2) The standard pipes of internal diameter nearest to the calculated diameter may be used. However, in case where the diameter of such standard pipes is small of the calculated value by 13mm or over, standard pipes of one grade higher diameter are to be used.

2. Bilge suction branch pipes In application to **404. 2** of the Rules, the bilge suction branch pipes are to be complied with the following.

(1) For bilge suction piping of hold bilges, the main bilge suction system (Christmas tree system) is, in principle, not to be adopted. In case where such an arrangement is unavoidable, the ship is to be ensured satisfying the one-sub-division flooding condition. The internal diameter of bilge suction pipe in such a system is to be calculated according to the **Fig 5.6.9** of the Guidance.

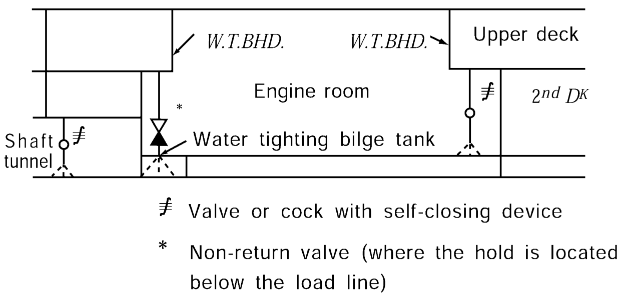


Fig 5.6.8 Example of Hold Bilge Drainage Line through the Watertight Construction

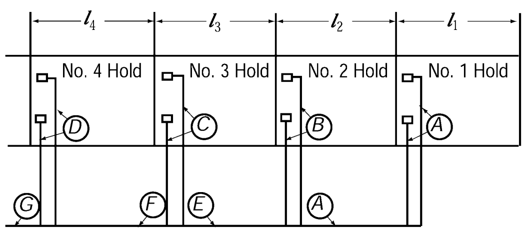


Fig 5.6.9 Example of Main Bilge Suction System for Hold Bilge Suction Line

(A) Pipes A, B, C and D are to be calculated as bilge suction branch pipe respectively by substituting l_1, l_2, l_3 and l_4 to l.
(B) Pipe E is to be calculated as main bilge line by regarding the sum of l_1+l_2 as L, and the sectional area of pipe E is to be sum of sectional areas of pipe A and B or more.
(C) Pipe F is to be calculated as main bilge line by regarding the sum of $l_1+l_2+l_3$ as L, and the sectional area of pipe F is to be sum of sectional areas of the largest two bilge suction

branch pipes among A, B and C.

(D) Pipe G is to be calculated as main bilge line by regarding the sum of $l_1+l_2+l_3+l_4$ as L, and the sectional area of pipe G is to be sum of sectional areas of the largest two bilge suction branch pipes among A, B, C and D. In this case, a screw-down type non-return valve is to be provided at the suction of each branch piping. In case where the installed position of such valve is not readily accessible, a remote control device is to be provided.

(2) Internal diameter of bilge suction pipe of a ship with double hull construction.
In ships with double hull construction, the inside diameter of bilge suction pipe may be determined by using the distance between the inner hull in place of the breadth of a ship.

(3) Internal diameter of the bilge branch suction pipes for ships is not required more than 100 mm, but internal diameter of the bilge suction branch pipes for ships engaged in international service area is not to be less than 50mm . In case of **401. 2** (3) of the Rules, internal diameter of the bilge branch suction pipes is to have a capacity of not less than 125 % of the capacity required in water spraying system, etc.

405. Bilge pumps

1. Number of bilge pumps

(1) Ships other than passenger ship may be provided with a bilge eductor instead of 1 set of bilge pump required **405. 1** of the Rules. In this case, pump supplying sea water to bilge eductor is to be pump other than main cooling water pump.

(2) Minimum number of combined using pumps for essential services (fire pump, ballast pump, bilge pump and auxiliary gas scrubber pump) of non-continuous nature in ships of 500 GT and over are in accordance with the following.

(A) On tankers provided with inert gas system, a minimum of 4 pumps, including an emergency fire pump, are to be required.

(B) On other cargo ships and tankers not provided with inert gas system, a minimum of 3 pumps, including an emergency fire pump, are to be required.

2. The wording "to be considered appropriate by the Society" specified in **405. 4** of the Rules means as below.

(1) Internal diameter of bilge suction pipes
The internal diameter of bilge suction pipes is not to be less than the value obtained by the following formula.

$$d = 1.68\sqrt{l(B+D)} + 25 \quad (\mathrm{mm})$$

Where

d : Internal diameter of bilge suction pipe (mm)

l : Length of cargo hold (m)

B : Breadth of cargo hold (m)

D : depth of ship (m)

(2) Suction capacity of eductor
The suction capacity of eductors is to be not less than that obtained from the formula.

$$Q = 5.66d^2 \times 10^{-3} \quad (\mathrm{m^3/h})$$

where

Q : Bilge suction capacity of eductor ($\mathrm{m^3/h}$)

d : Same as in (1) above

(3) Amount of driving water for eductor
The eductor is to be so arranged as to be driven by two or more units of pumps. In case where bilges in two or more cargo holds are discharged by the eductors driven by these pumps, the amount of driving water of each pump is to be sufficient to draw bilges in at least two

cargo holds simultaneously with the suction capacity as specified in (2) above.

(4) Eductor driving water stop valve and bilge discharge valve are to be provided. These valves are to be operable from a position on the bulkhead deck or upward, except where these valves are provided in the engine room.

(5) Bilge high level alarm device

(A) To prevent the back-flow of the eductor driving water to the bilge wells, a bilge high level alarm device is to be provided in each bilge well which activates the alarm when the back-flow occurs. The bilge high level alarm device is to activate audible and visible alarm in a normally manned position at which the cargo hold whose bilge level in the bilge well becomes high can be identified.

(B) The circuit of bilge high level alarm device is to have a self-monitoring function or at least two independent circuits are to be arranged in each cargo hold.

(C) The bilge high level alarm device in cargo holds loaded with coal is to comply with the requirements in **Pt 7, Ch 3, 1602.** of the Rules.

(6) Eductor driving water pipes passing through a side tank

In ships omitted bulkhead subject to double bottoms, where eductor driving water pipes pass through a side tank, open end of bilge suction pipes is provided with a non-return valve. And eductor driving water pipes, bilge discharge pipes and eductors in side tanks, as far as practicable, are to be located in the vicinity of longitudinal bulkhead of cargo hold side.

(7) Rose boxes at bilge suction ends

The rose boxes provided at bilge suction ends are to be of adequate ones matching the bilge suction capacity of eductor and comply with the requirements specified in **406. 9** of the Rules.

(8) Protection of bilge piping system in cargo holds

The eductor driving water piping, bilge discharge piping and eductor are to be so arranged as not to be damaged by cargo.

(9) Common use of eductor driving water with fire water

In case where eductor driving water is taken from the fire piping, consideration is to be so given that no adverse effect is cause on the fire-fighting function.

406. Pipe systems and their fittings

1. Bilge suction pipes and ballast suction pipes passing through deep tanks In application to **406. 4** of the Rules, the bilge suction pipes and ballast suction pipes passing through deep tanks are to be dealt with under the following requirements.

(1) For the bilge suction pipes passing through deep tank serving as the exclusive ballast tank, welded pipe joints may not be required if flange joints corresponding to a nominal pressure one rank higher than that according to the design pressure are used.

(2) In case where gravitational ballasting/deballasting is intended by using sea chests provided in the exclusive ballast tanks, double stop valves being operable from a position on the freeboard deck are to be provided.

(3) Suction pipes such as the bilge suction pipes and ballast suction pipes are not to pass through deep tanks carrying cargo oil, except that in case where th pipes are installed in pipe tunnel provided within the deep tanks.

(4) In the application of the requirements specified in (1) to (3) above, bilge hoppers are to be regarded as deep tanks.

2. Mud box In application to **406. 8** of the Rules, where ships having length less than 50 m, a rose box is provided instead of a mud box fitted in open end of bilge suction pipes and reserve bilge suction pipes according to the discretion of the Society.

Section 5 Feed Water and Condensate System for Boiler

501. Feed water pumps

1. Where feed water system of main boilers is group system, a stand-by feed water pump having capacity same as one set among feed water pumps in the group is to be provided. And, when one set among feed water pumps in the group is out of order during operating, the stand-by feed water pump is to be easily operated instead of it.

2. In essential auxiliary boilers having heat surface area 50 m^2 or less, a injector may be provided instead of one set among two sets of feed water pump.

502. Feed water piping

1. In application to **502. 1** of the Rules, the examples of a single penetration in the steam drum from two separate means of feed are as shown in **Fig 5.6.10** of the Guidance.

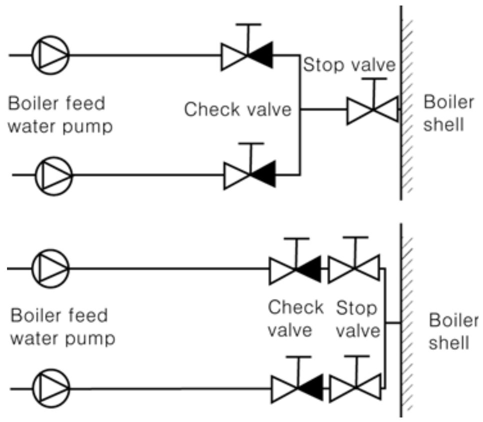


Fig 5.6.10

2. In application to **502. 1** of the Rules, where two or more adequately sized boilers are installed and the feed water for each of these boilers is supplied by a single feed water pipe, the level of redundancy for the piping of the feedwater system is considered to comply with **502. 1** of the Rules.

3. One feed water system may be accepted to provide for small package type auxiliary boilers which are required for essential services according to the discretion of the Society. In this case, one set of spare feed water pump is to be provided and when feed water pump is out of order, the spare feed water pump is to be easily exchanged for it.

4. Essential auxiliary boilers or other boilers intended to supply steam for fuel oil heating necessary for the operation of the main propulsion or cargo heating that is required continuously are to be provided with feed water systems in accordance with **501.** and **502.** of the Rules. The requirements in **501. 1, 2** and **502. 1** of the Rules need not to be applied provided that an alternative means is available to ensure the normal navigation and cargo heating with the feed water system being out of operation. For an auxiliary boiler used exclusively for the fuel oil heating necessary for the operation of main propulsion machinery and the cargo heating requiring continuously, only one feed water system may be accepted when one complete spare unit of feed water pump and one set of feed water check valve capable of being replaced in a short period of time.

Section 6 Steam and Exhaust Gas Piping

601. Steam piping

1. Piping In application to **601. 1** of the Rules, steam piping is to comply with the following.

(1) Steam heating pipes are to be so supported as not to be in direct contact with the hull members such as floor plates, etc.
(2) In principle, steam pipes are not to be led through cargo holds, but where it is impracticable to avoid this arrangement, pipes are to be insulated and protected by steel plate and, all joints are to be welded.
(3) Steam piping for steam turbine is to be in accordance with **Ch 2** of the Rules.
(4) Steam piping for boiler safety valves is in accordance with **Ch 5** of the Rules.

2. Where main steam lines of two or more boilers connected to common steam line, main steam valve of each boiler is to be screw down check valve and a stop valve is to be fitted between the screw down check valve and the common steam line.

3. Oil heating pipes In application to **601. 3** of the Rules, where oil heating pipe is jointed between heating main line and heating branch line for cargo oil tanks, duplicate stop valves or spectacle flanges are to be fitted in the heating branch line.

Section 7 Cooling System

702. Stand-by cooling water pumps

1. In application to **702. 3** of the Rules, the capacity of stand-by circulating pump in ships with main turbine propulsion machinery is to be of assuring sufficient engine output to develop speed of the ship to 7 knots or over, and speed effectively capable of steering.

2. In application to **702.** of the Rules, ships complied with the following as ships having a gross tonnage less than 500 tons may be omitted to provide the stand-by cooling pump.

(1) Ships engaged in smooth water service.
(2) Ships engaged in coastal service area, and equipped with two sets of main engine and independent cooling water pump for each main engine.

3. In application to **702. 7** of the Rules, high speed rotating engine of specific construction which can not be changed to spare pump without complete engine overhaul may be omitted to provide with spare pump.

4. In application to **702. 8** of the Rules, engines in small ship means a main engine or a auxiliary engine which are installed in ships having length less than 30 m. In case of a main engine, one set of spare pump is to be provided.

703. Sea inlets

Two sea inlets are located at bottom plate and, as far as practicable, are to be departed from each other to ship sides.

704. Strainers

1. In application to **704**. of the Rules, "the strainers which can be cleaned without interruption to the cooling water supply" is to comply with the following.

(1) For multi propeller ships and where single strainer is fitted between the sea water suction valves and the cooling water pump of internal combustion engine which coupled with each shafting system
(2) Where two or more the independent driven engines are coupled with one shafting system and single strainer is fitted in the individual engine
(3) Where two or more internal combustion engines driving essential auxiliary machinery are installed and single strainer is fitted in the individual engine

2. In application to **704.** of the Rules, "in small ship, the strainers may be omitted with approval of Society" is to comply with the following.

(1) In ships having length lass than 30 m, internal combustion engine driving main engine and essential auxiliary machinery may be omitted to provide the strainers.
(2) In ships having length lass than 30 m or over, and less than 50 m, internal combustion engine driving essential auxiliary machinery may be omitted to provide the strainers.

Section 8 Lubricating Oil System

802. Lubricating oil pumps

1. In **802.** of the Rules, ships complied with the following as ships having gross tonnage less than 500 tons may be omitted to provide the stand-by lubricating oil pump.

(1) Ships engaged in smooth water service.

(2) Ships engaged in coastal service area, and equipped with two sets of main engine and independent lubricating oil pump for each main engine.

2. In application to **802. 3** of the Rules, high speed rotating engine of specific construction which can not be changed to spare pump without complete engine overhaul may be omitted to provide with spare pump.

3. In application to **802. 6** of the Rules, the engine means a main engine or an auxiliary engine. In case of a main engine, one set of spare pump is to be provided.

803. Piping

Where steam heaters or heaters using other heating media are provided in lubricating oil systems, the heaters are to comply with **901. 11** (1) and (2) of the Rules.

804. Lubricating oil filters and purifiers

1. In application to **804. 2** of the Rules, the following may be accepted as "filters capable of being cleaned without stopping the supply of filtered lubricating oil".

(1) Auto cleaner or self cleaning filter

(2) Where single filter capable of being readily replaced or cleaned is fitted and by-pass line is provided in the ships engaged in smooth water service or coastal service.

(3) In case where a high-rotating-speed internal combustion engine of specific construction has single filter and differential pressure alarm device for the filter, and is provided with automatic lubricating oil feed line, and the Society considers appropriate.

(4) For multi propeller ships and where single filter is fitted in each engine which coupled with each shafting system.

(5) Where two or more the independent driven engines are coupled with one shafting system and single filter fitted in the individual engine.

2. In application to **804. 3** of the Rules, where any one of following is fulfilled, lubricating oil purifiers or equal effective filters may be omitted.

(1) In case where ships having a gross tonnage less than 500 tons and engaged in coastal service area have lubricating oil storage tank with sufficient capacity to exchange the system lubricating oil one time.

(2) In case where fishing vessels have lubricating oil storage tank with sufficient capacity to exchange the system lubricating oil one time regardless of tonnage and navigation area.

Section 9 Fuel Oil System

901. General

1. Arrangement of fuel oil system In application to the **901. 2** of the Rules, it is recommendable for fuel oil tanks not to be installed above main engine, auxiliary boiler and such others as far as practicable in consideration of oil leakage from tanks and accumulation of inflammable gas. In case where installation of oil tanks above the high temperature units is unavoidable, the following requirements are to apply, in addition to the relevant requirements provided in **Pt 5, Ch 6, Sec 1** and **Sec 9** of the Rules. The existing ships, if they are of such consideration as mentioned above, are to be reconstructed accordingly as far as practicable.

(1) Provision of means such as to install, if necessary, mechanical ventilation ducts and others, is to be considered, for the purpose of improving ventilation at the compartment installed the tanks.

(2) Drip trays are to have an adequate area as well as a sufficient depth. The trays are recommended to have their surface made less by increasing its depth than its area when the trays are intended to increase their volume.
(3) Oil drains from drip trays to oil drain tanks through drain pipes having suitable diameter. In this case, care is to be taken to arrange the pipes shortest possible with ample declivity and to permit no oil to stay in pipes. Drain tanks are to be equipped with the sounding gauge or to be of the construction being capable of sounding its depth.
(4) The overflow pipes fitted to fuel oil tanks are to comply with the requirements provided in the following.
 (A) The fuel oil tanks having its opening within machinery space like the case of fitting internal mount type float gauge into fuel oil tank, are to be provided with the overflow pipes having their aggregate sectional area 1.25 times or above as much the aggregate sectional area of filling pipes to such tanks.
 (B) The highest point of overflow pipes is to be located lower than the opened portion of fuel oil tank.
 (C) Overflow pipes are to be short and declined as far as possible.
 (D) Overflow pipes are to be fitted with non-return valve at a suitable position in order to prevent oil or water from counter-flowing into fuel oil tank when the tanks to receive overflow oil are being filled with oil or water. The non-return valve intended for this purpose is not to be of screw-down type. In case, however, the use of such type is necessary, suitable notice plate is to be affixed to the valve.
 (E) Excepting the non-return valves specified in the preceding (d), no stop valve is to be fitted to overflow pipes.
 (F) Overflow pipes and drain pipes are not to be connected mutually.
(5) Exhaust gas manifolds in the vicinity of which are installed fuel oil tanks, are to be adequately insulated for heat and further be covered, including their flanges, with the oil tight metal casing or with the cloth specially coated by oil resistant compound.

2. Fuel oil pipes and their fittings In application to **901. 3** (5) of the Rules, "hot surfaces" means all surfaces with temperatures above 220 °C.

3. Drainage system In **901. 4** of the Rules, the drainage systems are to be complied with the following.
(1) Drain valves of settling tanks for fuel oil pipe systems are to be of self-closing valves or cocks
(2) Fuel oil heaters having possibility to get pressure exceeding its maximum working pressure are to be provided with an relief valve, and the relieved drain is to be led to drain tanks or alternatively be disposed of by other means so as not to get scattered.
(3) In case where fuel oil tanks are unavoidably installed intermediately above the high temperature units, fuel oil drain is to be comply with the requirements in above **2** (1) (B) and (C).

4. Construction of fuel oil tanks In application to **901. 5** of the Rules, "small tanks" means fuel oil tanks having 1 m^3 or less in its full capacity.

5. Valves for tank suction pipe **901. 7** of the Rules is to be in accordance with the following.

The air piping for the remote shut-down valves of fuel oil tank main suction valve is to be arranged separately from piping for other purposes, and the air outlet valve from the air reservoir is to be fitted with name tag for clear identification of the intended service.

6. Fuel oil transfer pumps In application to **901. 9** of the Rules, the following may be accepted.
(1) The fuel oil transfer pumps may be in accordance with the following.
 (A) For main engine with output 368 kW or above but less than 1,471 kW or ships having length less than 50 m, the main fuel oil transfer pump is to be a power pump. Stand-by pump may be acceptable by hand pump.
 (B) Where main engine output is 368 kW or less, hand pump may be acceptable.
 (C) In case of ships equipped with two or more engines, the main engine output means total output of the engines.
(2) In case of ships engaged in smooth water service, 1 set of fuel oil transfer pump may be acceptable.

7. Fuel oil piping In application to **901. 10** of the Rules, for tanks used in common service with fuel oil tanks and ballast tanks, piping arrangement is to be made in such a way that either fuel oil or ballast water can be drawn individually under any circumstances. (refer to **Fig 5.6.11** of the

Guidance)

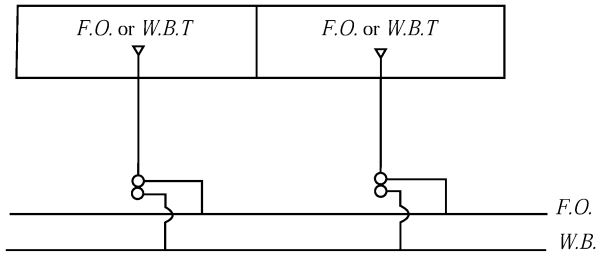


Fig 5.6.11 Example of Piping Arrangement for Fuel Oil Tank and Ballast Tank in Common Service

8. No fuel oil pipes are to be led through drinking water tanks, and no drinking water pipes are to be led through fuel oil tanks.

9. In application to **901. 13** of the Rules, the example of two fuel oil service tanks for each type of fuel oil used on board are as shown in **Fig 5.6.12** of the Guidance. This requirement applies only to ships subject to the requirements of the SOLAS.

(1) Example 1

(A) Requirement according to SOLAS : main, auxiliary engines and boilers operating with Heavy Fuel Oil(HFO) (one fuel ship)

HFO service tank capacity for at least 8 h Main engine + Aux. engine + Aux. boiler	HFO service tank capacity for at least 8 h Main engine + Aux. engine + Aux. boiler	MDO tank For initial cold starting or repair work of engines/boiler

(B) Equivalent arrangement

HFO service tank capacity for at least 8 h Main engine + Aux. engine + Aux. boiler	MDO service tank capacity for at least 8 h Main engine + Aux. engine + Aux. boiler

(Note)

1. this arrangement only appies where main and auxiliary engines can operate with heavy fuel oil under all load conditions and, in the case of main engines, during maneuvering.
2. For pilot burners of auxiliary boilers of provided, an additional MDO tank for 8 hours may be necessary.

(2) Example 2

(A) Requirement according to SOLAS : main engines and auxiliary boilers operating with Heavy Fuel Oil(HFO), auxiliary engines operating with Marine Diesel Oil(MDO)

HFO service tank capacity for at least 8 h Main engine+Aux. boiler	HFO service tank capacity for at least 8 h Main engine+Aux. boiler	MDO service tank capacity for at least 8 h Aux. engine	MDO service tank capacity for at least 8 h Aux. engine

(B) Equivalent arrangement

HFO service tank capacity for at least 8 h Main engine+Aux. boiler	MDO service tank Capacity for at least the highest of : · 4 h Main engine+Aux. engine+Aux. boiler or · 8 h Aux. engine+Aux. boiler	MDO service tank Capacity for at least the highest of : · 4 h Main engine+Aux. engine+Aux. boiler or · 8 h Aux. engine+Aux. boiler

(Note)

1. The arrangements in above apply, provided the propulsion and vital systems which use two type of fuel support rapid change over and are capable of operating in all normal operating conditions at sea with both types of fuel(MDO and HFO).
2. Service tank is a fuel oil tank which contains only fuel of a quality ready for use. use of a setting tank with or without purifiers, or purifiers alone, and one service tank is not acceptable as an equivalent arrangement to two service tank.

Fig 5.6.12 Example of Application for Fuel Oil Service Tank

902. Burning systems for boiler

1. Burning system For an auxiliary boiler used exclusively for the fuel oil heating necessary for the operation of main propulsion machinery or the cargo heating requiring continuously, only one burning system may be accepted, when one complete spare unit of burning pump capable of being replaced in a short period of time is equipped, notwithstanding the requirements in **902. 1** (2) of the Rules.

2. For small package type auxiliary boilers, where it is difficult to arrange two burning systems, one burning system may be accepted. In this case, one set of spare burning pump is to be provided and when burning pump is out of order, the spare burning system is to be easily exchanged for it.

903. Fuel oil supply system of internal combustion engines

1. Fuel oil supply pumps In application to **903. 1** of the Rules, the following are to apply.

(1) In case of ships complied with the following as ships having gross tonnage less than 500 tons may be omitted to provide the stand-by fuel oil supply pump.
   (A) Ships engaged in smooth water service
   (B) Ships engaged in coastal service area, and equipped with two sets of main engine and independent fuel oil supply pump for each main engine.
(2) In application to **903. 1** (4) of the Rules, the engine means a main engine or an auxiliary engine. In case of a main engine, one set of spare pump is to be provided.
(3) In ships engaged in smooth water service area and coastal service area, where internal combustion engines use lighting fuel oil supplied by gravity, the fuel oil supply pump may be omitted.
(4) In application to **903. 1** (6) of the Rules, engine of specific construction which can not be changed to spare pump without complete engine overhaul may be omitted to provide with spare pump.

2. Fuel oil filters

In Application to **903. 2** (2) of the Rules, "the filters are to be capable of being cleaned without stopping the supply of filtered fuel oil" is to comply with the following.
(1) Auto cleaner or self cleaning filter
(2) For multi propeller ships and where single filter is fitted in each engine which coupled with each shafting system.
(3) Where two or more the independent engines are coupled with one shafting system and single filter fitted in the individual engine.

3. Fuel oil heaters and purifiers In application to **903. 3** of the Rules, in principle, "low grade oil" means heavy oil which have a kinematic viscosity(50 ℃, cSt) more than 150.

Section 10 Thermal Oil System

1003. Pumps for thermal oil system

1. The wording “the thermal oil system for important use" specified in **1003. 1** of the Rules means the one in which thermal oil is used for either of the following :
(1) The fuel oil heating necessary for the operation of main propulsion machinery
(2) The cargo oil heating requiring continuously

2. Notwithstanding the requirements in **1003.** of the Rules, the thermal oil system for important use may be provided with only one fuel oil burning pump where one complete spare unit of the pump capable of being replaced in a short period of time is placed onboard.

Section 11 Compressed Air System

1101. Compressed air starting devices

1. Number and total capacity of main air reservoirs In **1101. 1** of the Rules, the total capacity of the starting air reservoirs is to be sufficient to provide, without replenishment, not less than the number of consecutive starts as specified in the following.
(1) For direct reversible engines

$$N = 12C$$

where;
N : Total number of starts of each engine
C : Constant determined by the arrangement of main propulsion engines and shafting sys-

tem, where the following values are to be referred to as the standard.

C = 1.0
For single screw ships, where one engine is coupled with the shaft either directly or through reduction gears

C = 1.5
For twin screw ships, where two engines are coupled with the shafts either directly or through reduction gear, or for single screw ships, where two engines are coupled with the shaft through deductable coupling provided between engine and reduction gear

C = 2.0
For single screw ships, where two engines are coupled with the shaft without any declutchable coupling between engine and reduction gear

C = 2.3
For triple screw ships, where three engines are coupled with the shaft either directly or through reduction gear, or for single screw ships, where four engines are coupled with the shaft through declutchable coupling provided between engine and reduction gear, or for twin screw ships, where four engines are coupled with the shaft through declutchable coupling provided between engine and reduction gear

C = 3.0
For twin screw ships, where four engine are coupled with the reduction gear directly

(2) For non-reversible type engines, 1/2 of the total number of starts specified in above may be accepted.
(3) For electric propulsion ships

$$N = 6+3(k-1)$$

N : Total number of starts of engine
k : Number of engines and it is not necessary for the value of k to exceed 3.

2. Number and total capacity of air compressors In application to **1101. 2** and **3** of the Rules, the following are to apply.
(1) "Small engines" mean engines having output 368 kW or less.
(2) In case where the capacity of compressors are different, the compressor having a little capacity is to supply within one hours air sufficient to provide not less than 4 consecutive starts for direct reversible engines, and 2 consecutive starts for in-direct reversible engines.
(3) The compressor driven by engine capable to manual start may be accepted to use for emergency.
(4) In case of ships equipped with diesel engine having output 88 kW or less, a manual operating compressor may be considered as equivalent to one unit among the compressors. Ships engaged in smooth water service area may be accepted to be provided with only a compressor.

3. Emergency air compressor

In application to **1101. 3** of the Rules, where the motor driving air compressor is powered by the emergency generator, emergency air compressor may be omitted.

1102. Construction and safety devices

In application to **1102. 1** (4) of the Rules, the following is to be applied for the strength of crankshaft of air compressor.
(1) The required diameters d_k of journals and crank pins are not to be less than that given by the following formula.

$$d_k = 0.126 \cdot \sqrt[3]{D^2 \cdot p_c \cdot C_l \cdot C_W \cdot (2 \cdot H + f \cdot L)} \quad (\mathrm{mm})$$

D = Cylinder bore for single-stage compressors (mm)

= D_{Hd} : Cylinder bore of the second stage in two-stage compressors with separate pistons

= $1.4 \cdot D_{Hd}$: for two stage compressors with a stepped piston as in **Fig 5.6.13** of the Guidance

= $\sqrt{(D_{Nd})^2 - (D_{Hd})^2}$: for two stage compressors with a differential piston as in **Fig 5.6.14** of the Guidance

p_c : Design pressure, applicable up to 40 (bar)

H : Piston stroke (mm)

L : a value of distance between main bearing centers (mm) X following factor.

① Where one crank is located between two bearings : 1.0

② Where two cranks at different angles are located between two main bearings : 0.85

③ Where 2 or 3 connecting rods are mounted on one crank : 0.95

f : ① Where the cylinders are in line : 1.0

② V or W type

- where the cylinders are at 90° : 1.2
- where the cylinders are at 60° : 1.5
- where the cylinders are at 45° : 1.8

C_l : Coefficient according to **Table 5.6.3** of the Guidance

z : Number of cylinders

C_w : Material factor according to **Table 5.6.4** or **Table 5.6.5** of the Guidance

R_m : Specified minimum tensile strength ($\mathrm{N/mm^2}$)

(2) Special consideration may be given to the diameter of crank shafts not complying with the requirements of above (1), if the detailed data and calculations on the strength of crank shafts are submitted.

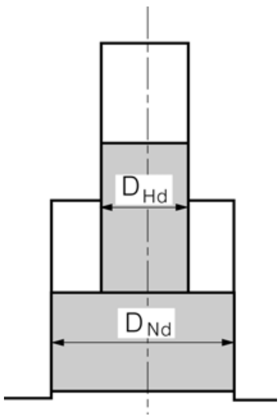


Fig 5.6.13

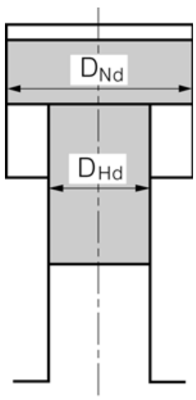


Fig 5.6.14

Table 5.6.3 Values of C_l

z	1	2	4	6	≥ 8
C_l	1.0	1.1	1.2	1.3	1.4

Table 5.6.4 Values of C_w for steel shaft

R_m	C_w
400	1.03
440	0.94
480	0.91
520	0.85
560	0.79
600	0.77
640	0.74
≥ 680	0.70
720[1)]	0.66
≥ 760[1)]	0.64
1) Only for forged crank shafts.	

Table 5.6.5 Values of C_w for nodular cast iron shafts

R_m	C_w
370	1.20
400	1.10
500	1.08
600	0.98
700	0.94
≥ 800	0.90

Section 12 Refrigerating Machinery

1201. General

1. Application

(1) In application to **1201. 1** (1) of the Rules, "the refrigerating machinery forming refrigerating cycle“ contains compressor, condenser, receiver, evaporator, pipings and associated equipments, etc.
(2) The refrigerating machinery with compressors of 7.5 kW or less using $R22$, $R\ 134a$, $R\ 404A$, $R\ 407C$, $R\ 410A$ or $R\ 507A$ as the primary refrigerant is to be suitable for use, service condition and environment on board.
(3) Refrigerating machinery using $R\ 717$ as the primary refrigerant is to comply with the requirements specified in (4) to (14) given below, in addition to those specified in the Rules.
(4) Plans and documents to be submitted, in addition to those specified in **Pt 5, Ch 1, 209.** of the Rules are generally as the following :
  (A) $R\ 717$ Refrigerant Piping Diagram
  (B) Gas Detector Arrangement
  (C) General Arrangement of Refrigerating Machinery Compartment
(5) General requirements of ammonia refrigerating machinery
  (A) Pressure vessels used in refrigerating machinery is to be classed into Class 1 pressure vessels specified in **Pt 5, Ch 5, Sec 3** of the Rules, and the primary refrigerant pipes (hereinafter referred to as refrigerant pipes) are to be classified into Class I pipes specified in **Pt 5, Ch 6, Sec 1** of the Rules.

(B) The design pressure of pressure vessels and pipes which form the refrigerating machinery is not to be less than 2.3 MPa at the high pressure side and not to be less than 1.8 MPa at the low pressure side.

(6) Materials of ammonia refrigerating machinery

(A) Material capable of highly corrosion (copper, zinc, cadmium, or their alloys) and materials containing mercury are not to be used at locations where ammonia comes into contact.

(B) Nickel steel is not to be used in pressure vessels and piping systems.

(C) Cast iron valves are not to be used in the refrigerant piping system.

(D) Material for sea water-cooled condenser is to be selected considering the corrosion due to sea water.

(E) Where flat tanks of quick freezers(contact freezers) are manufactured by extrusion molding of aluminium alloy, the material is to be approved in accordance with **Ch 2, Sec 6** of "**Guidance for approval of Manufacturing Process and Type Approval, Etc**".

(7) Piping arrangement of ammonia refrigerating machinery

(A) Refrigerant piping is not to pass through accommodation spaces.

(B) Pipe joints of the refrigerant piping system are to be butt welded as far as practicable.

(C) The refrigerant gas discharged from a pressure relief valve is to be absorbed in water, except when leading the gas to the low pressure side.

(D) If liquid level gauges made of glass are used at locations where pressure exists permanently, they are to comply with the following requirements ;

(a) Flat type glass is to be used in the liquid level gauge, and the construction is to be such that the gauge is adequately protected against external impacts.

(b) The construction of the stop valve for the liquid level gauge is to be such that the flow of liquid is automatically cut off if the glass breaks.

(E) The gas discharged from the purging valve is not to be discharged directly to the atmosphere, but absorbed in water.

(F) The discharge pipes of cooling sea water for the condenser is to be used the independent pipes. The piping is to be led directly overboard without passing through accommodation spaces.

(8) Control and alarm system of ammonia refrigerating machinery

Refrigerant compressors are to be provided with means for automatically stopping the compressor when the pressure on the high pressure side of the refrigerant piping system becomes excessively high. Also, an alarm system which generates visible and audible alarms when this means are in operation is to be installed in the refrigerating machinery compartment and monitoring position.

(9) Ammonia refrigerating machinery compartment

(A) The compartment where the compressor, receiver and condenser are installed (hereinafter referred to as **refrigerating machinery compartment**) is to be special compartment isolated by gastight bulkheads and decks from all other compartments so that leaked ammonia does not enter other compartments. Also, the refrigerating machinery compartment is to be provided with doors which comply with the following requirements :

(a) Except for small compartments, at least two access doors are to be provided in the refrigerating machinery compartment as far apart as possible from each other.

(b) Access doors not leading to weather deck are to be of high tightly and self-closing type.

(c) Access doors are to be capable of being operated easily and are to open outward.

(B) Penetrations on gastight bulkheads and decks where cables and piping from the refrigerating machinery compartment pass through, are to be of gastight construction.

(C) Passages leading to the refrigerating machinery compartment are to be isolated from accommodation spaces, hospital room or control room by gastight bulkheads and decks.

(D) An independent drainage system is to be provided in the refrigerating machinery compartment so that the drainage is not discharged into open bilge wells or bilge ways of other compartments.

(10) Ammonia gas expulsion system

A gas expulsion system consisting of ventilation system and water screening system is to be installed in the refrigerating machinery compartment, in accordance with (A) to (B) below so that gas leaked out accidentally can be expelled quickly from the refrigerating machinery compartment.

(A) A exhaust type mechanical ventilation system which complies with the following requirements as a rule, is to be installed in the refrigerating machinery compartment so that this space can be ventilated all the time.

(a) The ventilation system is to have adequate capacity to ensure at least 30 air changes per hour in the refrigerating machinery compartment.

(b) The ventilation system is to be independent of other ventilation systems on board the ship, and is to be capable of being operated from outside the refrigerating machinery compartment.

(c) Exhaust outlets are to be installed properly so as to prevent exhaust air from flowing in through air intake openings, openings of accommodation spaces, service spaces and control stations.

(d) Exhaust fans and the exhaust ducts in which the fans are installed, are to be of a construction such that sparks are not generated according to any of the following.

(i) Either the impeller or the casing, or both, are made of non-electrostatic, nonmetallic materials.

(ii) Non-ferrous metallic material is used in the impeller and the casing.

(iii) In case where ferrous material is used in the impeller and the casing, the tip clearance is greater than 13 mm. However, use of a combination of aluminium or magnesium alloy with ferrous material has possibilities of generating sparks regardless of the tip clearance, therefore, such materials are not to be used in the refrigerating machinery compartment. As a rule, motors for driving the fans are to be of the exterior mounted type.

(B) All doors of the refrigerating machinery compartment are to be provided with water screening system which can be operated from outside the compartment.

(11) Ammonia gas detection and alarm systems

Fixed type ammonia gas detection and alarm systems are to be provided to activate alarms inside and outside of the refrigerating machinery compartment.

(12) Electrical equipment for ammonia refrigerating machinery

(A) Electrical equipment in the refrigerating machinery compartment required to be operated in the event of leakage accidents, gas detection and alarm system and emergency lights are to be of certified safe types for use in the flammable atmosphere concerned.

(B) Electrical equipment in the refrigerating machinery compartment other than mentioned in (A) above, are required to switch off automatically by means of circuit breakers outside the refrigerating machinery compartment when the flammable gas detector specified in (11) activates.

(13) Safety and protective equipment for ammonia refrigerating machinery

Safety and protective equipment for ammonia refrigerating machinery as given below, as a rule, are to be provided, and are to be stored at locations outside the refrigerating machinery compartment so that they can be easily retrieved in the event of leakage of the refrigerant. Storage locations are to be marked with signs so that they can be identified easily.

(A) Protective clothing (helmet, safety boots, gloves, etc.) × 2
(B) Self-contained breathing apparatus (capable of functioning for at least 30 minutes) × 2
(C) Protective goggles × 2
(D) Eye washer × 1
(E) Boric acid
(F) Emergency electric torch × 2
(G) Electric insulation resistance meter × 1

(14) Requirements for fishing vessels, etc.

Refrigerating installations provided in fishing vessels of length under 55 m or refrigeration machinery retaining ammonia not more than 25 kg are to be according to (A) to (E) given below, notwithstanding (9) to (12).

(A) Refrigerating machinery may be installed in the engine room. In this case, drain trays are to be provided at a position lower than the refrigerating machinery.

(B) Ammonia gas exclusion system is to comply with the following.

(a) Ventilation system with special hoods above the refrigerating machinery is to be provided for exhaust capable of ventilation without accumulation of ammonia gas. The fans of the ventilation systems are to be independent of those of engine room ventilation systems.

(b) A water sprinkler system capable of absorbing enough leaked ammonia gas is to be provided in the vicinity of the space where the refrigerating machinery is installed.

Sprinkler hoses and water spraying nozzles are to be positioned so that water can be dispersed quickly when a leak occurs.

(C) Ammonia gas detection and alarm systems are to be provided to activate visible and audible alarms in the monitoring room (or control room) and engine room entrance. In this case, the detectors are to be installed in the vicinity of the upper parts of the refrigerating machinery, exhaust outlets and other locations deemed necessary by the Society.

(D) As far as possible, electrical equipment are not to be installed in the vicinity of the refrigerating machinery.

(E) Two(2) sets of protective clothing (helmet, safety boots, gloves, etc.) and two(2) sets of self-contained breathing apparatus (capable of functioning for at least 30 minutes) are to be provided. And, if the escape route from the monitoring room (or control room) passes through the engine room, one of the self-contained breathing apparatus sets is to be provided in the monitoring room (or control room).

Section 13 Tests and Inspections

1301. Tests of auxiliary machinery

In application to **1301. 1** of the Rules, "where otherwise specified" means those specified in other Chapters and **Table 5.6.6** of the Guidance.

Table 5.6.6

Item	Hydrostatic test pressure
Hydrulic motor	1.5 times the design pressure of hydraulic pump

1302. Hydrostatic tests of valves and pipe fittings

1. In application to **1302. 1** of the Rules, the hydrostatic test of following valves and pipe fittings may be omitted.

(1) Pipe flanges and pipe pieces(elbow, reducer, tee, bend, socket, etc.), etc.

(2) Valves and pipe fittings not exceeding 25 A

2. In application to **1302. 2** of the Rules, the valve means valve body.

3. Considering the characteristics and purpose of valves, scoop valves may be subjected to a leak test at pressure side only.

4. Dimension and visual inspection may be omitted for the valves and pipe fittings not exceeding 25 A.

1303. Hydrostatic tests of fuel tanks

1. When hydrostatic test is replaced by gastight tests, the pressure of gastight test is to be 0.02 MPa.

1304. Tests on workmanship of pipes

1. Welding procedure qualification tests Welding procedure qualification tests specified in **1304. 1** of the Rules are to comply with **Pt 2, Ch 2, Sec 4** of the Guidance.

2. Welding joints of hydraulic pipes belong to Class I and passed through the spaces other than engine room, cargo pump room, steering gear room and accommodation space may be applied with the requirements for pipes belong to Class II specified in **1304. 2** of the Rules.

3. RST 422, 423 or 424 used for design temperature 550 °C and over, and belong to Grade 4 of steel pipes for pressure piping, specified in **Pt 2, Ch 1** of the Rules and over are to be carried out hydrostatic test by 2 times the design pressure. However, the test pressure P_h is not required to be more than the value calculated by the following formula. And in case where a bent of pipes, tee, etc. have a risk of excessive stress at the test, the test pressure may be reduced to 1.5 times the design pressure.

$$P_h = \frac{378t}{D-t} \quad (\text{MPa})$$

where

D : Outside diameter of pipe (mm)

t : Thickness of pipe (mm)

4. When water residue by the hydraulic test completion of shipboard installation of piping systems may not be desirable, the hydraulic test may be omitted in case where adequate non-destructive tests are carried out on welded joints with results free from defects.

1305. Tests of piping system on board

1. In application to **1305. 1.** (2) of the Rules, "tests by hydrostatic pressure" are to be in accordance with the following.

(1) In principle, tests by hydrostatic pressure are to be carried out hydrostatic tests using liquid such as water, etc.

(2) In general, airtight tests instead of hydrostatic test are not permitted. Where it is impracticable to carry out the required hydrostatic test, airtight tests may be considered.

(3) In such case, the procedure for carrying out the airtight test, having regard to safety of personnel, is to be submitted to the Surveyr. ⚓

CHAPTER 7 STEERING GEARS

Section 1 General

101. Application

1. Manual steering gears are to be in accordance with the requirements of **Pt 5, Ch 7, Sec 1, 201.** through **203. 208.** through **210., 301., Sec 4** (excluding **409. 2**) and **Sec 5** of the Rules and the relevant requirements of the Guidance.

103. Drawings and documents

1. Operating instructions for hydraulic type steering gear are to include informations about importance of hydraulic fluid quality and its influence to probability of hydraulic locking possibility of two simultaneously operated power units. The operating instructions of same contents as above-mentioned ones, are to be kept on the bridge.

104. Display of operating instructions

In application to **104. 2** of the Rules, the "appropriate instructions for emergency procedures" are to simply indicate emergency procedures corresponding to the design of steering gear (for example, to shut down the failed system indicated by the alarming system), and are to be fitted at a suitable place on steering control post on the navigation bridge where applicable.

Section 2 Performance and Arrangement

201. Number of steering gears

1. In case where ships whose required upper stock diameter is not more than 120 mm according to **Pt 4, Ch 1** of the Rules and engaged in the service in smooth water area, or ships with a gross tonnage less than 50 tons, provide that spare parts liable to wear down such as packings, bearings are provided where the main steering gear is operated by power, the auxiliary steering gear required by **201.** of the Rules may be omitted.

2. In case where the auxiliary steering gear as specified in **201. 1** of the Rules is of hydraulic type, the rudder actuator can serve in common with that for the main steering gear. Further, part of the hydraulic piping of the rudder actuator of the main steering gear may be used in common with that for the auxiliary steering gear. In this case, but the pipe length of the part of common use is to be as short as practicable.

202. Performances of main steering gear

In application to **202. 2** of the Rules, the diameter specified in **Pt 4, Ch 1** of the Rules is to be taken as having been calculated for upper rudder stock of mild steel with a yield strength of 235 N/mm^2 (i.e. with a material factor K_s = 1).

203. Performances of auxiliary steering gear

In application to **203. 2** of the Rules, the diameter specified in **Pt 4, Ch 1** of the Rules is to be taken as having been calculated for upper rudder stock of mild steel with a yield strength of 235 N/mm^2 (i.e. with a material factor K_s = 1).

204. Piping

1. In case of steering gears complied with the following, the requirements of **204. 5** and **6** of the Rules may not be applied.

(1) Steering gears equipped in ships with a gross tonnage less than 500 tons
(2) Steering gears equipped in ships engaged in domestic coastal or smooth water service area

(excluding where auxiliary steering gear is omitted by **201. 2** of the Rules)

206. Alternative source of power

1. In case of steering gears complied with the following, the requirements of **206.** of the Rules may not be applied.

(1) Steering gears equipped in ships with a gross tonnage less than 500 tons, or
(2) Steering gears equipped in ships engaged in domestic coastal or smooth water service area

207. Electric installations for electric and electro-hydraulic steering gear

1. In case of manual auxiliary steering gears for a ship which SOLAS is not applicable to, the power supply circuit from the main switchboard to the steering gear may be one circuit.

2. In case of steering gears complied with the following, the requirements of **207. 1, 5** (excluding short circuit protection) and **7** of the Rules may not be applied.

(1) Ships with a gross tonnage less than 500 tons, or
(2) Ships engaged in domestic coastal or smooth water service area

3. In application to **207. 5** and **6** of the Rules, steering gear motor circuits which are limited to full load current via an electronic converter are exempt from the requirement to provide protection against excess current, including starting current, of not less than twice the full load current of the motor. In this case, the required overload alarm is to be set to a value not greater than the normal load of the electronic converter.

209. Means of communication

1. Means of communication between the navigating bridge and the steering gear compartment are not to depend solely on the shipboard telephone system for general purpose.

2. In case of ships complied with the following, the means of communication specified in **209.** of the Rules and above **1** may be alternated with appropriate means of communication.

(1) Ships with a gross tonnage less than 500 tons, or
(2) Ships engaged in domestic coastal or smooth water service area

Section 3 Controls

301. General

1. It may be acceptable that only one set of floating lever or other mechanical follow-up control system is provided.

2. The control system specified in the requirements of **301. 1** (2) of the Rules is to comply with following requirements.

(1) The control system is in principle to be of the follow-up type.
(2) Control systems and components are to be so designed and arranged that the failure of one of them will not render the other one inoperative.
(A) Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles are to be separated as far as practicable. Where physical separation is not practicable, separation may be achieved by means of a fire retardant plate.
(B) All electric components of the steering gear control systems are to be duplicated. This dose not require duplication of the steering wheel or steering lever.
(C) If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, the connections for the circuits of the control systems are to be divided accordingly and separated from each other by an isolating plate or by air gap.
(D) In the case of double follow-up control, the amplifiers are to be designed and fed so as to be electrically and mechanically separated.
(E) Control circuits for additional control systems, e.g. steering lever or autopilot are to be de-

signed for all-pole disconnection.

(F) The feed-back units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

(G) Hydraulic system components in the power actuating or hydraulic servo systems controlling the power systems of the steering gear (e.g. solenoid valves, magnetic valves) are to be considered as part of the steering gear control system and are to be duplicated and separated. Hydraulic system components in the steering gear control system that are part of a power unit may be regarded as being duplicated and separated when there are two or more separate power units provided and the piping to each power unit can be isolated.

3. Failure detection and system response upon failure of the control system specified in the requirements of **301. 1** (2) of the Rules is to comply with following requirements

(1) The most probable failures that may cause reduced or erroneous system performance are to be detected, and are to consider at least the following:

(A) Power supply failure

(B) Loop failures in closed loop systems, both command and feedback loops (normally short circuit, broken connections and earth faults)

(C) If programmable electronic system are used, data communication errors, computer hardware and software failures (Also the system is to be complied with the requirements of system category Ⅲ in **Pt 6, Ch 2, 201. 7.**)

(D) Hydraulic locking.

(2) Alternatively to (1) (B) and (C), depending on the rudder characteristic, critical deviations between rudder order and response are to be indicated visually and audibly as steering failure alarm on the navigating bridge. The following parameters are to be monitored:

(A) Direction (Actual rudder position follows the set value)

(B) Delay (Rudder's actual position reaches set position within acceptable time limits)

(C) Accuracy (The end actual position is to correspond to the set value within the design offset tolerances)

(3) Hydraulic locking is always to be warned individually unless system design makes manual action unnecessary.

(4) The most probable failures (i.e : power supply failure, loop failures, etc.) are to result in the least critical of any new possible conditions.

4. Amplifiers, relays, etc., included in the control system may be used also for the automatic pilot systems.

5. In electro-hydraulic steering gears equipped with power units comprising variable-displacement pumps, two sets each of hydraulic servo cylinders and associated hydraulic system (including pump driving electric motors and control equipment) or electric servo motors for controlling displacement of the pump plungers are to be provided.

6. In case of ships complied with the following, the means of communication specified in **301. 3** of the Rules may not be applied.

(1) Ships with a gross tonnage less than 500 tons, or

(2) Ships engaged in domestic coastal or smooth water service area

7. In application to **301. 4** of the Rules, in general, following cases are not considered as the case of “where hydraulic locking, caused by a single failure, may lead to loss of steering”.

(1) Steering systems with performance at least equal to that required for an auxiliary steering gear are fitted as stand-by systems and are operable from navigating bridge. In this case, the stand-by systems are so designed not to run parallel using an interlocking devices, etc.

(2) Not less than 3 systems are operated parallel and, in the case of a single failure, steering capability at least equal to that required for an auxiliary steering gears are maintained.

(3) Steering gears designed to avoid leading to loss of steering by by-passing the failed system automatically using duplicated control valve system. This arrangement is subject to special consideration with respect to reduced reliability due to increased complexity.

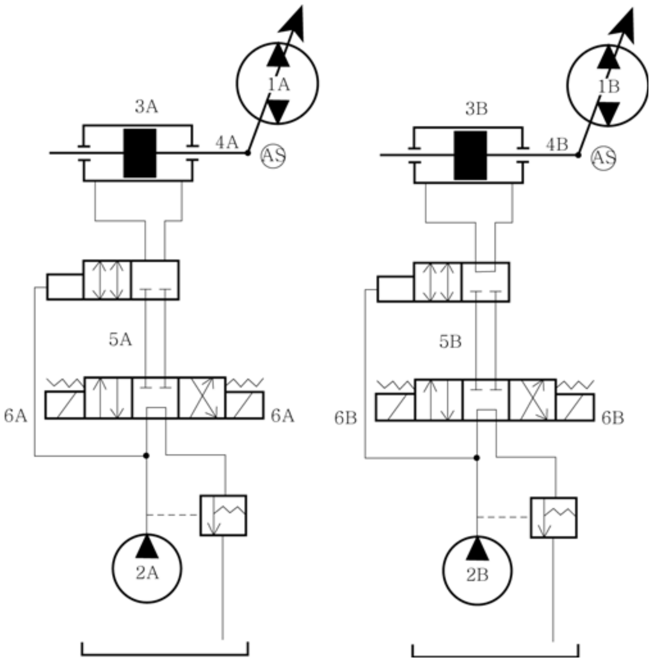
8. In application to **301. 4** of the Rules, the "audible and visual alarm, which identifies the failed system" is to be activated in following conditions in general.

(1) Position of the variable displacement pump control system does not correspond with given order.

(2) Incorrect position of 3-way full flow valve or similar in constant delivery pump system is

detected.

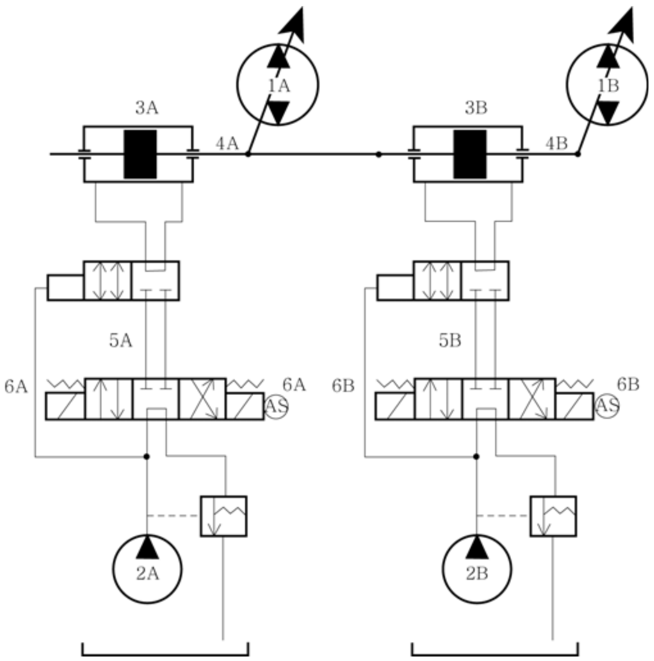
9. The location of sensors of alarm specified in aforementioned **8**, are to be as near actuator as possible. For the part of steering gears, where two or more pumps are mechanically interconnected by floating bar or similar, their breakage may not be considered. The example of acceptable location of alarm sensors are indicated in **Fig 5.7.1**.



(a) Separated system

(AS) : denoted location of alarm sensors

1. Main pump of variable displacement type.
2. Pilot pump
3. Control actuator
4. Control linkage
5. Solenoid controlled 3-way valve.
6. Solenoid.



(b) Mechanically interconnected system

(Note)

Where systems are so designed not to run 1A & 1B IN (a) nor 2A & 2B in (b), the alarm devices are not required.

Fig 5.7.1 Example location of hydraulic locking alarm sensors

302. Change over from automatic to manual steering

1. At any rudder angle, the change over from automatic to manual steering is to be available within 3 seconds by two attempts of control operation at the most.

2. The change over from automatic to manual steering is to be available under any circumstances including the case of failure of the automatic pilot.

3. The device to change over from automatic to manual steering is to be installed close to the normal steering position.

Section 4 Materials, Constructions and Strength

401. Materials

Scantling of tillers made of casting or ductile materials are to be 1.05 times the values specified in the requirements of **407.** of the Rules.

407. Tillers, etc.

1. Scantling of tiller having two arms In the case of tiller having two arms, where power units are connected to each arm and these two power units are driven simultaneously, the scantling of each tiler may be reduced to 0.6 times those required in **407. 1** (1) (B) and (C) of the Rules.

2. The scantling of tillers for the exclusive use of auxiliary steering gear are to have the strength assures 1/2 or more of that specified in the requirements of **407.** 1 (1) of the Rules.

409. Buffers

In case of ships having smooth water service area and ships with a gross tonnage less than 500 tons, the buffers required by **409.** of the Rules may be omitted.

Section 5 Testing

503. Sea trials

1. In Application to **503. 1** (1) of the Rules, where trials are conducted in conditions other than full load because it is impractical to conduct trials at full load, trials are to be conducted as close to full load draught and zero trim as possible and special attention are also to be given to ensuring that sufficient propeller immersion exists in the trial condition. And the trial results to the full load condition are to be predicted using a reliable method. (i.e. model tests or reliable computer simulation)

2. In application to **503. 1** (9) of the Rules, the wordings “steering gear is designed to avoid hydraulic locking” means steering gears designed not to run parallel using an interlocking devices, etc. or steering gears designed to maintain their steering capability or to recover them by by-passing the failed system automatically. For the steering systems which are dispensed with the consideration of hydraulic locking because of that considerations of the breakages at mechanical linkage of floating bar or similar are waived, these demonstrations may not be carried out. ⚓

CHAPTER 8 WINDLASSES AND MOORING WINCHES

Section 1 General

101. Application

1. In application to **101. 1** of the Rules, manual operating windlasses are to be complied with the following.

(1) In the case of windlasses complied with the following, the manual operating windlasses may be accepted.

(A) In the case of windlasses for anchor with weight 250 kgf or less

(B) In the case of windlasses for anchors with weight 500 kgf or less equipped on barges engaged in domestic service area and ships engaged in smooth water service area

(2) Manual operating windlasses are to be capable of lifting anchor and chain at the nominal speed of at least 0.033 m/s. In this case, the human power driving them is to be 147 N or less when their crank radius of 350 mm is rotated about 30 rpm.

(3) Materials used in the major parts are complied with *Korean Industrial Standards* or other recognized standards.

(4) For manual operating windlasses, brake test and load test are to be carried out. The test procedures are to be applied with appropriate modifications of the requirements of **205. 2** of the Guidance. However, the nominal speed and the human power driving them are to be applied with (2) above.

102. Materials

1. In application to **102.** of the Rules, "major parts" means the following.

(1) Driving shafts and gears of power transmission system
(2) Chain lifters and shafts of chain lifter (Windlass)
(3) Rope drums and shafts of rope drum (Mooring winch)
(4) Brake bands and spindles
(5) Chain stoppers (Windlass)

Section 2 Windlasses

205. Tests and Inspections

1. No load test

Windlasses are to be run without load in normal and reverse direction, for a sum of each 15 minutes, under the rated voltage at the rotating speed equivalent to the rated speed at the shop. During the test, tightness against oil leakage, temperature of bearings and presence of abnormal noise are to be checked. However, when it is difficult to be carried out the test at the shop, the test may be carried out on board.

2. Brake test and load test

Windlasses are, after installation on board, to be tested and checked about the following at the location ensured depth of water deeper than the total length of 3 lengths of anchor chain and anchor.

(A) Brake test
The anchor chain cable is to be hoisted to the position that the anchors are submerged in water, and the anchor is to be fallen freely until getting to sea-bed. At this time, brake systems are to be checked every 1/2 length. In this case, it is considered as a standard that braking distance of brake systems is to be 7 m or less.

(B) Load test

(a) At the condition that 3 lengths of chain cable is submerged in water but anchor is not got to sea-bed, 2 lengths of one side anchor chain are to be hoisted and 2 lengths of the other side anchor chain are to be hoisted, and 1 length remained in each side is to be hoisted simultaneously.

(b) The average speeds are to be measured when 2 lengths of each side anchor chain are hoisted according to above (a), and are to be 0.15 m/s or over.

(c) Particulars required identification of capability, utility, and conditions for constructions and components of the windlass are to be checked during load test.

(C) In the case where the depth of water deeper than the total length of 3 lengths of anchor chain and anchor is difficult to be ensured geographically at sea trial, load test may be carried out according to the following. However, in this case, the tests are to be carried out at the deepest area among the sea trial area.

(a) Symmetrical double cable-lifter windlasses

(i) The anchor chain cable of each side is to be lifted until the position that the anchor gets to the surface of water. And the anchor of each side is to be fallen in the water until 1 length of chain cable is submerged in water but anchor is not got to sea-bed.

(ii) The average speeds are to be measured when each 1 length of both sides anchor chain is lifted simultaneously, and are to be 0.15 m/s or over at the conditions mentioned above (i).

(b) Single cable lifter windlasses

Average speed is to be measured by anyone among the following after identifying the above (a) (i).

(i) Where windlass is capable to lift simultaneously anchor chain cable of both sides by use of independent hydraulic pump unit of one side, the average speed is to be 0.15 m/s or over at the test mentioned in above (a) (i) making use of a hydraulic pump unit of one side.

(ii) Where windlass is incapable to lift simultaneously anchor chain cable of both sides by use of independent hydraulic pump unit of one side, the average speed of recovery of chain cables, when the maximum length of anchor chain cables are submerged but freely suspended at commencement of lifting is to be 0.15 m/s or over by comparing with the measurements for capability particulars and the estimated performance curve. In case of where the result is doubted by comparing with performance curve, it may be carried out retesting.

(iii) Single cable lifter windlasses driven by electric motor or steam are to be applied with appropriate modifications of the requirements of (ii) above.

(c) Couple windlasses

Couple windlasses are to be applied with appropriate modifications of the requirements of above (a). In this case, 2 sets of prime mover may be used for lifting anchors of one side or both sides simultaneously. ⚓

ANNEX

Annex 5-1 Requirements for the Water-jet Propulsion Systems and Azimuth or Rotatable Thrusters

1. Water-jet propulsion systems

(1) General

(A) The requirements in this Guidance apply to the surveys, construction, strength and materials for the installation of ships equipped with two or more water-jet propulsion systems driven by high speed engines (hereinafter referred to as the propulsion systems).

(B) For items not specified in this Guidance, the relevant requirements specified in **Pt 5** of the Rules apply.

(C) Propulsion systems of special type or other which have unavoidable but justifiable reasons precluding the due compliance with the requirements of this Guidance are to be examined in consideration of each design.

(D) Equivalency

Propulsion systems which do not comply with the requirements of this Guidance may be accepted provided that they are deemed by the Society to be equivalent to those specified in this Guidance.

(E) Terminology

The terms used in this Guidance are defined as follows:

(a) **Propulsion system** is a system, including next (ii) to (vii) that receives water through an inlet duct and discharges it through a nozzle at increased velocity to produce propulsive thrust.

(b) **Impeller** is a rotating assembly provided with blades to give energy to the water.

(c) **Main shaft** is a shaft that transmits power to the impeller blades.

(d) **Water intake duct** is the portion that leads the water drawn from the water intake to the impeller inlet.

(e) **Nozzle** is the portion that injects the rectified water from the impeller.

(f) **Deflecter** is the device serving as a rudder by leading the water injected from the nozzle either to port or to starboard.

(g) **Reverser** is the device to thrust the ship to go astern by reversing the flow direction of the water injected from the nozzle.

(h) **High speed engine** is the high-rotating-speed internal combustion engine specified in **Pt 1, Ch 2, 303. 3** of the Guidance or gas turbine.

(2) Drawings and Data to be Submitted

Before the work is commenced, the manufacturers of propulsion systems are to submit drawing in triplicate and a copy of data specified below, to the Society for approval.

(A) General arrangement and sectional assembly (showing the materials and dimensions of various parts including the water intake duct, etc.)

(B) Shafting arrangement (showing the arrangements, shapes and construction of the main engine, gear, clutch, coupling, main shaft, main shaft bearing, thrust bearing, sealing device, impeller, etc.)

(C) Details of water intake duct

(D) Construction of impeller (showing the detailed blade sections, the maximum diameter of blade from the centre of the main shaft, number of blades, and material specifications)

(E) Details of main shaft bearings, thrust bearing, and forward sealing device of the main shaft

(F) Details of deflecter

(G) Hydraulic piping system diagram

(H) Details of reverser

(I) Torsional vibration calculation sheets and calculation sheets of the bending natural frequency when bending vibration due to self-weight is expected

(J) Strength calculation sheets for deflector and reverser

(K) Others considered to be necessary by the Society

(3) Materials, Construction and Strength

(A) Materials

The materials of parts of the propulsion system are to be suitable for respective uses in-

tended, and the following important components are to comply with the requirements in **Pt 2, Ch 1** of the Rules. However, the Society may accept to use those made of materials which comply with Korean Industrial Standards or standards as considered equivalent therto.
(a) Main shaft
(b) Shaft coupling and coupling bolts
(c) Impeller
(d) Water intake duct, nozzle and impeller casings which are composing a part of shell plating

(B) Construction and strength
(a) Main shaft
The minimum diameter of the main shaft is to be not less than the value determined by the following formula:

$$d_s = k \cdot \sqrt[3]{\frac{H}{Z}}$$

where
d_s : Required diameter of main shaft (mm)
H : Maximum continuous output of main engine (kW)
Z : Number of revolutions of main shaft at the maximum continuous output (rpm)
k : Values shown in **Table 5.1**

Table 5.1 Values of k according to Fitting Method

<table>
<tr><td colspan="2" rowspan="2">Position
Fitting method
Shaft material</td><td colspan="4">Fitting part of shaft with impeller and shaft coupling</td><td rowspan="2">Other positions</td></tr>
<tr><td>With key way</td><td>With spline</td><td>With flange coupling</td><td>Force fitting</td></tr>
<tr><td rowspan="2">Carbon steel or low alloy steel</td><td>Shaft of Class 2</td><td>105</td><td>108</td><td>102</td><td>102</td><td>105</td></tr>
<tr><td>Shaft of Class 1</td><td rowspan="2">a_1=100
a_2=80
in Note</td><td rowspan="2">a_1=102
a_2=82
in Note</td><td colspan="2" rowspan="2">a_1=98
a_2=78
in Note</td><td rowspan="2">a_1=100
a_2=80
in Note</td></tr>
<tr><td colspan="2">Austenitic stainless steel</td></tr>
<tr><td colspan="2">Precipitation hardened stainless steel</td><td>80</td><td>82</td><td>78</td><td>78</td><td>80</td></tr>
<tr><td colspan="7">NOTES : For $200 \leq \sigma_y \leq 400$
$k = a_1 - 0.1(\sigma_y - 200)$
For $\sigma_y > 400$
$k = a_2$
σ_y : Specified yield point or 0.2 % of proof strength of shaft material (N/mm^2)</td></tr>
</table>

(b) Shaft couplings and coupling bolts
(i) The minimum diameter of the shaft coupling bolts at the joining face of the couplings is to be not less than the value determined by the following formula:

$$d_b = 15{,}300\sqrt{\frac{H}{Z} \cdot \frac{1}{nDT_b}}$$

where
d_b : Required diameter of shaft coupling bolt (mm)
n : Number of bolts

D : Pitch circle diameter (mm)

T_b : Specified tensile strength of bolt material (N/mm²)

(ii) The thickness of the shaft coupling flange at the pitch circle is not to be less than the required diameter of shaft coupling bolts determined by the formula in (i) above. However, it is not to be less than 0.2 times the required diameter of the corresponding shaft.

(iii) The fillet radius at the base of the flange is not to be less than 0.08 times the diameter of the shaft. The fillets are to have a smooth finish. Where the fillet is recessed in way of nuts and bolt heads, the fillet radius at the base of the flange is not to be less than 0.125 times the diameter of the shaft.

(c) Water intake duct, etc.
The water intake duct, impeller casing and nozzle are to have strength according to the design pressure, and consideration is to be given for corrosion.

(d) Impeller blade
The strength of the impeller blade at root is to be determined so that the following formula is satisfied. In this case, the allowable stress value of the material is, in principle, to be 1/1.8 of the specified yield point (or 0.2 % of proof strength).

$$S \geq \frac{5.8 \times 10^5 H}{L t^2 Z N} + 2.2 \times 10^{-7} D^2 N^2$$

where

S : Allowable stress of impeller material (N/mm²)

H : Maximum continuous output of main engine (kW)

N : Value obtained by dividing the number of revolutions of impeller by 100 (rpm /100)

Z : Number of impeller blades

L : Width of impeller blade at root (mm)

t : Maximum thickness of impeller blade at root (mm)

D : Diameter of impeller (mm)

(C) Torsional vibration and bending vibration of main shaft

(a) General

(i) Notwithstanding the requirements specified in above (2) (I) concerning to submission of the torsional vibration calculation sheets for the main shafting systems, submission of those may be omitted in cases where the shafting system is of the same type as previously approved one or it can be readily assumed that the shafting system has no excessive vibration stress.

(ii) Measurements of torsional vibration to confirm accuracy of the estimated value are to be carried out. In cases, however, submission of the torsional vibration calculation sheets is omitted according to the requirements in above (1), or the Society considers that there is no critical vibration within the service speed range, the measurement of torsional vibration may be omitted.

(b) Allowable limit of torsional vibration stress
The torsional vibration stress of the shafting system is to be in accordance with the following requirements within the service speed range of the shafting system.

(i) The torsional vibration stresses produced when the revolutions of the engine are within the range from 80 % to 105 % of maximum continuous revolutions are not to exceed τ_1 given in following :

$$\tau_1 = A - B\lambda^2 \quad (\lambda \leq 0.9) \text{ and}$$
$$\tau_1 = C \quad (\lambda > 0.9)$$

where

τ_1 : Allowable limit of torsional vibration stresses for the range of $0.8 < \lambda \leq 1.05$ (N/mm^2)

λ : Ratio of the number of maximum continuous revolutions to the number of service revolution of the engine

A, B and C : Values shown in **Table 5.2**

Table 5.2 Values of A, B and C

	Carbon steel or low alloy steel		Austenitic stainless steel	Martensite precipitation hardened type stainless steel
	Shaft of Kind 1	Shaft of Kind 2		
A	24.3	9.0	26.4	39.6
B	24.1	6.2	26.4	37.1
C	4.8	4.0	5.0	9.6

In case where the specified tensile strength of materials of carbon steel shafts or low alloy steel shafts of Kind 1 exceeds 400 N/mm^2 the value of τ_1 may be increased by multiplying the factor k_m given in the following formula:

$$k_m = (T_s + 160)/56$$

where

k_m : Correction factor

T_s : Specified tensile strength of main shaft material (N/mm^2)

(ii) The torsional vibration stresses of the main shaft within the range below and at 80 % of the maximum continuous revolutions of the engine are not to exceed τ_2 given in following. In case where torsional vibration stresses exceed the value calculated by the formula of τ_1 shown in (i), the barred speed ranges are to be imposed. In this case, the formula for τ_1 is the one for the range of $\lambda \leq 0.9$.

$$\tau_2 = 2.3\tau_1$$

where

τ_2 : Allowable limit of torsional vibration stresses for the range of $\lambda \leq 0.8$ (N/mm^2)

(c) Bending vibration
For the main shafting system of the propulsion system, consideration is to be given to natural vibrations due to bending of the shafting system.

(D) Steering systems
Deflector is to be capable of steering from 30 degrees on one side to 30 degrees on the other side with ship at its load draught while running ahead at the speed specified in **Pt 3, Ch 1, 120.** of the Rules and, under the same conditions, from maximum steering angle on either side to maximum steering angle on the other side in not more than 28 seconds. However, where the detailed documents for construction, steering capability, etc. of deflector are submitted by manufacturer and it is deemed appropriate by the Society, the maximum steering angle and steering capability of deflector may be reduced.

(E) Reversing gear and astern power
(a) The reverser is to be such that it provide sufficient power for going astern to secure proper control of the ship in all normal circumstances, and when transferred from ahead to astern runs, it is to have an astern power to provide effective breaking for the ship.

(b) The reverser is to have sufficient strength against the thrust at the maximum astern power output.

(F) Hydraulic system
The hydraulic system driving the deflecter and the reverser is to be duplicated or to be provided with an emergency hydraulic power source, in case where it is not equipped for each shafting independently.

(4) Tests and Inspections

(A) Hydrostatic test

(a) Hydrostatic tests are to be carried out at a pressure 1.5 times the design pressure for impeller casing.

(b) Hydrostatic tests are to be carried out at a pressure of at least 0.2 MPa or 1.5 times the design pressure whichever is higher for the forward bearing tube of the main shaft and the sealing device.

(B) Dynamic balancing test
Dynamic balancing test of the impeller are to be carried out.

(C) Test after installation on board
The propulsion systems are to be subjected to running trials after being installed on board and the following items are to be verified:

(a) Verification of steering performance specified in (3) (D)

(b) Operating test of reverser specified in (3) (E)

(c) Measurement of torsional vibration is to be in accordance with **Ch 4, 103.** of the Rules.

2. Azimuth or rotatable thrusters

(1) General

(A) Ships equipped with azimuth or rotatable thrusters as main propulsion system are to have at least two azimuth or rotatable thrusters.

(B) For items not specified in this Guidance, the relevant requirements specified in **Pt 5** of the Rules apply.

(C) Propulsion systems of special type or others which have unavoidable but justifiable reasons precluding the due compliance with the requirements of this Guidance are to be examined in consideration of each design.

(2) Drawings and data to be submitted
Before the work is commenced, the manufacturers of propulsion systems are to submit drawing in triplicate and a copy of data specified below, to the Society for approval.

(A) Drawings

(a) General arrangement and sectional assembly (showing the materials and dimensions of various parts including nozzle ring)

(b) Details of shafting arrangement, gears, shaft couplings and coupling bolts

(c) Details of steering systems

(d) Specification of bearings

(e) Piping systems

(B) Data

(a) Data for strength calculation according to kind of main propulsion engine

(b) Torsional vibration calculation sheets of shafting

(c) Strength calculations for main component parts

(d) Operating manual

(3) Materials, constructions and strength

(A) Materials, constructions and strength of shafting arrangement, propellers, gears and steering systems are to be applied with appropriate modifications of the relevant requirements of **Ch 3, Ch 4** and **Ch 7** of the Rules.

(B) Materials, constructions and strength of piping systems and auxiliaries are to be applied with appropriate modifications of the relevant requirements of **Ch 6** of the Rules.

(4) Tests and inspections

(A) Tests and inspections of shafting arrangement, propellers, gears and steering systems are to be applied with appropriate modifications of the relevant requirements of **Ch 3** and **Ch 7** of the Rules.

(B) Tests and inspections of piping systems and auxiliaries are to be applied with appropriate modifications of the relevant requirements of **Ch 6** of the Rules.

(C) On-board tests and inspections

(a) Torsional vibration of shafting are to be applied with the requirements of **Ch 4, 103.** of the Rules.

(b) Operating tests of various parts are to be carried out according to operating manual.

Annex 5-2 Guidance for Calculation of Crankshaft Stress (1)

The direct calculation method of the local stress at crankpin fillet or crankjournal fillet of the crankshaft is as follows:

(1) Stress af fillet due to bending moment is to be obtained by the following formula:

$$\sigma_x = 1.08\alpha_{KB}\frac{M_W}{Z} \text{ --------------- } (1)$$

$$\sigma_y = 0.285\alpha_{KB}\frac{M_W}{Z} \text{ -------------- } (2)$$

where

σ_x : Axial stress due to bending moment at fillet

σ_y : Circumferential stress due to bending moment at fillet

α_{KB}: Stress concentration factor for bending, as shown in **Ch 2, 208. 2** (2) of the Guidance

Z : Section modules of crankpin or journal

M_W: Bending moment at the centre of the arm thickness, normal to the crankplane

(A) As external forces acting on the crankshaft, combustion pressure, and inertial forces of reciprocating and unbalanced rotating mass may only be considered. It is assumed that external force acts on the centre of crankpin bearing as a concentrated load, and the shaft is supported at the centre of each main bearing.

(B) Bending moment (M_i) at the support is to be determined by solving a set of simultaneous continuous beam equations taking account of the deflection of support due to reaction force. (See **Fig 5.1**)

Calculation is to be developed in such a way that at least one each span directly afore and abaft the crank throw under consideration are included.

$$\begin{aligned}
&\frac{3}{32}\frac{L_{i-1}^2}{L_i}M_{i-2}+\left\{L_i-\frac{2}{32}\frac{L_{i-1}^2}{L_i}\left(1+\frac{L_{i-1}}{L_i}\right)-\frac{3L_i}{32}\left(1+\frac{L_i}{L_{i+1}}\right)\right\}M_{i-1}\\
&+\left[2(L_i+L_{i+1})+\frac{3}{32}\left\{\frac{L_{i-1}^3}{L_i^2}+L_i\left(1+\frac{L_i}{L_{i+1}}\right)^2+L_{i+1}\right\}\right]M_i\\
&+\left[L_{i+1}-\frac{3}{32}\left\{\frac{L_i^2}{L_{i+1}}\left(1+\frac{L_i}{L_{i+1}}\right)+L_{i+1}\left(1+\frac{L_{i+1}}{L_{i+2}}\right)\right\}\right]M_{i+1}+\frac{3}{32}\frac{L_{i+1}^2}{L_{i+2}}M_{i+2}\\
&+\frac{3}{32}\left\{\frac{L_{i-1}^2}{L_i}\sum_j W_{i-1\times j}\,a_{i-1\times j}-L_i\left(1+\frac{L_i}{L_{i+1}}\right)\sum_j W_{ij}a_{ij}\right.\\
&+\frac{L_{i-1}^3}{L_i^2}\sum_j W_{ij}(L_i-a_{ij})+L_{i+1}\sum_j W_{i+1\times j}\,a_{i+1\times j}-\frac{L_i^2}{L_{i+1}}\\
&\left(1+\frac{L_i}{L_{i+1}}\right)\sum_j W_{i+1\times j}(L_{i+1}-a_{i+1\times j})+\frac{L_{i+1}^2}{L_{i+2}}\sum_j W_{ij}a_{ij}(L_i^2-a_{ij}^2)\\
&+\frac{1}{L_{i+1}}\sum_j W_{i+1\times j}a_{i+1\times j}(L_{i+1}-a_{i+1\times j})(2L_{i+1}-a_{i+1\times j})=0 \quad \text{------ } (3)
\end{aligned}$$

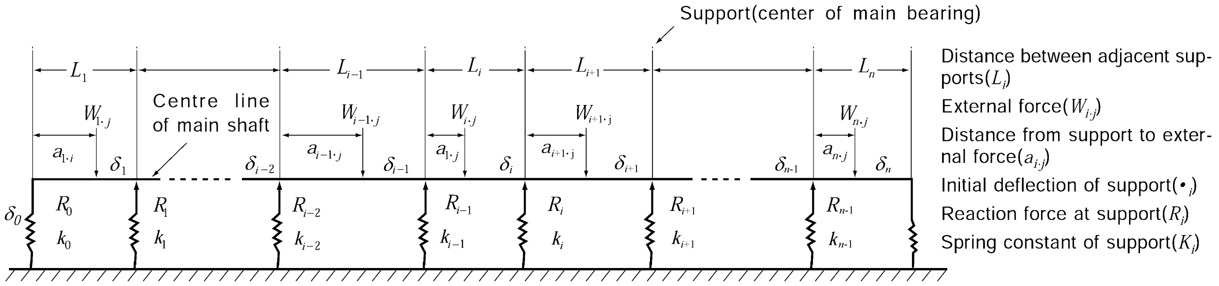


Fig 5.1 Continuous Beam

(C) Bending moment on the centre of crank web (M_W) is to be obtained by the following formulae: (see **Fig 5.2**)

$$M_{WFi} = \frac{L_i - l_{WFi}}{L_i} M_{i-1} + \frac{l_{WFi}}{L_i} M_i + l_W \sum_j \left(1 - \frac{a_{i\cdot j}}{L_i}\right) W_i$$

$$M_{WAi} = \frac{L_i - l_{WFi}}{L_i} M_{i-1} + \frac{l_{WFi}}{L_i} M_i + \left(L_i - l_{Wi} \sum_j \frac{a_{i\cdot j}}{L_i} W_i\right) \quad \text{--------------------} \quad (4)$$

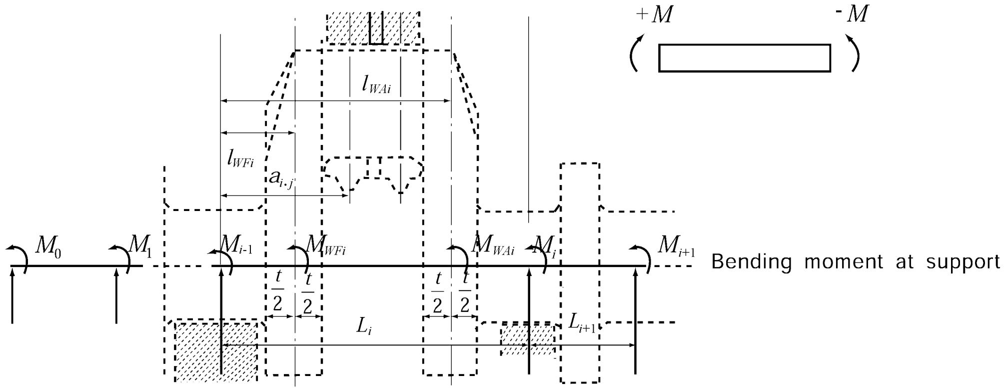


Fig 5.2 Bending Moment at Arbitrary Point

(2) The torsional stress at fillet due to twisting moment is to be obtained by the following formula:

$$\tau_f = \alpha_{KT} \frac{T}{Z_p} \quad \text{--------------------------} \quad (5)$$

where

τ_f : Torsional stress in fillet at the root of arms

α_{KT} : Stress concentration factor for torsion, as specified in **Ch 2, 208. 2** (2) of the Guidance

Z_P : Polar section modulus of crankpin or journal

T : Twisting moment acting on crankpin or journal, which is to be determined by summing up sequentially from the side on the free end. External forces to be considered are the same as in the case of bending moment.

(3) Principal stress is to be obtained by the following formula :

$$\left.\begin{matrix}\sigma_1\\ \sigma_2\end{matrix}\right\} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_f^2} \text{------ (6)}$$

$$\delta = \frac{1}{2} tan^{-1} \frac{2\tau_f}{\sigma_x - \sigma_u} \text{ ------------------------ (7)}$$

where

σ_1 : Maximum principal stress at fillet

σ_2 : Minimum principal stress at fillet

δ : Inclination of σ_1 against axial direction

(4) Single amplitude of equivalent stress σ_e is to be determined as follows.
The calculations specified in (1) through (3) are to be carried out for every 10° of crank angle; $\sigma_{resultont}$ is to be calculated by the following formula (8) through combining these values and the maximum value thus obtained is to be taken as the single amplitude of equivalent stress se of the crankthrow.

$$\sigma_{resultont} = \frac{1}{2}[\sigma_{1\theta I}\cos^2\theta - \sigma_{2\theta II}\sin^2(\theta + \delta_{\theta II} - \delta_{\theta I})] \text{------------------- (8)}$$

where

$$\theta = \frac{1}{2} tan^{-1} \frac{-2\sigma_{2\theta II}}{\sigma_{1\theta I} - \sigma_{2\theta II}} cot(\delta_{\theta II} - \delta_{\theta I})$$

$\sigma_{1\theta}$, σ_{θ} : σ_1 and δ obtained when shaft revolution angle is θ_I

$\sigma_{2\theta 1}$, $\sigma_{\theta 1}$: σ_2 and δ obtained when shaft revolution angle is θ_{II}

Annex 5-3 Guidance for Calculation of Crankshaft Stress (2)

1. General

(1) Scope
This Guidance is to apply to solid-forged and semi-built-up crankshafts of forged or cast steel, with one crankthrow between main bearings.

(2) Principles of calculation

(A) The design of crankshafts is based on an evaluation of safety against fatigue in the highly stressed areas.

(B) The calculation is based on the assumption that the areas exposed to highest stresses are as follows.

(a) Fillet transitions between the crankpin and web as well as between the journal and web

(b) Outlets of crankpin oil bores

(C) When journal diameter is equal or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.

(D) Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors, result in an equivalent alternating stress(uni-axial stress). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material. This comparison will show whether or not the crankshaft concerned is dimensioned adequately.

2. Calculation of Stresses

(1) Calculation of alternating stresses due to bending moments and radial forces

(A) Assumption

(a) The calculation of alternating stresses is based on a statically determined system, composed of a single crankthrow supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints(distance L_3, see **Fig 5.3** and **5.4**).

(b) The bending moments(M_{BR}, M_{BT}) are calculated in the relevant section based on triangular bending moment diagrams due to the radial component(F_R) and tangential component(F_T) of the connecting-rod force, respectively(see **Fig 5.3**).

(c) For crankthrows with two connecting-rods acting upon one crankpin, the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase(see **Fig 5.4**).

(d) Bending moments and radial forces acting in web

(i) The bending moment(M_{BRF}) and the radial force(Q_{RF}) are taken as acting in the centre of the solid web(distance L_1) and are derived from the radial component of the connecting-rod force.

(ii) The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crank web. This reference section results from the web thickness(W) and the web width(B)(see **Fig 5.5**).

(iii) Mean stresses are neglected.

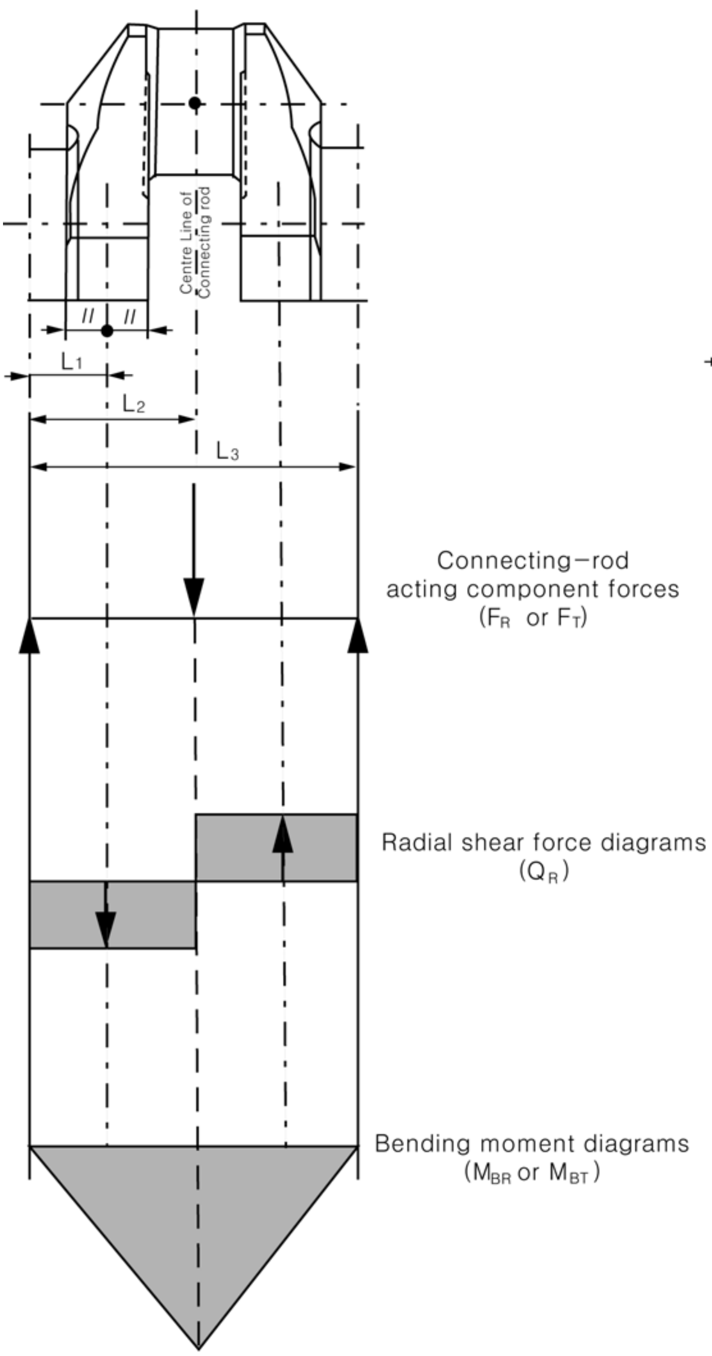


Fig 5.3 Crankthrow for in line engine

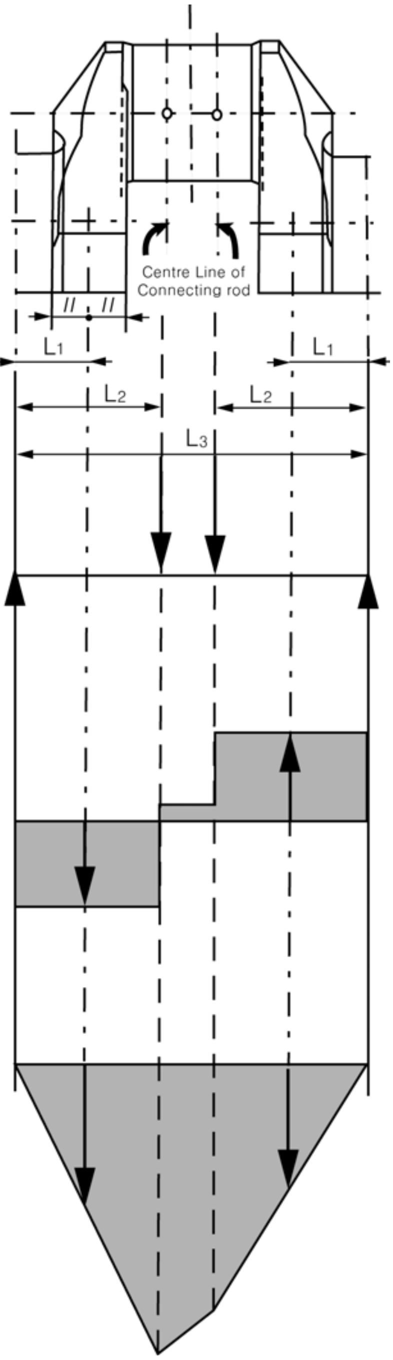
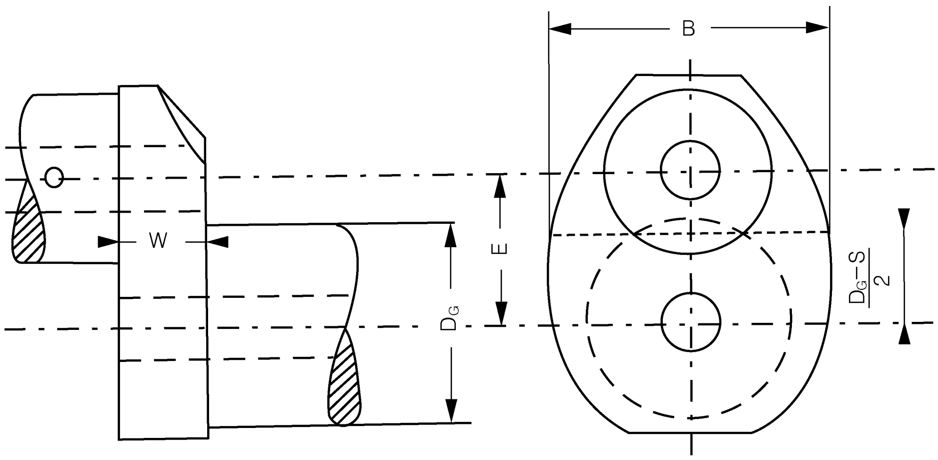


Fig 5.4 Crankthrow for Vee engine with 2 adjacent connecting-rods

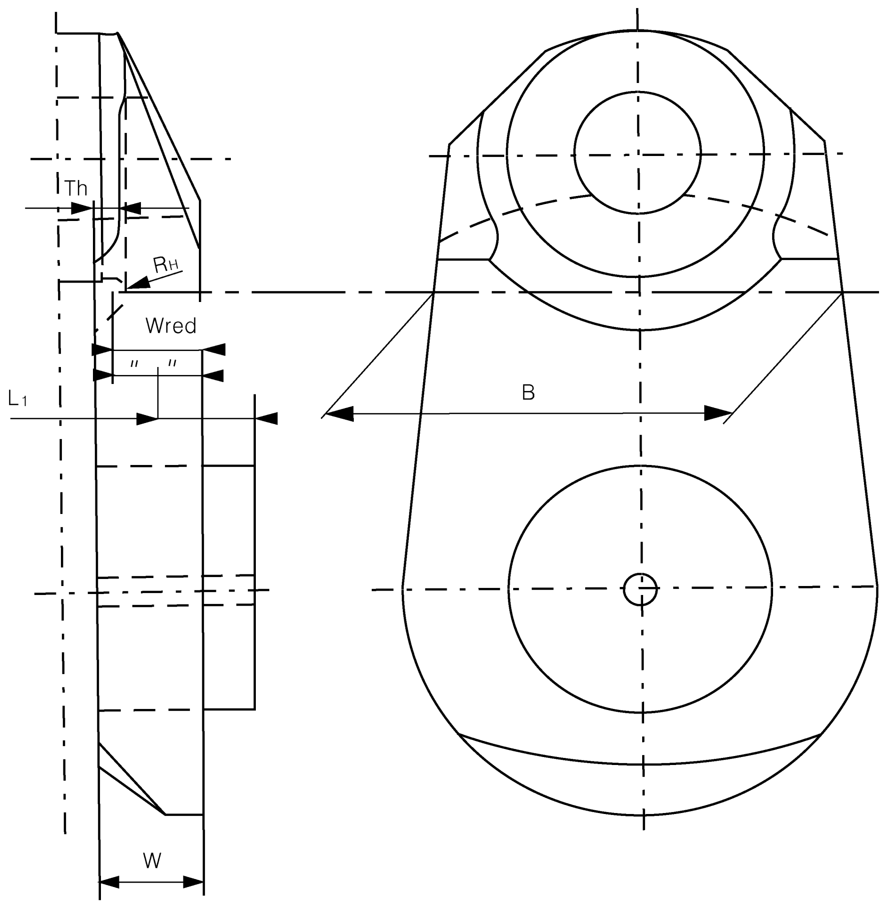
L_1 = Distance between main journal centre line and crankweb center(see also **Fig 5.5** for crankshaft without overlap)

L_2 = Distance between main journal centre line and connecting-rod centre

L_3 = Distance between two adjacent main journal centre lines



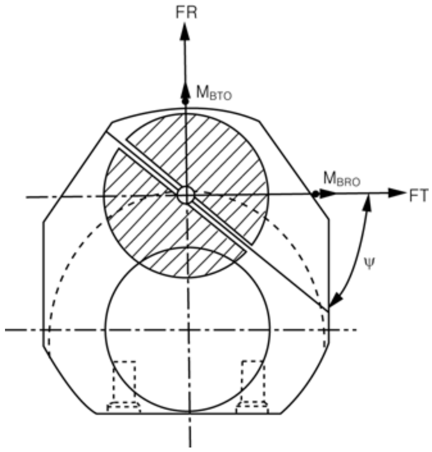
Overlapped crankshaft



Crankshaft without overlap

Fig 5.5 Reference area of crankweb cross section

(e) Bending acting in outlet of crankpin oil bore
(i) The two relevant bending moments are taken in the crankpin cross-section through the oil bore.
(ii) The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin.
(iii) Mean bending stresses are neglected.



M_{BRO} : is the bending moment of the radial component of the connecting-rod force

M_{BTO} : is the bending moment of the tangential component of the connecting-rod force

Fig 5.6 Crankpin section through the oil bore

(B) Nominal alternating bending and compressive stresses in web
(a) The methods of calculation are as follows.
(i) The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting-rod position will be calculated over one working cycle.
(ii) Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments (M_{BRF}, M_{BRO}, M_{BTO}) and radial forces(Q_{RF}) - as defined in (1) (A) (d) and (e) - will then be calculated.
(iii) In case of V-type engines, the bending moments - progressively calculated from the gas and inertia forces - of the two cylinders acting on one crankthrow are superposed according to phase. Different designs (forked connecting-rod, articulated-type connecting-rod or adjacent connecting-rods) shall be taken into account.
(iv) Where there are cranks of different geometrical configurations in one crankshaft, the calculation is to cover all crank variants.
(v) The decisive alternating values are to be calculated according to the following formula:

$$X_N = \pm \frac{1}{2}[X_{\max} - X_{\min}]$$

where

X_N : Alternative values considered as alternating force, moment or stress

$X_{\max}$: Maximum value within one working cycle

$X_{\min}$: Minimum value within one working cycle

(b) The calculation of the nominal alternating bending and compressive stresses is as follows.

$$\sigma_{BFN} = \pm \frac{M_{BRFN}}{W_{eqw}} \cdot 10^3 \cdot K_e$$

$$\sigma_{QFN} = \pm \frac{Q_{RFN}}{F} \cdot K_e$$

where,

σ_{BFN} : Nominal alternating bending stress related to the web (N/mm^2)

M_{BRFN} : Alternating bending moment related to the center of the web (N • m) (see **Fig 5.3** and **5.4**)

$$M_{BRFN} = \pm \frac{1}{2}\left[M_{BRF_{\max}} - M_{BRF_{\min}}\right]$$

W_{eqw} : Section modulus related to cross-section of web (mm^3)

$$W_{eqw} = \frac{B \cdot W^2}{6}$$

K_e : Empirical factor considering to some extent the influence of adjacent crank and bearing restraint with : K_e = 0.8 for 2-stroke engines
K_e = 1.0 for 4-stroke engines

σ_{QFN} : Nominal alternating compressive stress due to radial force related to the web (N/mm^2)

Q_{RFN} : Alternating radial force related to the web (N) (see **Fig 5.3** and **5.4**)

$$Q_{RFN} = \pm \frac{1}{2}\left[Q_{RF_{\max}} - Q_{RF_{\min}}\right]$$

F : Area related to cross-section of web (mm^2)

$$F = B \cdot W$$

(c) The calculation of nominal alternating bending stress in outlet of crankpin oil bore is as follows.

$$\sigma_{BON} = \pm \frac{M_{BON}}{W_e} \cdot 10^3$$

where,

σ_{BON} : Nominal alternating bending stress related to the crank pin diameter (N/mm^2)

M_{BON} : Alternating bending moment calculated at the outlet of crankpin oil bore ($N \cdot m$)

$$M_{BON} = \pm \frac{1}{2}\left[M_{BO_{\max}} - M_{BO_{\min}}\right]$$

$M_{BO} = (M_{BTO} \cdot \cos\psi + M_{BRO} \cdot \sin\psi)$ and ψ (°) angular position (see **Fig 5.6**)

W_e : Section modulus related to cross-section of axially bored crankpin (mm^3)

$$W_e = \frac{\pi}{32}\left[\frac{D^4 - D_{BH}^4}{D}\right]$$

(C) Alternating bending stresses in fillets

(a) The calculation of stresses for the crankpin fillet is to be carried out as the following formula:

$$\sigma_{BH} = \pm(\alpha_B \cdot \sigma_{BFN})$$

where,

σ_{BH} : Alternating bending stress in crankpin fillet (N/mm^2)

α_B : Stress concentration factor for bending in crankpin fillet (see **3.** (2))

(b) The calculation of stresses for the journal fillet is to be carried out as the following formula(not applicable to semi-built crankshaft):

$$\sigma_{BG} = \pm((\beta_B \cdot \sigma_{BFN} + \beta_Q \cdot \sigma_{QFN})$$

where,

σ_{BG} : Alternating bending stress in journal fillet (N/mm^2)

β_B : Stress concentration factor for bending in journal fillet (see **3.** (2))

β_Q : Stress concentration factor for compression due to radial force in journal fillet (see **3**. (2))

(D) The calculation of alternating bending stresses in outlet of crankpin oil bore is to be carried out as the following formula:

$$\sigma_{BO} = \pm(\gamma_B \cdot \sigma_{BON})$$

where,

σ_{BO} : alternating bending stress in outlet of crankpin oil bore (N/mm^2)

γ_B : stress concentration factor for bending in crankpin oil bore (see **3.** (2))

(2) Alternating torsional stresses

(A) Nominal alternating torsional stresses

(a) The maximum and minimum torques are to be ascertained for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0.5th order up to and including the 12th order for 4-stroke cycle engines.

(b) The allowance must be made for the damping that exists in the system and for unfavourable conditions such as misfiring in one of the cylinders.

(c) The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

(d) Where barred speed ranges are necessary, they shall be arranged so that satisfactory operation is possible despite their existence. There are to be no barred speed ranges above a speed ratio of $\lambda \geq 0.8$ for normal firing conditions.

(e) The nominal alternating torsional stress in every mass point, which is essential to the assessment, results from the following equation.

$$\tau_N = \pm \frac{M_{TN}}{W_P} \cdot 10^3$$

where,

τ_N : Nominal alternating torsional stress referred to crankpin or journal (N/mm^2)

M_{TN} : Maximum alternating torque (N · m)

$$M_{TN} = \pm \frac{1}{2}\left[M_{T_{\max}} - M_{T_{\min}}\right]$$

$M_{T_{\max}}$: Maximum value of the torque (N • m)

$M_{T_{\min}}$: Minimum value of the torque (N • m)

W_P : Polar section modulus related to cross-section of axially bored crankpin or bored journal (mm^3)

$$W_P = \frac{\pi}{16}\left(\frac{D^4 - D_{BH}^4}{D}\right) \text{ 또는 } W_P = \frac{\pi}{16}\left(\frac{D_G^4 - D_{BG}^4}{D_G}\right)$$

(f) For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in further calculations is the highest calculated value, according to above method, occurring at the most torsionally loaded mass point of the crankshaft system. Where barred speed ranges exist, the torsional stresses within these ranges are not to be considered for assessment calculations.

(g) The approval of crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by engine manufacturer).

(B) Alternating torsional stresses in fillets and outlet of crankpin oil bore

(a) The calculation of stresses for the crankpin fillet is to be carried out as the following equation.

$$\tau_H = \pm(\alpha_T \cdot \tau_N)$$

where,

τ_H : Alternating torsional stress in crankpin fillet (N/mm^2)

α_T : Atress concentration factor for torsion in crankpin fillet (see **3.** (2))

τ_N : Nominal alternating torsional stress related to crankpin diameter (N/mm^2)

(b) The calculation of stresses for the journal fillet is to be carried out as the following equation(not applicable to semi-built crankshafts).

$$\tau_G = \pm(\beta_T \cdot \tau_N)$$

where,

τ_G : Alternating torsional stress in journal fillet N/mm^2(N/mm^2)

β_T : Stress concentration factor for torsion in journal fillet (see **3.** (2))

τ_N : Nominal alternating torsional stress related to journal diameter (N/mm^2)

(c) The calculation of stresses for the outlet of the crankpin oil bore is to be carried out as the following equation.

$$\sigma_{T0} = \pm(\gamma_T \cdot \tau_N)$$

where,

σ_{T0} : Alternating stress in outlet of crankpin oil bore due to torsion (N/mm^2)

γ_T : Stress concentration factor for torsion in outlet of crankpin oil bore (see **3.** (2))

τ_N : Nominal alternating torsional stress related to crankpin diameter (N/mm^2)

3. Stress Concentration Factors

(1) General

(A) The stress concentration factors are evaluated by means of the formulae according to **3.** (2), (3) and (4) applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. It must be noticed that stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil hole. All formulae are based on investigations of FVV (Forschungsvereinigung Verbrennungskraftmaschinen) for fillets and on investigations of ESDU(Engineering Science Data Unit) for oil holes(All crank dimensions necessary for the calculation of stress concentration factors are shown in **Fig 5.7**).

(B) The stress concentration factor for bending (α_B, β_B) is defined as the ratio of the maximum equivalent stress (VON MISES) - occurring in the fillets under bending load - to the nominal bending stress related to the web cross-section (see **Fig 5.9**).

(C) The stress concentration factor for compression (β_Q) in the journal fillet is defined as the ratio of the maximum equivalent stress (VON MISES) - occurring in the fillet due to the radial force - to the nominal compressive stress related to the web cross-section.

(D) The stress concentration factor for torsion (α_T, β_T) is defined as the ratio of the maximum equivalent shear stress - occurring in the fillets under torsional load - to the nominal torsional stress related to the axially bored crankpin or journal cross-section(see **Fig 5.9**).

(E) The stress concentration factors for bending(γ_B) and torsion(γ_T) are defined as the ratio of the maximum principal stress - occurring at the outlet of the crankpin oil-hole under bending and torsional loads - to the corresponding nominal stress related to the axially bored crankpin cross section(see **Fig 5.10**).

(F) When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their analysis method have to be submitted to the Society in order to demonstrate their equivalence to present rules evaluation.

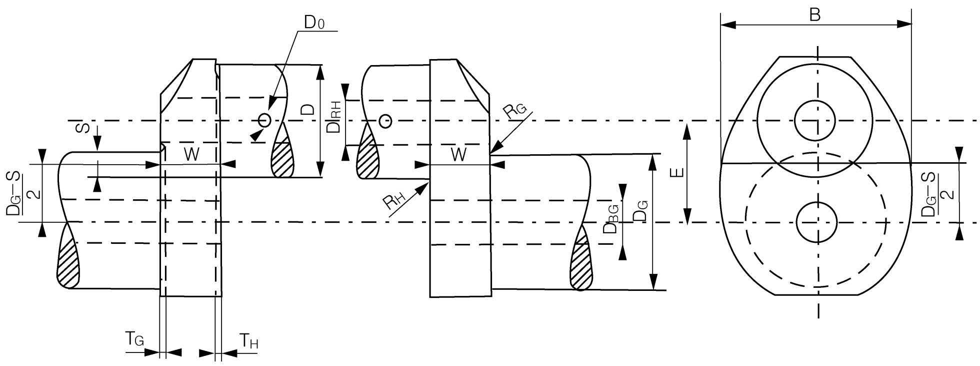


Fig 5.7 Crank dimension

(G) The symbols mean as follows.

D : Crankpin diameter (mm)
D_{RH} : Diameter of axial bore in crankpin (mm)
D_O : Diameter of oil bore in crankpin (mm)
R_H : Fillet radius of crankpin (mm)
T_H : Recess of crankpin fillet (mm)
D_G : Journal diameter (mm)
D_{BG} : Diameter of axial bore in journal (mm)
R_G : Fillet radius of journal (mm)
T_G : Recess of journal fillet (mm)
E : Pin eccentricity (mm)
S : Pin overlap (mm)

$$S = \frac{D+D_G}{2} - E$$

W : web thickness (mm)

B : web width (mm)

In the case of 2 stroke semi-built crankshafts :

- When $T_H > R_H$, the web thickness(W) must be considered as equal to :

$$W_{red} = W-(T_H-R_H)$$ [refer to **Fig 5.5**]

- Web width(B) must be taken in way of crankpin fillet radius centre according to **Fig 5.5.**

The following related dimensions will be applied for the calculation of stress concentration factors in :

Crankpin fillet	Journal fillet
$r = R_H/D$ (0.03 $\leq r \leq$ 0.13)	$r = R_G/D$ (0.03 $\leq r \leq$ 0.13)
$s = S/D$ ($s \leq$ 0.5) $w = W/D$ (0.2 $\leq w \leq$ 0.8) (crankshafts with overlap) W_{red}/D (0.2 $\leq w \leq$ 0.8) (crankshafts without overlap) $b = B/D$ (1.1 $\leq b \leq$ 2.2) $d_o = D_O/D$ (0 $\leq d_O \leq$ 0.2) $d_G = D_{BG}/D$ (0 $\leq d_G \leq$ 0.8) $d_H = D_{BH}/D$ (0 $\leq d_H \leq$ 0.8) $t_H = T_H/D$ $t_G = T_G/D$	

(H) Low range of s can be extended down to large negative values provided that :
- If calculated f(recess) < 1 then the factor f(recess) is not to be considered (f(recess) = 1)
- If s < -0.5 then $f(s, w)$ and $f(r, s)$ are to be evaluated replacing actual value of s by -0.5.

(2) Stress concentration factors for crankpin fillet

(A) The stress concentration factor for bending(α_B) is given as follows.

$$\alpha_B = 2.6914 \cdot f(s,w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(recess)$$

where,

$$f(s,w) = -4.1883 + 29.2004 \cdot w - 77.5925 \cdot w^2 + 91.9454 \cdot w^3 - 40.0416 \cdot w^4$$
$$+ (1-s) \cdot (9.5440 - 58.3480 \cdot w + 159.3415 \cdot w^2 - 192.5846 \cdot w^3 + 85.2916 \cdot w^4)$$
$$+ (1-s)^2 \cdot (-3.8399 + 25.0444 \cdot w - 70.5571 \cdot w^2 + 87.0328 \cdot w^3 - 39.1832 \cdot w^4)$$

$$f(w) = 2.1790 \cdot w^{0.7171}$$

$$f(b) = 0.6840 - 0.0077 \cdot b + 0.1473 \cdot b^2$$

$$f(r) = 0.2081 \cdot r^{-0.5231}$$

$$f(d_G) = 0.9993 + 0.27 \cdot d_G - 1.0211 \cdot d_G^2 + 0.5306 \cdot d_G^3$$

$f(d_H) = 0.9978 + 0.3145 \cdot d_H - 1.5241 \cdot d_H^2 + 2.4147 \cdot d_H^3$

$f(recess) = 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$

(B) The stress concentration factor for torsion(α_T) is given as follows.

$$\alpha_T = 0.8 \cdot f(r,s) \cdot f(b) \cdot f(w)$$

where,

$f(r,s) = r^{-0.322 + 0.1015(1-s)}$

$f(b) = 7.8955 - 10.654 \cdot b + 5.3482 \cdot b^2 - 0.85 \cdot b^3$

$f(w) = w^{-0.145}$

(3) Stress concentration factors for journal fillet (not applicable to semi-built crankshaft)

(A) The stress concentration factor for bending (β_B) is given as follows.

$$\beta_B = 2.7146 \cdot f_B(s,w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r) \cdot f_B(d_G) \cdot f_B(d_H) \cdot f(recess)$$

where,

$f_B(s,w) = -1.7625 + 2.9821 \cdot w - 1.527 \cdot w^2 + (1-s) \cdot (5.1169 - 5.8089 \cdot w + 3.1391 \cdot w^2)$
$+ (1-s)^2 \cdot (-2.1567 + 2.3297 \cdot w - 1.2952 \cdot w^2)$

$f_B(w) = 2.2422 \cdot w^{0.7548}$

$f_B(b) = 0.5616 + 0.1197 \cdot b + 0.1176 \cdot b^2$

$f_B(r) = 0.1908 \cdot r^{-0.5568}$

$f_B(d_G) = 1.0012 - 0.6441 \cdot d_G + 1.2265 \cdot d_G^2$

$f_B(d_H) = 1.0022 - 0.1903 \cdot d_H + 0.0073 \cdot d_H^2$

$f(recess) = 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$

(B) The stress concentration factor for compression (β_Q) due to the radial force is given as follows.

$$\beta_Q = 3.0128 \cdot f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r) \cdot f_Q(d_H) \cdot f(recess)$$

where,

$f_Q(s) = 0.4368 + 2.1630 \cdot (1-s) - 1.5212 \cdot (1-s)^2$

$f_Q(w) = \dfrac{w}{0.0637 + 0.9369 \cdot w}$

$f_Q(b) = -0.5 + b$

$f_Q(r) = 0.5331 \cdot r^{-0.2038}$

$f_Q(d_H) = 0.9937 - 1.1949 \cdot d_H + 1.7373 \cdot d_H^2$

$f(recess) = 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$

(C) The stress concentration factor for torsion (β_T) is given as follows.

(a) If the diameters and fillet radii of crankpin and journal are the same.

$$\beta_T = \alpha_T$$

(b) If crankpin and journal diameters and/or radii are of different sizes.

$$\beta_T = 0.8 \cdot f(r,s) \cdot f(b) \cdot f(w)$$

where,

$f(r,s)$, $f(b)$ and $f(w)$ are to be determined in accordance with item 3. (2), however, the radius of the journal fillet is to be related to the journal diameter :

$$r = \frac{R_G}{D_G}$$

(D) The stress concentration factor for outlet of crankpin oil bore

(a) The stress concentration factor for bending(γ_B) is given as follows.

$$\gamma_B = 3 - 5.88 \cdot d_O + 34.6 \cdot d_O^2$$

(b) The stress concentration factor for torsion(γ_T) is given as follows.

$$\gamma_T = 4 - 6 \cdot d_O + 30 \cdot d_O^2$$

4. Additional Bending Stresses σ_{add}

(1) In addition to the alternating bending stresses in fillets further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying additional bending stresses(σ_{add}) as given by table.

Type of engine	σ_{add} (N/mm^2)
Crosshead engines	± 30 (1)
Trunk piston engines	± 10

NOTES : The additional stress of ± 30 N/mm^2 is composed of two components.
1) An additional stress of ± 20 N/mm^2 resulting from axial vibration
2) An additional stress of ± 10 N/mm^2 resulting from misalignment/bedplate deformation

(2) It is recommended that a value of ± 20 N/mm^2 be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine/shafting/gearing/propeller) are not available.

(3) Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

5. Calculation of Equivalent Alternating Stress

(1) General

(A) In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a Von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location(see **Fig 5.9**). As a result the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet by using the Von Mises criterion.

(B) At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased(see **Fig 5.10**).

(C) The above two different ways of equivalent stress evaluation both lead to stresses which may be compared to the same fatigue strength value of crankshaft assessed according to Von Mises criterion.

(2) The equivalent alternating stress for the crankpin fillet is calculated in accordance with the formulae given.

$$\sigma_v = \pm \sqrt{(\sigma_{BH}+\sigma_{add})^2 + 3 \cdot \tau_H^2}$$

(3) The equivalent alternating stress for the journal fillet is calculated in accordance with the formulae given.

$$\sigma_v = \pm \sqrt{(\sigma_{BG}+\sigma_{add})^2 + 3 \cdot \tau_G^2}$$

(4) The equivalent alternating stress for the outlet of crankpin oil bore is calculated in accordance with the formulae given.

$$\sigma_V = \pm \frac{1}{3}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{T0}}{\sigma_{BO}}\right)^2}\right]$$

where,

σ_V : equivalent alternating stress (N/mm^2)

for other parameters **see 2**, (1) (C), **2.** (2) (B) and **4**.

6. Fatigue Strength

(1) Fatigue strength related to the crankpin diameter

The fatigue strength related to the crankpin diameter may be evaluated by means of the following formula.

$$\sigma_{DW} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot D^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_X}}\right]$$

where,

$R_X = R_H$ (in the fillet area)

$R_X = D_O/2$ (in the oil bore area)

(2) Fatigue strength related to the journal diameter

(A) The fatigue strength related to the journal diameter may be evaluated by means of the following formula.

$$\sigma_{DW} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot D_G^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_G}}\right]$$

where,

σ_{DW} : Allowable fatigue strength of crankshaft (N/mm^2)

K : Factor for different types of crankshafts without surface treatment. Values greater than 1 are only applicable to fatigue strength in fillet area.

= 1.05 for continuous grain flow forged or drop-forged crankshafts

= 1.0 for free form forged crankshafts (without continuous grain flow)

Factor for cast steel crankshafts with cold rolling treatment in fillet area

= 0.93 for cast steel crankshafts manufactured by companies using approved cold rolling process of the Society

σ_B : minimum tensile strength of crankshaft material (N/mm^2)

For other parameters **see 3.** (1). However, for calculation purposes R_H, R_G or R_X are to be taken as not less than 2 mm.

(B) When a surface treatment process is applied, it must be approved by the Society.

(C) Surfaces of the fillet, the outlet of the oil bore and inside the oil bore(down to a minimum depth equal to 1.5 times the oil bore diameter) shall be smoothly finished.

(3) Alternative method

(A) The fatigue strength of the crankshaft can be determined by experiment based either on full size crankthrow (or crankshaft) or on specimens taken from a full size crankthrow.

(B) The experimental procedure for fatigue evaluation of specimens and fatigue strength of crankshaft assessment have to be submitted for approval to the Society(method, type of specimens, number of specimens(or crankthrows), number of tests, survival probability, confidence number,.⋯).

7. Acceptability Criteria

The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison has to be carried out for the crankpin fillet, the journal fillet, the outlet of crankpin oil bore and is based on the formula.

$$Q=\frac{\sigma_{DW}}{\sigma_V} \geq 1.15$$

where,

Q : Acceptability factor

8. Calculation of Shrink-fits of Semi-built crankshaft

(1) General

(A) All crank dimensions necessary for the calculation of the shrink-fit are shown in **Fig 5.8.**

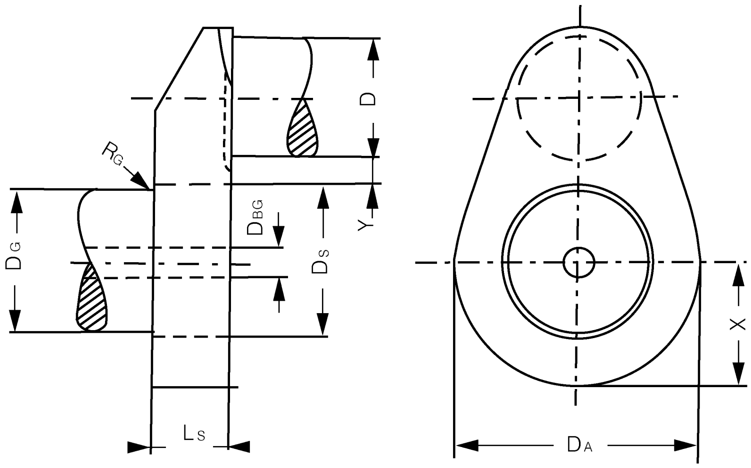


Fig 5.8 Crankthrow of semi-built crankshaft

(B) the symbols means as follows.

D_A : Outside diameter of web or twice the minimum distance(X) between centre-line of journals and outer contour of web, whichever is less (mm)

D_S : Shrink diameter (mm)

D_G : Journal diameter (mm)

D_{BG} : Diameter of axial bore in journal (mm)

L_S : Length of shrink-fit (mm)

R_G : Fillet radius of journal (mm)

Y : Distance between the adjacent generating lines of journal and pin (mm)

- $Y \geq 0.05 \cdot D_S$
- Where Y is less than $0.1 \cdot D_S$ special consideration is to be given to the effect of the stress due to the shrink-fit on the fatigue strength at the crankpin fillet.

(C) Respecting the radius of the transition from the journal to the shrink diameter, the following should be complied with :

$$R_G \geq 0.015 \cdot D_G$$

and

$$R_G \geq 0.5 \cdot (D_S - D_G)$$

where the greater value is to be considered.

(D) The actual oversize(Z) of the shrink-fit must be within the limits $Z_{\min}$ and $Z_{\max}$ calculated in accordance with **8.** (3) and (4).

(E) In the case where **8.** (2) condition cannot be fulfilled then **8.** (3) and **8.** (4) calculation methods of $Z_{\min}$ and $Z_{\max}$ are not applicable due to multizone-plasticity problems. In such case $Z_{\min}$ and $Z_{\max}$ have to be established based on FEM calculations.

(2) Maximum permissible hole in the journal pin

(A) The maximum permissible hole diameter in the journal pin is calculated in accordance with the following formula:

$$D_{BG} = D_S \cdot \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{\max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{sp}}}$$

S_R : Safety factor against slipping, however a value not less than 2 is to be taken unless documented by experiments.

$M_{\max}$: A bsolute maximum value of the torque($M_{T_{\max}}$) in accordance with **2.** (2) (A) (N • m)

μ : Coefficient for static friction, however a value not greater than 0.2 is to be taken unless documented by experiments.

σ_{SP} : Minimum yield strength of material for journal pin (N/mm^2)

(B) This condition serves to avoid plasticity in the hole of the journal pin.

(3) Necessary minimum oversize of shrink-fit

The necessary minimum oversize is determined by the greater value calculated according to the following formula:

$$Z_{\min} \geq \frac{\sigma_{SW} \cdot D_S}{E_m}$$

$$Z_{\min} \geq \frac{4000}{\mu \cdot \pi} \cdot \frac{S_R \cdot M_{\max}}{E_m \cdot D_S \cdot L_S} \cdot \frac{1 - Q_A^2 \cdot Q_S^2}{(1 - Q_A^2) \cdot (1 - Q_S^2)}$$

where,

$Z_{\min}$: Minimum oversize (mm)

E_m : Young's modulus (N/mm^2)

σ_{SW} : Minimum yield strength of material for crank web (N/mm^2)

Q_A : Web ratio, $Q_A = \frac{D_S}{D_A}$

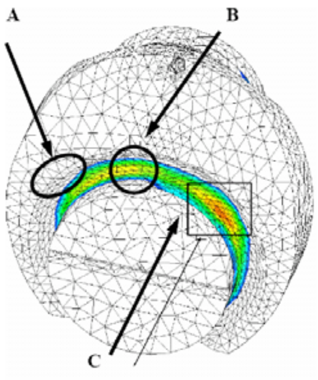
Q_S : Shaft ratio, $Q_S = \frac{D_{BG}}{D_S}$

(4) Maximum permissible oversize of shrink-fit

(A) The maximum permissible oversize is calculated according to the following formula:

$$Z_{\max} \leq D_S \bullet \left(\frac{\sigma_{SW}}{E_m} + \frac{0.8}{1000} \right)$$

(B) This condition serves to restrict the shrinkage induced mean stress in the fillet.



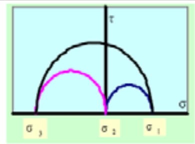
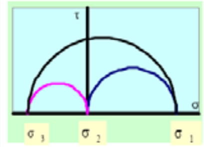
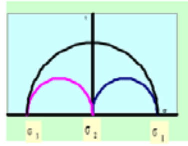
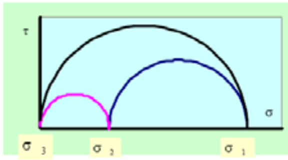
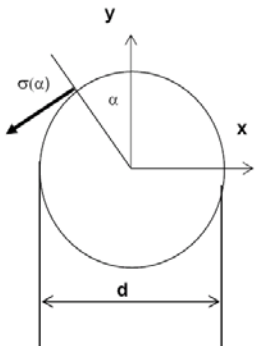
Loading	Stress	Max $\|\|\sigma_3\|\|$	Max σ_1	
Torsional loading	Location of maximal stresses	A	C	B
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	 $\|\|\sigma_3\|\| > \sigma_1$	 $\sigma_1 > \|\|\sigma_3\|\|$	 $\sigma_1 \approx \|\|\sigma_3\|\|$
	Equivalent stress and S.C.F.	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ $S.C.F. = \frac{\tau_{equiv}}{\tau_n}$ for α_T, β_T		
Bending loading	Location of maximal stresses	B	B	B
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$			$\sigma 2 \neq 0$
	Equivalent stress and S.C.F.	$\sigma_{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 . \sigma_2}$ $S.C.F. = \frac{\sigma_{equiv}}{\sigma_n}$ for $\alpha_B, \beta_B, \beta_Q$		

Fig 5.9 Definition of Stress Concentration Factors in crankshaft fillets



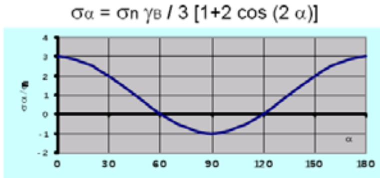
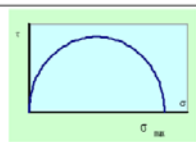
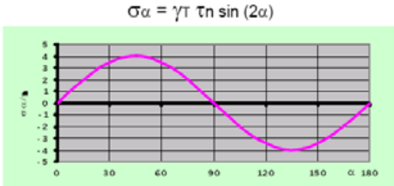
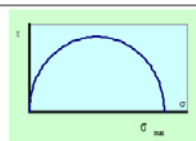
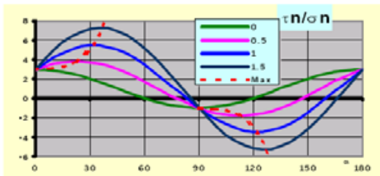
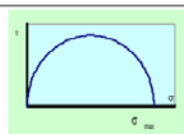
Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's circle diagram
Tension	$\begin{bmatrix} \sigma_n & 0 \\ 0 & 0 \end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3 \, [1+2\cos(2\alpha)]$ 	 $\gamma_B = \sigma_{max} / \sigma_n$ for $\alpha = k\pi$
Shear	$\begin{bmatrix} 0 & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \gamma_T \tau_n \sin(2\alpha)$ 	 $\gamma_T = \sigma_{max} / \tau_n$ for $\alpha = \frac{\pi}{4} + k\frac{\pi}{2}$
Tension + shear	$\begin{bmatrix} \sigma_n & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_B}{3}\sigma_n \left\{1 + 2\left[\cos(2\alpha) + \frac{3}{2}\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\sin(2\alpha)\right]\right\}$ 	 $\sigma_{max} = \frac{\gamma_B}{3}\sigma_n \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\right)^2}\right]$ for $\alpha = \frac{1}{2}\mathrm{tg}^{-1}\left(\frac{3\gamma_T\tau_n}{2\gamma_B\sigma_n}\right)$

Fig 5.10 Stress Concentration factors and distribution at the edge of oil drillings

Annex 5-4 Strength Calculation for Gears of Power Transmission Systems

1. General

(1) Application

This Guidance is to apply to enclosed gear used for transmission system which transmit power from main propulsion machinery and prime movers driving generators and essential auxiliaries(excluding auxiliary machinery for specific use etc,).

(2) Basic principles

(A) The methods for calculation of strength of gears specified in this Guidance deal with surface durability(pitting) and tooth root bending strength.

(B) All influence factors related to strength are defined regarding their physical interpretation. Some of the influence factors are determined by the gear geometry or have been established by conventions. Other factors, which are approximations, can be calculated according to methods acceptable to the Society.

2. Symbols and units

a : Center distance (mm)

b : Common facewidth (mm)

$b_{1,2}$: Facewidth of pinion, wheel (mm)

C_r : Tooth mesh stiffness (mean total mesh stiffness per unit face width) (N/mm • μm)

d : Reference diameter (mm)

$d_{1,2}$: Reference diameter of pinion, wheel (mm)

$d_{a1,2}$: Tip diameter of pinion, wheel (mm)

$d_{b1,2}$: Base diameter of pinion, wheel (mm)

$df_{1,2}$: Root diameter of pinion, wheel (mm)

$d_{W1,2}$: Working diameter of pinion, wheel (mm)

F_t : Nominal tangential load (N)

F_{bt} : Nominal tangential load on base cylinder in the transverse section (N)

F_β : Total tooth alignment deviation (mm)

$F_{\beta x}$: Actual longitudinal tooth flank deviation before running (mm)

$F_{\beta y}$: Actual longitudinal tooth flank deviation after running (mm)

F_m : Nominal tangential tooth load (N)

f_{pb} : Maximum base pitch deviation of wheel (μm)

f_{pt} : Face pitch deviation (μm)

f_{ma} : Tooth flank misalignment due to manufacturing errors (mm)

f_{sh} : Tooth flank misalignment due to wheel and pinion deflections (mm)

h : Total depth of tooth (mm)

hF : Bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact (mm)

m_n : Nominal module (mm)

m_t : Transverse module (mm)

$n_{1,2}$: Rotational speed of pinion, wheel (rpm)

P : Maximum continuous power transmitted by the gear set (kW)

R_a : Surface roughness (mm)

R_z : Mean peak to-valley roughness of tooth root fillets (μm)

$R_{z1,2}$: Mean peak to-valley roughness of tooth root fillets for pinion, wheel after running (μm)

R_{z100} : Mean peak to-valley roughness of tooth root fillets with relative radius of curvature 10 mm at the pitch of center distance ρ=100 mm
q_s : Notch parameter
sF_n : Root fillet radius in the critical section (mm)
$T_{1,2}$: Torque in way of pinion, wheel (N • m)
u : Gear ratio
V : Linear speed at pitch diameter (m/s)
$x_{1,2}$: Addendum modification coefficient of pinion, wheel
y_α : Running in base pitch allowance (μm)
$y_{\alpha 1,2}$: Running in base pitch allowance of pinion, wheel (mm)
y_β : Running in allowance (μm)
z : Number of teeth
$z_{1,2}$: Number of teeth of pinion, wheel
z_n : Virtual number of teeth
$z_{n1,2}$: Virtual number of teeth of pinion, wheel
α_n : Nominal pressure angle at reference cylinder (degree)
α_t : Transverse pressure angle at ref. cylinder (degree)
α_{tw} : Transverse pressure angle at working pitch cylinder (degree)
αFen : Pressure angle at the outer point of single tooth pair contact in the normal section (degree)
β : Helix angle at reference diameter (degree)
β_b : Helix angle at base diameter (degree)
ε_α : Transverse contact ratio
ε_β : Overlap ratio
ε_γ : Total contact ratio
ρF : Root fillet radius in the critical section (mm)
σ_b : Tensile strength (N/mm^2)
φ_p : Allowance value

3. Geometrical definitions

$z_2, a, d_2, d_{a2}, d_{b2}$ and d_{w2} are positive for external gearing, and are negative for internal gearing. u is positive for external gears, and is negative for internal gears. The absolute value of the gear ratio, defined as follows, is always greater or equal to the unity.

$$u = z_2/z_1 = d_{w2}/d_{w1} = d_2/d_1$$

The pinion is defined as the gear with the smaller number of teeth.In the equation of surface durability b is the common facewidth on the pitch diameter. In the equation of tooth root bending stress b_1 and b_2 are the facewidth at the respective tooth roots.

$\tan \alpha_t = \tan a_n / \cos \beta$

$\tan \beta_b = \tan \beta \cos \alpha_t$

$d = z m_n / \cos \beta$

$d_b = d \cos \alpha_t = d_w \cos \alpha_{tw}$

$a = 0.5(d_{w1} + d_{w2})$

$z_n = z / (\cos^2 \beta_b \cos \beta)$

$m_t = m_n / \cos \beta$

$inv\, \alpha = \tan \alpha - \pi \alpha / 180 (\alpha = \text{degree})$

$inv\, \alpha_{tw} = inv\, \alpha_t + 2 \tan \alpha_n (x_1 + x_2) / (z_1 + z_2)$

$$\varepsilon_a = \frac{0.5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0.5\sqrt{d_{a2}^2 - d_{b2}^2} - a sin a_{tw}}{\pi m_n \cos\alpha_t / \cos\beta}$$

(the positive sign is used for external gears, the negative sign for internal gears)

$\varepsilon_\beta = b sin \beta / p m_n$

(for double helix, b is to be taken as the width of one helix)

$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$

$v = d_{1,2} n_{1,2} /$ 19,099

4. Nominal tangential load, F_t

The nominal tangential load is calculated directly from the maximum continuous power transmitted by the gear set by means of following equations.

$F_t = 2{,}000\, T_{1,2} / d_{1,2}$ (N)

$T_{1,2} = 9{,}549 P / n_{1,2}$

5. General influence factors

(1) Application factor, K_A
The application factor accounts for dynamic overloads from sources external to the gearing, and is defined as the ratio between the maximum repetitive cyclic torque applied to the gear set and the nominal rated torque, and is in accordance with the **Table 5.3.** However, where the calculation sheets or data are submitted or the factor is measured actually, the value may be applied according to the discretion of the Society.

(2) Load sharing factor, K_γ
The load sharing factor which accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicycle, double helix, etc.), is defined as the ratio between the maximum load through an actual path and the evenly shared load, and is in accordance with the **Table 5.4.** However, where the calculation sheets or data are submitted or the factor is measured actually, the value may be applied according to the discretion of the Society.

Table 5.3 Application Factor, K_A

Driving engine	Construction or method of connection	K_A
Main propulsion	Diesel engine with hydraulic or electromagnetic slip coupling	1.00
	Diesel engine with high elasticity coupling	1.30
	Diesel engine with other couplings	1.50
Auxiliary	Electric motor, diesel engine with hydraulic or electromagnetic slip coupling	1.00
	Diesel engine with high elasticity coupling	1.20
	Diesel engine with other couplings	1.40

Table 5.4 Load sharing factor

Planetary gears	K_γ
up to 3	1.0
4	1.2
5	1.3
6	1.4

(3) Dynamic factor, K_V
The dynamic factor which accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other, is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t K_A K_\gamma$), and can be calculated as follows.
(A) Application
(a) Steel gears of heavy rims sections
(b) $F_t/b > 150$ N/mm
(c) $Z_1 < 50$
(d) Running speed in the subcritical range
(i) for helical gears: $(vz_1)/100 < 14$
(ii) for spur gears: $(vz_1)/100 < 10$
(iii) others: $(vz_1)/100 < 3$
(B) Calculation formula
(a) Helical gears
(i) For overlap ratio $(\varepsilon_\beta) > 1$
The dynamic factor is obtained from **Fig 5.11**
(ii) For overlap ratio $(\varepsilon_\beta) < 1$
The dynamic factor is obtained from the formula

$$K_V = K_{V2} - \varepsilon_\beta (K_{V2} - K_{V1})$$

K_{V1} : K_V value for helical gears, given by **Fig 5.11**
K_{V2} : K_V value for spurl gears, given by **Fig 5.12**
(b) Spur gears
The dynamic factor is obtained from **Fig 5.12**
(c) The dynamic factor can also be determined as follows.

$$K_V = 1 + K_1 (vz_1)/100$$

K_1 : Values specified in the **Table 5.5**

(C) Where the gears other than those applied with (A), The dynamic factor is the value according to the calculation sheets or data submitted to the Society and recognized appropriateness by the Society.

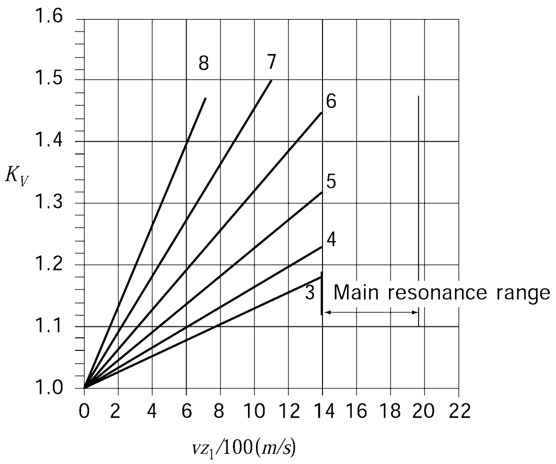


Fig 5.11 Dynamic Factor for Helical Gear. ISO Grades of Accuracy 3-8

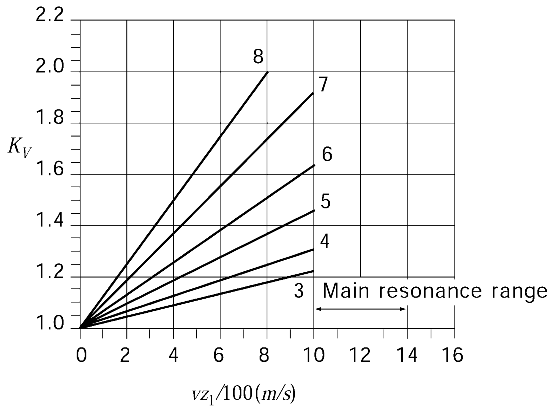


Fig 5.12 Dynamic Factor for Spur Gear. ISO Grades of Accuracy 3-8

Table 5.5 Values of K_1

Kind of gear	K_1 (*ISO* 1328 grades of accuracy)					
	3*	4*	5*	6*	7*	8*
Spur gear	0.022	0.030	0.043	0.062	0.092	0.125
Helical gear	0.0125	0.0165	0.0230	0.0330	0.0480	0.070

NOTE
* ISO grades of accuracy according to *ISO* 1328. In case of mating gears with different grades of accuracy the grade corresponding to the lower accuracy is to be used.

(4) Face load distribution factors $K_{H\beta}, K_{F\beta}$

(A) The face load distribution factors, $K_{H\beta}$, for contact stress, $K_{F\beta}$, for tooth root bending stress, account for the effect of non-uniform distribution of load across the facewidth. $K_{H\beta}$ and $K_{F\beta}$ are defined as follows:

$$K_{H\beta} = \frac{Maximum\ load\ per\ unit\ facewidth}{Mean\ load\ per\ unit\ facewidth}$$

$$K_{F\beta} = \frac{Maximum\ bending\ stress\ at\ tooth\ root\ per\ unit\ facewidth}{Mean\ bending\ stress\ at\ tooth\ root\ per\ unit\ facewidth}$$

(B) The face load distribution factors, $K_{H\beta}$, for contact stress, and $K_{F\beta}$ for tooth root bending stress, can be determined according to the method $C2$ outlined in the *ISO* 6336/1 standard. However, where the calculation sheets or data are submitted or the factors are measured actually, the values may be applied according to the discretion of the Society.

(a) The face load distribution factors for contact stress, $K_{H\beta}$

At the stage of design, $K_{H\beta}$, is the value calculated by the following formula under allowable manufacturing deviation.

(i) For $\frac{bF_{\beta y}C_{\gamma}}{2F_m} \geq 1$:

$$K_{H\beta} = \sqrt{\frac{2bF_{\beta y}C_\gamma}{F_m}}$$

(ii) For $\frac{bF_{\beta y}C_\gamma}{2F_m} < 1$:

$$K_{H\beta} = 1 + \frac{bF_{\beta y}C_\gamma}{2F_m}$$

where

$F_m = F_t F_A F_V F_g$

$F_{\beta y} = F_{\beta x} - y_b$

$F_{\beta x} = f_{sh} + f_{ma}$

$f_{sh} = (F_m/b) f_{sho}$

f_{sho} : The values specified in the following.

- For gears without helix correction and without end relief

f_{sho} = $23\,\gamma\,10^{-3}$ (μm mm/N)

- For gears without helix correction but with end relief

fsho = $16\,\gamma\,10^{-3}$ (μm mm/N)

$\gamma: = \left(\frac{b}{d_1}\right)^2$: For single helical and spur gears

$= 3\left(\frac{b}{2d_1}\right)^2$: For double helical gears

- The following minimum values are applicable, these also being the values where helix correction has been applied.
  - · For helical gears : 10 x 10^{-3} μm mm/N
  - · For spur gears : 5 x 10^{-3} μm mm/N

$$C_\gamma = \frac{0.8}{q} cos\beta(0.75\varepsilon_a + 0.25)$$

$$q = 0.4723 + \frac{0.15551}{z_{n1}} + \frac{0.25791}{z_{n2}} - 0.00635x_1 - 0.11654\frac{x_1}{z_{n1}} - 0.00193x_2 - 0.24188\frac{x_2}{z_{n2}} + 0.00529x_1^2 + 0.00182x_2^2$$

$$z_{n1,2} = \frac{z_{1,2}}{\cos\beta_b^2 \cos\beta}$$

(For internal gears, z_{n2} = ∞)

f_{ma} : The values specified in the following

- For gears without helix correction : F_β
- For gears with helix correction and with crown : 0.5 F_β
- For gears with helix correction and with end relief : 0.7 F_β

F_β: Where the face width is more than 160 mm, F_β is the values calculated accordance with the **Table 5.6.** However, in case where the face width is 160 mm or less, F_β is the value according to the calculation sheets or data submitted to the Society and recognized appropriateness by the Society.

y_β: The values specified in **Table 5.7.**

Table 5.6 Total Tooth Alignment Deviation

Grades according to *ISO* 1328	Total tooth alignment deviation F_β (μm)	Grades according to *ISO* 1328	Total tooth alignment deviation F_β (μm)
1	$0.315\sqrt{b}+1.6$	7	$1.25\sqrt{b}+6.3$
2	$0.40\sqrt{b}+2$	8	$2\sqrt{b}+10$
3	$0.50\sqrt{b}+2.5$	9	$3.15\sqrt{b}+16$
4	$0.63\sqrt{b}+3.15$	10	$5\sqrt{b}+25$
5	$0.80\sqrt{b}+4$	11	$8\sqrt{b}+40$
6	$1\sqrt{b}+5$	12	$12.5\sqrt{b}+63$

Table 5.7 Running in Allowance

Materials of gear and heat-treatment	y_b(mm)	Maximum limit of y_b (μm)		
		Range of circumferential speed v (m/s)		
		$v > 10$	$10 \geq v > 5$	$v \leq 5$
Quenched steels	$\frac{320}{\sigma_{Hlim}} F_{\beta x}$	$\leq \frac{12,800}{\sigma_{Hlim}}$	$\leq \frac{25,600}{\sigma_{Hlim}}$	-
cast irons	0.55 F_{bx}	$\leq$22	$\leq$45	-
Surface hardened steels	0.15 F_{bx}	-	$\leq$6	-

(b) The face load distribution factor, $K_{F\beta}$ for bending stress, is the value calculated by the following formula.

$$K_{F\beta} = K_{H\beta}{}^{N}$$

$$N = \frac{(b/h)^2}{1+(b/h)+(b/h)^2}$$

b/h : b_1/h_1 or b_2/h_2, whichever is the minimum value

(For gears with little load or without load acted on the end of face width, or for gears with end relief or crowning, $K_{F\beta}$ may be $K_{H\beta}$.)

(5) Transverse load distribution factors for surface durability and bending strength, $K_{H\alpha}$, $K_{F\alpha}$

The transverse load distribution factors, $K_{H\alpha}$, $K_{F\alpha}$ account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh, and can be determined according to method *B* outlined in *ISO* 6336. However, where the calculation sheets or data are submitted or the factors are measured actually, the values may be applied according to the discretion of the Society.

(A) For $\varepsilon_r < 2$, the transverse load distribution factors, $K_{H\alpha}$, $K_{F\alpha}$, are the values calculated by the following formula.

$$K_{F\alpha} = K_{H\alpha} = \frac{\varepsilon_r}{2}\left[0.9+0.4\frac{C_\gamma(f_{pb}-y_a)b}{F_{tH}}\right]$$

(B) For $\varepsilon_r \geq 2$, the transverse load distribution factors, $K_{H\alpha}$, $K_{F\alpha}$, are the values calculated by the following formula.

$$K_{F\alpha} = K_{H\alpha} = 0.9 + 0.4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left[\frac{C_\gamma(f_{pd} - y_\alpha)b}{F_{tH}}\right]$$

Where, in above formulas, $KH\alpha$ is determined by the values of $\frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2}$

For $K_{H\alpha} < 1$, $K_{H\alpha} = 1$
For $K_{F\alpha} > \varepsilon_r$, $K_{F\alpha} = \varepsilon_r$
For $K_{F\alpha} < 1$, $K_{F\alpha} = 1$

$F_{tH} = F_t K_A K_r K_v K_{HB}$ or $F_{tH} = F_t K_A K_r K_v K_{F\beta}$

C_γ : Same as (4) (B) (a) (ii)

f_{pb} : Maximum base pitch deviation of wheel and pinion (μm). Generally, when tip relief for the surface load of gear is applied using the base pitch deviation of wheel, f_{pb} is to be half of the allowance. However, where it is difficult to determine the value, the value calculated by the following formula may be applied.

$$f_{pb} = f_{pt}\cos\alpha$$

f_{pt} : The values calculated by **Table 5.8.**

y_α : The values calculated by **Table 5.9.** However, for pinion and wheel used different materials, the value calculated by the following formula is to be applied.

$$y_\alpha = 0.5(y_{\alpha 1} + y_{\alpha 2})$$

Table 5.8 Face Pitch Deviation

Grades according to ISO 1328	Face pitch deviation f_{pt} (μm)
1	0.063 φ_P + 0.8
2	0.10 φ_P + 1.25
3	0.16 φ_P + 2
4	0.25 φ_P + 3.15
5	0.40 φ_P+ 5
6	0.63 φ_P+ 8
7	0.90 φ_P + 11.2
8	1.25 φ_P + 16
9	1.8 φ_P + 22.4
10	2.5 φ_P + 31.5
11	3.55 φ_P + 45
12	5 φ_P + 63
NOTE: $\varphi_P = m_n + 0.25\sqrt{a}$	

Table 5.9 Running in Base Pitch Allowance

Materials of gear and hea-treatment	y_α(mm)	Maximum limit of y_α (mm)		
		Range of circumferential speed v (m/s)		
		v> 10	10 ≥ v> 5	v ≤ 5
Quenched steels Spheroidal graphite cast irons	$\frac{160}{\sigma_{Hlirn}} f_{pt}$	$\le \frac{6,400}{\sigma_{Hlirn}}$	$\le \frac{12,800}{\sigma_{Hlirn}}$	-
Surface hardened steels	0.75 f_{pb}	≤3		

6. Surface durability

The criterion for surface durability is based on the Hertz pressure on the operating pitch point or at the inner point of single pair contact. The contact stress σ_H is to be equal to or less than the permissible contact stress σ_{HP}.

(1) Basic equations

(A) Contact stress, σH

$$\sigma_H = \sigma_{Ho}\sqrt{K_A K_\gamma K_v K_{H\alpha} K_{H\beta}} \le \sigma_{HP}$$

$$\sigma_{Ho} = Z_B Z_N Z_E Z_\epsilon Z_\beta \sqrt{\frac{F_t}{d_1 b}\frac{u+1}{u}} \text{ : Pinion}$$

$$\sigma_{Ho} = Z_D Z_H Z_E Z_\epsilon Z_\beta \sqrt{\frac{F_t}{d_1 b}\frac{u+1}{u}} \text{ : Wheel}$$

where

σ_{Ho} : Basic value of contact stress for pinion and wheel

Z_B : Single pair mesh factor for pinion

Z_D : Single pair mesh factor for wheel

Z_H : Zone factor

Z_E : Elasticity factor

Z_ε : Contact ratio factor

Z_β : Contact ratio factor

F_t : Nominal tangential load

(B) Allowable contact stress, σ_{HP}

$$\sigma_{HP} : (\sigma_{Hlim}\, Z_n / S_H) Z_L Z_V Z_R Z_W Z_X$$

where

σ_{Hlim}: Endurance limit for contact stress

Z_n : Life factor for contact stress

Z_L : Lubrication factor

Z_V : Speed factor

Z_R : Roughness factor

Z_W : Hardness ratio factor

Z_X : Size factor for contact stress

S_H : Safety factor for contact stress

(2) Single pair mesh factor, Z_B, Z_D

Single pair mesh factors, Z_B for pinion and Z_D for wheel account for the influence on contact stresses of tooth flank curvature at the inner point of single pair contact in relation to zone factor, and can be determined as follows :

(A) For spur gears

Z_B = M_1 or 1, whichever is the larger value

Z_D = M_2 or 1, whichever is the larger value

$$M_1 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \left(\frac{2\pi}{z_1}\right)\right]\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - (\epsilon_\alpha - 1)\left(\frac{2\pi}{z_2}\right)\right]}}$$

$$M_2 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \left(\frac{2\pi}{z_2}\right)\right]\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\epsilon_\alpha - 1)\left(\frac{2\pi}{z_1}\right)\right]}}$$

(B) For helical gears

(a) When $\varepsilon_\beta \geq 1$

$$Z_B = Z_D = 1$$

(b) When $\varepsilon_\beta < 1$, Z_B and Z_D can be determined as follows;

$$Z_B = M_1 - \varepsilon_\beta(M_1 - 1),\ Z_B \geq 1$$
$$Z_D = M_2 - \varepsilon_\beta(M_2 - 1),\ Z_D \geq 1$$

M_1 and M_2 : same as (A)

(3) Zone factor, Z_H

The zone factor, Z_H accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and relates the tangential force at the reference cylinder to the normal force at the pitch cylinder, and can be determined as follows :

$$Z_H = \sqrt{\frac{2\cos\beta_b \cdot \cos\alpha_{tw}}{\cos^2\alpha_t \cdot \sin\alpha_{tw}}}$$

(4) Elasticity factor, Z_E

The elasticity factor is the value haven relevance with the material properties affeted contact stress, and can be determined as follows :

(A) For steel pinions and wheels (E = 206,000 N/mm^2, ν = 0.3)

$$Z_E = 189.8(\sqrt{N/mm^2})$$

E : Modulus of elasticity (N/mm^2)

ν : Poisson's ratio

(B) Where material used in pinions and wheels are other than steel, where the calculation sheets are submitted or the factor is measured actually, the value may be applied according to the discretion of the Society.

(5) Contact ratio factor, Z_ε

The contact ratio factor, Z_ε, account for the influence of transverse contact ratio and the overlap ratio on the specified surface load of gears, and can be determined as follows :

(A) For spur gear

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$$

(B) For helical gears

For $\varepsilon_\beta < 1$, $Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$

For $\varepsilon_\beta \geq 1$, $Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$

(6) Helix angle factor, Z_β
The helix angle factor, Z_β, account for the influence of helix angle on surface durability, allowing for such variable as the distribution of load along the lines of contact, and can be determined as follows :

$$Z_\beta = \sqrt{\cos\beta}$$

(7) Endurance limit for contact stress, σ_{Hlim}
The value of σ_{Hlim} can be regarded as the level of contact stress, and is the values calculated in accordance with the **Table 5.10.**

(8) Life factor, Z_n
The life factor, Z_n, account for the higher permissible contact stress in case a limited life (number of cycles)is required, and is 1. However, for reversing gears, intermediate gears or special purpose gears, the life factor, Z_n, may be of the value more than 1 according to the discretion of the Society.

Table 5.10 Endurance Limit for Contact Stress

Heat treatment		σ_{Hlim} (N/mm^2)
Pinion	Wheel	
Quenched	Quenched	0.46 σ_b + 255
Surface hardened	Through hardened	0.42 σ_b + 415
Carburized, nitrided or induction hardened	Induction hardened	0.88HV + 675
Carburized, nitrded or induction hardened	Soft bath nitrided (Tufftrided)	1,000
Carburized, nitrided	Nitrided	1,300
Carburized	Carburized	1,500
NOTE : HV; Vickers hardness		

(9) Influence factor on lubrication film, Z_L, Z_V, Z_R

(A) Lubricant factor, Z_L
The lubricant factor, Z_L, account for the influence of the type of lubricant and its viscosity, and can be determined as follows :

$$Z_L = C_{ZL} + \frac{4(1.0 - C_{ZL})}{(1.2 + 134/v_{40})^2}$$

C_{ZL} :The values specified in the following.

- For 850 < σ_{Hlim} < 1,200 N/mm^2

$$C_{ZL} = \frac{0.08(\sigma_{Hlim} - 850)}{350} + 0.83$$

- For $\sigma_{Hlim} \leq 850\ N/mm^2$, C_{ZL} = 0.83
- For $\sigma_{Hlim} \geq 1200\ N/mm^2$, C_{ZL} = 0.91

v_{40} : nominal kinematic viscosity of the oil at 40 ℃ (mm^2/s)

(B) Speed factor, Z_V
The speed factor, Z_V, can be calculated from the following equations :

$$Z_V = C_{ZV} + \frac{1(1.0 - C_{Zv})}{\sqrt{0.8 + 32/v}}$$

C_{ZV} : The values specified in the following.

- For 850 < σ_{Hlim} < 1,200 N/mm^2,

$$C_{ZV} = \frac{0.08(\sigma_{Hlim} - 850)}{350} + 0.85$$

- For $\sigma_{Hlim} \leq$ 850 N/mm^2, C_{ZV} = 0.85
- For $\sigma_{Hlim} \geq$ 1,200 N/mm^2, C_{ZV} = 0.93

(C) Roughness factor, Z_R

The roughness facto, Z_R, can be calculated from the following equations;

$$Z_R = \left(\frac{3}{R_{z100}}\right)^{C_{ZR}}$$

R_{z100} : The values calculated by the following formula

$$R_{z100} = R_z \cdot \sqrt[3]{\frac{10}{\rho_{red}}}$$

R_z : The values calculated by the following formula

$$R_z = \frac{R_{z1} + R_{z2}}{2}$$

$R_{z1,2}$: If the roughness stated is an R_a value the following approximate relationship can be applied.

$$R_{z1,2} = 6 R_{a1,2}$$

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2}$$

$$\rho 1,2 = 0.5 d_{b1,2} \tan \alpha_{tw}$$

C_{ZR} : The values specified in the following

- For 850 < σ_{Hlim} < 1,200 N/mm^2, C_{ZR} = 0.32 - 0.0002 σ_{Hlim}
- For $\sigma_{Hlim} \leq$ 850 N/mm^2, C_{ZR} = 0.150
- For $\sigma_{Hlim} \geq$ 1,200 N/mm^2, C_{ZR} = 0.080

(10) Hardness ratio factor, Z_W

The hardness ratio factor, Z_W, accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear with a smooth surface, and can be determined as follows. However, for HB < 130, Z_W = 1.2 will be used, and for HB > 470, Z_W = 1.0 will be used.

$$Z_W = 1.2 - \frac{HB - 130}{1,700}$$

HB : Brinell hardness of the softer material

(11) Size factor, Z_X

The size factor, Z_X, accounts for the influence of tooth dimensions on permissible contact stress, and is the values specified in the **Table 5.11.**

(12) Safety factor for contact stress, S_H
The safety factor for contact stress, S_H, is the values specified in the follows. However, where the calculation sheets or data are submitted or the factor is measured actually, the value may be applied according to the discretion of the Society.
(A) Main propulsion gears : 1.20
(B) Auxiliary gears : 1.15

Table 5.11 Size Factor, Z_X

Pinion heat treatment	Range	Z_X
Carburized and induction	$m_n \leq 10$	1.0
	$10 < m_n < 30$	1.05 - 0.005 m_n
	$m_n \geq 30$	0.9
Nitrided	$m_n \leq 7.5$	1.0
	$7.5 < m_n < 30$	1.08 - 0.01 m_n
	$m_n \geq 30$	0.75
Quenched	-	1.0

7. Bending strength

The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress, σ_F and the permissible root stress, σ_{FP} is to be calculated separately for the pinion and the wheel. σ_F is not to be exeed σ_{FP}.

(1) Basic equations

(A) Tooth root bending stress for pinion and wheel, σ_F (N/mm^2)

$$\sigma_F = (F_t/bm_n)\, Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\alpha} K_{F\beta} \leq \sigma_{FP}$$

Y_F : Tooth form factor
Y_S : Stress correction factor
Y_β : Helix angle factor
$K_A, K_\gamma, K_v, K_{F\alpha}, K_{F\beta}$: refer to **4.**

(B) Permissible tooth root bending stress for pinion and wheel, σ_{FP} (N/mm^2)

$$\sigma_{FP} = (\sigma_{FE} Y_d / S_F)\, Y_N Y_{\sigma relT} Y_{RelR} Y_X$$

σ_{FE}: Bending endurance limit
Y_d : Design factor
Y_N : Life factor
$Y_{\sigma relT}$: Relative notch sensitivity factor
Y_{RelT} : Relative surface factor
Y_X : Size factor
S_F : Safety factor for tooth root bending stress

(C) Tooth form factor, Y_F
The tooth form factor, Y_F, is the values calculated by the following formula. (refer to **Fig 5.13**)

$$Y_F = \frac{6\frac{hF}{m_n}cos\alpha Fen}{\left(\frac{sFn}{m_n}\right)^2 \cos\alpha_n}$$

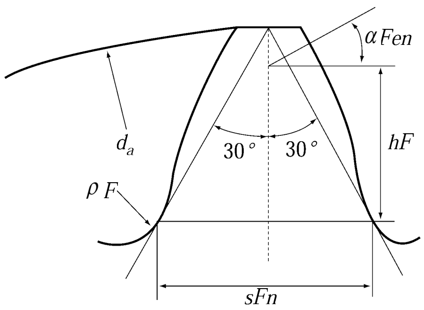


Fig 5.13 For the Calculation of hF, sFn and αFen

(D) Stress correction factor, Y_S

The stress correction factor, Y_S, is used to convert the nominal bending, and is the values calculated by the following formula. (having range of validity: $1 \leq q_s < 8$)

$$Y_S = (1.2 + 0.13L) q_s^{\frac{1}{\left(1.21 + \frac{2.3}{L}\right)}}$$

$$q_s = \frac{sFn}{2\rho F}$$

$$L = \frac{sFn}{hF}$$

(E) Helix angle factor, Y_B

The helix angle factor, Y_B, account for the influence of helix angle on bending stress, and is the values calculated by the following formula. However, 1.0 is substituted for ε_β when $\varepsilon_\beta > 1$, 30° is substituted for β when $\varepsilon_\beta > 30°$.

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

(F) Bending endurance limit, σ_{FE}

Bending endurance limit is to be in accordance with following formula;

$$\sigma_{FE} = 2 \bullet \sigma_{Flim}$$

σ_{Flim} is a factor for regarding the endurance limit of bending stress and to be determined in accordance with the **Table 5.12.**

(G) Design factor, Y_d

The design factor, Y_d, takes into account the influence of load reversing and shrinkfit prestressing on the tooth root strength. The design factor, Y_d, for load reversing, can be determined as follows. However, for shrinkfit, The design factor is the value according to the calculation sheets or data submitted to the Society and recognized appropriateness by the Society.

$Y_d = 1$: In general (For gears with uniformed load direction and not shrinkfit)

$Y_d = 0.9$: For gears with occasional part load in reverse direction, such as main wheel in reversing

Y_d = 0.7 : For idler gears

Table 5.12 Bending Endurance Limit, σ_{Flim}

Remarks	σ_{Flim} (N/mm^2)
Quenched carbon steels	$0.09\ \sigma_b + 150$
Quenched alloy steels	$0.1\ \sigma_b + 185$
Induction hardened steels	$0.35\ HV + 125$
Soft bath nitrided (tufftrided) steels	330
Gas nitrided steels	390
Carburized steels other than Cr Ni Mo steels	410
Carburized Cr-Ni-Mo steels	450
NOTE : HV ; Vicker's hardness	

(H) Life factor, Y_N

The life factor, Y_N, accounts for the higher tooth root bending stress permissible in case a limited life (number of cycles) is required, and is 1. However, for reversing gears, intermediate gears or special purpose gears, the life factor, Y_N, may be required the value more than 1 according to the discretion of the Society.

(I) Relative notch sensitivity factor, $Y_{\sigma relT}$

The relative notch sensitivity factor, $Y_{\sigma relT}$, indicates the extent to which the theoretically concentrated stress and can be determined as follows;

(a) For $1.5 < q_s < 4$

$$Y_{\sigma relT} = 1$$

(b) For $q_s \leq 1.5$ or $q_s \geq 4$

The relative notch sensitivity factor is the value accoring to the calculation sheets or data submitted to the Society and recognized appropriateness by the Society.

(J) Relative surface factor, Y_{RelT}

The relative surface factor, Y_{RelT}, takes into account the dependence of the root strength on the surface condition in the tooth root fillet, and is the values specified in the **Table 5.13.**

Table 5.13 Relative Surface Factor, Y_{RelT}

Y_{RelT}		Remarks
$R_z < 1$	$1 \leq R_z \leq 40$	
1.120	$1.675 - 0.53\,(R_z + 1)^{0.1}$	Carburized steels, Quenched steels ($\sigma_b \geq 800$N/mm^2)
1.070	$5.3 - 4.2\,(R_z + 1)^{0.01}$	Non-hardened steels ($\sigma_b < 800$N/mm^2)
1.025	$4.3 - 3.26\,(R_z + 1)^{0.001}$	Nitrided steels
NOTE : R_z : same as 6. (9) (C)		

(K) Size factor, Y_X

The size factor, Y_X, takes into account the decrease of strength with increasing size. and is the values caculated in accordance with the **Table 5.14.**

Table 5.14 Size Factor, Y_X

Remarks	Range	Y_X
-	$m_n \leq 5$	1
Non-hardened steels and Quenched steels	$5 < m_n < 30$	$1.03 - 0.06\, m_n$
	$m_n \geq 30$	0.85
Surface hardened steels	$5 < m_n < 25$	$1.05 - 0.010\, m_n$
	$m_n \geq 25$	0.8

(L) Safety factor for tooth root bending stress, S_F
The safety factor for tooth root bending stress, S_F, is the values specified in the following. However, the safety factor for tooth root bending stress is the value according to the calculation sheets or data submitted to the Society and recognized appropriateness by the Society.
(a) Main propulsion gears : 1.55
(b) Auxiliary gears : 1.40

Annex 5-5 Requirements of Equipment for Gas welding

1. Gas bottles and piping systems are to be satisfied with the following :

(1) Materials for piping systems are to comply with the standards recognized by the Society
(2) The Society may accept to use bottles manufactured according to the *Korean Government Rules for Safety Management of Gas* in spite of **Pt 5, Ch 5** of the Rules.
(3) For pipes, valves and pipe fittings, hydraulic tests may be omitted carrying.

2. Location of gas bottles is to be as specified below :

(1) Gas bottles are not to be located in machinery spaces of category A and accommodation spaces.
(2) Acetylene gas bottles are to be located in the area where the temperature can be maintained at 38 ℃ or less.
(3) Gas bottles are to be stored in areas not exposed to direct sun beam and also safe against waves, flame and high temperature.
(4) Except when located in a store room, gas bottles are to be placed in areas sufficiently distant from accommodation spaces and openings from which hydrocarbon gases, etc. are likely to flow out.
(5) Gas bottles are to be stored at areas of good ventilation free from stagnation of leaked gases.
(6) The store room of gas bottles is to have such a construction as to allow access only from the weather deck.

3. Gas bottles are to be so stored that the safety against ship motions and vibrations is ensured, and they are to stand upright as far as practicable. Acetylene bottles and oxygen bottles are to be store apart to the extent practicable. Further, means are to be provided so that gas bottles can be transferred quickly in case of fire.

4. In case where permanent piping is arranged between the gas bottles and working area, the following requirements are to be complied with :

(1) Steel pipes are to be used for acetylene gas piping, and steel or copper pipes are to be used for oxygen gas piping. Use of flexible joints made of non-metal material ensleeved in metal sheath in part of the piping may be accepted.
(2) No cast iron is to be used as the material of valves and pipe fittings. Further, no copper or copper alloy with a copper content exceeding 62 % is to be used as the material of valves and pipe fittings in the acetylene gas piping.
(3) The procedures of piping arrangement are to be as specified below :
  (A) Acetylene gas piping and oxygen gas piping are not to be led through the accommodation spaces and enclosed spaces which are susceptible to fire.
  (B) On acetylene gas piping and oxygen gas piping, stop valves are to be fitted at adequate locations of the penetrations through the casing of the store room and working area.
  (C) Joints between pipes and pipe fittings are to be of welded joint or flange joint as far as practicable.
  (D) For clear distinction of the acetylene gas piping system and oxygen gas piping system, the piping systems are to be provided with adequate means of identification.

5. In case where rubber hoses are used, the following apply:

(1) Hoses are to comply with *KS M* 6543 for acetylene gas and *KS M* 6557 for oxygen gas, or equivalent.
(2) The joint methods between rubber hose and permanently installed pipes are to comply with *KS B* 4604, or equivalent.

6. After completion of shipboard installation, piping systems are to be subjected to air-tightness test at a pressure of 1.25 times or more of the maximum working pressure of the pressure regulator (refer to *KS B* 4603).

Annex 5-6 Plastic Pipes

1. Application

(1) The requirements in this Annex apply to plastic pipes/piping systems on ships.
(2) Plastic pipes may be used for Class III piping system. Proposals for the use of plastic pipes in Class I and Class II piping system will be specially considered.
(3) The requirements in this Annex are not applicable to flexible pipes and hoses and mechanical couplings used in metallic piping systems.

2. Definitions

(1) Plastic(s) is both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.
(2) Fire endurance is the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

3. Materials

(1) PVC pipes and GRP pipes are to be those approved by the Society in accordance with "**Guidance for Approval of Manufacturing Process and Type Approval, etc.**" and adequate for their service conditions.
(2) Notwithstanding the requirement in (1), pipes complying with the recognized standards e.g. *Korean Industrial Standards* and equivalent standard having self-extinguishing property and adequate for their service condition may be used for drinking water pipes, domestic water pipes (including hot water pipes) and sanitary pipes within accommodation spaces and engine room and deck scuppers within the identical spaces.

4. General requirements

The specification of piping is to be in accordance with a recognised national or international standard approved by the Society. In addition, the following requirements apply:

(1) Strength
(A) The strength of the pipes is to be determined by a hydrostatic test failure pressure and collapse pressure of a pipe specimen under the following standard conditions. The hydrostatic test failure pressure and collapse pressure may be determined by testing or may be determined by a combination of testing and calculation., where deemed appropriate by the Society.

atmospheric pressure : 0.1 MPa
relative humidity : 30 %
fluid temperature : 25 ℃

(B) The strength of fittings and joints is to be not less than that of the pipes.
(C) The design pressure is to be specified with due regard for design temperatures in accordance with Manufacturer's recommendations.
(D) Internal pressure
The internal pressure of pipes is to be not lesser of the following, and is to be more than the design pressure of system intended to use the pipes.

$$P_{int} \le \frac{P_{sth}}{4} \text{ or } P_{int} \le \frac{P_{lth}}{2.5}$$

P_{int} : Internal Pressure
P_{sth} : Short-term hydrostatic test failure pressure
P_{lth} : Short-term hydrostatic test failure pressure (> 100,000 h)

(E) External pressure
External pressure is to be determined by the following.

$$P_{ext} \le \frac{P_{col}}{3}$$

P_{ext} : External pressure

P_{col} : Pipe collapse pressure. In no case is the collapse pressure to be less than 0.3 MPa.

The design external pressure is a sum of the vacuum inside the pipe and a head of liquid acting on the outside of the pipe.

(2) Axial strength

(A) The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

(B) In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition prescribed in (1) (D) above.

(3) Impact Resistance

(A) Plastic pipes and joints are to have a minimum resistance to impact in accordance with recognised national or international standards.

(B) After the test, the specimen is to be subjected to hydrostatic pressure equal to 2.5 times the design pressure for at least 1 hour.

(4) Temperature

(A) The design temperature depending on the working pressure is to be in accordance with Manufacturer's recommendations, but in each case it is to be at least 20 ℃ lower than the minimum heat distortion temperature of the pipe material, determined according to *ISO 75* method A, or equivalent.

(B) The minimum heat distortion temperature is to be not less than 80 ℃.

5. Requirements for pipes/piping systems depending on service and/or locations

(1) Fire endurance

(A) Pipes and their associated fittings whose integrity is essential to the safety of ships are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO Res A.753 (18).

(B) Depending on the capability of a piping system to maintain its strength and integrity, there exist three different levels of fire endurance for piping systems.

(a) Level 1(L1) : Piping having passed the fire endurance test specified in Appendix 1 of IMO Res. A. 753 (18) for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard.

(b) Level 2(L2) : Piping having passed the fire endurance test specified in Appendix 1 of IMO Res. A 753 (18) for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard.

(c) Level 3(L3) : Piping having passed the fire endurance test specified in Appendix 2 of IMO Res. A .753 (18) for a duration of a minimum of 30 minutes in the wet condition is considered to meet level 3 fire endurance standard.

(C) Permitted use of piping depending on fire endurance, location and piping system is given in **Table 5.15.**

(2) Flame spread

(A) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels and ducts are to have low surface flame spread characteristics not exceeding average values specified in **Ch 3, 2604. 3** of the **"Guidance for Approval of Manufacturing Process and Type Approval, etc."**.

(B) Surface flame spread characteristics are to be determined using the procedure specified in **Ch 3, 2604. 3** of the **"Guidance for Approval of Manufacturing Process and Type Approval, etc."** with regard to the modifications due to the curvilinear pipe surfaces as listed in Appendix 3 of IMO Resolution A.753 (18).

(C) Surface flame spread characteristics may also be determined using the text procedures given in national or international standards.

(3) Fire protection coatings

(A) Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

(a) The pipes are generally to be delivered from the manufacturer with the protective coating on.

(b) The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.

(c) In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations, and elasticity are to be taken into account.

(d) The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

(4) Electrical conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed $1 \times 10^5\ \Omega/\mathrm{m}$.

(5) Durability against chemicals

The pipes are to be resistant to any chemical substances expected during service.

6. Installation

(1) Supports

(A) Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe Manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected. Combination of loads is to be considered.

(B) Each support is to evenly distribute the load of the pipe and its contents over the full width of the support. Measures are to be taken to minimize wear of the pipes where they contact the supports.

(C) Heavy components in the piping system such as valves and expansion joints are to be independently supported.

(2) Expansion

(A) Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

(a) The difference in the coefficients of thermal expansion;

(b) deformations of the ship's hull and its structure.

(B) When calculating the thermal expansions, account is to be taken of the system working temperature and the temperature at which assembly is performed.

(3) External loads

(A) When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowances are to include at least the force exerted by a load (person) of 100 *kg* at mid-span on any pipe of more than 100 mm nominal outside diameter.

(B) Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with **4** (1) above, may be increased upon the demand of the Society taking into account the conditions encountered during service on board ships.

(C) Pipes are to be protected from mechanical damage where necessary.

(4) Strength of connections

(A) The strength of connections is to be not less than that of the piping system in which they are installed.

(B) Pipes may be assembled using adhesive-bonded, welded, flanged or other joints.

(C) Adhesives, when used for joint assembly, are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

(D) Tightening of joints is to be performed in accordance with Manufacturer's instructions.

Table 5.15 Fire Endurance Requirements Matrix

Piping system	Location										
	A	B	C	D	E	F	G	H	I	J	K
	Machinery spaces of category A	Other machinery spaces & pump rooms	Cargo pump rooms	Ro/Ro cargo holds	Other dry cargo holds	Cargo tanks	Fuel oil tanks	Ballast water tanks	Cofferdams void spaces pipe tunnel & ducts	Accommodation service & control spaces	Open decks
Cargo (Flammable cargos, f.p ≤ 60 °C)											
1. Cargo lines	NA	NA	L1	NA	NA	O	NA	O[10]	O	NA	L1[2]
2. Crude oil washing lines	NA	NA	L1	NA	NA	O	NA	O[10]	O	NA	L1[2]
3. Vent lines	NA	NA	NA	NA	NA	O	NA	O[10]	O	NA	X
Inert gas											
4. Water seal effluent lines	NA	NA	O[1]	NA	NA	O[1]	O[1]	O[1]	O[1]	NA	O
5. Scrubber effluent lines	O[1]	O[1]	NA	NA	NA	NA	NA	O[1]	O[1]	NA	O
6. Main lines	O	O	L1	NA	NA	NA	NA	NA	O	NA	L1[6]
7. Distribution lines	NA	NA	L1	NA	NA	O	NA	NA	O	NA	L1[2]
Flammable liquids (f.p > 60 °C)											
8. Cargo lines	X	X	L1	X	X	NA[3]	O	O[10]	O	NA	L1
9. Fuel oil	X	X	L1	X	X	NA[3]	O	O	O	L1	L1
10. Lubricating oil	X	X	L1	X	X	NA	NA	NA	O	L1	L1
11. Hydraulic oil	X	X	L1	X	X	O	O	O	O	L1	L1
Seawater[1]											
12. Bilge main & branches	L1[7]	L1[7]	L1	X	X	NA	O	O	O	NA	L1
13. Fire main water spray	L1	L1	L1	X	NA	NA	NA	O	O	NA	L1
14. Foam system	L1	L1	L1	NA	NA	NA	NA	NA	O	L1	L1
15. Sprinkler system	L1	L1	L3	X	NA	NA	NA	O	O	L3	L3
16. Ballast	L3	L3	L3	L3	X	O[10]	O	O	O	L2	L2
17. Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	O	O	NA	L2
18. Tank cleaning services fixed machines	NA	NA	L3	NA	NA	O	NA	O	O	NA	L3[2]
19. Non-essential system	O	O	O	O	O	NA	O	O	O	O	O
Freshwater											
20. Cooling water essential services	L3	L3	NA	NA	NA	NA	O	O	O	L3	L3
21. Condensate return	L3	L3	L3	O	O	NA	NA	NA	O	O	O
22. Non-essential system	O	O	O	O	O	NA	O	O	O	O	O
Sanitary/Drain/Scuppers											
23. Deck drains (internal)	L1[4]	L1[4]	NA	L1[4]	O	NA	O	O	O	O	O
24. Sanitary drains (internal)	O	O	NA	O	O	NA	O	O	O	O	O

Table 5.15 Fire Endurance Requirements Matrix (continued)

Piping system	Location										
	A	B	C	D	E	F	G	H	I	J	K
	Machinery spaces of category A	Other machinery spaces & pump rooms	Cargo pump rooms	Ro/Ro cargo holds	Other dry cargo holds	Cargo tanks	Fuel oil tanks	Ballast water tanks	Cofferdams void spaces pipe tunnel & ducts	Accommodation service & control spaces	Open decks
25. Scuppers and discharges (overboard)	O[1,8]	O[1,8]	O[1,8]	O[1,8]	O[1,8]	O	O	O	O	O[1,8]	O
Sounding/Air											
26. Watertanks/ dry spaces	O	O	O	O	O	O[10]	O	O	O	O	O
27. Oil tanks (f.p > 60 °C)	X	X	X	X	X	X[3]	O	O[10]	O	X	X
Miscellaneous											
28. Control air	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	NA	O	O	O	L1[5]	L1[5]
29. Service air (non-essential)	O	O	O	O	O	NA	O	O	O	O	O
30. Brine	O	O	NA	O	O	NA	NA	NA	O	O	O
31. Auxiliary low pressure steam (≤ 7 MPa)	L[2]	L[2]	O[9]	O[9]	O[9]	O	O	O	O	O[9]	O[9]

Abbreviations :

- L1 Fire endurance test (IMO Resolution A.753(18), Appendix 1) in dry conditions, 60 min.
- L2 Fire endurance test (IMO Resolution A.753(18), Appendix 1) in dry conditions, 30 min.
- L3 Fire endurance test (IMO Resolution A.753(18), Appendix 2) in wet conditions, 30 min.
- 0 No fire endurance test required
- NA Not applicable
- X Metallic materials having a melting point greater than 925 °C

Footnotes :

1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).
2. Remote closing valves to be provided at the cargo tanks.
3. When cargo tanks contain flammable liquids with f.p. > 60 °C, "O may replace "NA or "X".
4. For drains serving only the space concerned, "O may replace "L1"
5. When controlling functions are not required by statutory requirements or guidelines, "O may replace "L1"
6. For pipe between machinery space and deck water seal, "O may replace "L1"
7. For passenger vessels, "X is to replace "L1".
8. Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the International Convention on Load Lines, 1966, are to be "X throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.
9. For essential services, such as fuel oil tank heating and ship's whistle, "X is to replace "O".
10. For tankers where compliance with paragraph 3 (f) of regulation 13F of Annex I of MARPOL 73/78 is required, "NA is to replace "O".

Table 5.15 Fire Endurance Requirements Matrix (continued)

Location definitions - A (Machinery spaces of category A) : Machinery spaces of category A as defined in SOLAS* regulation II-2/3.19. - B (Other machinery spaces and pump rooms) : Spaces, other than category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces. - C (Cargo pump rooms) : Spaces containing cargo pumps and entrances and trunks to such spaces. - D (Ro-ro cargo holds) : Ro-Ro cargo holds are Ro-Ro cargo spaces and special category spaces as defined in SOLAS* regulation II-2/3.14 and 3.18. - E (Other dry cargo holds) : All spaces other than Ro-Ro cargo holds used for non-liquid cargo and trunks to such spaces. - F (Cargo tanks) : All spaces used for liquid cargo and trunks to such spaces. - G (Fuel oil tanks) : All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces. - H (Ballast water tanks) : All spaces used for ballast water and trunks to such spaces. - I (Cofferdams, voids, etc.) : Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments. - J (Accommodation, service) : Accommodation spaces, service spaces and control stations as defined in SOLAS * regulation II-2/3.10, 3.12, 3.22. - K (Open decks) : Open deck spaces as defined in SOLAS* regulation II-2/26.2.2. (5). * SOLAS 74 as amended by the 1978 SOLAS Protocol and the 1981 and 1983 amendments (consolidated text).

(5) Installation of Conductive Pipes
(A) Piping system for fluids with conductivity less than 1,000 pico siemens per metre (pS/m) such as refined products and distillates use is to be made of conductive pipes.
(B) Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed $1 \times 10^6\ \Omega$. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.
(C) After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection.
(6) Application of Fire Protection Coatings
(A) Fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance prescribed **5.** (3) above, after performing hydrostatic pressure tests of the piping system.
(B) The fire protection coatings are to be applied in accordance with Manufacturer's recommendations, using a procedure approved in each particular case.
(7) Penetration of divisions
(A) Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that the fire endurance is not impaired. These arrangements are to be tested in accordance with fire test procedures for "A" and "B" bulkheads specified in **Ch 3, 2604. 2** of the "**Guidance for Approval of Manufacturing Process and Type Approval, etc.**".
(B) When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained.
(C) If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.
(8) Control during installation
(A) Installation is to be in accordance with the Manufacturer's guidelines.
(B) Prior to commencing the work, joining techniques are to be approved by the Society.
(C) The tests and examinations specified in this Annex are to be completed before shipboard piping installation commences.

(D) The personnel performing this work are to be properly qualified and certified to the satisfaction of the Society.
(E) The procedure of making bonds is to include:
(a) Materials used,
(b) Tools and fixtures,
(c) Joint preparation requirements,
(d) Cure temperature,
(e) Dimensional requirements and tolerances, and
(f) Tests acceptance criteria upon completion of the assembly.
(F) Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be requalified.

(9) Bonding procedure quality testing
(A) A test assembly is to be fabricated in accordance with the procedure to be qualified and it is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.
(B) When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor 2.5 times the design pressure of the test assembly, for not less than one hour. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.
(C) Selection of the pipes used for test assembly, is to be in accordance with the following:
(a) When the largest size to be joined is 200 A nominal outside diameter, or smaller, the test assembly is to be the largest piping size to be joined.
(b) When the largest size to be joined is greater than 200 A nominal outside diameter, the size of the test assembly is to be either 200 A or 25 % of the largest piping size to be joined, whichever is greater.
(D) Bonding operator performance qualification tests
When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies prescribed in (A) through (C), the size and number of which are to be as required above.

(10) Shop tests
(A) Plastic pipes except for piping systems specified in **3** (2) above are to be subjected to the following tests and measurements of dimension after the manufacturer. The number of test specimens, testing procedures, results, procedures of measurement of dimension and tolerance are to be complied with the manufacturer's approved by the Society.
(a) Tensile test
(b) Hydrostatic test of each pipe/fitting(A hydrostatic pressure is to be not less than 1.5 times the nominal pressure). Alternatively, where pipe/fittings are not employing hand lay up techniques and are manufactured in accordance with *Korean Industrial Standards or equivalent* by manufacturer who has an effective quality system accepted by this Society, the hydrostatic pressure test may be carried out in accordance with the standards.
(c) Outside diameter and wall thickness measurements
(d) Ascertainment of uniform quality and no harmful defect
(f) Electric conductivity test(only for pipes required for electric conductivity by specified in **5** (4) above)
(g) Depending upon the intended application, the Society may require the pressure testing of each pipe/fitting.
(B) For tests and measurements specified in (A), in case where the manufacture has been assessed in accordance with **Pt 1, Annex 1-11** of the Guidance, testing items under the Surveyor's attendance may be omitted. In this case, the Society's surveyor may require submission of the test results.

(11) Testing after installation on board
(A) Piping systems for essential services are to be subjected to a test pressure not less than 1.5 times the design pressure or 0.4 MPa whichever is greater.
(B) Piping systems for non-essential services are to be checked for leakage under operational conditions.
(C) For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

Annex 5-7 Control and Safety System for Dual Fuel Diesel Engines

1. Application

In addition to the requirements of **Pt 5, Ch 2, Sec 2** of the Rules and **Pt 7, Ch 5, Sec 5** and **Sec 16** of the Rules, as far as found applicable, the following requirements are to be applied to dual-fuel diesel engines utilizing high pressure Methane gas fuel injection (hereinafter referred to as **DFD engines**).

2. Operation mode

(1) DFD engines are to be of the dual-fuel type employing pilot fuel ignition and to be capable of immediate change-over to oil fuel only.
(2) Only oil fuel is to be used when starting the engine.
(3) Only oil fuel is, in principle, to be used when the operation of an engine is unstable, and/or during maneuvering and port operations.
(4) In case of shut-off of the gas fuel supply, the engines are to be capable of continuous operation by oil fuel only.

3. Protection of crankcase

(1) Crankcase relief valves are to be fitted in way of each crank throw. The construction and operating pressure of the relief valves are to be determined considering explosions due to gas leaks.
(2) If a trunk piston type engine is used as DFD engine, the crankcase is to be protected by the following measures.
  (A) Ventilation is to be provided to prevent the accumulation of leaked gas, the outlet for which is to be led to a safe location in the open through flame arrester.
  (B) Gas detecting or equivalent equipment(It is recommended that means for automatic injection of inert gas are to be provided.)
  (C) Oil mist detector
(3) If a cross-head type engine is used as DFD, the crankcase is to be protected by oil mist detector or bearing temperature detector.

4. Protection for piston underside space of cross-head type engine

(1) Gas detecting or equivalent equipment is to be provided for piston underside space of cross-head type engine.

5. Engine Exhaust System

(1) Explosion relief valves or other appropriate protection system against explosion are to be provided in the exhaust, scavenge and air inlet manifolds.
(2) The exhaust gas pipes from DFD engines are not to be connected to the exhaust pipes of other engines or systems.

6. Starting air line

(1) Starting air branch pipes to each cylinder are to be provided with effective flame arresters.

7. Combustion Monitoring

(1) A failure mode and effect analysis (FMEA) examining all possible faults affecting the combustion process is to be submitted.
(2) Details of required monitoring will be determined based on the outcome of the analysis.

8. Gas fuel supply to engine

(1) Flame arresters are to be provided at the inlet to the gas supply manifold for the engine.
(2) Arrangements are to be made so that the gas supply to the engine can be shut-off manually from starting platform or any other control position.

(3) The arrangement and installation of the gas piping are to provide the necessary flexibility for the gas supply piping to accommodate the oscillating movements of DFD engine, without risk of fatigue failure.

9. Gas fuel supply piping systems

(1) Gas fuel piping may pass through or extend into machinery spaces or gas-safe spaces other than accommodation spaces, service spaces and control stations provided that they fulfil one of the following :

(A) The system complying with **Pt 7, Ch 5, 1603. 1.** (1) of the Rules, and in addition, with (a), (b and (c) given

(a) The pressure in the space between concentric pipes is monitored continuously. Alarm is to be issued and automatic valves specified in **Pt 7, Ch 5, 1603. 6** of the Rules(hereinafter referred to as "**interlocked gas valves**") and the master gas fuel valves specified in **Pt 7, Ch 5, 1603. 7** of the Rules(hereinafter referred to as "**master gas valve**") are to be closed before the pressure drops to below the inner pipe pressure (however, an interlocked gas valve connected to vent outlet is to be opened).

(b) Construction and strength of the outer pipes are to comply with the requirements of **Pt 7, Ch 5, 502.** of the Rules.

(c) It is to be so arranged that the inside of the gas fuel supply piping system between the master gas valve and the DFD engine is to be automatically purged with inert gas, when the master gas valve is closed; or

(B) The system complying with **Pt 7, Ch 5, 1603. 1.** (2) of the Rules, and in addition, with (a) through (c) given below.

(a) Materials, construction and strength of protection pipes or ducts and mechanical ventilation systems are to be sufficiently durable against bursting and rapid expansion of high pressure gas in the event of gas pipe burst.

(b) The air intakes of mechanical ventilating systems are to be provided with non-return devices effective for gas fuel leaks. However, if a gas detector is fitted at the air intakes, these requirements may be dispensed with.

(c) The number of flange joints of protective pipes or ducts is to be minimized; or

(C) Alternative arrangements to those given in paragraph (A) and (B) will be specially considered based upon an equivalent level of safety.

(2) High pressure gas piping system are to be ensured to have sufficient constructive strength by carrying out stress analysis taking into account the stresses due to the weight of the piping system including acceleration load when significant, internal pressure and loads induced by hog and sag of the ships.

(3) All valves and expansion joints used in high pressure gas fuel supply lines are to be of an approved type.

(4) Joints on entire length of the gas fuel supply lines are to be butt-welded joints with full penetration and to be fully radiographed, except where specially approved by the Society.

(5) Pipe joints other than welded joints at the locations specially approved by the society are to comply with the appropriate standards recognised by the society, or those whose structural strength has been verified through tests and analysis as deemed appropriate by the Society.

(6) For all butt-welded joints of high pressure gas fuel supply lines, post-weld heat treatment are to be performed depending on the kind of material.

10. Shut-off of gas fuel supply

(1) In addition to the causes specified in **Pt 7, Ch 5, 1603. 6.** of the Rules, supply of gas fuel to DFD engines is to be shut off by the interlocked gas valves in case following abnormality occurs;

(A) Abnormality specified in **7.** (1) above.

(B) DFD engine stops from any cause

(C) Abnormality specified in **9.** (1) (A) (a) above.

(2) In addition to the causes specified in **Pt 7, Ch 5, 1603. 7.** of the Rules, the master gas valve is to be closed in case of any of the following:

(A) Oil mist detector or bearing temperature detector specified in **3.** (2) (B) and **3.** (3) above detects abnormality.

(B) Any kind of gas fuel leakage is detected.

(C) Abnormality specified in **9.** (1) (A) (a) above
(D) Abnormality specified in **11.** (1) below

(3) The master gas valve is recommended to close automatically upon activation of the interlocked gas valves.

11. Emergency stop of the DFD engines

(1) DFD engine is to stopped before the gas concentration detected by the gas detectors specified in **Pt 7, Ch 5, 1602. 2.** of the Rules reached 60 % of lower flammable limit.

12. Gas fuel make-up plant and related storage tanks

(1) Construction, control and safety system of high pressure gas compressors, pressure vessels and heat exchangers constituting a gas fuel make-up plant are so arranged as to the satisfaction of the Society.

(2) The possibility for fatigue failure of the high pressure gas piping due to vibration is to be considered.

(3) The possibility for pulsation of gas fuel supply pressure caused by the high pressure gas compressor is to be considered.

Annex 5-8 The Additional Requirements on Electronically-Controlled Diesel Engines

1. Application

The requirements in this Guidance apply to electronically-controlled diesel engines in addition to the requirements prescribed in **Pt 5, Ch 2** of the Rules.

2. Definitions

(1) Accumulator is a small pressure vessel provided for each cylinder which provides hydraulic oil to the actuator attached to the fuel injection device or the exhaust valve driving gear.
(2) Common accumulator is a pressure vessel common to all cylinders for providing hydraulic oil or pressurized fuel oil.
(3) Control valve is a component to control the delivery of hydraulic oil to drive the actuator, as a generic name of on-off-controlled solenoid valve, proportional-controlled valve or variable-controlled valve, etc.
(4) Fuel oil pressure pump is a pump to provide pressurized fuel oil for the common accumulator.
(5) Hydraulic oil pressure pump is a pump to provide hydraulic oil for the equipment, e.g. fuel injection devices, exhaust valve driving gears or control valves, through the common accumulator.
(6) Functional block is a block to classify all items structuring the whole system into the groups of systems, sub-systems, components, assemblies and parts, functionally
(7) Reliability block diagram is a logical figure showing the relations between the functional blocks and the analytic level.
(8) Normal operation of the main propulsion machinery is an operation at normal out-put condition, under using the governor and all safety devices.
(9) High-pressure piping is a piping in the downstream of the fuel oil pressure pump or hydraulic oil pressure pump.

3. Plans and Documents

The following plans and documents are to be submitted. However, for systems and equipment having particular construction, the Society may require to submit other plans and documents.

(1) Plans and documents for approval
 (A) Construction of accumulators
 (B) Construction of common accumulators
(2) Plans and documents for reference
 (A) Construction of control valve
 (B) Construction of fuel oil high-pressure pumps
 (C) Construction of hydraulic oil pressure pumps
 (D) Construction of step-up gear (if application)
 (E) Results of Failure Mode Effective Analysis (including reliability block diagrams)

4. Construction and Associated Installations

(1) General
Essential components are to be so arranged that the normal operation of the main propulsion machinery is capable of being sustained or restored even though one of them becomes inoperable, except where special consideration is given by the Society to the reliability of a single arrangement. A single component provided for each cylinder, of which spare is not required, may be acceptable in case where the failed part can be isolated.
(2) Control valves
 (A) Control valves are to be capable of retaining the expected functions for a period prescribed by the manufacturer. In principle, this period is to be set up at least 3 years.
 (B) Control valves are to be independently provided for each function(e.g. fuel injection, exhaust valve driving).
(3) Accumulators and common accumulators
 (A) Accumulators and Common Accumulators are to comply with the requirements in **Pt 5, Ch 5, Sec 3** of the Rules.

(B) Accumulators are to be capable of retaining the expected functions for a period prescribed by the manufacturer. In principle, this period is to be set up at least 3 years.
(C) Common Accumulators are to be independently provided at least two in different uses, in principle. In case where the result of fatigue analysis upon the fluctuating stress is submitted and approved by the Society, a single arrangement may be acceptable.

(4) Fuel Oil Piping System and Hydraulic Oil Piping System
(A) Piping systems are to comply with the requirements in **Pt 5, Ch 6, Sec 1** of the Rules.
(B) Fuel oil pressure pumps and hydraulic oil pressure pumps are to be independently provided at least two in different uses respectively. In this case, even though one of the pumps becomes inoperable, the remained pumps are capable of supplying a sufficient amount of oil at the maximum continuous output of the main propulsion machinery. These pumps are to be connected ready for use anytime.
(C) The piping arrangement from the fuel oil pressure pump to the fuel injection device and from the hydraulic oil pressure pump to the exhaust valve driving gear is to be protected with a jacketed piping system or an oil tight enclosure, to prevent the spread oil from igniting.
(D) The common piping arrangement from a fuel oil pressure pump or a hydraulic oil pressure pump to a common accumulator, from a common accumulator to an other common accumulator and from a common accumulator to the position where distributed to each cylinder is to be independently provided at least two in different uses, respectively. In case where the result of fatigue analysis upon the fluctuating stress is submitted and approved by the Society, a single arrangement may be acceptable.
(E) Valves or cocks provided on a piping connected to an equipment, e.g. an accumulator or a pump, are to be located as close to the equipment as practicable.
(F) In the high-pressure piping, a high-pressure alarm is to be provided. A relief valve is also to be provided at the proper position, so as to lead the released oil to the lower-pressure side.
(G) In case where a pressure gauge using a bourdon-tube is provided in a high-pressure piping, it is to be of one to comply with a recognized industrial standard, e.g. ISO, and of vibration-proof and heat-resistant type.

5. System Design

(1) Electronic control system
(A) In case of a single failure in any part of equipment or circuit, the system is to be so arranged that the function of the whole system is capable of being sustained or restored.
(B) Controllers for the system are to comply with the following.
(a) At least two main controllers which are integrated to control every function, e.g. fuel injection, exhaust valve drive, cylinder lubrication and supercharge, are to be provided.
(b) Notwithstanding the requirement in (a) above, a single main controller may be acceptable, in case where the normal operation of the main propulsion machinery is available by using a control system independent from the main controller.
(C) Sensors essential for the operation of the main propulsion machinery, e.g. for the following uses, are to be independently provided at least two. In case where the normal operation for the main propulsion machinery is available without any feedback from these sensors, a single arrangement may be acceptable.
(a) Number of revolutions
(b) Crank angle
(c) Pressure of fuel in common accumulators
(D) The power for the control system is to be supplied from two independent sources, one of which is to be a battery supply, and through two independent circuits.
(E) The power for driving solenoid valves is to be supplied from two independent sources, and through two independent circuits.
(F) An electronic-control system of the main propulsion machinery to comply with the requirements prescribed in **5.** (1) (A) through (E) is regarded as the one to comply with the following requirements.
(a) **Pt 6, Ch 2, 201. 4.** (5) (A) of the Rules
(b) **Pt 6, Ch 2, 202. 2.** (3) (C) of the Rules

(2) Failure Mode Effective Analysis(FMEA)
Failure Mode Effective Analysis(FMEA) is to be carried out for the electronic control system in accordance with the following, in order to confirm that any one equipment or circuit in the system which becomes out of function may not cause any malfunction or deterioration in the other equipment or circuits.
(A) The system is to be divided into each functional block and drawn out in the reliability block diagram in which the function blocks are systematically organized.
(B) The analytic level may be sufficient up to the extent of the functional block regarding sub-systems and components.
(C) FMEA is to be resulted in a table shown in **Table 5.16** or equivalent thereto.
(D) For the failure mode, every possible failure from minor to catastrophic is to be considered.

Table 5.16 Failure Mode Effective Analysis Table

System				Element								
ID Number	Component	Sub-system	Operating mode	Failure mode	Failure cause	Failure detection means	Effect of failure			Failure severity	Corrective action	Remarks
							On component	On sub-system	On system			

NOTES :
1. Example of Operating Mode : back-up operation, fuel cost priority operation, NOx reduce operation, etc.
2. Example of Failure Mode : piston pin stuck, connecting rod broken, lubricating oil leaked out, etc.(Failure parts are to be shown.)
3. Failure Severity
(a) catastrophic : loss of complete function, explosion, loss of life(Design change is to be compulsory.)
(b) major : loss or deterioration of a part of function(Possible design change is to be investigated.
(c) minor : negligible affect on function(Design change may not be required.

6. Others

(1) Safety measures
(A) Means are to be provided to stop the main propulsion machinery at a local position in addition to the emergency stopping device in **Pt 6, Ch 2, 202. 2.** (3) (E) of the Rules.
(B) Means are to be provided to prevent fuel oil from continuously flowing into a cylinder due to a failure of a control valve.
(2) Spare parts
The spare parts for the electronically-controlled diesel engine are to be in accordance with **Table 5.17.**

Table 5.17 Spare Parts

Items	Number required	Remarks
Control valves	Each 1 in different types	
Accumulators diaphragms	Each 2 in different types	
Sensors provided for each cylinder	Each 1 in different types	spare parts may be omitted where the normal operation of the main propulsion machinery is available without these sensors.

Annex 5-9 Flexible Pipes

1. Scope

(1) The requirements apply to flexible pipes of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporary connected flexible pipes or hoses of portable equipment.
(2) Flexible pipe assemblies may be accepted for use in oil fuel, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, and Class III steam systems where they comply with the requirements. flexible pipes in high pressure fuel oil injection systems are not to be accepted.
(3) These requirements for flexible pipe assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

2. Design and construction

(1) Flexible pipes are to be designed and constructed in accordance with *Korean Industrial Standards or equivalent.*
(2) Flexible pipes constructed of rubber materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single, double or more closely woven integral wire braid or other suitable material reinforcement. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics materials hoses are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the reinforcement mentioned above. Flexible pipes for use in steam systems are to be of metallic construction.
(3) Flexible pipes are to be completed with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with **104. 5** of the Rules and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.
(4) The use of hose clamps and similar types of end attachments is not acceptable for flexible pipes in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0.5 MPa and provided there are double clamps at each end connection.
(5) Flexible pipe assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by **4.** are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.
(6) Flexible pipe assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to **ISO 15540**(or **KS V 0820**) and **ISO 15541**(or **KS V 0821**).
(7) Flexible pipe assemblies are to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any requirements of the Society.

3. Installation

(1) In general, flexible pipes are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.
(2) Flexible pipe assemblies are not to be installed where they may be subjected to torsion deformation(twisting) under normal operating conditions.
(3) The number of flexible pipes, in piping systems mentioned in **1.** (2) of the Guidance is to be kept to minimum and to be limited for the purpose stated in **1.** (1) of the Guidance.

(4) Where flexible pipes are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the pipe assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other similar protection to the satisfaction of the Society.
(5) Flexible pipes are to be installed in clearly visible and readily accessible locations.
(6) The installation of flexible pipe assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following.
(A) Orientation
(B) End connection support (where necessary)
(C) Avoidance of hose contact that could cause rubbing and abrasion
(D) Minimum bend radii

4. Marking

(1) Flexible pipes are to be permanently marked by the manufacturer with the following details.
(A) Hose manufacturer's name or trademark
(B) Date of manufacture (month/year)
(C) Designation type reference
(D) Nominal diameter
(E) Pressure rating
(F) Temperature rating
(2) Where a flexible pipe assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 5 MACHINERY INSTALLATIONS

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Rules for the Classification of Steel Ships

Part 6 Electrical Equipment and Control Systems

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Guidance Relating to the Rules for the Classification of Steel ships

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Part 6

Electrical Equipment and Control Systems

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KOREAN REGISTER OF SHIPPING

APPLICATION OF
PART 6 "ELECTRICAL EQUIPMENT AND CONTROL SYSTEMS"

1. Unless expressly specified otherwise, the requirements in the Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date : 20 August 2010 (based on the application date for classification survey)

CHAPTER 2 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 2 System and Control
- 202. 3 (3) has been amended.

Effective Date : 1 July 2011

CHAPTER 1 ELECTRICAL EQUIPMENT

Section 1 General
- 109. 1 (1) and 2 have been amended.

Section 2 Rotating Machinery
- 209. 1 has been amended.
- 209. 15 and 16 have been newly added.

Section 5 Distribution
- 507. 4 has been amended.

Section 10 Lighting Fittings, Heating Appliances and Wiring Accessories
- 1002. 2 (4) and 3 have been newly added.

Section 11 Internal Communications
- 1106. has been newly added.

CONTENTS

CHAPTER 1 ELECTRICAL EQUIPMENT

Section 1 General

101. General

1. Application

(1) The requirements of this Chapter apply to the electrical equipment and electric propulsion machinery intended for ships without special limitations for their service or purpose. For electrical equipment and electric propulsion machinery intended for ships with special limitations for their service or purpose and intended for small ships of less than 500 ton gross tonnage, the requirements in this Chapter may be modified within an extent considered appropriate by this Society.
(2) Except where a specific statement is made to the contrary, all requirements specified in this chapter are equally applicable to *a.c.* and *d.c.* installations.
(3) When the Society considers necessary, requirements specified in international electrical standards may apply.

2. Special electrical equipment

Electrical equipment and electric propulsion machinery not specified in this Chapter are to be as deemed appropriate by the Society.

3. Passenger ships

The electrical equipment of passenger ships engaged on international voyages is to comply with the requirements in this Part and in addition, attention is to be paid to compliance with the requirements of passenger ships specified in the International Convention for the Safety of Life at Sea (hereinafter referred to as the "SOLAS Convention").

4. Terminology

Terms used in this Chapter are as follows:

(1) **Dangerous spaces** are the following areas or spaces where flammable or explosive substances are placed and where it is likely to arise flammable or explosive gases or vapours from these substances and they are classified according to generation frequency and period of life for explosive gas atmosphere.
  (A) Zone 0 : area in which an explosive gas atmosphere is present continuously or is present for long periods.
  (B) Zone 1 : area in which an explosive gas atmosphere is sometimes likely to occur in normal operation..
  (C) Zone 2 : area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.
(2) **Selective tripping** is such an arrangement that only the protective device nearest to a fault point is opened automatically in order to maintain the power supply to the rests of sound circuits, in the event of a fault in the circuit having protective devices connected in series.
(3) **Preference tripping** is such an arrangement that the protective devices for unimportant circuits are opened automatically in order to ensure the power supply for vital services, when any one generator becomes overloaded or likely.
(4) **Normal operational and habitable condition** is a condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, fire and flooding safety, internal and external communication and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally. All electrical services necessary for maintaining the ship in normal operational and habitable conditions are essential services and services for habitability.
(5) **Emergency condition** is a condition under which any services needed for normal operational and habitable conditions are not in working order due to failure of the main source of electrical power.
(6) **Main source of electrical power** is a source intended to supply electrical power to the main

switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable conditions.

(7) **Main generating station** is the space in which the main source of electrical power is situated.

(8) **Main switchboard** is a switchboard which is directly supplied by the main source of electrical power and is intended to distribute electrical energy to the ship's services.

(9) **Emergency source of electrical power** is a source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main source of electrical power.

(10) **Emergency switchboard** is a switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to distribute electrical energy to the emergency services.

(11) Electrical services are classified into essential services and services for habitability.

(12) Essential services are those services essential for propulsion and steering, and safety of the ship, which are made up of "primary essential services" and "secondary essential services". Definitions and examples of such services are given in (A) and (B) below.

(A) Primary essential services are those services which need to be in continuous operation to maintain propulsion and steering. Examples of equipment for primary essential services are as follows:

(a) Steering gears
(b) Pumps for controllable pitch propellers
(c) Scavenging air blower, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for propulsion
(d) Forced draught fans, feed water pumps, water circulating pumps, vacuum pumps and condensate pumps for steam plants on steam turbine ships, and also for auxiliary boilers on ships where steam is used for equipment supplying primary essential services
(e) Oil burning installations for steam plants on steam turbine ships and for auxiliary boilers where steam is used for equipment supplying primary essential services
(f) Azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps
(g) Electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
(h) Electric generators and associated power sources supplying the primary essential service equipment
(i) Hydraulic pumps supplying the primary essential service equipment
(j) Viscosity control equipment for heavy fuel oil
(k) Control, monitoring and safety devices/systems for equipment to primary essential services

(B) Secondary essential services are those services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety. Examples of equipment for secondary essential services are as follows:

(a) Windlass
(b) Fuel oil transfer pumps and fuel oil treatment equipment
(c) Lubrication oil transfer pumps and lubrication oil treatment equipment
(d) Pre-heaters for heavy fuel oil
(e) Starting air and control air compressors
(f) Bilge, ballast and heeling pumps
(g) Fire pumps and other fire extinguishing medium pumps
(h) Ventilating fans for engine and boiler rooms
(i) Services considered necessary to maintain dangerous spaces in a safe condition
(j) Navigation lights, aids and signals
(k) Internal safety communication equipment
(l) Fire detection and alarm system
(m) Lighting system
(n) Electrical Equipment for watertight closing appliances
(o) Electric generators and associated power sources supplying the secondary essential service equipment
(p) Hydraulic pumps supplying the secondary essential service equipment

(q) Control, monitoring and safety systems for cargo containment systems
(r) Control, monitoring and safety devices/systems for equipment to secondary essential services

(13) Services for habitability are those services which need to be in operation for maintaining the vessel's minimum comfort conditions for the crew and passengers. Examples of equipment for maintaining conditions of habitability are as follows:
(A) Cooking
(B) Heating
(C) Domestic refrigeration
(D) Mechanical ventilation
(E) Sanitary and fresh water
(F) Electric generators and associated power sources supplying the above equipment

(14) Dead ship condition means a condition under which:
(A) the main propulsion plant, boilers and auxiliary machinery are not in operation due to the loss of the main source of electrical power, and
(B) in restoring propulsion, the stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed to be not available. It is assumed that means are available to start the emergency generator at all times.

102. Drawings and data

The drawings and data to be submitted for approval before the commencement of work are generally as follows:

1. Drawings and data to be submitted by the shipyard

(1) Investigation table of electrical load analysis (main and emergency sources including batteries)
(2) Wiring diagram for power systems (including emergency source)
(3) Wiring diagram for lighting systems (including emergency lightings)
(4) Wiring diagram for control systems
(5) Wiring diagram for navigation and communication systems
(6) Wiring diagram for radio systems
(7) Wiring diagram for fire detection and alarm systems
(8) General arrangement for electrical systems (bridge, radio room, accommodation space, engine room, all decks, etc.)
(9) Arrangement for navigation and signal lights
(10) Drawings indicating dangerous spaces (if necessary)
(11) Drawings of measuring equipment for cargo tanks (if necessary)
(12) List of particulars of high voltage electrical equipment(if necessary)
(13) Calculation sheets of short-circuit current in the circuits(if the sum of rated power is 500 kVA (kW) and over)
(14) Drawings and data as deemed necessary by the Society (in case of special construction ships)

2. Drawings and data to be submitted by the manufacturers of electrical equipment

(1) Manufacturing drawings for generators of 100 kVA and above and motors of 100 kW and above
(2) Drawings of main and emergency switchboard (including battery charging and discharging board)
(3) Drawings of control panel in bridge
(4) Drawings of control panel in engine room
(5) Drawings of remote control system (for main engine, generator and boiler)
(6) Manufacturing drawings for alarm and control system (including list of alarm points)
(7) Drawings of explosion-proof electrical equipment
(8) Drawing of control panel for electric propulsion unit (including electronic coupling and frequency changer)
(9) Drawings and data as deemed necessary by the Society (in case of special equipment)

103. Construction and installation

1. Construction

Electrical equipment is to be so constructed as to provide easy accessibility to all parts requiring inspection, overhaul and repair.

2. Protection against corrosion

(1) Bolts, nuts, pins, screws, terminals, studs, springs and such other small parts are to be made of corrosion resistant materials or those suitably protected against corrosion.
(2) If electrical fittings, not of aluminium, are attached to aluminium, suitable means are to be taken to prevent corrosion.

3. Protection against electrical shock

(1) Where the operators are liable to inadvertently touch the live part of electrical apparatus due to ship's inclination and vibration, such parts are to be protected with suitable means to prevent electrical shock.
(2) The moving parts, reciprocating parts, high temperature parts or charged parts of electrical equipment are to be provided with suitable protections for one who watches, operates or approaches the equipment to avoid injury.
(3) To minimize shock from high-frequency voltage induced by the radio transmitter, handles, handrails, etc. of metal on the bridge or upper decks are to be in good electrical connection with the hull or superstructure.

4. Installation of propulsion machines

Means are to be provided to prevent the accumulation of bilge under propulsion machines (generators, motor-generators, motors, electro-magnetic slip couplings).

5. Installation and protective enclosure

Electrical equipment is to be accessibly placed in well ventilated and adequately lighted spaces in which inflammable gases cannot accumulate and where it is not exposed to the risk of mechanical injuries or damage from water, steam or oil, and is to be so installed that space is available for maintenance. Where, however, electrical equipment are unavoidably installed in spaces not fulfilled the above conditions, they are to be of the following construction.

(1) Drip-proof construction where water drip and oil are liable to drop.
(2) Water-proof construction where installed on exposed decks liable to get wet by sea water, rain or bilge water.
(3) Submersible construction where employed in water.
(4) Explosion-proof construction where explosive or inflammable materials are stored or liable to accumulate.

6. Insulating materials and insulated windings

Insulating materials and insulated windings are to be of resisting quality against moisture, sea air and oil vapour.

7. Power source control switches

Electrical equipment is not to remain alive through the control circuits or pilot lamps when switched off by the control switch.

8. Mechanical lock

All nuts and screws used in connection with current carrying parts and working parts are to be effectively locked.

9. Consideration of magnetic compass

Electrical equipment and cables are to be placed at such a distance from the magnetic compasses that the interfering external magnetic field is negligible, even when circuits are switched on and off.

10. Electromagnetic compatibility

Electrical and electronic equipment on the bridge are to be so installed that electromagnetic interference does not affect the proper function of navigational systems and equipment.

104. Earthing of electrical equipment

1. Fixed electrical equipment

All accessible non-current-carrying metal parts of fixed electrical equipment are to be effectively earthed. Where earthing connections are necessary, the sectional area of the earthing conductor is to be as deemed appropriate by the Society. (refer to the Guidance)

2. Exposed metal parts of electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live are to be earthed unless the machines or equipment are:

(1) supplied at a voltage not exceeding 50 V *d.c.* or 50 V *a.c.*, root mean square between conductors; auto-transformers are not to be used for the purpose of achieving this voltage; or
(2) supplied at a voltage not exceeding 250 V by safety isolating transformers supplying only one consuming device; or
(3) constructed in accordance with the principle of double insulation.

3. Additional safety means are to be provided for portable electrical apparatus for use in confined or exceptionally damp spaces where particular risks due to conductivity exist.

105. System of supply

The following systems of supply are considered as standard:
(1) Two-wire for direct current.
(2) Three-wire for direct current (three-wire insulated system or three-wire mid-wire earthed system).
(3) Single phase two-wire for alternating current.
(4) Three phase three-wire for alternating current.
(5) Three phase four-wire for alternating current.

106. Voltage and frequency

1. Supply voltage

Supply voltage is not to exceed:

(1) 500V for cooking and heating equipment permanently connected to fixed wiring.
(2) 15,000 V *a.c.* or 3,000 V *d.c.* for electric propulsion equipment.
(3) 15,000 V *a.c.* or 500 V *d.c.* for generators and power equipment.
(4) 250 V for lighting, heaters in cabins and public rooms and other applications not mentioned (1), (2) and (3) above.

2. Standard frequency

Frequency of 50 Hz or 60 Hz is recognized as a standard.

3. Voltage and frequency variations

(1) All electrical appliances supplied from the main or emergency systems are to be so designed and manufactured that they are capable of operating satisfactorily under the normally occurring variations in voltage and frequency.
(2) Unless otherwise stated in the national or international standards, all equipment are to operate satisfactorily with the variations from its rated value shown in the **Tables 6.1.1** on the following conditions.
  (A) For alternative current components, voltage and frequency variations shown in the **Table 6.1.1** (a) are to be assumed.
  (B) For direct current components supplied by *d.c.* generators or converted by rectifiers, voltage variations shown in the **Table 6.1.1** (b) are to be assumed.
  (C) For direct current components supplied by electrical batteries, voltage variations shown in the **Table 6.1.1** (c) are to be assumed.
(3) Any special systems, e.g. electronic circuits, whose function cannot operate satisfactorily within the limits shown in **Table 6.1.1** is not to be supplied directly from the system but by alternative means, e.g. through stabilized supply.

4. Harmonic distortion

The total harmonic distortion(THD) in the voltage waveform in the distribution systems is not to exceed 8% and any single order harmonics not to exceed 3%. Other higher values may be accepted provided the distribution equipment and consumers are designed to operate at the higher limits.

107. Ambient conditions

1. The ambient conditions given in **Table 5.1.2** and **Table 5.1.3** in **Pt 5, Ch 1** are to be applied unless otherwise specified, to the design, selection and arrangement of electrical installations as to ensure proper operation. However, ambient temperatures for electrical equipment installed in environmentally controlled spaces are to be in accordance with the requirements which the Society considers appropriate.

2. The operation of all electrical equipment is to be sufficient under such conditions of vibration as to arise in normal practice.

Table 6.1.1 Voltage and frequency variations

(a) Voltage and frequency variations for *a.c.* distribution systems

Type of variations	Variations	
	Permanent	Transient
Frequency	± 5 %	± 10 % (5 sec)
Voltage	+ 6 %, -10 %	± 20 % (1.5 sec)

(b) Voltage variations for d.c distribution systems

Parameters	Variations
Voltage tolerance (continuous)	± 10 %
Voltage cyclic variation deviation	5 %
Voltage ripple(*a.c.* r.m.s. over steady *d.c.* voltage)	10 %

(c) Voltage variations for battery systems

Systems	Variations
Components connected to the battery during charging (see Note)	+30 %, -25 %
Components not connected to the battery during charging	+20 %, -25 %

(Note)
Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered.

108. Clearance and creepage

1. The clearances and creepages between live parts and between live part and earthed metal (hereinafter to be called the “clearance and creepage”) are to be adequate for the working voltage having regard to the nature and service condition of the insulating material.

2. The clearance and creepage for the inside terminal box of rotating machinery, the switchboard busbar and the controlling equipment, etc. are to conform to the values as required in each relevant Section in this Chapter.

109. Testing and inspection

1. General

(1) The following electrical equipment is to be tested, in principle, in accordance with relevant requirements of this Chapter at the manufacturer's works or at other works having the adequate apparatus for testing and inspections.

(A) Rotating machines for propulsion and their control gears
(B) Ship service generators (main, auxiliary and emergency)
(C) Control gears for the motors, and motors which drive essential auxiliaries specified in **Pt 5, Ch 1, 102.** of the Guidance and exceed the output 7.5 kW (For the output of not more than 50 kW, if there are manufacturer's own test reports, a part or all of tests and inspections in the presence of the Society's Surveyor may be omitted subject to the Society's permission)
(D) Main switchboards, emergency switchboards, battery charging and discharging boards, and control consoles
(E) Transformers for power and lighting of single phase 1 kVA or more and 3 phase 5 kVA or more (For the transformer with running capacity of less than 100 kVA, if there are manufacturer's own test reports, a part or all of tests and inspections in the presence of the Society's Surveyor may be omitted subject to the Society's permission)
(F) Power semi-conductor rectifiers of 5 kW or more, uninterrupted power supplies for control monitoring/alarm of 5 kVA or more, uninterrupted power supplies for emergency source of electrical power of 50 kVA or more.

(2) The following electrical appliances and cables are to be type approved in accordance with the 「Guidance for Approval of Manufacturing Process and Type Approval, etc.」 before being taken into use.
(A) Fuses
(B) Circuit-breakers
(C) Electro-magnetic contactors
(D) Explosion-proof electrical equipment
(E) Cables
(F) Cable trays/protective casings made of plastic materials
(G) Protection relay

2. Inspections based on Quality Assurance Scheme

Where the electrical equipment is manufactured by Quality Assurance Scheme specified in 「Guidance for Approval of Manufacturing Process and Type Approval, etc.」, a part or all of the tests and inspections in the presence of the Society's Surveyor may be omitted.

3. Tests after installation on board

Electrical equipment and cables, after installation on board the ship, are to be tested and inspected in accordance with the requirements in **Sec 18.**

4. Additional tests and inspections

The Society may require, when it deems necessary, other tests and inspections than those specified in this Chapter.

5. Exemption from tests and inspections

Electrical equipment having the certificate considered acceptable by the Society may be exempted partially or wholly from the tests and inspections.

6. Tests and inspections on type approved products

Tests and inspections on type approved products are to be in accordance with the requirements which the Society considers appropriate.

Section 2 Rotating Machinery

201. General

1. Requirements of electrical installation

(1) All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be ensured without recourse to the emergency source of electrical power.
(2) Electrical services essential for safety will be ensured under various emergency conditions.

(3) The safety of crew and ship from electrical hazards will be ensured.

2. Main source of electrical power

(1) A main source of electrical power of sufficient capacity to supply essential services and services for habitability is to be provided. This main source of electrical power is to consist of at least two generating sets.
(2) The capacity of these generating sets is to be such that in the event of any one generating set being stopped it will still be possible to supply essential services and services for habitability.
(3) The arrangements of the ship's main source of electrical power is to be such that the essential services and services for habitability can be maintained regardless of the speed and direction of rotation of the propulsion machinery or shafting.
(4) The generating sets are to be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets are to be capable of providing the electrical services necessary to start the main propulsion plant from a dead ship condition. The emergency source of electrical power may be used for the purpose of starting from a dead ship condition if its capability either alone or combined with that of any other source of electrical power is sufficient to provide at the same time those services required to be supplied by **1402. 2** (1) to (5).
(5) Where the main source of electrical power is necessary for propulsion and steering of the ship, the system is to be so arranged that the electrical supply to equipment necessary for propulsion and steering and to ensure safety of the ship will be maintained or immediately restored in the case of loss of any one of the generators in service. Preference tripping or other equivalent arrangements are to be provided to protect the generators against sustained overload.

3. Fault current

Ship's service generators are to be capable of withstanding the mechanical and thermal effects of fault current for the duration of any time delay which may be fitted in a tripping device for discrimination purposes.

4. Clearance and creepage inside terminal box

The clearance and creepage for the inside terminal box of rotating machine are not to be less than as required **Table 6.1.2.** However, the requirements in the above are not applied to small motors such as controlling motors, self synchronous motors, etc. and also not applied when an insulating barrier is used.

Table 6.1.2 Minimum Clearance and Creepage inside the Terminal Box of Rotating Machine

Rated voltage (V)	Clearance (mm)	Creepage (mm)
61 ~ 250	5	8
251 ~ 380	6	10
381 ~ 500	8	12

5. Air coolers and means of prevention of moisture condensation

(1) Where air coolers are provided for rotating machines they are so arranged as to prevent the possibility of water into the machines by leakage or condensation in the air coolers.
(2) Where there is fear of deterioration of insulations by moisture condensation within rotating machines, it is to be provided with means, such as space heater, etc., to prevent it.

202. Prime movers for generators

1. Application

Prime movers are to be constructed in accordance with the following requirements in addition to the requirements of the applicable Chapters of the Rules.

2. Governors

Governors on prime movers driving main or emergency electric generators are to be capable of automatically maintaining the speed within the following limits:

(1) Prime movers for driving generators of the main and emergency sources of electrical power are to be fitted with a speed governor which will prevent transient frequency variations in the electrical network in excess of ±10% of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off. In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device specified in **Pt 5, Ch 2, 203. 1** (1).

(2) Application of electrical load is to be possible with 2 load steps and must be such that prime movers - running at no load - can suddenly be loaded to 50% of the rated power of the generator followed by the remaining 50% after an interval sufficient to restore the speed to steady state. Steady state conditions are to be achieved in not more than 5 seconds. Steady state conditions are those at which the envelope of speed variation does not exceed +1% of the declared speed at the new power.

(3) At all loads between no load and rated power the permanent speed variation should not be more than ±5% of the rated speed.

(4) Emergency generator sets must satisfy the governor conditions as per items (1) and (3) even when:

(A) their total consumer load is applied suddenly, or

(B) their total consumer load is applied in steps, subject to:

- the total load is supplied within 45 seconds since power failure on the main switchboard.
- the maximum step load is declared and demonstrated.
- the power distribution system is designed such that the declared maximum step loading is not exceeded.
- the compliance of time delays and loading sequence with the above is to be demonstrated at ship's trials.

3. Governors on prime movers operating in parallel

For *a.c.* generating sets operating in parallel, the governors or prime movers are to have such characteristics that load sharing stipulated in **206. 4** is ensured, and are to be of those easily conducting the load adjustment, at normal frequency, within 5 % of the rated load.

4. Turbine-driven *d.c.* generators operating in parallel

Turbine-driven *d.c.* generators arranged to run in parallel are to be fitted with switching device to open the generator circuit-breakers when the emergency governor comes into function.

203. Rotating machinery shaft

1. Rotating machinery shaft

The diameter of rotating machinery shaft in the length from the section where rotor is fixed to the shaft end of prime mover side or load side is not to be less than value obtained from the formula specified in **Pt 5, Ch 3, 203.** of the Rules. P, n and F in the formula mean as follows:

P = Output of rotating machinery (kW).

n = Number of revolutions of rotating machinery (rpm).

F = Values given in **Table 6.1.3.**

In case where the stress concentration remains on the part of minimum shaft diameter or where it is apprehended that the transient torque is remarkably greater than the normal torque in operation, F is to be increased by the value recognized by the Society.

2. Shaft coupling

Where bearings are fitted at both ends of rotating machinery shaft, the diameter of the shaft near the coupling part of the driving side and the shaft of bearing contacting parts may be taken as 93% of the values obtained from the formula in **Par 1** provided that there is no sudden change in the shape of the shaft.

3. Torsional vibration

Generator shafting is to be so designed to prevent any excessive vibration within the operating range. The torsional vibration of generator shafting driven by diesel engine is to conform to the requirements equivalent to those given in **Pt 5, Ch 4, 203.**

Table 6.1.3 Values of Constant F

Bearing arrangement of a rotating machinery shaft	In case of generator driven by steam or gas turbine, generator driven by diesel engine through slip type coupling[(1)], or electrical motor	In case of generator driven by diesel engine other than those mentioned in the left-hand column
Where bearings are arranged at both sides of a rotating machinery shaft	110	115
Where no bearing is arranged at prime mover side or load side of a rotating machinery shaft	120	125
(NOTE) (1) Slip type coupling signifies hydraulic coupling, electro-magnetic coupling or the equivalent		

204. Temperature rise

1. The temperature rise of rotating machines is not to exceed the values in **Table 6.1.4** when continuously operated at the rated load or intermittently operated according to their duties.

2. The temperature rise of static exciters is to comply with the requirements in **307. 2.**

3. The temperature rise of rotating machines equipped with air cooler may be increased by 13℃ from the values in the Table, provided that the temperature of cooling water at the inlet of air cooler does not exceed 32℃.

4. Where the ambient temperature exceeds 45℃, limits of temperature rise are to be decreased by the difference from the values given in **Table 6.1.4.**

5. Where the ambient temperature does not exceed 45℃, the limits of temperature rise may be increased by the difference from the values in the **Table 6.1.4.** In this case, the ambient temperature is not to be set below 40℃.

205. Ship's service *d.c.* generator

1. *D.C.* **generators**

D.C. generators other than those referred to in **Par 2** are to be either of the following types:

(1) Compound-wound generator
(2) Shunt-wound generator with an automatic voltage regulator

2. *D.C.* **generators used for charging batteries**

D.C. generators used for charging batteries without series of regulating resistor are to be either of the following types:

(1) Shunt-wound generator
(2) Compound-wound generator with switches arranged so that the series winding can be made inoperative at the time of charging

Table 6.1.4 Temperature Rise of Rotating Machines (°C) (Based on 45℃ ambient temperature)

Item		Part of machine	Class A insulation			Class E insulation			Class B insulation			Class F insulation			Class H insulation		
			T	R	E.T.D.	T	R	E.T.D.	T	R	E.T.D.	T	R	E.T.D.	T	R	E.T.D.
1	a)	A.C. windings of machines having outputs of 5,000 kW (or kVA) or more	-	55	60	-	-	-	-	75	80	-	95	100	-	120	125
	b)	A.C. windings of machines having outputs above 200 kW (or kVA) but less than 5,000 kW (or kVA)	-	55	60	-	70	-	-	75	85	-	100	105	-	120	125
	c)	A.C. windings of machines having outputs of 200 kW (or kVA) or less, other than those in items 1d) or 1e) *1	-	55	-	-	70	-	-	75	-	-	100	-	-	120	-
	d)	A.C. windings of machines having rated outputs of less than 600 W (or VA) *1	-	60	-	-	70	-	-	80	-	-	105	-	-	125	-
	e)	A.C. windings of machines which are self-cooled without fan and/or with encapsulated windings *1	-	60	-	-	70	-	-	80	-	-	105	-	-	125	-
2		Windings of armatures having commutators	45	55	-	60	70	-	65	75	-	80	100	-	100	120	-
3		Field winding of a.c. and d.c. machines having d.c. excitation other than those in item 4	45	55	-	60	70	-	65	75	-	80	100	-	100	120	-
4	a)	Field windings of synchronous machines with cylindrical rotors having d.c. excitation winding embedded in slots except synchronous induction motors	-	-	-	-	-	-	-	85	-	-	105	-	-	130	-
	b)	Stationary field windings, of d.c. machines, having more than one layer	45	55	-	60	70	-	65	75	85	80	100	105	100	120	130
	c)	Low resistance field winding of a.c. and d.c. machines and compensating windings of d.c. machines having more than one layer	55	55	-	70	70	-	75	75	-	95	95	-	120	120	-
	d)	Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines *2	60	60	-	75	75	-	85	85	-	105	105	-	130	130	-
5		Permanently short-circuited windings	The temperature rise is in no case to reach such a value that there is a risk of injury to any insulating material on adjacent parts.														
6		Magnetic cores and all structural components, whether or not in direct contact with insulation (excluding bearings)															
7		Commutators and slip-rings and their brushes and brush gear	The temperature rise is in no case to reach such a value that there is a risk of injury to any insulating material on adjacent parts. Additionally, the temperature is not to exceed that at which the combination of brush grade and commutator/slip-ring materials can handle the current over the complete operating range.														

T = Thermometer method, R = Resistance method, E.T.D. = Embedded temperature detector

(NOTES)

1. With application of the super position method to windings of machines rated 200 kW (or kVA) or less with insulation classes A, E, B and F, marked with *1, the limits of temperature rise given for the resistance method may be exceeded by 5℃
2. Also includes multiple layer windings provided that the under layers are each in contact with the circulating primary coolant.

3. Field regulator for *d.c.* generators

Field regulator for *d.c.* generator is to be capable of adjusting the voltage of the generator to within 0.5 % of the rated voltage for machines above 100 kW and 1 % of the rated voltage for smaller machines respectively at all loads between no load and full load at the operating temperature.

4. Overall voltage regulation of *d.c.* generators

The overall voltage regulation of *d.c.* generators is to conform to the following requirements. The rotating speed is to be adjusted with the rated speed at full load.

(1) Shunt-wound generator : After the temperature test, when the voltage sets at full load, the steady voltage at no load is not to exceed 115 % of the full load value, and the voltage obtained at any value of load is not to exceed the no load value.

(2) Compound-wound generator : After the temperature test, when the voltage at 20 % load is adjusted within ±1 % of rated voltage, the voltage at full load is to be within ±1.5 % of the rated voltage and the average of the ascending and descending load / voltage curves between 20 % load and full load is not to vary by more than 3 % from the rated voltage. However, for the compound-wound generators operating in parallel, the drop in voltage may be acceptable up to 4 % of the rated voltage when the load is gradually increased from 20 % load to 100 % load.

(3) Three-wire generator : In addition to conforming to (1) and (2) above, when the generator is operating at the rated current on either positive or negative leads and a current of 25 % of the rated current in the neutral wire, the resulting difference in voltage between the positive and neutral leads or the negative and neutral leads is not to exceed 2 % of the rated voltage between the positive and negative leads.

5. Load sharing of *d.c.* generators

When *d.c.* generators are run in parallel, the load on any generator is not to differ by more than ±10 % of the rated output of the largest generator from its proportionate share, based on the generator ratings, of the combined load, for any steady-state condition in the combined load between 20 % and 100 % of the sum of the rated outputs of all the generators. The starting point for the test is to be at 75 % load with each generator carrying its proportionate share.

6. Series winding of compound-wound generator

The series winding of each two-wire compound-wound generator is to be connected to the negative terminal.

7. Equalizer connection

Equalizer connections of *d.c.* generator are to have a cross-sectional area not less than 50 % of that of the negative connection from the generator to the switchboard.

206. Ship's service *a.c.* generator

1. Automatic voltage regulators

Each *a.c.* generator, unless of the self-excited type, is to be provided with an automatic voltage regulator.

2. Overall voltage regulation of *a.c.* generators

The overall voltage regulation of *a.c.* generators is to be such that at all loads from zero to full load at the rated power factor, the rated voltage is to be maintained under steady conditions within ±2.5 %, except that for emergency generators the limits may be increased to ± 3.5 %.

3. Exciters of *a.c.* generators

Exciters of *a.c.* generators are to be capable of maintaining the current of at least three times its rated current for a duration up to 2 seconds, unless protection selectivity requirements which allow different characteristics exist.

4. Load sharing of *a.c.* generators

When *a.c.* generators are run in parallel, each generator is to be stable in running and the load on any generator is not to differ by more than 15 % of the rated output of the largest generator from its proportionate share, based on the generator ratings, of the combined load for any steady-state condition in the combined load between 20 % and 100 % of the sum of the rated loads of all the generators. The starting point for the test is to be at 75 % load with each generator carrying its proportionate share.

207. Shaft currents

Suitable measures are to be taken to prevent the ill effects of flow of currents circulating between the shaft and bearings.

208. Welding

When welding is applied to the shaft and other torque members of rotating machines, this is subject to the approval of the Society.

209. Testing and inspection

1. General

Rotating machines of essential use are to meet the requirements of this Section in their construction and are to be tested in accordance with the requirements of the following articles. However, the tests in the presence of the Surveyor may be omitted subject to the Society's permission for rotating machines of small capacity.

2. Material test of shaft

(1) The shaft materials for rotating machines (except emergency generator) of 100 kW(kVA) and above are to be tested in accordance with the requirements in **Pt 2, Ch 1.**
(2) The shaft materials for rotating machines of less than 100 kW(kVA) or emergency generator are to comply with the relevant Korean Industrial Standards (KS) or the equivalents.

3. Temperature test

After the rotating machine has run continuously under full rated load until a final steady temperature, the temperature rises in the machine are not to exceed the values in **204.**

4. Overcurrent or excess torque test

After the temperature test, rotating machines, except special type, are to withstand the following overcurrent or excess torque test while maintaining the voltage, revolving speed and frequency as near their rated values as possible. In the above, special types involve deck machinery motors (winch, windlass, capstan, etc.) and single phase *a.c.* motors.

Kinds	Overcurrent or excess torque	Seconds
D.C. generators	50 % overcurrent	15
A.C. generators	50 % overcurrent	120
D.C. motors	50 % excess torque	15
Synchronous motors	50 % excess torque	15
Induction motors	60 % excess torque	15

5. Overspeed test

Rotating machines are to withstand the overspeed test specified in the following for 2 minutes.

Kinds		Testing speed
Generators	Turbine driven	115 % of rated speed
	Internal combustion engine driven	120 % of rated speed
	All others	125 % of rated speed
Motors	Shunt-wound motors	125 % of rated speed
	Series-wound motors	200 % of rated speed
	Compound-wound motors	125 % of no load speed
	Synchronous motors	125 % of synchronous speed
	Induction motors	125 % of synchronous speed

6. Insulation resistance test

(1) Immediately after the temperature test and the high voltage test, the insulation resistance of the rotating machine are to be measure using a direct current insulation tester between:

(A) All current carrying parts connected together and earth.

(B) All current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

(2) The minimum values of test voltages and insulation resistances are given in the following.

Rated voltage Un(V)	Minimum test voltage(V)	Minimum insulation resistance(MΩ)
$Un \leq$ 250	$2 \times Un$	1
250 < $Un \leq$ 1,000	500	
1,000 < $Un \leq$ 7,200	1,000	$1+\frac{U_n}{1,000}$
7,200 < $Un \leq$ 15,000	5,000	

7. High voltage test

Rotating machines are to withstand for 1 minute the high voltage test between live parts and between live parts and earth with a.c. voltage in commercial frequency as given in **Table 6.1.5.**

8. Voltage regulation test

Generators are to be subjected to voltage regulation test specified in the following and are to pass the requirements.

(1) Test for the requirements specified in **205. 4** or **206. 2** of the Rules

(2) When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage is not to fall below 85 % nor exceed 120 % of the rated voltage. The voltage of the generator is then to be restored to within plus or minus 3 % of the rated voltage for the main generator sets in not more than 1.5 seconds. For emergency sets, these values may be increased to plus or minus 4 % in not more than 5 seconds, respectively.

9. Winding resistance measurement

The resistances of the machine windings are to be measured using an appropriate bridge method, or voltage and current method.

10. Commutation test

Rotating machines with commutators are to work with fixed brushes setting from no load to 50 % overload without injurious sparking.

11. Verification of steady short-circuit condition

It is to be verified that under steady-state short-circuit conditions, the generator with its voltage regulating system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of 2 seconds or, where precise data is available, for a duration of any time delay which may be fitted in a tripping device for discrimination purposes.

12. No load test

Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor or if a generator it is to be driven by a suitable means and excited to give rated terminal voltage. During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

13. Parallel operation test

Generators to run in parallel operation are to be subjected to parallel operation test and are to pass the requirements in **205. 5** or **206. 4.**

Table 6.1.5 Testing Voltage

Item	Machine or part		Testing voltage (r.m.s.) (V)
1	Insulated windings of rotating machines of size less than 1 kW (or kVA), and of rated voltage less than 100V with exception of those in items 3 to 6		$2E + 500$
2	Insulated windings of rotating machines with exception of those in item 1 and items 3 to 6		$2E + 1{,}000$ (Minimum 1,500V)
3	Separately-excited field windings of d.c. machines		$2E_f + 1{,}000$ (Minimum 1,500V)
4	Field windings of synchronous generators, synchronous motors and synchronous condensers	$E_x \leqq 500$ V $E_x > 500$ V	$10E_x$ (Minimum 1,500V) $2E_x + 4{,}000$
		When intended to be started with the field winding short-circuited or connected across a resistance of value less than ten times the resistance of the winding	$10E_x$ (Minimum 1,500V, Maximum 3,500V)
		When intended to be started with the field winding on open circuit or connected across a resistance of value equal to, or more than, ten times the resistance ofthe winding	$2E_y + 1{,}000$ (Minimum 1,500V)
5	Secondary (usually rotor) windings of induction motors or synchronous induction motors if not permanently short-circuited (e.g. if intended for the rheostatic starting)	For non-reversing motors or motors reversible from standstill only	$2E_s + 1{,}000$
		For motors to be reversed or braked by reversing the primary supply while the motor is running	$4E_s + 1{,}000$
6	Exciters with the exception of : Exciters of synchronous motors (including synchronous induction motors) if connected to earth or disconnected from the field windings during starting; and Separately excited field windings of exciters		$2E_i + 1{,}000$ (Minimum 1,500V)

(NOTES)

1. E = Rated voltage
   E_f = Maximum rated voltage in field circuit
   E_x = Rated field voltage
   E_y = Induced terminal voltage between the terminals of field windings and starting rotor windings when applied the starting voltage to armature winding during the rotor's standstill and terminal voltage in such condition that the field windings or starting windings are started by connecting with the resistance
   E_s = Induced voltage between the terminals of secondary windings when the machine is at a standstill
   E_i = Rated exciter voltage
2. For two-phase windings having one terminal in common, the voltage in the formula is to be the highest r.m.s. voltage arising between any two terminals during operation.
3. High voltage tests on machines having graded insulation may be as deemed appropriate by the Society.
4. For the semi-conductor rectifier of exciters, the requirements for semi-conductor rectifiers for power in **Sec 12** are to be applied.

14. Verification of bearings

Upon completion of the above tests, machines which have plane bearings are to be opened upon request for examination by the Surveyor, to establish that the shaft is correctly seated in the bearing shells.

15. Verification of degree of protection

Degree of protection is to be verified in accordance with **Table 6.1.1** to **Table 6.1.6** or (KS C) IEC 60034-5.

16. Tests

The tests of rotating machinery are as following table according to its kinds

No.	Tests	A.C. Generator		A.C. Motors		D.C. Machines	
		Type test*	Routine test(1)	Type test*	Routine test(1)	Type test*	Routine test(1)
1	Examination of the technical documentation, visual inspection	X	X	X	X	X	X
2	Material test of shaft	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)
3	Temperature test	X	X(8)	X	X(8)	X	X(8)
4	Overcurrent or excess torque test	X	X(3)	X	X(3)	X	X(3)
5	Overspeed test	X	X	X(4)	X(4)	X(4)	X(4)
6	Inspection resistance test	X	X	X	X	X	X
7	High voltage test	X	X	X	X	X	X
8	Voltage regulation test	X	X(5)				
9	Winding resistance measurement	X	X	X	X	X	X
10	Commutation test					X(6)	
11	Verification of steady short-circuit condition (7)	X	X(8)				
12	No load test	X	X	X	X	X	X
13	Verification of bearings	X	X	X	X	X	X
14	Verification of degree of protection	X	X(8)	X	X(8)	X	X(8)

(Notes)
* Type tests on prototype machine or tests on at least the first batch of machines.
(1) Test report of machines routine tested is to contain the manufacturer's serial number of the machine which has been type tested and the test result.
(2) Only applicable for rotating machines of 100kW and more (except emergency generators).
(3) Only applicable for rotating machines of essential services rated 100kW and more.
(4) Not applicable for squirrel cage motors.
(5) Only functional test of voltage regular system.
(6) Only applicable for rotating machines with commutators.
(7) Only applicable for synchronous generators.
(8) Test and verification may be omitted subject to the Society's permission (type approval, etc).

Section 3 Switchboards, Section Boards, Distribution Boards and Protective Equipment

301. General

1. Installation

(1) Switchboards are to be installed in dry places away from the vicinity of steam, water and oil pipes.
(2) The main switchboard is to be so placed relative to one main generating station that, as far as is practicable, the integrity of the normal electrical supply may be affected only by a fire or other casualty in one space. An environmental enclosure for the main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating the switchboards from the generators.

2. Space for operation and maintenance

Sufficient space for operation is to be provided in front of switchboards. Where necessary, space at the rear of switchboards is to be ample to permit operation and maintenance of disconnecting switches, switches, fuses and other parts. The space is not to be less than 0.5 m in width.

3. Safety precautions to operators

Where the live parts of switchboards face a passageway, the following means are to be provided.
(1) Insulated handrails are to be provided.
(2) Insulated mats are to be provided on the floor of passageway.

302. Construction

1. Construction

(1) Busbars, circuit-breakers and other electrical appliances of the main switchboards are to be so arranged that the electrical equipment of essential services installed in duplicate will not become out of action simultaneously by a single fault.
(2) The generator switchboard is to be provided for each generator, and the switchboards adjoining each other are to be partitioned by the walls of steel or flame-retardant material. The main busbars are to be subdivided into at least two parts which are to be normally connected by the circuit breaker or other approved means. So far as is practicable, the connection of generating sets and other duplicated equipment of essential services are to be equally divided between the parts.
(3) Cable entries of switchboard are to be so constructed that no ingress of water be permitted into the switchboard along the cables.

2. Dead-front type switchboards

For voltage between poles, or to earth, exceeding 55V *d.c.* or 55V *a.c.* switchboards are to be of dead-front type.

3. Materials of insulation and wiring for switchboards

(1) Insulating materials used in the construction of switchboards are to be mechanically strong, flame-retardant and moisture-resistant.
(2) Insulated wires for switchboard are to be those of flame-retardant and moisture-resistant, having the maximum permissible conductor temperature not less than 75℃.
(3) Ducts and straps for wiring are to be of flame-retardant materials.
(4) Insulated wires for control and instrument circuits are not to be bunched together with wires for main circuits, unless the rated voltage and maximum permissible conductor temperature of both wires are the same.

303. Busbars and equalizer connections

1. Busbars

(1) Busbars are to be of copper having the conductivity of 97 % or more.
(2) Busbar connections are to be so made as to inhibit corrosion and oxidization.
(3) Busbars and their connections are to be so supported as to withstand the electromagnetic force

resulted from short-circuiting.

(4) Temperature rises of busbars, connecting conductors and their connections are not to exceed 45℃ at the limit ambient temperature of 45% when carrying full load current.

(5) The clearances and creepages of busbars are not to be less than the values in **Table 6.1.6.**

Table 6.1.6 Clearances and Creepages of Busbars

Rated voltage(V)	Clearance (mm)	Creepage (mm)
250 or less	15	20
251 ~ 660	20	30
Exceeding 660	25	35

2. Equalizer for *d.c.* generator

(1) The current rating of equalizer connections and equalizer switches is not to be less than 50 % the rated full-load current of the generator.

(2) The current rating of equalizer busbars is not to be less than 50% the rated full-load current of the largest generator in the group of parallel operation.

304. Measuring instruments for switchboards

1. *D.C.* ship's service generator panels

D.C. ship's service generator panels are at least to be provided with the instruments given in **Table 6.1.7.**

Table 6.1.7 Instruments for *D.C.* Generator Panel

<table>
<tr><th rowspan="2">Operation</th><th rowspan="2">Type of instrument</th><th colspan="2">Quantity</th></tr>
<tr><th>2-wire system</th><th>3-wire system</th></tr>
<tr><td rowspan="2">Not parallel</td><td>Ammeter</td><td>1 for each generator (positive pole)</td><td>* 2 for each generator (positive and negative poles)</td></tr>
<tr><td>Voltmeter</td><td>1 for each generator</td><td>1 for each generator (voltage measurement between positive and negative poles or between positive or negative pole and neutral pole)</td></tr>
<tr><td rowspan="2">Parallel</td><td>Ammeter</td><td>1 for each generator (positive pole)</td><td>* 2 for each generator (in case of compound winding, between equalizer and armature, and in case of shunt winding, for positive and negative poles)</td></tr>
<tr><td>Voltmeter</td><td>2 (busbar and each generator)</td><td>2 (voltage measurement between busbar and positive and negative poles of each generator, or between positive or negative pole and neutral pole)</td></tr>
<tr><td colspan="4">(NOTES)
1. For * in the Table, a zero center ammeter is to be added to earth line when employed neutral line earthed system.
2. One voltmeter is to be capable of measuring shore supply voltage.
3. Where a control panel is provided for automatic control of generators, the instruments in the above table may be installed on the control panel, except that, if the control panel is installed outside engine rooms, the minimum number of instruments required to carry out single or parallel operation of generators are to be mounted on switchboards.</td></tr>
</table>

2. *A.C.* ship's service generator panels

A.C. ship's service generator panels are at least to be provided with the instruments given in **Table 6.1.8.**

Table 6.1.8 Instruments for *A.C.* Generator Panel

Operation	Type of instrument	Quantity
Not parallel	Ammeter Voltmeter Wattmeter Frequency meter * Ammeter	1 for each generator (current measurement of each phase) 1 for each generator (voltage measurement between each phase) 1 for each generator (It may be omitted for 50 kVA or less) 1 (frequency measurement of each generator) 1 for exciting circuit of each generator
Parallel	Ammeter Voltmeter Wattmeter Frequency meter Synchroscope * Ammeter	1 for each generator (current measurement of each phase) 2 (voltage measurement between each phase of generators and busbar) 1 for each generator 2 (frequency measurement of each generator and busbar) 1 set 1 for exciting citcuit of each generator

(NOTES)
1. For * in the Table, the ammeters are to be provided only if necessary.
2. One of the voltmeters is to be capable of measuring shore supply voltage.
3. Where a control panel is provided for automatic control of generators, the instruments in the above table may be installed on the control panel, except that, if the control panel is installed outside engine rooms, the minimum number of instruments required to carry out single or parallel operation of generators are to be mounted on switchboards.

3. Instrument scales

(1) The upper limit of the scale of every ammeter is to be approximately 130 % of the normal rating of the circuit.
(2) The upper limit of the scale of every voltmeter is to be approximately 120 % of the normal voltage of the circuit.
(3) Ammeters for *d.c.* generators or wattmeters for *a.c.* generators which may operate in parallel are to be capable of indicating reverse current or reverse power up to 15 % respectively.

305. Protective devices

1. General

Electrical installations of ships are to be protected against accidental over-currents including short-circuit. The protective devices are to be capable of breaking the fault circuit and continuously serve other circuits as far as possible and at the same time eliminate the danger of damage to the system and fire hazard.

2. Protection of circuits

(1) Short-circuit protection is to be provided in each pole and phase of all insulated circuits except neutral and equalizer circuits.
(2) Overload protections are to be provided for all circuits liable to be overloaded as follows, except as permitted where the Society may exceptionally permit, and the rating or appropriate setting of the overload protective device for each circuit is to be permanently indicated at the location of the protective device.
 (a) Two-wire *d.c.* or single-phase *a.c.* system: at least one line or phase.
 (b) Three-wire *d.c.* system: both outer lines.
 (c) Three-phase, three-wire *a.c.* system: at least two phases.
 (d) Three-phase, four-wire *a.c.* system: at each phase.
(3) Fuse, non-linked circuit breaker or non-linked switch is not to be inserted in an earthed conductor and a neutral line.

3. Circuit breakers and fuses

(1) Circuit breakers and fuses are to comply with the requirements in **Sec 8.**
(2) Circuit breakers are to be such that repairs and replacement can be done without disconnecting from the busbar connections and switching off the power source. Where isolation switch is provided additionally, the requirement may be exempted.
(3) Overcurrent relays of circuit breakers for generators and overload protection except moulded-case

circuit breakers are to be capable of adjusting their current setting or time-delay characteristics.

4. Protection against overload

(1) The overcurrent tripping characteristics of circuit breakers and the fusing characteristics of fuses are to be chosen suitably taking into consideration of the thermal capacity of electrical equipment and cables to be protected thereby.
(2) Fuses of the rated current exceeding 200A are not to be used for overload protection.

5. Protection against short-circuit

(1) The rated breaking capacity of every protective device is not to be less than the maximum value of the short-circuit current which can flow at the point of installation at the instant of contact separation.
(2) Where the rated breaking capacity of the shortcircuit protection is not in compliance with the requirement in (1) above, fuses or circuit breakers having the rated breaking capacity not less than the prospective short-circuit current are to be provided at the power source side of the foregoing short-circuit protection. The generator breaker is not to be used for this purpose. The circuit breakers connected to the load side, are to be capable of being continuously in service without excessive damage in the following cases:
(a) When the short-circuit current is broken by the back-up circuit breaker or fuse.
(b) When the circuit breaker at the load side is closed on the short-circuit current, while the backup circuit breaker or fuse is broken.
(3) The making capacity of every circuit-breaker or switch intended to be capable of being closed, if necessary, on short-circuit, is not to be less than the maximum value of the short-circuit current at the point of installation.
(4) In the absence of precise data of rotating machines, the following tripping short-circuit currents are to be assumed. Where the motor is considered as load, the short-circuit current of the motor is to be added to that of generator.
(a) *D.C.* system
10 times the rated current for generators normally connected (including spare).
6 times the rated current for motors simultaneously in service.
(b) *A.C.* system
10 times the rated current for generators normally connected (including spare).
3 times the rated current for motors simultaneously in service.

6. Protection of generators

(1) Generators are to be protected against short-circuit and overcurrent by a multipole circuit-breaker arranged to open simultaneously all insulated poles. For generators with capacity of less than 65 kVA, however, a multipole-linked switch with a fuse or circuit-breaker in each insulated pole may be used for protection. The overload protection is to be adequate to the thermal capacity of generators.
(2) For *d.c.* generators arranged to operate in parallel, in addition to the requirement of (1), an instantaneous reverse-current protection, operating at a fixed value of reverse-current within the limits of 2 % to 15 % of the rated current of generators, is to be provided. This requirement, however, does not apply to the reverse-current generated from load side, e.g. cargo winch motors, etc.
(3) For *a.c.* generators arranged to operate in parallel, in addition to the requirement in (1), a reverse-power protection, with time delay, selected and set within the limits of 2 % to 15 % of full load to a value fixed in accordance with the characteristics of the prime mover, is to be provided.

7. Protection of power and lighting transformers

(1) The primary circuits of power and lighting transformers are to be protected against short-circuit and overload by circuit-breakers or fuses.
(2) When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary circuits. Switches and circuit-breakers are to be capable of withstanding surge currents.

8. Protection of motors

(1) Motors of rating exceeding 0.5 kW and all motors for essential services are to be protected individually against overload, except steering gear motors complying with the requirements in **Pt 5, Ch 7, 207.**

(2) The protective device is to have a delay characteristics to enable the motor to start.
(3) For motors of intermittent service, the protective device is to be chosen in relation to the service condition.

9. Protection of feeder circuits

(1) Feeder circuits to section boards, distribution boards, group starters and the similar are to be protected against overload and short-circuit by multi-pole circuit breakers or fuses. Where fuses are used for this purpose, the switches complying with the requirements in **1004. 3** are to be provided at the power source side of the fuses as a rule.
(2) Circuits which supply motors fitted with overload protection may be provided with short-circuit protection only.
(3) When fuses are used to protect three-phase *a.c.* motor circuits, consideration is to be given for protection against single phasing.

10. Protection of essential service

Where essential machinery is driven electrically, arrangements are to be made to disconnect automatically the excess non-primary essential service loads when the generators are overloaded. If required, this preference tripping may be carried out in two or more stages.

11. Protection of batteries

Storage batteries other than engine starting batteries, are to be protected against overload and short-circuit with devices placed as near as practicable to the batteries. Emergency batteries supplying essential services may have short-circuit protection only.

12. Protection of meters, pilot lamps and control circuits

(1) Protection is to be provided for voltmeters, voltage coils of measuring instruments, earth indicating devices and pilot lamps with their connecting leads by means of fuses fitted to each insulating pole. A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided that any damage of pilot lamp circuit does not cause failures on the supply to essential equipment. Consideration is to be given to the omission of fuses in circuits such as those of automatic voltage regulators where loss of voltage might have serious consequences.
(2) Insulated wires for control and instrument circuits directly led from busbars and generator mains are to be protected by fuses at the nearest location to the connecting points. Insulated wires from the connecting points to the fuses are not to be bunched together with the wires for other circuits.

306. Section boards and distribution boards

1. General

Insulations, busbars, wiring materials and electrical protective devices for section boards and distribution boards are to be those of being in compliance with the requirements of this Section.

2. Protective enclosures

Section boards and distribution boards are to be protected by suitable enclosures depending on their locations. The enclosures are to be made of incombustible and moisture resistant materials.

3. Arrangement of appliances

Where the same section board or distribution boards is used for the supply circuits having different voltages, all appliances are to be so arranged that the wires of different rated voltages can be laid without contacting each other within the boards. The section boards and distribution boards for emergency distribution circuits are in principle to be provided independently.

307. Testing and inspection

1. General

Switchboards are to meet the requirements of this Section in their construction and are to be tested in accordance with the requirements of the following articles. However, the test required by **Par 2** may be omitted subject to the Society‘s permission for each switchboard which is produced in series having identical type with its first unit tested in the presence of the Surveyor.

2. Temperature test

The temperature rises of switchboards are not to exceed the values given in **Table 6.1.9** under the specified current and/or rated voltage, except these provided in the relevant Sections of this Chapter.

Table 6.1.9 Limits of Temperature Rise of Electrical Appliances for Switchboard

(Based on ambient temperature 45℃)

Item and part			Limit of temperature rise (℃): Thermometer method	Limit of temperature rise (℃): Resistance method
Coil	Class A insulation		45	65
	Class E insulation		60	80
	Class B insulation		75	95
	Bare windings of single layer		75	-
Contact pieces	Mass form	Copper or copper alloy	40	-
		Silver or silver alloy	70	-
	Multilayer form	Copper or copper alloy	25	-
	Knife form	Copper or copper alloy	25	-
Terminals for external cables			45	-
Metallic resistors	Moulded-case type		245	-
	Those other than moulded-case type	For continuous service	295	-
		For intermittint service	345	-
	Exhaust (approx. 25 mm above the exhaust port)		170	-

(NOTE)
The temperature rise for the exciters incorporated in generators to which 50℃ is applied as a limit ambient temperature, is to take the value reduced by 5℃ as limit from the above Table.

3. Operation test

Operations of instruments, circuit-breakers, switching gears, etc. on switchboards are to be confirmed.

4. High voltage test

Switchboards with all components are to withstand the high voltage by applying the following voltage at commercial frequency for 1 minute between all current-carrying parts connected together and earth and between current-carrying parts of opposite polarity of phase. Instruments and auxiliary apparatus may be disconnected during the highvoltage test:

Rated voltage up to 60 V : 500 V

Rated voltage exceeding 60 V : 1,000 V + twice the rated voltage (min. 1,500 V)

5. Insulation resistance test

Immediately after high voltage test, the insulation resistance between all current-carrying parts connected and earth and between current-carrying parts of opposite polarity or phase is not to be less than 1 MΩ when tested with a direct current voltage of at least 500 volts.

Section 4 Cables

401. General

The application of cables used for electrical equipment in ships are to comply with the requirements of this Section. Where it is desired to use other cables than those stipulated in this Section, they are subject to the consideration of the Society.

402. Application of cables

1. Insulating materials

Insulating materials are to be as given in **Table 6.1.10.**

2. Sheath and armour

Cables are to be protected by sheath or armour in accordance with the following requirements.

(1) Cables fitted on weather decks, and in bath rooms, cargo holds, in any other location where water, oil or explosive gases may be present, are to have an impervious sheath.

(2) Cables fitted where they are likely to suffer from mechanical damages are to be metal armoured except where effective metallic casings or non-metallic casings are provided or except where approved by this Society.

3. Fire safety

Except special types of cables such as radio frequency cables, cables are to be satisfied with the required characteristic of flame retardant or fire resisting type.

Table 6.1.10. Permissible Temperature of Insulating Materials

Insulating material	Abbreviated designation	Maximum rated conductor temp.(℃)	
		Normal operation	Short-circuit
Polyvinyl chloride	PVC	70	150
Ethylene propylene rubber	EPR	90	250
High modulus or hard grade ethylene propylene rubber	HEPR	90	250
Cross-linked polyethylene	XLPE	90	250
Halogen free ethylene propylene rubber	HF EPR	90	250
High modulus or hard grade Halogen-free ethylene propylene rubber	HF HEPR	90	250
Halogen-free cross-linked polyethylene	HF XLPE	90	250
Cross-linked polyolefin for halogen-free cables	HF 90	90	250
Silicon rubber	S 95	95	350*
Halogen-free silicone rubber	HF S 95	95	350*
* : This temperature is applicable only to power cables and not appropriate for tinned copper conductors.			

403. Current rating of cable

1. Maximum continuous load

The highest continuous load carried by a cable is not to exceed its current rating specified in **Par 5.** The diversity factor of the individual load may be allowed for in estimating the maximum continuous load.

2. Voltage drop

The voltage drop from the main or emergency switch board busbars to any electrical installation, except for navigation lights, is not to exceed 6 % of the rated voltage of the installation, when the cables are carrying maximum load current under normal condition of service. For supplies from batteries of voltage not exceeding 24 volts, the voltage drop may be increased to 10 %.

3. Estimation of lighting load

In assessing the current rating of lighting circuits every lamp holder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 watts, unless the fitting is so constructed as to take only a lamp rated at less than 60 watts.

4. Short-time load

Where the motors used for cargo winches, windlasses and capstans are short time duty the current rating of the cables may be allowed to be increased according to their duty.

5. Current rating of cables

The current rating of cables is to comply with the following (1) to (5).

(1) Current rating of cables for continuous services
The current rating of cables for continuous services is not to exceed the values given in **Table 6.1.11.**

(2) Correction factor of ambient temperature
Where the ambient temperature is different from that specified in (1) above, the current rating of cables is to be calculated by multiplying the correction factor given in **Table 6.1.12.**

(3) Current rating of cables for short-time services
The current rating of cables for short-time services (30 minutes or 60 minutes) is to be calculated by multiplying the value given in **Table 6.1.11** by the following correction factor.

$$\text{correction factor : } \sqrt{\frac{1.12}{1-\exp\left(\frac{-t_s}{0.245\cdot d^{1.35}}\right)}}$$

where,

t_s : 30 or 60 (minute)

d : overall diameter of the finished cable (mm)

(4) Current rating of cables for intermittent services
The current rating of cables for intermittent services (for periods of 10 minutes, of which 4 minutes are with a constant load and 6 minutes without load) is to be calculated by multiplying the value given in **Table 6.1.11** by the following correction factor.

$$\text{correction factor : } \sqrt{\frac{1-\exp\left(-\frac{10}{0.245\cdot d^{1.35}}\right)}{1-\exp\left(-\frac{4}{0.245\cdot d^{1.35}}\right)}}$$

where,

d : overall diameter of the finished cable (mm)

(5) Where more than 6 cables belonging to the same circuit are bunched together, a correction factor of 0.85 is to be applied.

Table 6.1.11 Current Rating of Cables (for continuous services)

(Based on ambient temperature 45℃)

Nominal sectional area of conductor (mm^2)	Current rating (*A*)								
	PVC insulation (70℃)			Ethylene propylene rubber, High modulus or hard grade ethylene propylene rubber, Cross-linked polyethylene, Halogen free ethylene propylene rubber, High modulus or hard grade Halogen-free ethylene propylene rubber, Halogen-free cross-linked polyethylene, Cross-linked polyolefin for halogen-free cables insulation (90℃)			Silicon rubber, Halogen-free silicone rubber insulation (95℃)		
	1 core	2 core	3 core	1 core	2 core	3 core	1 core	2 core	3 core
1	11	9	8	18	15	13	20	17	14
1.5	15	13	11	23	20	16	24	20	17
2.5	22	19	15	30	26	21	32	27	22
4	29	25	20	40	34	28	42	36	29
6	37	31	26	52	44	36	55	47	39
10	51	43	36	72	61	50	75	64	53
16	69	59	48	96	82	67	100	85	70
25	91	77	64	127	108	89	135	115	95
35	112	95	78	157	133	110	165	140	116
50	140	119	98	196	167	137	200	170	140
70	173	147	121	242	206	169	255	217	179
95	210	179	147	293	249	205	310	264	217
120	243	207	170	339	288	237	360	306	252
150	279	237	195	389	331	272	410	349	287
185	318	270	223	444	377	311	470	400	329
240	374	318	262	-	-	-	-	-	-
300	430	366	301	-	-	-	-	-	-

Table 6.1.12 Correction Factor for Various Ambient Temperature

Maximum rated conductor temperature of insulation	Ambient temperature										
	35℃	40℃	45℃	50℃	55℃	60℃	65℃	70℃	75℃	80℃	85℃
60℃	1.29	1.15	1.00	0.82	-	-	-	-	-	-	-
65℃	1.22	1.12	1.00	0.87	0.71	-	-	-	-	-	-
70℃	1.18	1.10	1.00	0.89	0.77	0.63	-	-	-	-	-
75℃	1.15	1.08	1.00	0.91	0.82	0.71	0.58	-	-	-	-
80℃	1.13	1.07	1.00	0.93	0.85	0.76	0.65	0.53	-	-	-
85℃	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50	-	-
90℃	1.10	1.05	1.00	0.94	0.88	0.82	0.74	0.67	0.58	0.47	-
95℃	1.10	1.05	1.00	0.95	0.89	0.84	0.77	0.71	0.63	0.55	0.45

404. Installation of cables

1. General

Cable runs are to be, as far as possible, straight and accessible.

2. Expansion joints

The installation of cables across expanding parts in the ship's structure is, as far as possible to be avoided. Where this is not practicable a loop of cable of length proportional to the expansion of the part is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

3. Precaution against fire protection

(1) Where cables are installed in bunches and the risk of fire propagation is considered high, special precautions are to be taken in cable installation to prevent fire propagation.
(2) Cables and wiring serving essential or emergency power, lighting, internal communications or signals are to be so far as practicable routed clear of galleys, laundries, machinery spaces of category A and their casings and other high fire risk areas. Cables connecting fire pumps to the emergency switchboard are to be of a fire resistant type where they pass through high fire risk areas. Where practicable all such cables are to be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.
(3) Where cables for services required to be operable under fire conditions including their power supplies pass through high fire risk areas, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

4. Bunching

Cables having insulating materials with different maximum rated conductor temperature are not to be bunched together, or, where this is not practicable, the cables are to be operated so that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

5. Protection covering

Cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

6. Maximum internal radius of bend

When cables are to be installed bent, the minimum internal radius of bend is to be not less than the following values:

(1) 6 d for rubber and PVC insulated cables with metal covering.
(2) 4 d for rubber and PVC insulated cables without metal covering.
(3) 4 d for mineral insulated cables.
(d = overall diameter of cable)

7. Cables in refrigerated spaces

Cables are not to be installed in refrigerated spaces, as far as possible. Where cables are unavoidably installed in the spaces, however, the following requirements are to be observed.

(1) PVC insulated cables are not to be used.
(2) Cables are to have a lead sheath or cold-resisting impervious sheath.
(3) Cables are not to be, as a rule, embedded in structural heat insulation.
(4) Where cables must pass through structural heat insulation, they are to be installed at a right angle to such insulation and are to be protected by a pipe, preferably fitted with a watertight stuffing tube at each end.
(5) Cables are to be installed with ample space from ceilings, side walls or the face of air duct casings and are to be supported by plating, hangers or cleats.
(6) Supporting strips, plating or hangers used for securing the cable are to be galvanized or otherwise protected against corrosion.

405. Mechanical protection of cables

1. Cables in cargo holds

Cables in cargo holds and other space where there is exceptional risk of mechanical damage are to be suitably protected even if they are armoured, except where approved by this Society.

2. Mechanical protection of cables

Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

3. Non-metallic ducts or conduits

Non-metallic duct or conduit is to be of flame-retardant material. PVC conduit is not to be used in refrigerated spaces or on open decks.

406. Earthing

1. Earthing of metallic coverings of cables

Metal coverings of cables are to be effectively earthed at both ends, provided that in final sub-circuits earthing may be at the supply end only.

2. Electrical continuity of metallic coverings of cables

Effective means are to be taken to ensure that all metallic coverings of cables are made electrically continuous throughout their length.

3. Lead sheath

The lead sheath of lead-sheated cables is not to be used as the sole means of earthing the non-current carrying metal parts of items of equipment.

407. Securing of cables

1. General

Cables are to be effectively secured, except cables for portable appliances and those installed in pipes, conduits or special casings.

2. Supporting and fixing distance for cables

Supporting and fixing distance for cables are not to be more than the values given in **Table 6.1.13.**

Table 6.1.13 Supporting and Fixing Distance for Cables

Cable run	Cable run space	Supporting distance (cm)	Fixing distance (cm)
Vertical run	All space	30	30
Horizontal run	Cable run in exposed space	30	30
	Cable run in space except exposed space	30	*90

(NOTE)
* In case where the cables are not laid on a hanger, etc., the Fixing distance is not to be more than 30 cm

3. Clips, supports and accessories

(1) Clips are to be robust and are to be those by which cables are effectively secured without any damage on coverings of the cables.
(2) Clips, supports and accessories are to be of corrosion-resistant material or to be suitably treated to prevent corrosion.
(3) Clips and supports of non-metallic materials are to be flame-retardant.

(4) When cables secured by clips of non-metallic materials are not laid on top of horizontal cable trays or supports, special considerations are to be given to prevent the release of cables during a fire.

4. Cable trays/protective casings made of plastic materials

(1) Installation requirements
Cable trays/protective casings made of plastic materials are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. When plastic cable trays/protective casings are used on open deck, they are additionally to be protected against UV light. "Plastic" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP. "Protective casing" means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

(2) Safety working load
The load on the cable trays/protective casings is to be within the safe working load (SWL). The support spacing is not to exceed the spacing at the SWL test. In general the spacing is not to exceed 2 meters. The selection and spacing of cable tray/protective casing supports are to take into account:
(A) Cable trays/protective casings' dimensions
(B) Mechanical and physical properties of their material
(C) Mass of cable trays/protective casings
(D) Loads due weight of cables, external forces, thrust forces and vibrations
(E) Maximum accelerations to which the system may be subjected
(F) Combination of loads

(3) Cable occupation ratio in protective casing
The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

408. Penetration of bulkheads and decks

1. Penetration through bulkheads and decks

Where cables pass through bulkheads and decks which are required to have some degree of tightness, they are to be so constructed as to ensure that the strength and tightness are not impaired.

2. Penetration through fireproof bulkheads and decks

Where cables pass through bulkheads and decks which are required to have some degree of fire integrity, they are to be so constructed as to ensure that the fire integrity is not impaired.

3. Bushing

Where cables pass through non-watertight bulkheads or steel structures, the holes are to be bushed with lead or other suitable materials in order to avoid damage to cables. If the thickness of the steel is sufficient, adequately round edges may be accepted as the equivalent of bushing.

409. Metallic pipes and conduits

1. General

Metallic pipe or conduits are to be effectively earthed and are to be mechanically and electrically continuous across joints.

2. Internal radius of bend

The internal radius of bend of pipes and conduits is to be in accordance with the requirement in **404. 6.** Where, however, pipes exceed 64mm in outside diameter, the internal radius of bend is not to be less than twice the outside diameter of the pipe.

3. Internal cross-sectional area of pipes

The internal cross-sectional area of the pipe is not to be less than 250 % of the sum of the cross-sectional areas of the cables to be installed in the pipe.

4. Drainage

Horizontal pipes or conduits are to have suitable drainage.

5. Expansion joints

Where pipe arrangement is long, expansion joints are to be provided where necessary.

410. Cables for alternating current

Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20A, the following requirements are to be complied with:

(1) Cables are to be either non-armoured or armoured with non-magnetic material.
(2) Where installed in pipe or conduit, cables belong to the same circuit are to be installed in the same pipe or conduit.
(3) Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.
(4) Where two or three single-core cables forming respectively single-phase circuits or three-phase circuits are installed, the cables are to be in contact with one another as far as possible. In any event, the distance between adjacent cables is not to be greater than the diameter of the cable.
(5) If single-core cables of current rating greater than 250A are to run along steel bulkheads, wherever practicable, the cables should be spaced as far away from the steel bulkheads as possible.
(6) Where single-core cables of large cross section and exceeding 30 m in length are used, the phase are to be transposed at regular intervals of approximately 15 m in order to balance the impedances of circuits.
(7) In case of circuits involving two or more single-core cables in parallel per phase, all cables are to have the same length and the same cross-section.
(8) Magnetic material is not to be placed between single-core cables of a group. Where cables pass through steel plates, all cables of the same circuit are to pass through a plate or gland of non-magnetic material and the space between the cables and the magnetic material is not to be less than 75 mm wherever practicable.

411. Joints and branch circuits

1. Cable splices

Cable splice is to be made of fire resistant replacement insulation equivalent in electrical and thermal properties to the original insulation. The replacement jacket is to be at least equivalent to the original impervious sheath and is to assure a watertight splice. Splices are to be made using the splice kit, which is to contain the following:

(1) Connector of correct size and number
(2) Replacement insulation
(3) Replacement jacket
(4) Instructions for use

All cable splices are to be type approved before use.

2. Installation of cable splices

No splice is permitted in hazardous areas, except for cables of intrinsically safe circuits. Neither is splice permitted in propulsion cables. Where permitted, the following installation details are to be complied with:

(1) All splices are to be made after the cables are in place and are to be in locations accessible for inspection.
(2) The conductor splice is to be made using a pressure type butt connector.
(3) Armored cables having splices are not required to have the armor replaced, provided that the armor is made electrically continuous.
(4) Splices are to be so arranged that mechanical stresses are not carried by the splice.

3. Cable junction boxes

Live parts within the junction box are to be provided with suitable clearances and creepage distances, or with shielding by flame retarding insulation material. Junction boxes having compartments for different voltage levels are to have each compartment appropriately identified as to its rated voltage. Cables within the junction boxes are to be well supported so as not to put stress on the cable contacts.

4. Installation of cable junction boxes

Junction boxes are not to be used in propulsion cables, however. Where permitted, the following installation details are to be complied with:

(1) Junction boxes are to be in locations accessible for inspection.
(2) For low voltage systems(up to 1 kV AC), each voltage level is to be provided with its own junction box or separated by physical barriers within the same junction box. For high voltage systems (> 1 kV), a separate junction box is to be used for each of the voltage levels.
(3) Emergency circuits and normal circuits are not to share the same junction box.
(4) Armored cables are to have their armoring made electrically continuous.
(5) Cables arranged for connection at a junction box are to be well-supported and fastened so that conductor contacts are not subjected to undue stress.

5. Cable termination

Cables stripped of moisture-resistant insulation are to be sealed against the admission of moisture by methods such as taping in combination with insulating compound or sealing devices. Cable conductors for connection to terminals are to be fitted with crimp lugs of corresponding current rating, or equivalent. Soldered lugs are permitted for conductors up to 2.5 mm^2 only. Cables are to be secured to the terminal box or other sturdy structure in such a manner that stresses are not transmitted to the terminal. Where applicable, other properties of the cable, e.g., flame retarding, fire resistant, etc. are to be retained through to the terminal box.

412. Testing and inspection

Cables are to be in compliance with the requirements **109. 1** to **6.**

Section 5 Distribution

501. Methods of distribution

1. General

Every current-consuming appliance is to be supplied by either a switchboard or a section board or a distribution board.

2. Power and lighting circuits

Lighting circuits and power circuits are to be supplied from a switchboard independently.

3. Insulation monitoring system

(1) When a distribution system, whether primary or secondary, for power, heating or lighting, with no connection to earth is used, a device capable of continuously monitoring the insulation level to earth and of giving an audible or visual indication of abnormally low insulation values is to be provided.
(2) Earthing current flowing through the insulation monitoring system specified in (1) is not to exceed 30 mA under any circumstances.

4. Hull return distribution

(1) The hull return system of distribution is not to be used for power, heating, or lighting in a tanker or in a ship of 1,600 tons gross tonnage and upwards.
   (A) Impressed current cathodic protection system for outer hull protection only.
   (B) Earth indication devices or other alternative means, however, in no case the circulation current to exceed 30 mA.
   (C) Limited and locally earthed systems, such as starting and ignition systems of internal combustion engines.

(D) Electrical circuits having no fear of causing hull current in the dangerous spaces, subjected to the approval of the Society.

(2) Where the hull return system is used, all final subcircuits, i.e. all circuits fitted after the last protective device, are to be two-wire and special precautions are to be taken to the satisfaction of the Society.

502. Unbalance of circuits

1. Three-wire *d.c.* systems

Unbalance of loads between an outer conductor and the middle wire at the switchboards, section boards and distribution boards is not to exceed 15 % of the full load current as far as possible.

2. Three-wire *a.c.* systems

Unbalance of loads on each phase at the switchboards, section boards and distribution boards is not to exceed 15 % of the full load current as far as possible.

503. Shore connections

1. Installation of connection boxes

Where arrangements are made for the supply of electricity from a source on shore, a connection box is to be installed in a suitable position. And also high voltage shore connections(above 1 kV), are to comply with requirements in **Sec 16**.

2. Connection boxes

The connection box is to contain terminals to facilitate a satisfactory connection and a circuit-breaker or an isolating switch with fuses. Means are to be provided for checking the phase sequence (for three-phase alternating current) or the polarity (for direct current).

3. Cables between connection box and main switchboard

Cables between the connection box and the main switchboard are to be permanently fixed and a pilot lamp for source and a switch or a circuit-breaker are to be provided on the main switchboard.

504. Power feeders

1. Essential power circuits

The circuits supplying electrical equipment which is disconnected at sea are, as a rule, not to be connected to the power circuits supplying electrical equipment required for essential services.

2. Independently supplied circuits

The feeders of the auxiliaries in main engine room and boiler room, cargo gear motors, radio equipment, searchlights, ventilating sets, etc. are to be independently supplied from switchboards or distribution boards.

3. Circuits for ventilation fans

Fans for cargo hold ventilation and for accommodation ventilation are not to be supplied from the same feeder.

505. Steering gear circuits

Steering gear power unit circuits are to comply with the relevant requirements in **Pt 5, Ch 7.**

506. Navigation light circuits

1. Final sub-circuits of navigation lights

Navigation lights are to be connected separately to the navigation light indicator.

2. Control and protection

Each navigation light is to be controlled and protected in each insulated pole by a switch with fuses and a circuit-breaker fitted on the navigation light indicator.

3. Feeder circuits of navigation lights

The navigation light indicator is to be supplied by two alternative circuits, one from the main source of power and one from the emergency source of power.

4. Prohibition of switches and fuses

Switch and fuse are not to be provided on the feeder circuits of navigation lights, except the switchboard and indicator.

5. Installation of navigation light indicator

The navigation light indicator is to be placed in an accessible position on the navigation bridge.

507. Lighting circuits

1. Lighting in engine room, accommodation spaces, etc.

In main engine room, boiler room, large machinery spaces, large galleys, corridors, stairways leading to boat-decks and public spaces, lighting is to be supplied from at least two circuits and to be so arranged that failure of any one circuit will not leave these spaces in darkness. One of the circuits may be emergency lighting circuit.

2. The arrangement of the main electric lighting system is to be such that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, the main switchboard and the main lighting switchboard, will not render the emergency electric lighting system required by **1402. 2** (1) to (3) inoperative.

3. The arrangement of the emergency electric lighting system is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated transforming equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render the main electric lighting system required by **Par 1** inoperative.

4. Fixed lighting fittings of cargo holds and coal stores

Fixed lighting fittings of cargo holds and coal stores are to be controlled by multipole linked switches situated outside these areas. Provision is to be made to lock in the switches or switch boxes except where installed in cargo holds carrying cargoes with no danger of ignition.

508. Feeder circuits for communication and signalling system, other lights

1. Radio installation

Feeder circuits for radio installation are to be in compliance with the requirements of the relevant regulations.

2. Internal communications

Feeder circuits for internal communications are to comply with the requirements in **Sec 11.**

3. Daylight signalling lamp

The daylight signalling lamp is not to be solely dependent upon the ship's energy source of electrical power. When emergency source of electrical power is used for the lamp, it is to be in accordance with the requirements in **1402. 2.**

4. General emergency alarm systems

General emergency alarm systems specified in **7.2.1** of International Life-Saving Appliance Code (LSA Code) and public address system or other suitable means of communication specified in Regulation III / 6.4.2 of SOLAS Convention are to be supplied from both main source of electrical power and emergency source of electrical power.

5. Not under command lights and anchor lights

Not under command lights and anchor lights are to be supplied from both main source of electrical power and emergency source of electrical power.

509. Final sub-circuits

1. Motor circuits

In general, a separate final sub-circuit is to be provided for every motor of essential service and every motor of 1 kW or more in rating.

2. Lighting circuits

(1) Lighting fittings are not to be supplied from final sub-circuits for heaters and motors.
(2) The number of lighting points supplied from a final sub-circuit of 15 A or less in rating is not to exceed the followings, except the case where the number of lighting points and total load current are invariable, the number of lighting points may be increased, provided the aggregate load current does not exceed 80 % of the rating of protective device in the circuit.
For circuits of 50 V and below 10 ea.
For circuits of 51 V - 130 V 14 ea.
For circuits of 131 V - 250 V 24 ea.
(3) In a final sub-circuits for panel lighting and electric signs, where lamp holders are closely grouped, the number of points supplied is unrestricted, provided the maximum operating current in the sub-circuit does not exceed 10 A.

3. Heating circuits

A separate final sub-circuit is to be provided for each heater, except the small heaters up to 10 of aggregate current rating not exceeding 15 A may be supplied from a single final sub-circuit.

4. Final sub-circuits of rating exceeding 15 A

A final sub-circuit of rating exceeding 15 A is not to supply more than one point as a rule.

5. Protection of final sub-circuits

Each insulated pole of final sub-circuits is to be protected by a fuse or a circuit breaker.

510. Indication of circuits

The current-carrying capacity of each circuit is to be permanently indicated together with the rating or appropriate setting of the overload protective device.

Section 6 Transformers for Power and Lighting

601. General

1. Application

Transformers rated at 1 kVA or more for single phase and at 5 kVA or more for three-phase are to comply with the requirements of this Section.

2. Number and ratings of transformer

Where essential services are supplied, the number and ratings of transformers are to be sufficient to ensure the operation of essential services even when one transformer is out of service.

602. Construction

1. Transformers in accommodation spaces

Transformers in accommodation spaces are to be of dry, naturally cooled type. In machinery spaces they may be of oil-immersed, naturally cooled type.

2. Windings of transformers

Complete insulation is to be made between primary windings and secondary windings of transformers except those for motor starting.

3. Oil-immersed transformers rated at 10 kVA or more

Oil-immersed transformers rated at 10 kVA or more are to be provided with oil gauges and means for drainage, and when rated at 75 kVA or more with thermometers in addition.

4. Precautions against short-circuit current

All transformers are to be capable of withstanding the thermal and mechanical effects without damage, when carrying with short-circuit current for 2 seconds while in use.

603. Temperature rise

The temperature rise of transformers is not to exceed the values given in **Table 6.1.14** during continuous operation at rated output. Where, however, the ambient temperature is not more than 40℃, the table values may be increased by the amount of difference.

Table 6.1.14 Limit of Temperature Rise of Transformers

(Based on ambient temperature 45℃)

Part		Limit of temperature rise (℃)					
		Measuring method	Class A insulation	Class E insulation	Class B insulation	Class F insulation	Class H insulation
Windings	Dry type transformer	Resistance method	55	70	75	95	120
	Oil-immersed transformer	Resistance method	60	-	-	-	-
Oil		Thermometer method	45				
Core		Thermometer method	Temperature not injurious to insulation				

604. Voltage regulation

The voltage regulation of transformers is not to exceed the following values at full load and 100 % power factor.

Single phase 5 kVA or more and three-phase 15 kVA or more : 2.5 %

Single phase less than 5kVA and three-phase less than 15 kVA : 5 %

605. Testing and inspection

1. General

Transformers are to meet the requirements of this Section in their construction and are to be tested in accordance with the requirements of the following Paragraph. However, the test required by **Par 2** may be omitted subject to the Society's permission for each transformer which is produced in series having identical type with its first unit tested in the presence of the Surveyor.

2. Temperature test

The temperature rises of transformers under the rated full load are not to exceed the values given in **603.**

3. Voltage regulation test

Transformers are to be subjected to the voltage regulation test and comply with the requirements of

604. except that it may also be obtained by calculation.

4. High voltage test

After the temperature test, transformers are to withstand the test voltage by applying *a.c.* 1000V plus twice the maximum line voltage of commercial frequency between windings and between windings and earth for 1 minute. The test voltage in this test is to be at least 1500V.

5. Induced high voltage test

Transformers are to withstand for the duration of the test expressed by the following formula, when twice the normal voltage is induced on the winding at any frequency between 100 and 500Hz, but the duration of the test is to be at least for 15 seconds and not over 60 seconds.

$$\text{Testing time (second)} = 60 \times \frac{2 \times \text{Rated frequency}}{\text{Test frequency}}$$

6. Insulation resistance test

Before and after the high voltage test, the insulation resistance test for all current-carrying parts are to be carried out and minimum values are to be given in the following.

Rated voltage Un (V)	Minimum test voltage (V)	Minimum insulation resistance (MΩ)
$Un \leq 250$	$2 \times Un$	1
$250 < Un \leq 1,000$	500	
$1,000 < Un \leq 7,200$	1,000	$1 + \frac{U_n}{1,000}$
$7,200 < Un \leq 15,000$	5,000	

Section 7 Controlgears for Motors and Magnetic Brakes

701. Construction

1. General

(1) Controlgears for motors are to be of durable construction and provided with efficient means of starting, stopping, reversing and speed controlling of motors together with essential safety devices.
(2) Controlgears for motors are to have suitable protective enclosures depending on their locations and to be so constructed that operators can safely handle them.
(3) Where intrinsically safe electrical appliances are built in controlgears for motors, they are to be arranged in compliance with the requirements in **902. 3** (3) and the wires for intrinsically safe circuits are to be speparated from those for other circuits, and to be shielded electrically if necessary. Suitable measures are to be taken to identify the wires for intrinsically safe circuits easily.

2. Grouped starters

(1) In case where controlgears for motors of essential services which are to be provided in duplicate are built in a grouped starter panel, the busbars, appliances and others are to be so arranged that one fault on the appliances or the circuits do not render the motors for the same use unusable simultaneously.
(2) Transformers for power supply to control circuits are to be provided for each motor or each group of motors incorporated in an apparatus.

3. Wearing parts of controlgears for motors

All wearing parts of controlgears for motors are to be readily accessible for inspection and maintenance.

4. Control-gears for motors above 0.5 kW

Motors above 0.5 kW are to be provided with the following control apparatus :

(1) Means to prevent undesired restarting after a stoppage due to low voltage or complete loss of voltage. This does not apply to motors, the continuous availability of which is essential to the safety of the ship and the automatically operated motors.
(2) Efficient means of isolation are to be provided so that all voltage may be cut off from the motor, except that where means of isolation (that provided at the switchboard, section board, distribution board, etc.) are adjacent to the motor.
(3) Means for automatic disconnection of the supply are to be provided in the event of excess current due to mechanical overloading of the motor. This does not apply to steering motors.

5. Magnetic contactors and overcurrent relays for motors

(1) Magnetic contactors are to be in compliance with the requirements in **Sec 8.**
(2) Overcurrent relays for motors are to have suitable characteristics in relation to the thermal capacities of motors.

702. Temperature rise

The temperature rises of controlgears for motors are not to exceed the values given in **Table 6.1.15** under the specified currents and rated voltage, except where required in the relevant Sections of this Chapter.

703. Emergency stopping apparatus

Means are to be provided for stopping the motors of forced and induced draft fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps, oil separators(purifiers) and cargo pumps from accessible position outside the space where the motors are installed in case of fire in the space or in the vicinity thereof. But, each separate emergency stop control circuits of ventilators are to be provided for machinery space and other spaces.

704. Starters for steering motors

1. Starters for steering motors are to be of low-voltage release type and arranged in such a way that the steering motors are re-started automatically and safely when electric power is restored after a power failure.

2. Running indicators and overload alarms for steering motors are to be provided in accordance with the relevant requirements in **Pt 5, Ch 7.**

705. Magnetic brakes

1. Magnetic brakes of waterproof type motors

Electrical parts of magnetic brakes applied for waterproof type motors are to be waterproof construction.

2. *D.C.* shunt-wound brakes and *d.c.* compound- wound brakes

D.C. shunt-wound brakes are to operate satisfactorily at 85 % of rated voltage at working temperature, and *d.c* compound-wound brakes at the same conditions as above are to be operated satisfactorily at 85 % of starting current.

3. *D.C.* series-wound brakes

D.C. series-wound brakes are to release down at a current not less than 40 % of full-load current and in every case at the starting current, and are to set at a current 10 % or less of full-load current.

4. *A.C.* magnetic brakes

A.C. magnetic brakes are to be in accordance with the following requirements :

(1) *A.C.* magnetic brakes are to be operated satisfactorily at 80 % of rated voltage at working temperature.
(2) *A.C.* magnetic brakes are not to be noisy due to magnetic action in the working condition.

706. Clearance and creepage distances of control appliances

The clearance and creepage distances of control appliances (e.g., contactors, rheostats, control switches, limit switches, protection and control relays for motors, terminal boards, incorporating semi-conductors and their combinations) are to comply with the following requirements in (1) and (2) depending on the degree of protection of enclosures of the appliances or the atmosphere in which the appliances are installed.

(1) The minimum clearance and creepage distances of control appliances (e.g., electromagnetic contactors, control switches, terminal boards) are not to be less than the values given in **Table 6.1.16** if the appliances are designed and constructed in consideration of the moisture, dust, etc. or are operated in the ambient condition not accompanying the extremely high humidity and heavy deposit of dusts.
(2) The clearance and creepage distances of small control appliances of 15A or less in rating current may be shortened to the values as deemed appropriate by the Society, depending on the degree of protection of enclosures of the appliances or the ambient condition in which the appliances are installed, notwithstanding the requirements in (1) above.
(3) The requirements of above (1) and (2) are not applied to the following items :
  (a) Spark gaps.
  (b) Appliances used in secondary windings of induction motors.
  (c) Oil-immersed appliances.
  (d) Pilot lamp fittings and sockets.
  (e) Small switches in living quarters.
  (f) The sealed portion of the appliances which are of sealed construction.

707. Testing and inspection

1. General

Controlgears for motors are to meet the requirements of this Section in their construction and are to be tested in accordance with the requirements of th following **Pars 2** to **5.** However, the test required by **Par 2** may be omitted subject to the Society´s permission for each controlgear which is produced in series having identical type with its first unit tested in the presence of Surveyor.

2. Temperature test

Controlgears for motors are to be subjected to the temperature test under normal working condition, and than the temperature rise is not to exceed the values given in **702.**

3. Operation test

Operation of instruments, switching gears, protective devices, etc. for controlgears for motors are to be confirmed.

4. High voltage test

Controlgears with components are to withstand the high voltage by applying the following voltage at commercial frequency for 1 minute between all current-carrying parts of switching gears including control devices and earth and between poles or phases. Instruments and auxiliary apparatus may be disconnected during the high voltage test.

Rated voltage of 60V or less : 500V

Rated voltage exceeding 60V : 1,000V + twice the rated voltage (minimum 1,500V)

5. Insulation resistance test

Immediately after the high voltage test, the insulation resistance between all current-carrying parts and earth and between the current-carrying parts of poles or phases are not to be less than 1 megohm when tested with direct current voltage of at least 500V.

Table 6.1.15 Limit of Temperature Rise of Controlgears for Motors

(Based on ambient temperature rise 45℃)

Item and part				Limit of temperature rise (℃) Thermometer method	Limit of temperature rise (℃) Resistance method
Coils (air)	Class A insulation			60	80
	Class E insulation			75	95
	Class B insulation			85	105
	Class F insulation			110	130
	Class H insulation			135	155
	Class C insulation			no limit	no limit
	Single layer enamel windings	Class A insulation		80	-
		Class E insulation		95	-
		Class B insulation		105	-
		Class F insulation		130	-
		Class H insulation		155	-
		Class C insulation		no limit	-
Contact piece	Mass form	Continuous use over 8 hours	Copper or copper alloy	40	-
			Silver or silver alloy	70	-
		Switch on & off one time or more in about 8 hours	Copper or copper alloy	60	-
			Silver or silver alloy	70	-
	Multilayer form or knife form		Copper or copper alloy	35	-
Busbar and connecting conductor (Bare or Class A insulation and higher)				60	-
Terminals for external cables				45	-
Metallic resistors	Moulded-case type			245	-
	Those other than moulded-case type	For continuous use		295	-
		For intermittent use		345	-
		For starter use		345	-
	Exhaust (approx. 25 mm above exhaust port)			170	-

(NOTES)
1. Measurement of temperature of voltage coil is in principle to be made by resistance method only.
2. Where the insulation of single layer enamel windings is higher in class than that of the adjacent parts, the temperature rise associated with the class of insulation for the adjacent parts is to be applied.
3. For single layer bare windings, the temperature rise associated with the class of insulating material on the adjacent part is to be applied.
4. Moulded-case type metallic resistor means such a type as to be buried in the insulating material so as no surface of metallic resistor being exposed.

Table 6.1.16 Minimum Clearance and Creepage Distances for Control Appliances

Rated insulating voltage (V) (D.C. & A.C.)	Clearance (mm)						Creepage (3)(4) (mm)					
	Less than 15A (5)		15A or over and 63A or under (5)		Exceeding 63A (5)		Less than 15A (5)		15A or over and 63A or under (5)		Exceeding 63A (5)	
	$L-L$ (1)	$L-A$ (2)	$L-L$ (1)	$L-A$ (2)	$L-L$ (1)	$L-A$ (2)	a	b	a	b	a	b
Not exceeding 60	2	3	2	3	3	5	2	3	2	3	3	4
Exceeding 60 and 250 or under	3	5	4	5	5	6	3	4	6	6	6	8
Exceeding 250 and 380 or under	4	6	4	6	6	8	4	6	6	6	6	10
Exceeding 380 and 500 or under	6	8	6	8	8	10	6	10	6	10	8	12
Exceeding 500 and 660 or under	6	8	6	8	8	10	8	12	8	12	10	14
Exceeding 660	10	14	10	14	10	14	10	14	10	14	14	20

(NOTES) (1) to (5) marked in this Table are as follows

(1) "$L-L$" applies to clearances between bare live parts and between live part and earthed metal part.

(2) "$L-A$" applies to clearance between live part and metal part which accidentally becomes dangerous.

(3) Creepage distance is to be determined by type and shape of insulation. "a" applies to ceramic insulator(steatite and porcelain), and comparable other insulator which is particularly safe against leaked electricity provided with ribbed construction or vertical partitions proved to be equally effective as ceramic insulator through experiments having a tracking index greater than 140V e.g., phenol resins formed items. "b" applies to other insulation materials.

(4) In case where "$L-A$" is greater than the corresponding creepage "a" or "b" the creepage distances between live parts and insulated metals which operator may readilly touch and which becomes live parts by the deterioration of insulation are to be "$L-A$" or more.

(5) Current value is to ve expressed by the rated current-carrying value.

Section 8 Fuses, Circuit-breakers and Electromagnetic Contactors

801. General

Fuses, circuit-breakers and electromagnetic contactors are to comply with Korean Industrial Standards or equivalent thereto, and in addition, they are also to comply with the requirements of this Section.

802. Fuse

1. Construction

(1) Fuses are to be of enclosed type and the construction is to be such that its enclosure is not broken nor burnt and the adjacent insulation is not deteriorated by flowing of fused metal or emitting of gases, when the fuse element has blown out.

(2) Fuses are to be easily exchangeable for their spare parts without the risk of getting electric shock or burn on setting fuses in and out.

(3) Each fuse is to be clearly indicated of its rated voltage and rated current, and in addition rated breaking capacity, fusing characteristics and current-limiting characteristics according to its kind. Such indication may be made in terms of value or symbol.

2. Performance

(1) The temperature rise on the connecting terminals of cables is not to exceed 45℃, when the fuses and fuse-holders has been fitted up to the normal working condition and 100 % of the rated current is carried thereon.

(2) Fuses are to have the fusing characteristics corresponding to their kind, and under the circuit conditions specified in the standards referred to in **801.**, they are to be capable of breaking securely all currents whichever is below the rated breaking capacity and above the fusing current.

803. Circuit-breakers

1. Construction

(1) Circuit-breakers are to be of trip-free type and depending upon the field of their application, the trip attachments are to have a time-delay or an instantaneous overcurrent trip feature or both of them.
(2) The main contacts of the circuit-breakers are to be such as to have no undue burning and pitting. Arcing contacts except those of the moulded-case circuit-breakers are easily renewable.
(3) Instantaneous overcurrent trip devices are to be provided in each pole of the circuit-breakers and are to be so constructed as to be capable of tripping them directly by short-circuit current.
(4) Circuit-breakers are to be such that no accidental opening and closing occur due to the vibration of a ship, and furthermore, no malfunction is caused by the list of an angle of 30° in any direction.
(5) The fused circuit-breakers of moulded-case type are to be so constructed that single phasing does not occur in the event of blowing of fuses and that the fuses can be replaced easily without the risk of accidental touch to their live-parts.
(6) Each circuit-breaker is to be clearly indicated of its rated voltage and rated current, and in addition rated breaking capacity, rated making current and rated short-time current according to its kind. Each time-delay overcurrent trip device is to be indicated of its operating characteristics, except the moulded-case circuit-breakers.

2. Performance

(1) The temperature rise on the connecting terminals of cables is not to exceed 45°C when 100 % of the rated current is carried thereon.
(2) All circuit-breakers are, according to their kind, to be such as to be able to securely break the overcurrent not more than the rated breaking capacity and safely make the circuit to carry the current not more than the rated making current under the circuit conditions specified in the standards referred to in **801.**
(3) The time-delay overcurrent trip devices of circuit-breakers for generator circuits are to be such that the readjustment of the current setting does not cause remarkable change to the time-delay feature.
(4) The characteristics of the time-delay overcurrent trip devices are not to be affected excessively by ambient temperature.

804. Electromagnetic contactors

1. Construction

(1) Electromagnetic contactors are to be such that no accidental opening and closing occur due to the vibration of a ship, and furthermore, no malfunction is caused by the list of an angle of 30° in any direction.
(2) The contact pieces and magnetic coils are to be readily replaceable.
(3) Each electromagnetic contactor is to be clearly indicated of its rated voltage, rated current, rated voltage of magnetic coil, interruption current capacity and closed circuit current capacity. Such indication may be made in terms of value or symbol.

2. Performance

(1) The temperature rise on each part of electromagnetic contactor is not to exceed the values specified in **702.** when current-carrying is made continuously with the full load current corresponding to the rated capacity supplied to the main contacts and with the rated voltage applied to the magnetic coil.
(2) Electromagnetic contactors are to have a suitable interruption current capacity and closed-circuit current capacity depending on their application.

805. Testing and inspection

Fuses, circuit-breakers and electromagnetic contactors are to be in compliance with the requirements in **109. 1** to **6.**

Section 9 Explosion-protected Electrical Equipment

901. General

1. Applicable standards

Explosion-protected electrical equipments is to comply with (KS C) IEC 60079 or equivalent standards and they are to comply with the requirements in this Section.

2. The kind of explosion-protected construction

The explosion-protected construction used for electrical equipment on board ships is to be selected from the followings.

(1) Flameproof type (Ex-d)
(2) Intrinsically safe type
  (A) Category 'ia' intrinsically safe type (Ex-ia)
  (B) Category 'ib' intrinsically safe type (Ex-ib)
(3) Increased safety type (Ex-e)
(4) Pressurized protected type (Ex-p)
(5) Powder filling type (Ex-q)
(6) Oil immersion type (Ex-o)
(7) Encapsulation type (Ex-m)
(8) Non-sparking type (Ex-n)

3. Materials

(1) Materials for explosion-protected construction are to have an adequate electrical, mechanical, thermal and chemical resistance against the environmental condition and flammable gases or vapours (hereinafter referred to as "gases" at the location of the electrical equipment concerned.
(2) Enclosures and outer fittings of portable appliances are to be of material which minimizes the risk of spark by friction, or to have a non-metallic strong cover with hanging strap.
(3) Insulating compounds and sealing compounds used for integral parts of explosion-protected construction are to be such that no harmful expansion, contraction, softening or crack is found during in service. And the insulating compounds applied to bare live-parts are to be flame-retardant.

4. Construction

(1) The glazed ports of lighting fittings and the inspection windows of other electrical apparatus of flameproof type, increased safety type and pressurized protected type are, as a rule, to be provided with robust metallic guards.
(2) In case where a gasket is used with a view to give watertightness to the explosion protected electrical equipment installed on weather decks and other similar spaces, the gasket is to be so fitted as not to impair the explosion-proof characteristics due to its deterioration or breakage.
(3) The leading-in part of cables is to be of a construction suitable for ship cables. Consideration is to be given so that the cables can be surely fixed at the leading-in part, except where the cables are installed in steel conduits.
(4) Electrical equipment associated with intrinsically safe circuits and located in dangerous spaces are in principle to be of totally enclosed construction.
(5) Explosion-protected electrical equipment is to be clearly indicated of its type and the kind of gases for which the equipment is designed. And the lighting fittings are also to be indicated of the kind of lighting bulb applicable thereto and its wattage.

5. Ambient temperature

Reference ambient temperature for explosion-protected electrical equipment is to be 50℃.

902. Special requirements

Explosion-protected electrical equipment for each explosion-protected construction specified in **901. 2** is to be as deemed appropriate by the Society.

903. Testing and inspection

Explosion-protected electrical equipment is to be in compliance with the requirements in **109. 1** to **7.**

Section 10 Lighting Fittings, Heating Appliances and Wiring Accessories

1001. General

Lighting fittings, heating appliances and wiring accessories are to comply with Korean Industrial Standards or equivalent thereto, and in addition they are also to comply with the requirements in this Section.

1002. Lighting fittings

1. Construction and location

(1) Enclosures are to be composed of metal, glass or synthetic resin having a sufficient mechanical, thermal and chemical resistivity and to have a suitable degree of protection depending on their location. Synthetic resin enclosures which support current-carrying parts are to be flame retardant.
(2) Terminal box and leading-in part of cables are to be of construction suitable for ship cables. Consideration is to be given so that the insulation of cables may not be deteriorated at an early stage due to the temperature rise on terminals and other parts.
(3) Lighting fittings installed in engine room or similar spaces which are exposed to the risk of mechanical damage are to be provided with suitable grilled metallic guards to protect their lamps and glass globes against such damage.

2. Fluorescent lighting fittings

(1) Reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are liable to be subjected to high temperatures.
(2) Every capacitor of 0.5 microfarad or more is to be provided with a protective leak or other protective means which reduces the voltage of the capacitor to not more than 50V within 1 minute after disconnection from the supply sources.
(3) Transformers are to be installed as close as practicable to the associated discharge lamp.
(4) In principle, fluorescent lighting of electronic ballast stabilizer type installed in navigation bridge is to be approved by the Society.

3. LED lighting

In principle, LED lighting installed in navigation bridge is to be approved by the Society.

1003. Heating appliances

1. Construction and location

(1) In principle, no bare heating element is to be used.
(2) Where the heating element is employed in liquid, it is to be protected by anticorrosive metal sheath.
(3) The high temperature parts of electric heating appliances are to be so protected as to be kept from the risk of a combustible material to come in touch under normal working condition.
(4) Space heaters are to be installed in such a manner as to have no risk of dangerous heating of decks or bulkheads or other surroundings.

2. Control switches

Heating appliances are to be controlled by a fixed switch. Where a plug is used for the appliance, the fixed switch is to be placed in the immediate vicinity of the socket-outlet.

1004. Wiring accessories

1. Material

(1) Enclosures are to be of metal or of flame-retardant material.
(2) The insulating material of live parts is to be of flame-retardant and non-hygroscopic material.

2. Temperature rise

The temperature rise on live parts is not to exceed 30℃.

3. Switches

Switches are to be capable of breaking and making safely a load current equal to 150 % of their rated current at the rated voltage.

4. Plugs and receptacles

(1) Receptacles of rated current exceeding 15 amperes are to be provided with a switch so interlocked that the plug cannot be inserted or withdrawn when the switch is in the "on" position.
(2) Where distribution systems of different voltages are in use, receptacles and plugs are to be of such design that an incorrect connection cannot be made.
(3) Each receptacles and plug having the rated voltage of 55V and over for *d.c.* and 55V and over for *a.c.* are to be provided with an additional contactor for earthing the casing or frame of appliance, except those for double insulated appliances having no non-current carrying metal parts for which earthing is required. The earthing contactors are to make contact in advance of the live contact pins when inserting the plug.

Section 11 Internal Communications

1101. Applicable standards

Each internal communication apparatus is to comply with Korean Industrial Standard or equivalent and above.

1102. Essential internal communication systems

Electric internal communication and signal systems forming part of the essential operating systems of the ship are to be as independent and self-sustaining as possible.

1103. Induced interference suppression

All communication cables are to be so arranged that unwanted interference and cross-talk is avoided.

1104. Protective devices

Where numerous internal communication circuits are branched from common feeder, each circuit and feeder is to be protected by the fuses and other means, and the rating of feeder is to be based on the connected load.

1105. General emergency alarm system

No switch is to be provided for feeder circuits of general emergency alarm system, except for operation switch. Where circuit breaker is used for overcurrent protection, suitable means are to be taken to prevent the circuit breaker from being kept "off" position.

1106. Public address system

1. It is to be loudspeaker installation enabling the broadcast of messages into all spaces where crew members or passengers, or both, are normally present, and to muster stations.

2. Source of electrical power is to be supplied from the main source of electrical power and the emergency source of electrical power where used in order to supplement a general emergency alarm system.

3. It is to allow for the broadcast of messages from the navigation bridge and such at least one other places (cargo control station, fire control station, engine control station, etc) on board the ship as the Society deems necessary.

4. It is to be protected against unauthorized use.

5. It is to be installed with regard to acoustically marginal conditions and not require any action form the addressee.

6. With the ship underway in normal conditions, the minimum sound pressure levels for broadcasting emergency announcements shall be as follows.

(1) In interior spaces 75 dB(A) and at least 20 dB(A) above the speech interference level; and
(2) In exterior spaces 80 dB(A) and at least 15 dB(A) above the speech interference level.

7. It is to be arranged to minimize the effect of a single failure where used in order to supplement a general emergency alarm system.

Section 12 Semi-Conductor Rectifiers for Power

1201. General

1. The requirements in this Section are to be applied to the semi-conductor rectifiers for power (hereinafter referred to as "rectifiers") not less than 5 kW. Further, the rectifiers specified in this Section are to be taken as a rectifier including thyristor.

2. Accessories of the rectifier are to be in accordance with all applicable requirements in this Chapter.

1202. Construction and location

1. Construction

(1) Rectifier valve units, rectifier stacks or cells are to be so arranged that they can be removed from equipment without dismantling the complete unit.
(2) Air-cooled rectifiers are to be suitably installed or protected against the effects of salty air and humidity.
(3) Where mercury vapour are liable to be generated, self-cooling and air-cooled semi-conductor rectifiers are not to be used.
(4) Where rectifier elements are connected in series or parallel, they are so arranged that the voltage or current on each element will become equal as far as practicable.

2. Location

(1) Rectifiers are to be installed in such a manner that the circulation of cooling air is not impeded and that the temperature of the inlet air to the air-cooled rectifier stacks does not exceed the allowable value.
(2) Rectifiers are to be separated from resistors, steam pipes or other sources of radiant heat as far as practicable.

1203. Protective devices, etc.

1. Protective devices

(1) Where forced cooling is provided, the rectifier is to be so arranged that the rectifier can not remain loaded unless effective cooling is maintained.
(2) Where necessary, means are to be provided to guard against transient over-voltage caused by switching and breaking of the circuits and *d.c.* voltage rise due to regenerative power.

2. Temperature of rectifier cells

The maximum permissible temperature rise of junction of rectifier cells is to be such a value as will be specified by the manufacturer. Where the information is not available, the maximum permissible temperature rise of junction of rectifier cells is not to exceed the following values :

Selenium : 70℃

Silicon : 150℃ (thyristor : 125℃)

3. Transformers for rectifiers

Transformers for rectifier are to be of two separate windings.

1204. Thyristor control

1. Gate control circuits

Gate control circuits are to comply with the following requirements.

(1) Gate control circuits of thyristors are to be so arranged that they can generate the gate pulse not exceeding the gate rating and having the pulse width enough to fire all thyristors connected. The gate control circuits are also to be protected from misfire caused by electrostatic induction and electromagnetic induction.

(2) Where thyristors are connected in series or parallel, gate control circuits are to be so arranged that firing timings of each thyristor are not irregular.

2. Thyristor control for *d.c.* motor

Where *d.c.* motors are controlled by thyristor, the following requirements are to be applied.

(1) Where commutation of *d.c.* motor may be affected by the harmonics of thyristor output waveform, appropriate measures are to be taken to reduce such harmonics.

(2) Where electric sources may be affected by lower power factor resulted from the phase control of thyristor, means are to be provided to compensate it.

(3) In case where motors are operated in either direction of rotation by means of changing-over the field polarity, interlock is to be made so as to reverse the polarity of field after armature-current reaching zero, and in addition, suitable means are to be provided to limit electrical non-locked conditions of armature.

1205. Testing and inspection

1. General

Rectifiers and their accessories are to be tested in accordance with the following requirements. The test required by **Par 2,** however, may be omitted subject to the Society's permission for each product which is produced in series having identical type with its first unit tested in the presence of the Surveyor.

2. Temperature test

Temperature test of rectifiers and their accessories is to be carried out under normal working conditions, and the test results are to comply with the requirements in **1203. 2** not exceeding the values specified in the requirements in **702.** as well.

3. Operation test

Instruments, switching devices and protective devices are to be checked under operating conditions.

4. High voltage test

(1) Rectifiers are to withstand the high voltage by applying the following *a.c.* voltage for 1 minute between rectifier cells or live parts of accessories charged with main circuit potential and earth.

Testing voltage (V) = $1.5E_{pi} + 1{,}000$ (Minimum 2,000V)

Where : E_{pi} = Peak reverse voltage

Where *d.c.* voltage is less than 100V, minimum testing voltage may be 1,500V. Rectifier cell is to be short-circuited before the test.

(2) High voltage test between live parts and earth for accessories charged with auxiliary circuit potential is to be in accordance with the applicable requirements in **707. 4.**

5. Insulation resistance test

After the high-voltage test, insulation resistance between live parts of rectifiers and their accessories and earth is not to be less than 1 MΩ when tested with *d.c.* voltage of at least 500V.

Section 13 Accumulator Batteries

1301. Applicable standards

1. Lead-acid accumulator batteries are to comply with Korean Industrial Standard or equivalent and above.

2. Construction, arrangement, etc. of the secondary accumulator batteries other than vent type secondary accumulator batteries (capable of exchanging electrolyte, and vent gas when they charge and discharge) are to apply appropriate measures recognized by the Society.

1302. Construction

The cells of all batteries are to be so constructed and secured as to prevent spilling of the electrolyte due to the vibration, inclination, etc., of the ship and to prevent emission of acid or alkaline spray.

1303. Location

1. Batteries are to be located where they are not exposed to excessive heat, extreme cold, spray, steam or other conditions which would impair performance or accelerate deterioration.

2. Alkaline batteries and lead acid batteries are not to be in the same compartment.

3. Batteries are not to be placed in living quarters.

4. Large batteries are to be installed in a space assigned to the batteries only or alternatively in a deck box if such a space is not available, the batteries may be installed in appropriate space.

5. Engine starting batteries are to be located as close as practicable to the engines served. If such batteries cannot be accommodated in the battery room, they are to be installed so that adequate ventilation is ensured.

1304. Electrical installation in battery compartment

1. Lighting fittings in battery rooms are to be of explosion-proof type.

2. Switches, fuses and other electrical equipment liable to cause an arc are not to be fitted in battery compartments.

3. Cables, with the exception of those appertaining to the battery or the local lighting, are not to be installed in battery compartments as a rule.

1305. Protection against corrosion

The interior of all battery compartments is to be protected with lead-sheet lining of 1.6 mm thick or more or corrosion-resistant paint in accordance with the following Paragraphs :

(1) The entire floor and all walls up to 150 mm high of battery rooms are to be lined with lead-sheet and the linings are to be watertight. Where approved by the Society, lead-sheet lining may be substituted by acid-resisting paint.
(2) Ceilings, walls other than those specified in (1), battery shelves and wooden crates are to be painted with acid-resisting paint.
(3) Battery tray and sulfuric acid bottle base are to be lined with lead-sheet.
(4) Ventilating ducts and fans are to be made of corrosion-resisting material or their interior surfaces are to be coated with corrosion-resisting paint.

1306. Ventilation

1. All rooms, lockers and boxes for accumulator batteries are to be arranged to avoid accumulation of inflammable gas. Where batteries are arranged in two or more tiers, all shelves are to have not less than 50 mm space, front and back, for circulation of air.

2. The ventilation of battery room may be conducted with either natural ventilation or ventilating fan.

3. The battery room is to be provided with effective air inlet near floor surface.

4. Ventilating fans are to be so constructed and be of a material such as not to arise sparking in the event of the impeller touching the fan casing.

5. Fan motor associated with a duct used to exhaust the air from a battery space is, in principle, to be placed outside of the duct.

6. Ventilating ducts terminating at least 1.25 m above in a gooseneck shape or equivalent are to be provided above the top of battery boxes. Holes for air inlets are to be provided on at least two opposite sides of the box.

1307. Charging facilities

1. For floating service or for any other conditions where the load is connected to the battery while it is on charge, the maximum battery voltage is not to exceed the safe value of any connected apparatus. A voltage regulator or other means of voltage control may be provided for this purpose.

2. Battery charging facilities by means of *d.c.* generator and series resistor are to be provided with protection against reversal of current when the charging voltage is 20 % of the line voltage or higher.

1308. Maintenance record of battery

The record of the type, location and maintenance cycle of batteries is to be kept on board ship.

(1) Where batteries are fitted for use for essential and emergency services a schedule of such batteries is to be compiled and maintained. The schedule, which is to be reviewed by the Society, is to include at least the following information regarding the batteries:
   (A) Type and manufacturer's type designation
   (B) Voltage and ampere-hour rating
   (C) Location
   (D) Equipment and/or systems served
   (E) Maintenance/replacement cycle dates
   (F) Dates of last maintenance and/or replacement
   (G) For replacement batteries in storage, the date of manufacture and shelf life

(2) Procedures are to be put in place to ensure that where batteries are replaced that they are of an equivalent performance type.

(3) Where vented type batteries replace valve- regulated sealed types, it is to be ensured that there is adequate ventilation and that the Society's requirements relevant to the location and installation of vented types batteries are complied with.

(4) Details of the schedule and of the procedures are to be included in the ship's safety management system and be integrated into the ship's operational maintenance routine as appropriate to be verified by the Society's Surveyor.

Section 14 Emergency Electrical Equipment

1401. Application

1. A self-contained emergency source of electrical power is to provided.

2. The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and are to be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, except where permitted by the Society in exceptional circumstances.

3. The location of the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard are to be such as to ensure to the satisfaction of the Society that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard, or in any machinery space of category A will not interfere with the supply, control and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard are not to be contiguous to the boundaries of machinery spaces of category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, or the main switchboard.

4. Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

1402. Capacity of emergency source of power

1. The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.

2. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(1) For a period of 3 hours, emergency lighting at every muster and embarkation station and over the sides as required by regulations III/11.4 and III/16.7, Amendments to SOLAS 1974.

(2) For a period of 18 hours, following emergency lighting.

(A) In all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks ;

(B) In the machinery spaces and main generating stations including their control positions ;

(C) In all control stations, machinery control rooms, and at each main and emergency switchboard ;

(D) At all stowage positions for firemen's outfits ;

(E) At the steering gear ; and.

(F) At the fire pump referred to in (6) at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors.

(G) In all cargo pump rooms of tankers

(3) For a period of 18 hours, the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force.

(4) For a period of 18 hours ;
VHF radio installation required by regulations IV/7.1.1 and IV/7.1.2, MF radio installation required by regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3, INMARSAT Ship Earth Stations required by regulation IV/10.1.1 and MF/HF radio installation as required by regulations IV/10.2.1, IV/10.2.2 and IV/11.1 of SOLAS Convention.

(5) For a period of 18 hours, except those services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency.

(A) All internal communication equipment as required in an emergency.

(B) The navigational equipment as required by regulation V/19 of SOLAS Convention where such provision is unreasonable or impracticable the Society may waive this requirement for ships of less than 5,000 gross tonnage.

(C) The fire detection and fire alarm system.

(D) Intermittent operation of the daylight signalling lamp, the ship's whistle, the manual fire alarms and all internal signals that are required in an emergency.

(6) For a period of 18 hours, one of the fire pumps required by regulation II-2 / 10 of SOLAS Convention if dependent upon the emergency generator for its source of power.

(7) For the period of time required by **Pt 5, Ch 7** the steering gear where it is required to be so supplied by that requirement.

(8) In a ship engaged regularly in voyages of short duration, the Society if satisfied that an adequate standard of safety would be attained may accept a lesser period than the 18 hours period specified in (2) to (6) but not less than 12 hours.

1403. Kind and performance of emergency source of electrical power

The emergency source of electrical power is to be a generator, an accumulator battery or an uninterruptible power system(UPS), which is to comply with the following ;

(1) Where the emergency source of electrical power is a generator, it is to comply with the following :

(A) The emergency generator is to be driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43°C ;

(B) The emergency generator is to be started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with (C) is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to the requirements in **1404.** are then to be connected automatically to the emergency generator ;

(C) A transitional source of emergency electrical power as specified in **1404.** is to be provided unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(2) Where the emergency source of electrical power is an accumulator battery, it is to be capable of :

(A) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 % above or below its nominal voltage ;

(B) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power ; and

(C) immediately supplying at least those services specified in **1404.**

(3) Where the emergency source of electrical power is an uninterruptible power system(UPS), it is to comply with the requirements which the Society considers appropriate.

(4) Where electrical power is necessary to restore propulsion, the capacity is to be sufficient to restore propulsion to the ship in conjunction with other machinery, as appropriate, from a dead ship condition within 30 minutes.

1404. Transitional source of emergency electrical power

The transitional source of emergency electrical power where required by **1403.** is to consist of an accumulator battery suitably located for use in an emergency which is to :

(1) operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 % above or below its nominal voltage ; and

(2) be of sufficient capacity and be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation :

(A) The lighting required by **1402. 2** (1) to (3). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps ; and

(B) All services required by **1402. 2** (5) (a), (c) and (d) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

1405. Location, etc. of emergency source of electrical power

1. The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

2. Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired. No accumulator battery fitted in accordance with this regulation is to be installed in the same space as the emergency switchboard.

3. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged.

4. The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation the interconnector feeder is also to be protected at the emergency switch board at least against short circuit.

5. In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that electrical power is to be available automatically to the emergency circuits.

6. Emergency electrical system is to be provided with measures for periodic testing. The periodic testing is to include the testing of automatic starting arrangements.

1406. Starting arrangements for emergency generating sets

1. Emergency generating sets are to be capable of being readily started in their cold condition at a temperature of 0℃. If this is impracticable, or if lower temperatures are likely to be encountered, provision acceptable to the Society is to be made for maintenance of heating arrangements, to ensure ready starting of the generating sets.

2. Each emergency generating set arranged to be automatically started is to be equipped with approved starting devices approved by the Society with a storage energy capability of at least three consecutive starts. The source of stored energy is to be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy is to be provided for an additional three starts within 30 minutes unless manual starting can be demonstrated to be effective.

3. The stored energy is to be maintained at all times, as follows :

(1) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.
(2) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard.
(3) All of these starting, charging and energy storing devices are to be located in the emergency generator space.

4. Where automatic starting is not required, manual starting is permissible, such as manual cranking inertia starters, manually charged hydraulic accumulators, or power charge cartridges, where they can be demonstrated as being effective.

5. When manual starting is not practicable, the requirements of **Pars 2** and **3** are to be complied with except that starting may be manually initiated.

Section 15 Lightning Conductors

1501. General

Lightning conductors are to be fitted on each mast of ships having wooden masts.

1502. Size of lightning conductors

1. Lightning conductors are to be composed of continuous copper tape or rope having a section not less than 75 mm^2. Lightning conductors are to run as straight as possible and sharp bends are to be avoided.

2. The resistance of lightning conductor between the mast top and the point on the earth plate or hull is not to exceed 0.02 ohms.

Section 16 High Voltage Electrical Installations

1601. General

1. Application

(1) The requirements in this Section apply to *a.c.* three-phase supply systems with voltages in the range above 1 kV up to and including 15 kV. Nominal voltage is the voltage between phases.
(2) The high voltage electrical installations are to comply with (KS C) IEC 60092-503 and the applicable requirements in this Chapter in addition to those in this Section.

2. High-voltage, low-voltage segregation Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

1602. System Design

1. Distribution

(1) Network configuration for continuity of ship services
It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable. Services which are duplicated are to be divided between the sections.
(2) Earthed neutral systems
In case of earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault. It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.
(3) Neutral disconnection
Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.
(4) Hull connection of earthing impedance
All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.
(5) Divided systems
In the systems with neutral earthed, connection of the neutral to the hull is to be provided for each section.

2. Degrees of protection

(1) General
Each part of the electrical installation is to be provided with a degree of protection appropriate to the location, as a minimum the requirements of (KS C) IEC Publication 60092-201.
(2) Rotating machines
The degree of protection of enclosures of rotating electrical machines is to be at least IP 23. The degree of protection of terminals is to be at least IP44. For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.
(3) Transformers
The degree of protection of enclosures of transformers is to be at least IP23 For transformers installed in spaces accessible to unqualified personnel a degree of protection of at least IP4X is required. For transformers not contained in enclosures, see **1607. 1.**
(4) Switchgear, controlgear assemblies and converters
The degree of protection of metal enclosed switchgear, controlgear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static converters in-

stalled in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

3. Insulation

(1) Air clearance
In general, phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts of equipment are to be not less than those specified in Table as below;

Nominal Voltage(kV)	Minimum air clearance(mm)
3 (3.3)	55
6 (6.6)	90
10 (11)	120
15	160

(2) Creepage distances
Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with relevant IEC Publications for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions. For non-standardized parts within the busbar section of a switchgear assembly, the minimum creepage distance is to be at least 25 mm/kV and behind current limiting devices, 16 mm/kV.

4. Protection

(1) Faults on the generator side of circuit breaker
Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and to automatically de-excite the generator. In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.

(2) Faults to earth
Any earth fault in the system is to be indicated by means of a visual and audible alarm. Any earth fault in the system is to be indicated by means of a visual and audible alarm. In low impedance or direct earthed systems provision is to be made to automatic disconnect the faulty circuits. In high impedance earthed systems, where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.

(3) Power transformers
Power transformers are to be provided with overload and short circuit protection. When transformers are connected in parallel, tripping of the protective devices at the primary side has to automatically trip the switch connected at the secondary side.

(4) Voltage transformers for control and instrumentation
Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

(5) Fuses
Fuses are not to be used for overload protection.

(6) Low voltage systems
Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:
- direct earthing of the lower voltage system
- appropriate neutral voltage limiters
- earthed screen between the primary and secondary windings of transformers.

1603. Rotating machinery

1. Stator windings of generators

Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

2. Temperature detectors

Rotating machinery is to be provided with temperature detectors in their stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit. If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

3 Tests

In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with (KS C) IEC Publication 60034-15 is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

1604. Power Transformers

1. General

Dry type transformers have to comply with (KS C) IEC Publication 60076-11. Liquid cooled transformers have to comply with (KS C) IEC Publication 60076. Oil immersed transformers are to be provided with the following alarms and protections:

- liquid level (Low)-alarm / trip or load reduction
- liquid temperature (High)-alarm / trip or load reduction
- gas pressure relay (High)-trip

2. Test voltage of High voltage test

System nominal voltage(kV)	*a.c.* Test voltage of High voltage(kV), 1min. commercial frequency(50Hz or 60Hz)
≤ 1.1	3
3.6	10
7.2	20
12	28
15	38

1605. Cables

1. General

Cables are to be constructed in accordance with the (KS C) IEC Publication 60092-353 and 60092-354 or other equivalent Standard.

2. Test voltage of High voltage test

System nominal voltage(kV)	*a.c.* Test voltage of High voltage(kV), 5min. commercial frequency(50Hz or 60Hz)
1 ～ 1.1	3.5
3 ～ 3.3	6.5
6 ～ 6.6	11
10 ～ 11	15
15	22

1606. Switchgear and controlgear assemblies

1. General

Switchgear and controlgear assemblies are to be constructed according to IEC 62271-200 and the following additional requirements.

2. Construction

(1) Mechanical construction
Switchgear is to be of metal enclosed type in accordance with IEC 62271-200 or of the insulation enclosed type in accordance with IEC 60466.
(2) Locking facilities
Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible. Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.
(3) Shutters
The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.
(4) Earthing and short-circuiting
For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

3. Auxiliary systems

(1) Source and capacity of supply
If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two operations of all the components. However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources.
(2) Number of external supply sources
When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more than one generator set and/or set of essential services. Where necessary one source of supply is to be from the emergency source of electrical power for the start up from dead ship condition.

4. High voltage test

A power-frequency voltage test is to be carried out on any switchgear and controlgear assemblies. The test voltages are to be in accordance with the following **Table 6.1.17** and the test procedure is to be in accordance with the IEC Publication 62271-200.

Table 6.1.17 Test voltage of High voltage test

System nominal voltage(kV)	*a.c.* Test voltage of High voltage(kV), 1min. commercial frequency(50Hz or 60Hz)
1 ～ 1.1	2.8
3 ～ 3.3	10
6 ～ 6.6	20
10 ～ 11	28
15	38

1607. Installation

1. Electrical equipment

(1) Where equipment is not contained in an enclosure but a room forms the enclosure of the equip-

ment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

(2) At the entrance of the spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed which indicates danger of high-voltage. As regard the high-voltage electrical equipment installed out-side a.m. spaces, the similar marking is to be provided.

(3) The switchboard is to be provided with safe and effective measures to vent the accidental arc gases within the switchboard.

2. Cables

(1) Runs of cables
In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

(2) Segregation
High voltage cables are to be segregated from cables operating at different voltage ratings each other; in particular, they are not to be run in the same cable bunch, nor in the same ducts or pipes, or, in the same box. Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in **1602. 3** (1). However, high voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1kV and less.

(3) Installation arrangements
High voltage cables, in general, are to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic castings effectively bonded to earth.

(4) Terminations
Terminations in all conductors of high voltage cables are to be, as far as practicable, effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials.

(5) Marking
High voltage cables are to be readily identifiable by suitable marking.

(6) Test after installation
Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. The test is to be carried out after an insulation resistance test. When a *d.c.* voltage withstand test is carried out, the voltage is to be not less than:

- 1.6 (2.5 U_o +2 kV) for cables of rated voltage (U_o) up to and including 3.6 kV, or
- 4.2 U_o for higher rated voltages

where U_o is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed.

The test voltage is to be maintained for a minimum of 15 minutes. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test is then repeated. Alternatively, an *a.c.* voltage withstand test may be carried out upon advice from high voltage cable manufacturer at a voltage not less than normal operating voltage of the cable and it is to be maintained for a minimum of 24 hours.

Section 17 Electric Propulsion Unit

1701. General

1. Application

The electric propulsion unit is to meet the requirements in this Section in addition to (KS C) IEC 60092-501 and those in this Chapter.

2. Motor torque

(1) Torque available for maneuvering a ship is to be capable of stopping or reversing of the ship in a reasonable time when the ship is running at the maximum service speed.
(2) Adequate torque margin is to be provided in *a.c.* propulsion systems to guard against the motor to be pulled out of synchronism during rough weather and at the time of turning in a multiple-screw ship.

3. Protection against torsional vibration, etc.

Prime movers, generators, motors, shafting and propellers are to be such that harmful torsional vibrations or excessive electrical oscillations in alternating-current systems are not observed at any normal operating speed.

4. Protection against overload

Where arrangements permit a propulsion motor to be connected to the generating plant having a continuous rating greater than the motor rating, means are to be provided to prevent continuous operation at the overload or overtorque conditions not permitted to the motor and shafting.

5. Lubrication

(1) Lubrication of the bearings of propulsion motors and shafting is to be effective at all operational speeds including creep speeds.
(2) When a forced lubrication system is used for the bearings of rotating machines and prime movers, low oil pressure alarm is to be provided.

1702. Prime movers

1. General

Prime movers are to comply with the requirements of **Pt 5, Ch 2, Secs 2** and **3,** and their rated power in conjunction with their overloading facilities and load built-up facilities is to be adequate to supply the needed power during transitional changes in operating conditions of electrical equipment.

2. Speed governor

(1) Prime movers of any type are to be provided with a governor capable of maintaining the pre-set steady speed within a range not exceeding 5 % of the rated full-load speed for load changes from full-load to no load.
(2) The governors are to be such that they will automatically maintain the momentary speed within 10 % of the rated speed when the full load is suddenly thrown off.
(3) In the case of parallel operation of generators, the governing system used are to permit stable operation to be maintained over the entire operational speed range of the prime movers.
(4) Where the speed control of the propeller requires speed variation of the prime mover, the governor is to permit a very gradual variation of speed within the necessary speed range and means are to be provided to enable local manual control as well as remote control of the governor.
(5) The overspeed governor is to be set to a speed in excess of the highest possible speed during periods of regenerated power, and the generator set including prime mover is to be so designed that no damage will be caused by an overspeed equal to that at which the governor is set.

1703. Rotating machines

1. General

(1) When variable speed rotating machines are fitted with an integral fan and have to be operated at speeds below the rated speed with full-load torque, full-load current, full-load excitation or the like, temperature limits according to **Table 6.1.4** are not to be exceeded.
(2) The rotors are to be so constructed that they will withstand for 2 minutes at an overspeed in accordance with the requirements in **209. 5.** However, the overspeed of turbo-generators and electromagnetic slip-couplings is to be 120 % of the rated speed.
(3) The collector rings and commutators are to be suitably arranged to be maintained easily. For purposes of inspection and repair, provision is to be made for easy access to each kind of coils and bearings, and for withdrawal and replacement of the field coils as well.

(4) Effective means are to be provided in rotating machines to prevent accumulation of moisture and condensation even when they are idle for appreciable periods.

2. Generators and motors

(1) For *a.c.* generators and motors of 500 kW and above, embedded temperature detectors are to be provided in the stator windings, and the temperature indicator is to be mounted in a convenient position to read a temperature on the control board.
(2) For *d.c.* motors liable to overspeed excessively, overspeed protection devices are to be provided, and the rotors are to be suitably constructed to prevent damage due to temporary overspeed.

3. Means of excitation

(1) Separately excited rotating machines are to be provided with at least 2 independent sources of excitation.
(2) The strength of shafts and couplings of exciter is to be suitable for the increased output necessary during maneuvering and sudden short-circuit conditions.

4. Electromagnetic slip-couplings

(1) Means are to be provided to facilitate periodical checking of the air gaps of the magnetic circuit, and appropriate calibrated gauges are to be supplied for this purpose.
(2) Electromagnetic slip-couplings are to be at least of drip-proof type. Where they are of non-enclosed type, suitable means are to be taken to prevent accidental touch with rotating parts and ingress of foreign material.

1704. Control gear

1. General

(1) Control gears for propulsion equipment are to be designed for the appropriate voltages and are to include the apparatus necessary for starting, stopping, reversing and controlling the speed of motors together with essential instruments and safety devices.
(2) Where, on stopping or reversing the propeller, the regenerated energy transmitted by the propulsion motor is such as to cause a dangerous increase of speed in the prime mover, means are to be provided for suitably absorbing or limiting such energy.
(3) All levers, handles and their accessories for switches and contactors are to be of such proportions as to permit a satisfactory manual operation.
(4) All levers for operating contactors, line switches, field switches and the like are to be interlocked to prevent their wrong operation. These interlocks are to be of mechanical type as far as practicable.
(5) Where steam and oil gauges are mounted on the main control assembly, provisions are to be made so that in case of leakage, steam and oil may not come into contact with the energized parts.
(6) When power-aided control is used, other suitable means are to be provided to restore control in a short time in the event of power failure.
(7) The controlgears are to be so arranged that in case of damage to the equipment outside the engine room, control can always be executed from the engine room maneuvering control stations.

2. Location of maneuvering control

(1) Control of the propulsion machines may be carried out from the bridge or deck. Alternative control in the engine room is to be provided, Transfer of control to the engine room in an emergency is to be possible without excessive loss of time.
(2) When two or more control stations are provided, indicating lights are to be located at each control station to indicate which station is in control. Means are to be provided to make incapable of being operated simultaneously from different stations.

3. Main circuit and control circuit

(1) Propulsion system having two or more generator or motors respectively on one propeller shaft, is to be so arranged that any unit of them can be taken out of service and isolated electrically.
(2) Field circuits are to be provided with means of suppressing voltage rise when a field switch is opened.

4. Protection

(1) Over-current protective devices, if any, in the main circuits are to be set sufficiently high so

that there is no possibility of their operating due to over-currents caused by maneuvering or normal operation in heavy seas.

(2) Where separately driven *d.c.* generators are connected electrically in series, means are to be provided to prevent reversal of the rotation of a generator at the failure of the driving power of its prime mover.

(3) In excitation circuits, there is to be no overload protection causing the opening of the circuit.

(4) Means are to be provided to detect sudden short circuit currents and to protect against phase unbalance. When damage likely to cause to the electrical equipment is more serious than the possible consequences of losing propulsion power, consideration is to be given to providing means for rapid reduction of the magnetic fluxes of the generators or motors.

(5) Means for earth leakage detection are to be provided for the main propulsion circuit, and these are to be arranged to operate an alarm upon the occurrence of an earth fault.

(6) Insulated excitation circuits are to be provided with earth leakage detection which may consist of voltmeters or lamps.

5. Control gears for electromagnetic slip-couplings

Control gears for electromagnetic slip-couplings are to include a two-pole disconnecting switch, short-circuit protection and an ammeter for the coupling excitation circuit. Interlocking gear is to be provided to prevent the coupling from being energized when the driving machine control levers are in an inappropriate position. Such controlgear may be combined with the prime mover speed control and reversing gears.

6. Instruments

(1) The following instruments, where required, are to be mounted in the main control assembly or any other location :

(a) For *a.c.* systems
Ammeter, voltmeter, indicating wattmeter and field ammeter for each propulsion generator,
Field ammeter for each synchronous motor,
Speed indicator for each propeller shaft,
Temperature indicator for reading directly the temperature of each propulsion generator stator and motor stator.

(b) For *d.c.* systems
Ammeter for the main circuit,
Ammeter for each generator and motor field circuit,
Voltmeter for reading voltage in each generator, motor and exciter,
Speed indicator for each propeller shaft.

(2) Where control outside the engine room is used, instruments necessary for operation and monitoring of the main propulsion system are to be installed at a convenient location near such a station.

1705. Cables

Conductors of cables and wiring are to consist of not less than 7 strands and conductors of a cross sectional area smaller than 1.5 mm^2 are not to be installed except cables or wiring for automatic equipment not directly connected to main circuits.

1706. Testing and inspection

After electric propulsion plants are installed on board ship, sea trial is to be carried out.

Section 18 Tests after Installation on Board

1801. Insulation resistance test

1. Electric propulsion, auxiliary power and lighting circuits

Each circuit of electric propulsion, auxiliary power and lighting is to have insulation resistances not less than the values in **Table 6.1.18** between conductors and between each conductor and earth.

Table 6.1.18 Insulation Resistance

Load	Insulation resistance
Up to 5 A	2 MΩ
Up to 10 A	1 MΩ
Up to 25 A	400,000 Ω
Up to 50 A	250,000 Ω
Up to 100 A	100,000 Ω
Up to 200 A	50,000 Ω
Over 200 A	25,000 Ω
(NOTE) During the above test, any or all electric heaters, small appliance and the like connected thereto may be disconnected from the circuit.	

2. Internal communication circuits

Insulation resistances of internal communication circuits are to comply with the following requirements:

(1) Each circuit of 100 V and above is to have an insulation resistance not less than 1 MΩ between conductors and between each conductor and earth.
(2) For circuits below 100 V, the insulation resistance is to be at least 1/3 MΩ.
(3) During the test for (1) and (2) any or all appliances connected thereto may be disconnected from the circuit.

3. Generators and motors

The insulation resistance of each generator and motor under working temperature is to be in accordance with the requirements in **209. 6.**

4. Switchboards

The insulation resistance of each switchboard under working temperature is to be in accordance with the requirements in **307. 5.**

1802. Performance test

1. Generators

Generators are to be tested as follows:

(1) The operation of overspeed trip and other safety devices is to be demonstrated.
(2) If generators are intended to operate in parallel, they are to be tested over a range of loading sufficient to demonstrate that load sharing and parallel operation are satisfactory. Voltage regulation is to be satisfactory.
(3) All generators are to be run at full rated load for a duration sufficient to demonstrate that temperature rises, commutation, absence of vibration and others are satisfactory.

2. Switchboards

All switches, circuit-breakers and associated equipment on the switchboard are to be operated on load to demonstrate suitability, and also section boxes and distribution boxes are to be tested as above.

3. Motors

Motors are to be tested as follows :

(1) Motors and their controlgears are to be examined under working condition that wiring, capacity, speed and operation are satisfactory.
(2) Motors driving various auxiliary machinery pumps, etc. are to be operated to demonstrate that operating characteristics are satisfactory.
(3) Motors driving cargo winches and windlasses are to hoist and lower their specified loads.

4. Lighting system

Lighting system is to be tested as follows :

(1) Circuits are to be tested to demonstrate that all lighting fittings, branch boxes, switches, plugs, receptacles and other connected fittings are in suitable operating condition.

(2) Emergency lighting circuits are is to be tested in the same manner as specified in (1) above.

5. Electric heaters and electric cooking ranges

Electric heaters, electric cooking ranges and the like are to be tested to demonstrate that the heating elements function satisfactorily.

6. Internal communication systems

Each internal communication system is to be throughly tested to demonstrate its specified functioning. Particular attention is to be paid to the tests of operation of the ship's essential electric communication systems which include engine order telegraphs, helm indicators, fire alarms, emergency signals, morse signal lamp, navigation light indicator panel and telephones.

7. Voltage drop

During above tests, it is to be ascertained that the voltage drop of feeder circuits does not exceed the values specified in **403. 2.**

Section 19 Spare Parts, Tools and Instruments

1901. Spare parts

1. General

(1) For the rotating machines and controlgears intended for electric propulsion plants, the spare parts mentioned in **Tables 6.1.19, 6.1.21** and **6.1.23** are to be supplied.

(2) For ship´s service generators, essential service motors and their controlgears and switchboards, the spare parts mentioned in **Tables 6.1.19** to **6.1.23,** so far as applicable, are recommended to be supplied as a standard.

(3) Quantity mentioned in (1) and (2) is the quantity of spare parts for identical installation per ship.

(4) For steering gear motors and motor-generators, if no stand-by machine is installed, spare parts in **Table 6.1.20** are required in addition to the spare parts for motors enumerated in **Table 6.1.19.**

Table 6.1.19 Spare Parts for Generators, Exciters and Motors

Spare parts	Quantity (ea)	Remarks
Bearing or bearing linings	1 for each 4 or less	Including oil rings
Brush holders	1 for each 10 or less	
Springs	1 for each 4 or less	For brush holder
Brushes	1 for each 1	
Field coils	1 for each 10 or less	For *d.c.* machines only. Excluding uninsulated interpoles coils
Resistors for field rheostat and discharge resistors	See **Table 6.1.21**	For generators and exciters
Amatures of cargo winch	1 for 6 or more	Stator in case of *a.c.* cage-rotor motor. Rotor in case of *a.c.* wound-rotor motor.
Slip-rings	1 for each kind and size	Required for rotating machines for electric propulsion only.

Table 6.1.20 Additional Spare parts for Steering Gear Motors without Stand-by Motor-Generator

Spare parts		Quantity (ea)
D.C.	Amatures of motors and motor-generators	1 for each size (incl. shaft and coupling)
A.C.	Stators of cage-rotor motors	1
	Rotors of wound-rotor motors	1 (incl. shaft and coupling)

Table 6.1.21 Spare parts for Controlgear

Spare parts	Quantity (ea)	Remarks
Contact pieces	1 for each 2 sets or less	For arcing and wear parts only
Springs	1 for each 4 or less	
Operating and shunt coils	1 for each 10 or less	
Resistors	1 for each 10 or less	For each kind and size
Fuses and their elements	See **Table 6.1.23**	
Lenses and lamps for pilot lamps	See **Table 6.1.23**	

Table 6.1.22 Spare Parts for Brakes

Spare parts	Quantity (ea)	Remark
Shoe linings and rivets	1 for each 4 or less	
Springs	1 for each 4 or less	
Coils	1 for each 10 or less	

Table 6.1.23 Spare Parts for Switchboards, Section Boards and Distribution Boards

Spare parts	Quantity (ea)	Remarks
Fuses (not renewable)	1 for each 1	Need not exceed 20
Fuse (renewable)	1 for each 10	Need not exceed 10
Fuse elements	1 for each 1	
Arcing contacts	1 for each 1	Need not exceed 10
Springs	1 for each 1	Need not exceed 10
Complete trip element assembly for moulded case thermal type circuit-breakers	1 for each 10 identical trip elements or less	Applicable where interchangeable elements are used
Complete moulded case thermal type circuit-breakers	1 for each group of 10 identical breakers or less	Applicable where non-interchangeable trip elements are used
Potential coils	1 for each kind	
Resistors	1 for each kind	
Lenses of pilot and signal lamps	1 for each 10 identical lenses or less	
Lamps for pilot and singnal lamps	1 for each 1	

2. Emergency lighting fittings

Where the voltage of emergency lighting circuits are different from that of general service, 1 for each 2 lamps are to be supplied as the spare.

1902. Testing instruments

Ships having electrical equipment of 50 kW and above are to be provided with a 500 volt insulation resistance measuring instrument in order that the insulation may be tested at regular intervals. In addition, the following portable instruments are recommended :

(1) One portable voltmeter, *a.c.* or *d.c.* or both as required.

(2) One portable ammeter, *a.c.* or *d.c.* or both as required, with shunts or current transformers as required.

1903. Disassembling tools

Where special tools are required to adjust or to disassemble electrical equipment, one set of each tool is to be provided.

1904. Storing method

All spare parts, instruments and tools are to be packed in suitable wooden boxes or corrosion protected steel boxes and are to be marked to indicate the contents on the surface of boxes and are to be stored in suitable locations. Where lockers are provided to store these spare parts, individual boxes may be omitted. ⚓

CHAPTER 2 CONTROL SYSTEMS

Section 1 General

101. General

1. Application

(1) The requirements in this Chapter apply to the systems of control, alarm and safety which are used to control all machinery and equipment which are subject to Rule requirements.
(2) Where considered necessary by the Society, the requirements in this Chapter are correspondingly applied to the systems of control, alarm and safety which are used for controlling machinery and equipment.

2. Terminology

Terms used in this Chapter are defined as follows:

(1) **Monitoring station** (excluding control station) is a position where measuring instruments, indicators, alarms, etc. for the machinery and equipment are centralized and necessary information to grasp the operating condition of them can be obtained. Where, however, a monitoring station is provided with the ship in addition to a control station mentioned in (2) below, the requirements of the Rules relating to a monitoring station do not apply to the monitoring station concerned.
(2) **Control station** is a position which has a function as a monitoring station and from which the machinery and equipment can be controlled.
(3) **Main control station** is a control station provided with equipment necessary and sufficient to control the main propulsion machinery (this equipment will be referred to as "main control equipment" in this (3) and (4) and from which the main propulsion machinery is normally controlled, of the ship which provides the main control equipment at the outside of the navigation bridge.
(4) **Main control station on bridge** is a navigation bridge of the ship which provides main control equipment at the navigation bridge and that the main propulsion machinery is normally controlled there.
(5) **Sub-control station** is such a control station at which the main propulsion machinery is capable of being controlled, except for local control station for the main propulsion machinery, that is provided in the machinery room of the ship provided with a main control station on bridge.
(6) **Bridge control devices** are remote control devices for the main propulsion machinery or controllable pitch propellers provided on a navigation bridge or a main control station on bridge.
(7) **Sequential control** is a pattern of control that can be carried out automatically in the redetermined sequence.
(8) **Program control** is a pattern of control that desired values can be changed in the predetermined schedule.
(9) **Local control** is direct manual control of the machinery and equipment performed at or near their locations, receiving the necessary information from the measuring instruments, indicators and so on.
(10) **Safety system** is a system which operates automatically, in order to prevent damages to the machinery and equipment in case where serious impediments to functioning should occur on them during operation so that one of the following actions will take place.
(A) Starting of standby machinery or equipment.
(B) Reduction of outputs of the machinery or equipment.
(C) Shutting off the fuel or power supplies thereby stopping the machinery or equipment.
(11) **Computer-based system** is a system of one or more computers(including programmable electronic device), associated software, peripherals and interfaces, and the computer network with its protocol.
(12) **Integrated system** is a system consisting of two or more subsystem having independent functions connected by a data transmission network and operated from one or more workstations.
(13) **Expert system** is an intelligent knowledge-based system that is designed to solve a problem with information that has been compiled using some form of human expertise.

(14) **Software** is the program, procedures and associated documentation pertaining to the operation of the computer system.
(15) **Basic software** is the minimum software, which includes firmware and middleware, required to support the application software.
(16) **Application software** is a software performing tasks specific to the actual configuration of the computer-based system and supported by the basic software.
(17) **Interface** is a transfer point at which information is exchanged. (examples : interfaces including input/output interface; communications interface)
(18) **Peripheral** is a device performing an auxiliary function in the system(examples : printer, data storage device)
(19) **Failure mode and effect analysis(FMEA)** is a failure analysis methodology used during design to postulate every failure mode and the corresponding effect or consequences.

3. Drawings and data

(1) Drawings and data concerning automation
(A) List of measuring points
(B) List of alarm points
(C) Control devices and safety devices
(a) List of controlled objects and controlled variables
(b) Kinds of sources of control energy (self-actuated, pneumatic, electric, etc.)
(c) List of conditions for emergency stopping, speed reduction (automatic or demand for reduction), etc.
(2) Following drawings and data for the automatic control devices and remote control devices for main engines or controllable pitch propellers:
(A) Operating instructions of main engines such as starting and stopping, changeover of direction of revolution, increase and decrease of output, etc.
(B) Arrangements of safety devices (including those attached to the engines) and pilot lamps
(C) Controlling diagrams
(3) Following drawings and data for the automatic control devices and remote control devices for boilers:
(A) Operating instructions of sequential control, feed water control, pressure control, combustion control and safety devices
(B) Diagrams for automatic combustion control devices and automatic feed water control devices
(4) Diagrams and operating instructions for automatic control devices for electric generating sets (automatic load sharing devices, preference tripping devices, automatic starting devices, automatic synchronous making devices, sequential starting devices, etc.)
(5) Panel arrangements of monitoring panels, alarming panels and control stands at respective control stations
(6) Schedules of on-board tests and sea trials
(7) Drawings and data for computer-based systems
(A) Computer hardware
The documentation to be submitted is to include followings:
(a) Hardware information of importance for the application and a list of documents that apply to the system
(b) The supply circuit diagram
(c) A description of hardware and software tools for equipment configuration
(d) The information to activate the system
(e) General information for trouble shooting and repair when the system is in operation
(B) Computer software
The documentation to be submitted is to include
(a) A list of all main software modules installed per hardware unit with names and version numbers
(b) A description of all main software which is to include at least:
(i) A description of basic software installed per hardware unit, including communication software, when applicable
(ii) A description of application software
(C) System reliability analysis
The documentation to be submitted is to demonstrate the reliability of the system by means of appropriate analysis such as:

(a) A failure mode analysis describing the effects due to failures leading to the destruction of the automation system, In addition, this documentation is to show the consequences on other systems, if any.
(b) Mean time between failures (MTBF) calculation
(c) Any other documentation demonstrating the reliability of the system

(D) User interface description
The documentation is to contain:
(a) A description of the functions allocated to each operator interface(keyboard/screen or equivalent)
(b) A description of individual screen views (schematics, colour photos, etc.)
(c) A description of how menus are operated (tree presentation)
(d) An operator manual providing necessary information for installation and use.

(E) Test programs
The following test program are to be submitted:
(a) Software module/unit test
(b) Software integration test
(c) System validation test
(d) On-board test
Each test program is to include:
(i) A description of each test item
(ii) A description of the acceptance criteria for each tests.

Section 2 System and Control

201. System design

1. System design requirements

(1) Control systems, alarm systems and safety systems are to be so designed that one fault does not result in other faults as far as practicable and the extent of the damage could be kept to a minimum.
(2) Control systems, alarm systems and safety systems are to be designed on the fail-to-safe principle. The characteristics of fail-to-safe is to be evaluated on the basis not only of the respective systems themselves and associated machinery and equipment, but also the total safety of the ship.
(3) Systems of automatic or remote control are to be sufficiently reliable under service conditions.
(4) Cables for signals are to be installed in such a manner that harmful induced interference can be avoided.

2. Supply of power

(1) Supply of electric power
The supply of electric power is to be in accordance with the following:
(A) Electric supply circuits to control systems, alarm systems and safety systems are not to branch off from the power circuits and lighting circuits, except that the electric power to the control systems, alarm systems and safety systems may be supplied from the power circuits to the machinery and equipment they serve.
(B) The electric power to alarm systems and safety systems for electric generating sets is also to be supplied from an accumulator battery.

(2) Supply of oil pressure
The supply of control oil pressure is to be in accordance with the following:
(A) Sources of oil pressure are to be capable of supplying stably necessary pressure and quantity of purified oil.
(B) Overpressure preventive devices are to be provided on the delivery side of oil pressure pumps.
(C) Two or more sets of oil pressure pumps for the control of main engines and main shaftings are to be provided and they are to be so arranged that in case where one of the pumps in operation becomes out of action standby pump(s) may start automatically or may be readily remotely started. In this case, the oil pressure pumps are not to be used for the control of other machinery and equipment than main engines and main shaftings.

(3) Supply of pneumatic pressure
The supply of control air is to be in accordance with the following:
(A) Control systems are to be provided with an air reservoir having a capacity capable of supplying air to control devices at least for 5 minutes in the event of failure of the control air compressor.
(B) Where starting air reservoirs for main propulsion diesel engines are used as control air reservoirs, pressure reducing valves are to be duplicated.
(C) There are to be two or more sets of air compressors which may be used as a source of control air. Each air compressor is to have redundant capacity even in the event of failure of either one of them.
(D) Control air is to pass through a filter and, if necessary, a drier so that solid, oil and water may be removed to a minimum.
(E) Control air pipes are to be independent of general service air pipes and starting air pipes.

3. Environmental conditions

Systems of automatic or remote control are to be capable of withstanding the environmental conditions of the places where they are installed.

4. Control systems

(1) Independency of control systems
Control systems for main engines or controllable pitch propellers, boilers, electric generating sets and auxiliaries for main propulsion of the ship (hereinafter referred to as "essential auxiliary machinery") are to be independent each other or designed such that failure of one system does not degrade the performance of another system.
(2) Interconnection devices
In case of plural main engines, electric generating sets or important auxiliaries which are designed to be operated simultaneously in multiple under the same condition, interconnection devices may be provided between the control devices of these installations.
(3) Control characteristics
Remote control devices and automatic control devices are to have control characteristics in conformity with the dynamic properties of the machinery and equipment they serve and to be considered not to invite malfunction and hunting due to disturbance.
(4) Interlock
Control devices are to be provided with suitable interlocking arrangements in order to prevent damages to the machinery and equipment due to anticipated malfunction and maloperation of the machinery and equipment.
(5) Change-over to manual operating
Change-over to manual operating is to comply with the following requirements:
(A) Main engines, boilers, electric generating sets and auxiliaries for main propulsion of the ship are to be so arranged as to be manually started, operated and controlled even in the event where automatic control devices become out of action.
(B) Automatic control devices are generally to be provided with provisions to stop manually the automatic function of these devices.
(C) The provisions specified in (B) are to be capable of stopping the automatic function of the automatic control devices, even where any part of the automatic control devices become out of action.
(6) Cancellation of remote control function
For remote control devices, the function of remote control is to be capable of being manually cancelled.
(7) Indication of control locations
In case where the machinery and equipment are capable of being operated from more than one station, the following requirements in (A) and (B) are to be complied with. However, this requirement need not be complied with in case the safety of the machinery and equipment and the safety at the time of maintenance work can be obtained by means of other measures considered appropriate by the Society.
(A) At each control station there is to be an indicator showing which station is in control of the machinery and equipment.
(B) Control of the machinery and equipment is to be possible only from one station at a time.

5. Alarm systems

(1) Function of alarm systems is to comply with the following requirements:
(A) In case where an abnormal condition is detected devices to issue visual and audible alarms (hereinafter referred to as "alarm devices" in this Chapter) are to operate.
(B) In case where arrangements are made to silence audible alarms they are not to extinguish visual alarms.
(C) Two or more faults are to be indicated at the same time.
(D) Audible alarms for machinery and equipment are to be clearly distinguishable from other audible alarms such as general alarm, fire alarm, CO_2 flooding alarm, etc.
(2) Function of the alarm systems provided in the monitoring station for main engines or controllable pitch propellers is to comply with the following requirements, in addition to the requirements in (1).
(A) The visual indications of visual alarms are to remain until the fault has been corrected.
(B) The acceptance of any alarm is not to inhibit another alarm.
(C) If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, alarm devices are again to operate.
(D) Manual stopping of each alarm system is to be clearly indicated.
(3) Visual alarms are to be such that each abnormal condition of the machinery and equipment is readily distinguishable and so arranged that acknowledgement is clearly noticeable.

6. Safety systems

(1) Constitution of systems
Constitution of safety systems is to comply with the following requirements:
(A) The safety systems are to be, as far as practicable, provided independently of the control systems and alarm systems.
(B) The safety systems for the main engines, boilers, electric generating sets and auxiliaries for main propulsion of the ship are to be independent each other.
(2) Function of safety systems
Function of the safety systems is to comply with the following requirements:
(A) The alarm systems which have functions prescribed in **Par 5** are to operate when the safety system is put into action.
(B) In case where the safety system is put into action and the operation of the machinery or equipment is stopped, they are not to automatically restart before manual reset is made.
(3) Override arrangements
Where arrangements for stopping temporarily the functions of safety system in part or in whole(hereinafter referred to as "override arrangements") are provided, the following requirements in (A) and (B) are to be complied with:
(A) Visual indication is to be given at the relevant control stations of the machinery and equipment when an override is operated.
(B) The override arrangements are to be such that inadvertent operation is prevented.

7. Computer-based systems

(1) Application
(A) Computer-based systems where used for control, monitoring and safety systems are to comply with the provisons of this **Paragraph.**
(B) Computerized control systems, alarm systems and safety systems are divided into three categories as shown in **Table 6.2.1** based on the impact a single failure has on human and vessel safety, and the environment.
(2) Systems requirements
(A) System security
Computer-based systems are to be protected against unintentional or unauthorized modification of software.
(a) The systems categorized in Categories Ⅱ and Ⅲ in **Table 6.2.1** are to be protected against program modification by end users.
(b) For the systems categorized in Categories Ⅲ in **Table 6.2.1**, modifications of parameters by manufacturers are to be approved by the Society.
(c) Any modifications made after shipment are to be documented and traceable.

Table 6.2.1 Computer-based system categories

Category	Effects in case of failure	System functionality
Ⅰ	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Monitoring function for informational /administrative tasks
Ⅱ	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Alarm and monitoring functions - Control functions which are necessary to maintain the ship in its normal operational and habitable conditions
Ⅲ	Those systems, failure of which could immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Control functions for maintaining the vessel's propulsion and steering - Safety functions

(B) Program and memory data
To preclude the possible loss or corruption of data as a result of power disruption, programs and associated memory data considered to be essential for the operation of the specific system are to be stored in non-volatile memory.

(C) Start-up after power failure
The system's software and hardware is to be designed so that upon restoration of power supply after power failure, automatic or remote control and monitoring capabilities can immediately be available after the pre-established computer control access (sign-in) procedure has been completed.

(D) Self monitoring
Computer-based systems are to be self-monitoring and any incorrect operation or abnormal condition is to be alarmed at the computer workstation.

(E) Power supply
The power supply is to be monitored for voltage failure and protected for short circuit. Where redundant computer systems are provided to satisfy (F), they are to be separately fed.

(F) System independence
Control, monitoring and safety systems are to be arranged such that a single failure or malfunction of the computer equipment will not affect more than one of these system functions.

(G) Response time
Computer system's memory is to be of sufficient capacity to handle the operation of all computer programs as configured in the computer system. The time response for processing and transmitting data is to be such that an undesirable chain of events may not arise as a result of unacceptable data delay or response time during the computer system's worst data overload operating condition. For propulsion related system applications, the time limit on response delays for safety and alarm displays is not to exceed two(2) seconds. The response delay is to be taken as the time between detection of an alarm or safety critical condition and the display of the alarm or actuation of the safety system.

(H) Fail-safe
Computer-based system is to be designed such that failure of any of the system's components will not cause unsafe operation of the process or the equipment it controls. FMEA is to be used to determine that any component failure will not result in the complete loss of control, the shutdown of the process or equipment, or other undesirable consequences.

(3) Additional requirements for integrated systems

(A) General
Common hardware in an integrated system serving many subsystems, e.g., monitor, keyboard, microprocessor, etc., is to be duplicated or otherwise provided with a means of backup.

(B) Component independence
Failure of one part (individual module, equipment or subsystem) of the integrated system is not to affect the functionality of other parts, except for those functions directly dependent upon information from the defective part.

(C) Data communication

(a) Data link

(i) Any detected abnormal condition is to be alarmed at the centralized control station and on the navigation bridge.

(ii) Safeguards are to be provided to prevent unacceptable data transmission delays (overloading of network).

(iii) Alarm is to be activated prior to a critical data overload condition.

(b) Duplicated data link

(i) When the same data link is used for two or more essential functions (e.g., propulsion control and generator control), this link is to be duplicated, and each is to be routed as far apart from the other as practical.

(ii) The duplicate link is for standby purpose only and not to be used to reduce traffic in the online link.

(iii) Duplicated data link is to be arranged so that upon the failure of the on-line link, the standby link is automatically connected to the system. Switching between duplicated links is not to disturb data communication or continuous functioning of the system.

(iv) The failure of one link is to be alarmed at the centralized control station and on the navigation bridge.

(c) Connection failure

A complete failure in connectivity between component systems and the data highway is not to affect individual functionality of the component systems.

(d) Transmission software

(i) The transmission software is to be so designed that alarm or control data have priority over any other data.

(ii) The transmission protocol is to be chosen among international standards.

(iii) A means of transmission control is to be provided and designed so as to verify the completion of the data transmitted (Cyclic Redundancy Check(CRC) or equivalent acceptable method).

(iv) When corrupted data is detected, th number of retries is to be limited so as to keep an acceptable global response time.

(4) Expert system

The expert system software is not to be implemented on a computer linked with essential functions and is not to be used for direct control or operation.

(5) Hardware

(A) Design for ease of maintenance

(a) The design and layout of the hardware is to ensure ease of access to interchangeable parts for repairs and maintenance.

(b) Each replaceable part is to be simple to replace and is to be constructed for easy and safe handling.

(c) All replaceable parts are to be so designed that it is not possible to connect them incorrectly or to use incorrect replacements. Where this is not practicable, the replaceable parts and their mounting location, including their means of electrical connection, are to be clearly marked.

(B) User interface and input devices

(a) General

Input devices are to have clearly marked functions and, as far as practicable, are to be arranged to avoid conceivable inadvertent errors in their operations.

(b) Security

Input devices, such as keyboard, which can be used to effect changes to equipment or processes under control, are to be provided with security arrangement, such as password, so as to limit access to authorized personnel only.

Where a single action of, for example, pressing of a key is able to cause dangerous operating conditions or malfunctions, measures such as use of two or more keys are to be taken to prevent execution by a single action.

(c) Control Status

Where control action can be effected from more than one station, conflicting control station actions are to be prevented by means of interlock or warning. Control status is to be indicated at all stations.

(C) Visual display unit

(a) General

The size, color and density of text and graphic information displayed on a visual display unit are to be such that it may be easily read from the normal operator position under all operational lighting conditions. The brightness and contrast are to be capable of being adjusted.

(b) Alarm display

Where alarms are displayed by means of visual display unit, they are to appear in the sequence as the incoming signals are received. Alarming of the incoming fault signals is to appear on the screen, regardless of the mode the computer or the visual display unit is in.

(c) Propulsion monitoring

Where visual display unit is used to display monitored parameters, unless other display means are provided capable of displaying the same information, the centralized control station is to be provided with at least two computer monitors.

(d) Color monitor

The failure of a primary color is not to prevent an alarm from being distinctly indicated.

(D) Graphical display

(a) General

Information is to be presented clearly and intelligibly, according to its functional relations. Display presentations are to be restricted to the data which is directly relevant for the user.

(b) Alarms

Alarms are to be clearly distinguishable from other information and are to be visually and audibly presented with priority over other information, regardless of the mode the computer or the visual display unit is in.

(6) Software

(A) General

(a) The basic software is to be developed in consistent and independent modules and a self checking function is to be provided to identify failure of software module. When hardware (e.g. input/output devices, communication links, memory, etc.) is arranged to limit the consequences of failures, the corresponding software is also to be separated in different software modules ensuring the same degree of independence.

(b) Loading of software, when necessary, is to be performed in the aided conversational mode.

(c) A clear warning is to be displayed when using functions such as alteration of control condition, or change of data or programs in the memory of the system.

(B) Software development quality

(a) Software development si to be carried out according to a quality plan defined by the builder and records are to be kept.

(b) The standard ISO/IEC 90003:2004 Software Engineering - Guidelines for the application of ISO 9001:2000 to computer software or equivalent international standards, is to be taken as Guidance for the quality procedure.

(c) The quality plan is to include the test procedure for software and the results of the tests are to be documented.

202. Automatic and remote control of main engines or controllable pitch propellers

1. General

Remote control devices for main propulsion machinery or controllable pitch propellers are to be complied with the requirements of this **202**.

2. Remote control devices for main engines or controllable pitch propellers

(1) General

(A) The remote control devices for main engines or controllable pitch propellers are to be capable of controlling the propeller speed and the direction of thrust (the blade angle of propellers in the case of controllable pitch propellers) by means of a simple operation.

(B) The remote control devices for main engines or controllable pitch propellers are to be provided for each propeller.

(C) In case where the speed of the main diesel engines is controlled by governors, the governors are to be adjusted so that main engine may not exceed 103 % of the maximum continuous revolutions. The governors are to be capable of maintaining the safe minimum speed.

(D) In case where the program control is adopted, the program for increase and decrease of output is to be so designed that undue mechanical stresses and thermal stresses do not occur in any parts of machinery.

(E) In the remote control stations and monitoring stations for the main engines, the following instruments are to be provided:

(a) Indicators for propeller speed and direction of rotation in the case of solid propellers.

(b) Indicators for propeller speed and pitch position in the case of controllable pitch propeller.

(F) In the remote control stations for main engines or controllable pitch propellers, alarm devices necessary for the control of main engines are to be provided.

(2) Transfer of control

The remote control devices for main engines or controllable pitch propellers are to comply with the following requirements with respect to transfer of control:

(A) Each control station for main engines or controllable pitch propellers is to be provided with means to indicate which of them is in control.

(B) Remote control of the main engines is to be possible only from one location at a time.

(C) Transfer of control is to be possible only with order by the serving station and acknowledgement by the receiving station except for the following cases.

(a) Transfer of control between local control station for main propulsion machinery and main control station or sub-control station.

(b) Transfer of control during the stopping condition of the main propulsion machinery.

(D) The transfer of control between the navigating bridge and the local or main control station is to be possible only in the local or main control station.

(E) Means are to be provided to prevent the propelling thrust from altering significantly when transferring control from one location to another except for the transfer of control described in (C) (a) and (D).

(3) Failure of remote control systems of main engines or controllable pitch propellers

The following requirements are to be complied with in case of failure of remote control devices for main engines or controllable pitch propellers:

(A) In the remote control stations for main engines or controllable pitch propellers alarm devices which operate in the event of failure of the remote control devices for main engines or controllable pitch propellers are to be provided.

(B) In the event of failure of the remote control devices for main engines or controllable pitch propellers, the main engines are to be possible to control locally.

(C) In the event of failure of the remote control devices for main engines or controllable pitch propellers, the preset speed and direction of the propeller thrust are to be maintained until the control is in operation at the main control station or the local control station, unless this is considered impracticable by the Society.

(D) In the event of failure of the remote control devices for main engines or controllable pitch propellers, the transfer of control to the main control station or the local control station is to be possible by a simple operation.

(E) Remote control stations for main engines or controllable pitch propellers are to be provided with independent emergency stopping devices for the main engines, which are effective in the event of failure of the remote control devices for main engines or controllable pitch propellers.

(4) Remote starting of main diesel engines

Starting by means of remote control devices for main engines or controllable pitch propellers is to comply with the following:

(A) The number of starting of main engines is to satisfy the number specified in **Pt 5, Ch 6, 1101.**

(B) The remote control devices for main engines or controllable pitch propellers arranged to automatically start are to be so designed that the number of automatic consecutive attempts which fail to produce a start is limited to three times. In the event of failure of starting, a visual and audible alarm is to be issued at the relevant control station and the main control station or monitoring station for the main engines.

(C) Where compressed air is used for starting of the main engines, alarm devices to indicate the low starting air pressure are to be provided at the remote control station and the monitoring station for the main engines.
(D) The low starting air pressure mentioned in (C) for the operation of alarm devices is to be set at a level to permit further main engines starting operations.

3. Bridge control devices

Bridge control devices are to comply with the following requirements as well as those in **202. 2.**
(1) Even when the main engines are controlled from the navigating bridge, the telegraph orders at the navigating bridge are to be indicated in the main control station.
(2) The bridge control devices are to be provided with either one of the following devices in order to prevent prolonged running of main engines in critical speed range:
(A) Devices to make to pass automatically and rapidly through the critical speed range; or
(B) Alarm devices which operate in case where the main engines operate exceeding a pre-determined period in the critical speed range.
(3) Automation system is to be designed in a manner which ensures that threshold warning of impending or imminent slowdown or shutdown of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems shall control, monitor, report, alert and take safety action to slow down or stop propulsion which providing the officer in charge of the navigational watch an opportunity to manually intervene, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example in the case of overspeed.

4. Safety measures

(1) Safety measures for main engines or controllable pitch propellers
Safety measures for main engines or controllable pitch propellers are to comply with the following requirements:
(A) The following safety measures are to be taken to the remote control devices for the main engines:
(a) Necessary interlocking devices are to be provided to prevent serious damage due to mis-operation.
(b) Where the auxiliaries for propulsion of the ship are driven by electric motors, the main engines are to be so designed as to stop automatically in the event of failure of the main source of electric power or to be capable of being stopped.
(c) The main engines are to be so arranged as not to re-start automatically when electric power is restored after the failure of the main source of electric power whereas the main engines were stopped.
(d) The remote control devices for main engines or controllable pitch propellers are to be so designed that the engines may not be abnormally overloaded in the event of failure of them.
(B) Stopping devices for main engines or controllable pitch propellers are to be provided at the monitoring station for main engines or controllable pitch propellers.
(2) Safety systems of main engines
Safety systems of main engines are to comply with the following requirements:
(A) A device to shut off the fuel or steam supply to the main engines (this device hereinafter being referred to as "safety device") is not to be automatically activated except in cases which could lead to complete breakdown, serious damage or explosion.
(B) The safety systems for main engines or controllable pitch propellers are to be so designed as not to lose their function or as to fail-to-safe, even in the event of failure of main electric source or air source.
(3) Self-reversing diesel engines
As least the following safety measures are to be taken to the remote control devices for self-reversing diesel engines:
(A) Starting operation is to be possible only when the camshaft is surely at the position of "Ahead" or "Astern".
(B) During reversing operation, fuel is not to be injected.
(C) Reversing operation is to be conducted after "Ahead" revolution is reduced to a pre-determined value.
(4) Multi-engines to single shaft

At least the following safety measures are to be taken to the remote control devices for multi-engines coupled to a single shaft:
(A) Each engine is to be provided with an overload preventive device.
(B) Each engine is not to be subjected to an abnormally unbalanced load.
(5) Main propulsion machinery with clutch
At least the following safety measures are to be taken to the remote control devices for engines with clutch:
(A) The clutch equipped to a main propulsion machinery in a multi-engines coupled to a single shaft is to be disengaged when the main propulsion machinery is stopped in an emergency. While multi-engines are operating in different directions of rotation their clutches are not to be engaged simultaneously.
(B) Engaging and disengaging of clutches are to be carried out below a predetermined value of the number of revolutions of the main engines.
(C) A overspeed protective device specified in **Pt 5, Ch 2, 203. 1.** or **304. 1.**
(D) In case where there is fear that the speed of the propulsion motor would exceed 125 % of the rated revolutions when the clutch is disengaged, an overspeed protective device as deemed appropriate by the Society is to be approved.
(6) Main propulsion machinery driving controllable pitch propellers
At least the following safety measures are to be taken to the remote control devices for engines driving controllable pitch propellers:
(A) Overload preventive devices are to be provided.
(B) Starting of engines or engaging of clutches is to be performed while the propeller blades are in a neutral position.
(C) An overspeed protective device as specified in **Pt 5, Ch 2, 203. 1.** or **304. 1.**
(D) In case where there is fear that the speed of the propulsion motor would exceed 125 % of the rated revolutions when the propeller pitch is altered, an overspeed protective device as deemed appropriate by the Society is to be provided.

203. Automatic and remote control of boilers

1. General

(1) The systems of automatic control for both combustion and feed water of oil-fired boilers are to comply with the requirements in **Pars 2** to **4** respectively.
(2) The systems of automatic control for either combustion or feed water of oil-fired boilers are to comply with the relevant requirements in **Par 2** or **3** as well as the requirements in **Par 4.**
(3) Automatic control of boilers other than oil-fired boilers or having a special feature will be considered in each case.
(4) Remote water level indicators are to comply with the requirements in **Pt 5, Ch 5, 129.**

2. Automatic combustion control systems

(1) General
Automatic combustion control systems are to comply with the following requirements:
(A) The automatic combustion control systems are to be able to control so as to obtain planned steam amount, steam pressure and steam temperature and to secure stable combustion.
(B) The devices to control the fuel supply to meet the load imposed are to be capable of ensuring stable combustion in the controllable range of fuel supply.
(C) Where combustion control is carried out according to the pressure of the boiler, the upper limit of this pressure is to be lower than the set pressure of the safety valves.
(2) Combustion control devices for intermittent operation
The combustion control devices for intermittent operation are to comply with the following requirements and they are to operate according to the planned sequence:
(A) Before ignition on the pilot burner or before ignition on the main burner if the pilot burner is not fitted, the combustion chamber and flue are to be prepurged by air of not less than four times the volume of combustion chamber and flue up to the boiler uptake. For small boilers with only one burner, prepurge for not less than 30 seconds will be accepted.
(B) In case of direct ignition which is the method of ignition that the main burner is fired by ignition spark, opening of the fuel valve is not to precede the ignition spark.
(C) In case of indirect ignition which is a method of ignition that the main burner is fired by pilot burner, opening of the fuel valve for pilot burner (hereinafter referred to as "ignition

fuel valve") is not to precede the ignition spark, and opening of the fuel valve for main burner (hereinafter referred to as "main fuel valve") is not to precede the opening of ignition fuel valve.

(D) Firing is to be surely carried out within the planned period. Main fuel valve is to be so designed as to close after opening of the valve not exceeding 10 seconds in the case of direct ignition and 15 seconds in the case of indirect ignition if the firing on the main burner has failed.

(E) Firing on main burners is to be carried out at their low firing position.

(F) After closure of the main fuel valve, postpurge is to be carried out for not less than 20 seconds to ensure adequate combustion air to completely burn all fuel oil remaining between the fuel oil valve and the burner nozzle. This requirement need not be complied with in the case of auxiliary boilers where approved by the Society.

(3) Combustion control devices for the control of the number of firing burners
The combustion control devices for the control of the number of firing burners are to comply with the following requirements:

(A) Each burner is to be fired and extinguished according to the planned sequence. However, the base burner may be fired by manual operation and other burners may be fired by flame of a burner(s) already fired.

(B) The remaining fuel in the extinguished burner is to be automatically burnt up in order not to interfere the restarting. However, while the pilot burner is not fired, the remaining fuel in the base burner is not to be removed by steam or air when it is in place.

(C) The burners for main boilers are to be capable of being fired and extinguished from the main control station, except for the firing of base burner.

(4) Other combustion control devices
Other combustion control devices will be considered in each case by the Society, as well as they are to comply with the relevant requirements in (2) and (3).

3. Automatic feed water control devices

(1) The automatic feed water control devices are to be capable of controlling automatically the feed water in order to maintain the water level in the boilers in a predetermined range.

(2) Main boilers are to be provided with not less than three water level detectors used for feed water control device, remote water level indicator, low water level safety device and low-water level alarm device.

4. Safety measures

(1) Safety devices
Safety devices are to comply with the requirements in **Pt 5, Ch 5, 133. 1.**

(2) Heating of fuel oil
In case where heated fuel oil is used, an automatic temperature control device is to be provided to the heater and the boiler is to be provided with a device to shut off automatically the fuel supply to the burners or an alarm device which operates when the temperature of fuel oil falls below a predetermined value.

5. Alarms

Alarm devices are to comply with the requirements in **Pt 5, Ch 5, 133. 2.**

204. Control system of electric generating sets

1. General

(1) Electric generating set arranged to be automatically or remotely started is to be provided with interlocking devices necessary for safe operation.

(2) Electric generating set arranged to be automatically started is to be so designed that the number of automatic consecutive attempts which fail to produce a start is limited to two times and to be provided with an alarm device which operate at the time of the failure of starting.

(3) In case where a diesel engine to drive a propulsion generator is remote started the number of starting is to conform to the required number specified in **Pt 5, Ch 2, 202. 5.**

(4) Where automatic start of the standby generating set with automatic connection to the switchboard busbars is provided, automatic closure on to the busbars is to be limited to one attempt, in the event of the original power failure being caused by short circuit.

(5) Automatic control and remote control systems for the electric generating set, whose generator is driven by the main propulsion machinery and supplies electrical power to the electrical installations necessary for normal operating and living conditions and is operated while the main propulsion machinery is controlled by the bridge control devices, are to comply with the requirements in **Pt 6, Ch 1, 201. 2** in addition to those in this Article.

2. Emergency Source of Electric Power

Automatic or remote control devices for diesel engines to drive emergency generators for non-emergency purposes are to be complied with the following requirements:

(1) Alarm devices to be activated in the event of the abnormal conditions given in **Table 6.2.2** are to be provided.
(2) Devices referred to in (1) are to provide alarms at both local and control positions. The visual alarms at control positions may be of group indication.
(3) Each diesel engine with a maximum continuous output of 220 kW or over is to be provided with an overspeed protective device specified in **Pt 5, Ch 2, 203. 1** (2) of the Rules.
(4) When devices to shutdown the diesel engines are provided other than those referred to in **Table 6.2.2**, means are to be provided to override those devices automatically during navigation.
(5) The silencing of the audible alarms from the control positions is not to cause the silencing of the audible alarm at local position.

Table 6.2.2 Alarms for diesel engines to drive emergency generators

Monitored parameters [H=High L=Low O=Abnormal status]			AA	Auto Shut down with alarm	Notes [AA=Alarm Activation ●=apply]
Temp.	Lub. oil inlet	H	●		For engines having a power of 220 kW or over
	Cooling water(or cooling air) outlet	H	●		
Press.	Lub. oil inlet	L	●		
	Pressure or flow of cooling water inlet	L	●		For engines having a power of 220 kW or over
Others	Oil mist concentration in crankcase(H) or main & connecting rod bearing temp. (or oil outlet temp.)(H) or an equivalent device	H	●		For engines having a power of more than 2250 kW, or a cylinder bore of more than 300 mm An equivalent device could be interpreted as measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.(1)
	Fuel oil leakage from pressure pipes	O	●		
	Overspeed	O	●	●	For engines having a power of 220 kW or over

(NOTE)
(1) Oil mist detection system is to be of the approved type by the Society, tested by **Ch 3, Sec. 10** of **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.** and applied to **Pt.5 Ch 2, 203.**

205. Automatic and remote control of auxiliary machinery

1. Automatic operation of air compressors

In case where air compressors for starting and air compressors for controlling are automatically operated, alarm devices are to be provided to indicate pressure drop in air reservoirs.

2. Automatic starting and stopping of bilge pumping arrangements

In case where the bilge pumps are capable of being started and stopped automatically, alarm devices are to be provided to indicate high level of bilge in the relevant bilge wells and running of pumps for a long time.

3. Thermal oil installations

Thermal oil installations arranged to be automatically controlled are to comply with the following:

(1) Standby pumps
Pumps listed in the following of the thermal oil installations for important use are to be provided in two sets or more. The standby pumps are to be so arranged that they can start automatically or are capable of being started without delay from the relevant monitoring station when the discharge pressure or flow rate from the working pump falls below a predetermined value or when the pump stops.
(A) Thermal oil circulating pumps
(B) Fuel oil supply pumps

(2) Control devices
Control devices are to comply with **203. 2** (1) and (2), and also with **Pt 5, Ch 5, 202. 1** and **2.**

(3) Safety devices
Safety devices are to comply with **Pt 5, Ch 5, 201.** and **202. 5.**

(4) Alarm devices
Thermal oil installations are to be provided with alarm devices which operate in the following cases:
(A) When the safety devices required in (3) have operated.
(B) When the temperature of fuel at the inlet of burner has fallen.

4. High temperature alarm for oil heaters

In case where temperature for fuel oil and lubricating oil is automatically controlled, high temperature alarm devices are to be provided, except where oils are not heated above the flashpoint.

5. Opening and closing devices for sea valves

In case where sea valves to be fitted on the shell plating below the load water line are remotely or automatically controlled, other opening and closing devices which can be easily operated even in the event of failure of the automatic or remote control devices are to be provided.

6. Liquid level alarm systems for fuel oil tanks

In case where fuel transfer to fuel oil tanks is automatically controlled, the receiving tanks are to be provided with high and low level alarm systems.

7. Mooring arrangements

In case where mooring arrangements are provided with remote control devices, the mooring arrangements are to be capable of being locally operated.

8. Fuel oil filling arrangements

In case where arrangements for filling fuel oil into respective fuel oil tanks from the outside of the ships (hereinafter referred to as "fuel oil filling arrangements" in this Chapter) are provided with remote control devices, the fuel oil filling arrangements are to be such as not to interfere with filling of fuel even in the event of failure of the remote control devices.

9. Emergency Diesel Engines

The requirements in **204. 2** apply correspondingly to the automatic or remote control devices for emergency diesel engines used for non-emergency purposes other than those mentioned in **204. 2**.

206. Control system of electric propulsion unit

It is to comply with the requirements in **Ch 1, Sec 17** in addition to the relevant requirements of this Chapter.

Section 3 Tests

301. Shop test

1. Type approval

Devices, units and sensors (hereinafter referred to as "automatic devices" in the Rules) and automatic equipment composed of automatic devices and basic software (if applicable) are to be type approved, in principle, according to the test methods approved by the Society before being taken into use.

2. Shop tests of automation system

The automatic devices which have passed through the type approval tests specified in **Par 1.** are to be subjected to the following tests after completion of assembly as automation system.

(1) Hardware
- (A) External examination
- (B) Operation tests and performance tests
- (C) Insulation resistance tests and high voltage tests (to be applied to electric devices, electronic devices and so on)
- (D) Pressure tests (to be applied to hydraulic devices, pneumatic devices and so on)
- (E) Other tests considered necessary by the Society

(2) Software
Software acceptance tests of computer-based systems are to be carried out to verify their adaptation to their use on board, and concern mainly the application software
- (A) The software modules of the application software are to be tested individually and subsequently subjected to an integration test. The test results are to be documented and to be part of the final file. The followings are to be checked.
  - (a) The development work has been carried out in accordance with the plan
  - (b) The documentation includes the proposed test, the acceptance criteria and the result.

Repetition tests may be required to verify the consistency of test results.
- (B) Software acceptance will be granted subject followings
  - (a) Examination of the avaliable documentation
  - (b) A function test of the whole system

302. On-board tests

After installed on board the systems of automatic or remote control of the machinery and equipment are to be confirmed that they operate effectively, under as far practical condition as possible. However, part of these tests may be carried out during sea trials. The proper documents, in which test procedures, set value for alarms and for operation of safety systems and so on are recorded, are to be kept on board.

303. Sea trials

1. Main propulsion machinery and controllable pitch propellers

The control systems for main engines or controllable pitch propellers are to be subjected to the following tests. After completion of the test on transfer of control specified in (3), it is to be shown that the main engines can be smoothly operated from the respective control stations.

(1) The main engines are to be subjected to starting tests, ahead-astern tests and running tests in the whole range of output, by means of the remote control devices from the main control station.

(2) In addition to output increase and decrease tests, the operation tests of the main engines using the bridge control devices are to be carried out at the discretion of the Society.

(3) In case where there are other control stations for main engines or controllable pitch propellers such as navigating bridge, the test on transfer of control for main engines or controllable pitch propellers is to be carried out during ahead and astern operations of the main engines. In case where, however, considered appropriate by the Society, the test on transfer of control to the local control stations may be carried out during stoppage of the main engines.

2. Boilers

The control systems for boilers are to be subjected to the following tests.

(1) With respect to the main boilers, it is to be confirmed that the feed water control devices, combustion control devices and so on can operate stably in response to load variation of the main boilers, and the main boilers can supply steam stably to the main engines, electric generating sets and auxiliaries for propulsion of the ship, without local manual operation.
(2) With respect to auxiliary boilers used for important use, it is to be confirmed that they can supply steam stably to the auxiliaries for propulsion of the ship without manual operation.
(3) In case where an exhaust gas economizer is used as a source of steam supply to a turbine for driving a generator and steam supply from a boiler is carried out automatically in the case of low power condition of the main engines, operation tests of automatic control devices for this system are to be carried out.

3. Electric generating sets

In case where generators which supply electric power to the loads necessary for propulsion of ships and whose motive power is relying upon the propulsion systems, the systems of automatic or remote control of electric generating sets are to be subjected to operation tests.

4. Electric propulsion plants

After electric propulsion plants are installed on board ship, sea trial is to be carried out in accordance with the test procedure. ⚓

KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 6

Electrical Equipment and Control Systems

GA-06-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF
PART 6 "ELECTRICAL EQUIPMENT AND CONTROL SYSTEMS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date : 20 August 2010 (based on the application date for classification survey)

CHAPTER 2 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 2 System and Control

- 202. 3 (2) has been newly added.

Effective Date : 1 July 2011

CHAPTER 1 ELECTRICAL EQUIPMENT

Section 1 General

- 101. 1 (4) and (5) have been amended.
- 101. 1 (7) has been newly added.
- 103. 2 (1) Table 6.1.6 has been amended.

Section 2 Rotating Machinery

- 209. 1 has been deleted.

Section 3 Switchboards, Section Boards, Distribution Boards and Protective Equipment

- 301. 4 has been amended.

Section 4 Cables

- 402. 1 has been deleted.
- 404. 1 (1) has been amended.

Section 5 Distribution

- 506. 1 has been amended.

Section 9 Explosion−protected Electrical Equipment

- 902. 8 has been newly added.

Section 10 Lighting Fittings, Heating Appliances and Wiring Accessories

- 1002. 2 has been newly added.

Section 11 Internal Communications

- 1106. has been newly added.

Section 14 Emergency Electrical Equipment

- 1402. 2 (5) has been amended.

CHAPTER 2 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 3 Tests

- 301. 1 (1) has been amended.
- 301. 2 has been newly added.

CONTENTS

CHAPTER 1 ELECTRICAL EQUIPMENT

Section 1 General

101. General

1. Application

(1) The requirements in **Pt 6, Ch 1** of the Rules do not apply to the following electrical equipment except the case where the explosion-protected construction is necessary:
   (A) Radiotelegraph or radiotelephone equipment installed in accordance with the international laws or law of the flag state.
   (B) Navigation aids installed in accordance with the international laws or law of the flag state (those prescribed in regulation V/19 of Amendment 2009 to SOLAS Convention 1974)

(2) Electrical equipment for working and cargo handling, and home electrical appliances to be brought to ships such as television sets, radio sets, etc., are not applied to the requirements specified in **Pt 6, Ch 1** of the Rules excluding protection against electrical shock, firing and other casualties(including explosion). Electrical appliances not applied to the requirements of the Rules, as far as possible, are to comply with Korean Industrial Standards.

(3) Cables and protection devices (circuit breakers and fuses) connected to the electrical equipment or appliances stipulated in the requirements of (1) and (2) above, are to comply with the relevant requirements in **Pt 6, Ch 1** of the Rules.

(4) In application to **101. 1** (1) of the Rules, ships with special limitations for their service or small ships (less than 500 tons) mean the ships specified in the following:
   (A) Ships having service restriction notations of equipment of C, S or equivalent thereto as ships with gross tonnage less than 500 tons.
   (B) Ships not having service restriction notations of equipment specified in (A) above as ships with gross tonnage less than 500 tons.
   (C) Ships having service restriction notations of equipment specified in (A) above as ships with 500 tons gross tonnage or more, and ships complying with the requirements in **Pt 8 Annex 8-3, 12, 13, 14**.
   (D) Ships having class notations "$n \cdot f$" and service restriction notations of equipment specified in (A) above as ships with 500 tons gross tonnage or more and ships not complying with the requirements in **Pt 8 Annex 8-3, 12, 13, 14**.

(5) Electrical equipment on board the ships specified in (4) above are to be in accordance with (1) through (3) above, and the following:

Mitigated requirements for ships described in (A) to (D)

	Relevant requirements[1]	(mitigated requirements)	(A)	(B)	(C)	(D)
(a)	Rule 107.	Ambient conditions	O		O	
(b)	Rule 302. 1 (1)	Main switchboards' construction	O	O	O	
	Rule 302. 1 (2)	Generator switchboard's construction	O	O	O	
(c)	Rule 304. 1	D.C. ship's service generator panels	O		O	
(d)	Rule 304. 2	A.C. ship's service generator panels	O		O	
(e)	Rule 701. 2	Grouped starters	O	O		
(f)	Rule 404. 3 (2)	Precaution against fire protection of cables	O	O	O	
(g)	Rule 1203.	Protective devices, etc.	O	O	O	
(h)	Rule 201. 2	Main source of electrical power	O	O[2]	O	
(i)	Rule 601.	Transformers	O		O	
(j)	Rule 14	Emergency electrical equipment	O	O	O	
(k)	Rule 506. 3	Feeder circuits of navigation lights indicator	O	O	O[3]	
(l)	Rule 1901.	Spare parts	O		O	O
(m)	Rule 501. 3	Insulation monitoring system	O			
(n)	Rule 305. [3 (2)]	Protective devices [circuit breakers and fuses]	O		O[4]	
(o)	Rule 201. 2 (5)	Where the main source of electrical power is necessary for propulsion and steering of the ship	O	O	O	O
(p)	Rule 1106.	Public address systems	O	O	O	O

NOTES)
1) : The detailed contents are to comply with the below (A)
2) : The detailed contents are to comply with the below (B) (b)
3) : The detailed contents are to comply with the below (C) (c)
4) : The detailed contents are to comply with the below (C) (b)

(A) Ships specified in (4) (A) above

(a) In **107.** of the Rules, air temperature may apply 40℃ instead of 45℃, and sea water temperature may apply 27℃ instead of 32℃. However, ships engaged in tropical regions service are to be applied to the requirements in the Table. (refer to **Pt 5, Table 5.1.3** of the Rules)

(b) The requirements in **302. 1** (1) and (2) of the Rules do not apply.

(c) In **304. 1** of the Rules, where ships are provided with two or more d.c. generators engaged in single running only, ammeter and voltmeter are provided with each 1 set and are used in common for the generators. But, where the number of meters are made reduce, portable ammeter and voltmeter complied with the requirements in **1902.** of the Rules are to be equipped.

(d) In **304. 2** of the Rules, where the ships are provided with two or more a.c. generators engaged in single running only, ammeter, voltmeter and wattmeter are provided with each 1 set and are used in common for the generators. But, where the number of meters are made reduce, portable ammeter and voltmeter complied with the requirements in **1902.** of the Rules are to be equipped.

(e) The requirements in **701. 2** of the Rules do not apply.

(f) The requirements in **404. 3** (2) of the Rules do not apply.
(g) The requirements in **1203.** of the Rules do not apply.
(h) In application to **201. 2** (1) of the Rules, a generator driven by independent auxiliary engine may be provided with 1 set, except ships having class notation UMA and ships with coastal service.
(i) In **601.** of the Rules, where a accumulator battery with sufficient capacity necessary for electrical services of lightings, signal devices, radio equipment, etc. is provided, a reserved transformer may be omitted.
(j) The requirements in **1401.** of the Rules do not apply. However emergency source of electrical power capable of supplying simultaneously the following services at least for 3 hours (for a period of 30 minutes with continuous operation for the below (iv) & (v) system), is to be provided.
(i) All internal communication equipment required in an emergency
(ii) Navigation lights and signal lights (not under command lights, anchor lights)
(iii) Emergency lights installed in the following station
① Embarkation station of life raft, etc. and over the sides
② Accommodation alleyways, stairways and exits
③ Machinery spaces and spaces installed emergency source of electrical power
④ Control stations for main engine
(iv) Intermittent operation of the daylight signalling lamp, the ship's whistle, and all internal signals that are required in an emergency.
(v) The fire detection system and manually operated call point.
(k) In **506. 3** of the Rules, navigation light indicators may be served by one circuit fed from the emergency source. The following may be considered the emergency source.
① Either of the two generators which come into immediately operation in the event of loss of the normal power
② Charging devices for electric batteries
(l) In case of ships provided with efficient manual auxiliary steering gear, the requirements in **1901.** of the Rules do not apply.
(m) In **501. 3** of the Rules, a earth indicator may be installed instead of the device capable of continuously monitoring the insulation level to earth. in case of lamp type earth indicator, the indicator is to be of 2 lamp type or 3 lamp type having metal filament of capacity of 30W or less, and distance between lamps less than 150 mm.
(n) The requirements in **305. 3** (2) of the Rules do not apply. But, for the passenger ships, tankers and ships carrying dangerous chemicals in bulk, the plug-in type is to be applied only for the main switchboard and group start panels.
(o) The requirements in **201. 2** (5) of the Rules do not apply.
(p) The requirements in **1106.** of the Rules do not apply.
(B) Ships specified in (4) (B) above
(a) The requirements in (A) (b), (e), (f), (g), (j), (k), (o) and (p) above apply.
(b) In **201. 2** (2) of the Rules, the capacity of generator is to be possible to supply services necessary to provide normal operational conditions of propulsion and safety in spite of the event of any one generating set being stopped.
(C) Ships specified in (4) (C) above
(a) The requirements in (A) (a), (b), (c), (d), (f), (g), (h), (i), (j), (l), (o) and (p) above apply.
(b) The requirements in **305.** of the Rules do not apply. Group stater panels separated No.1 group and No.2 group are to be provided.
(c) In **506. 3** of the Rules, The navigation light indicator may be fed from the main switchboard and emergency switchboard or a lighting distribution board installed in the wheel house.
(D) Ships specified in (4) (D) above
(a) The requirements in (A) (l), (o) and (p) above apply.
(6) Where a ship applied to the requirements of (4) and (5) above makes an alteration of service area, purpose, etc., electrical equipment are to be installed in accordance with the Rules.
(7) The requirements for the emergency power on board passenger ships employed to domestic voyage are to apply as follows;
(A) The passenger ships employed to domestic voyage shall be equipped with the independent emergency power which satisfies following requirement of (a). However, for the passenger

ships, of which navigation area is below the level of smooth water area, provided with the batteries for main power, if these batteries satisfy the item (7) with the following requirements of (a), the independent emergency power requirement is exempted.

(a) The batteries (equipped with electric discharge indicator) shall be charged with needed power always and be able to be charged imminently without radical drop of voltage

(b) For the case of the generator driven by the independent oil suppliers and the effective motors with the starter recognized to be proper by the Society.(limited to the ones of which fuel oil's flash point of not less than 43 ℃). Emergency switchboard is to be installed as near as possible to emergency power.

(B) Emergency power according to the above (A) shall be charged imminently and automatically in the event of failure of the main source of electrical power due to malfunction, etc.

(C) Emergency source of electric power installed according to the above requirement (A) is to be supplied at least for 12 hours for the following services. However, in case of the ships expected voyage period with less than 6 hour, electric power may be supplied for 6 hours.

(a) Navigation lights
(b) Signal lights supplied from main source of electric power
(c) Emergency lights installed in the following stations.
(i) Corridors, stairways, ladders and exits
(ii) Main engine room, main generating room and engine control room
(iii) Navigation bridge, chart rooms and radio rooms
(iv) Places installed life boats, life rafts or life buoys and embarkation places.
(v) Other places where considered necessary by the Society
(d) Electric alarm system and indicators
(e) Fire detection system and manually operated call point.
(f) Other communication system, etc.

(D) Emergency source of electric power installed according to the above (A) is to be installed in accordance with the requirements of the followings.

(a) It is to be located above the uppermost continuous deck
(b) It is not to be contiguous to the boundaries of the engine room.
(c) It is to be located afterward of the collision bulkhead
(d) Supply of emergency electrical power is not to be interfered due to a fire or other casualty in spaces of engine rooms
(e) It is to be separated and ventilated from a fire or electrical sparks.

2. In application to **101. 2** of the Rules, International Electrotechnical Commission Publication and etc. may be referred.

3. In application to **101. 4** (1) of the Rules, a gas explosive atmosphere is the condition in which the gas that combustion can be continuous because it is not ignited and consumed in atmospheric condition and combustible materials in vapour condition are compounded. Where concentration of mixture exceeds the upper explosive limit, because it is easy to be explosible spaces, although it is not a gas explosive atmosphere, this condition is considered as a gas explosive atmosphere.

103. Construction and installation

1. Protection devices In application to **103. 3** of the Rules, power source switch of electrical equipment is to be so arranged that the equipment is not charged through control circuit or pilot lamp when the switch is in "off" position.

2. Installation and protective enclosure

(1) In a case where the characteristic letter IP showing the protection type of enclosures in accordance with the International Electrotechnical Commission 60529 is used for the protective enclosures of electrical equipment, the following requirements are to be complied with.

(A) Degree and expression of protection of enclosures
The degree of protection of enclosures is to be as given in **Table 6.1.1** of the Guidance. Protection type is to be expressed by the combination of symbol IP, first characteristic numeral which shows the degree of protection against access to hazardous parts and ingress of solid foreign objects, second characteristic numeral which shows degree of protection against ingress of water with harmful effects and additional letter which shows the protection against access to hazardous parts.

(B) Construction and test method of degree of protection

Construction and test methods of degree of protection are in accordance with **Table 6.1.2, Table 6.1.3, Table 6.1.4** and **Table 6.1.5** of the Guidance. The manufacturer is to carry out the relevant test for initial product at least, and is to identify effectiveness of protection type marked on the product. An individual test for the products may be carried out according to the discretion of the Surveyor.

(C) Application of degree of protection
As a guide for the selection of degree of protection for the electrical equipment on the basis of the circumstances of the place of installation, the requirements given in **Table 6.1.6** of the Guidance are to be taken into consideration.

Table 6.1.1 Degree of Protection and Expression

Code letters	First characteristic numeral	Second characteristic numeral	Additional letter(optional)	Supplementary letter(optional)
	Against access to hazardous parts and ingress of solid foreign objects	Against ingress of water with harmful effects	Against access to hazardous parts	Supplementary information
IP	0 1 2 3 4 5 6	0 1 2 3 4 5 6 7 8	A B C D	H M S W

(NOTES)
Out of expression, when either one of the first characteristic numeral or the second characteristic numeral is to be expressed, the degree of protection unnecessary is to be represented by X
Examples : IPX8 - Degree of protection only against ingress of water with harmful effects
IP5X - Degree of protection only against access to hazardous parts and ingress of solid foreign objects

Table 6.1.2 Degree of protection against access to hazardous parts and ingress of solid foreign objects shown by the first characteristic numeral

First characteristic numeral	Construction of protection	Testing methods and criteria
0	Non protected	-
1	Protected against access to hazardous parts with the back of a hand and protected against solid foreign objectsof 50mmϕ and greater	The sphere of 50(+0.05, -0) mm is not to fully penetrate with 50 N ±10 % of test force and adequate clearance form hazardous parts is to be kept.
2	Protected against access to hazardous parts with a finger and protected against solid foreign objects of 12.5 mmϕ and greater	The jointed test finger of 12 mmϕ, 80 mm length, may penetrate up to its 80 mm length with test force of 10 N±10 %, but adequate clearance form hazardous parts is to be kept. In addition, the sphere of 12.5(+0.05, -0) mm is not to fully penetrate with 30 N± 10 % of test force.
3	Protected against access to hazardous parts with a tool and protected against solid foreign objects of 2.5 mmϕ and greater	The test rod of 2.5(+0.05, -0) mm is not to penetrate with 3N± 10 % of test force and adequate clearance form hazardous parts is to be kept.

Table 6.1.2 Degree of protection against access to hazardous parts and ingress of solid foreign objects shown by the first characteristic numeral

First characteristic numeral	Construction of protection	Testing methods and criteria
4	Protected against access to hazardous parts with a wire and protected against solid foreign objects of 1.0 mmϕ and greater	The test rod of 1.0(+0.05, -0) mm is not to penetrate with 1N± 10 % of test force and adequate clearance form hazardous parts is to be kept.
5	Protected against access to hazardous parts with a wire and dust-protected	(1) Testing methods and criteria against the first characteristic numeral 4 are to be complied with. (2) The enclosure where the normal working cycle of the equipment causes reductions in air pressure within the enclosure below that of the surrounding air, e.g., due to thermal cycling effects (hereinafter referred to as Category 1 enclosure) is to comply with the following (a) and (b). At the end of the test, talcum powder is not to be accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety. (a) The test is to be made using a dust chamber. The powder circulation pump circulates and floats the talcum powder-continuously in the test chamber. The talcum powder used is to be capable of passing through a square meshed sieve the nominal wire diameter of which is 50 μm and the nominal width between wires 75 μm. The amount of talcum powder is to be 2 kg/m^2 of the testchamber. It is not to be used for more than 20 tests. The enclosure under test is to be supported inside the chamber by fixing or hanging. The pressure inside the enclosure is to be maintained below the surrounding atmospheric by a vacuum pump. The depression of the pressure is not to exceed 2 kPa. (b) If an extraction rate of 40 to 60 vol/hour is obtained the duration of the test is to be 2 hours. If, with a maximum depression of 2 kPa, the extraction rate is less than 40 vol/hour, the test is to be continued until 80 vol. have been drawn through, or a period of 8 *hours* has elapsed (3) Enclosures where no pressure difference relative to the surrounding air is present (hereinafter referred to as Category 2 enclosures) are to comply with the above (2) tests in condition that the enclosure under the test is supported in its normal operating position, but is not connected to a vacuum pump. The test is to be continued for a period of 8 hours. At the end of the test, talcum powder is not to be accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety.
6	Protected against access to hazardous parts with a wire and dust-tight	(1) Testing methods and criteria against the first characteristic numeral 4 are to be complied with. (2) The above (2) tests against the first characteristic numeral 5 are to be carried out and deposit of dust is not to be observed inside the enclosure at the end of the test.
(NOTES) The detailed test methods and criteria are referred to (KS C) IEC 60529.		

Table 6.1.3 Degree of protection against ingress of water with harmful effects shown by the second characteristic numeral

Second characteristic numeral	Construction of protection	Testing methods and criteria
0	Non protected	-
1	Protected against vertically falling water drops	The enclosure under test is to be placed in its normal operating position and 200 mm below the drip box. A flow of water drops, of which flow rate is 1(+0.5, -0) mm/min are to be produced for 10 min. At the end of the test, water is not to have accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety
2	Protected against vertically falling water drops when enclosure tilted up to 15 degrees	The enclosure under test is to be placed in its normal operating position and 200 mm below the drip box. A flow of water drops, of which flow rate is 3(+0.5, -0) mm/min, are to be produced for 2.5 min in each of four fixed positions. These positions are to be 15 degrees on either side of the vertical. At the end of the test, water is not to have accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety
3	Protected against spraying water	The enclosure under test is to be placed in its normal operating position. A uniform flow of water drops are to be produced over the whole area between vertical and 60 degrees on either side of the vertical at the distance of 300 mm to 500 mm from the enclosure. The delivery rate of water flow is to be 10(+0.5, -0.5) mm/min. The pressure to achieve this delivery rate is to be the range of 50 kPa to 150 kPa. The test duration is to be 1 min/m^2 of the calculated surface area of the enclosure(excluding any mounting surface), with a minimum of 5 min. At the end of the test, water is not to have accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety
4	Protected against splashing water	The enclosure under test is to be placed in its normal operating position. A uniform flow of water drops are to be produced over the whole area between vertical and 180 degrees on either side of the vertical at the distance of 300 mm to 500 mm from the enclosure. The delivery rate of water flow is 10(+0.5, -0.5) l/min. The pressure to achieve this delivery rate is to be the range of 50 kPa to 150 kPa. The test duration is to be 1 min/m^2 of the calculated surface area of the enclosure(excluding any mounting surface), with a minimum of 5 min. At the end of the test, water is not to have accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety
5	Protected against water jet	The enclosure under test is to be placed in its normal operating position. A stream of water from a standard nozzle of which internal diameter is 6.3 mm is to be sprayed to the enclosure from all directions. The distance between the nozzle and the enclosure is to be 2.5 m. The delivery rate is (12.5 l ± 0.5 %)/min. Core of the substantial stream is to be a circle of approximately 40mm diameter at 2.5 m distance from nozzle. Test duration per square metre of enclosure surface area likely to be sprayed is to be 1 min. Minimum test duration is to be 3 min. At the end of the test, water is not to have accumulated in a quantity or location such that it could interfere with the correct operation of the equipment or impair safety
6	Protected against powerful jet	The enclosure under test is to be placed in its normal operating position. A stream of water from a standard nozzle, of which internal diameter is 12.5 mm, is to be sprayed on the enclosure from all directions. The distance between the nozzle and the enclosure is to be 2.5 m to 3 m. The delivery rate is (100 l ± 0.5 %)/min. Core of the substantial stream is to be a circle of approximately 120 mm diameter at 2.5 m distance from nozzle. Test duration per square metre of enclosure surface area likely to be sprayed is to be 1 min. Minimum test duration is to be 3 min. At the end of the test, no water is to have entered into the enclosure.

Table 6.1.3 Degree of protection against ingress of water with harmful effects shown by the second characteristic numeral

Second characteristic numeral	Construction of protection	Testing methods and criteria
7	Protected against the effects of temporary immersion in water	The highest point of enclosures is to be located deeper than 150 mm below the surface of water, and also the lowest point of the enclosures is to be located deeper than 1000 mm below the surface of water. The duration of the test is to be 30 min. The water temperature is not to differ from that of the equipment by more than 5K. However, it may be waived where the equipment is energized and/or its parts in motion. At the end of the test, no water is to have entered into the enclosure.
8	Protected against the effects of continuous immersion in water	The test conditions are to be subject to agreement between manufacturer and user, but they are to be more severe than the conditions for the second characteristic numeral 7 and they are to take account of the condition that the enclosure will be continuously immersed in actual use. At the end of the test, no water is to have entered into the enclosure.
(NOTES) The detailed test methods and criteria are referred to (KS C) IEC 60529.		

Table 6.1.4 Degree of protection against access to hazardous parts shown by the additional letters

Additional letter	Construction of enclosure	Test methods and criteria
A	Protected against access with the back of the hand	The access probe, sphere of 50 mmϕ, is to have adequate clearance form hazardous parts with 50 N ± 10 % of test force.
B	Protected against access with a finger	The jointed test finger of 12 mmϕ, 80 mm length, is to have adequate clearance form hazardous parts with 10 N ± 10 % of test force.
C	Protected against access with a tool	The access probe of 2.5 mmϕ, 100 mm length, is to have adequate clearance form hazardous parts with 3 N ± 10 % of test force.
D	Protected against access with a wire	The access probe of 1.0 mmϕ, 100 mm length, is to have adequate clearance form hazardous parts with 1 N ± 10 % of test force.
(NOTES) The detailed test methods and criteria are referred to (KS C) IEC 60529.		

Table 6.1.5 Supplementary information shown by the supplementary letters

Supplementary letter	Significance
H	High voltage apparatus
M	Tested for harmful effects due to the ingress of water when the movable parts of the equipment, e.g., the rotor of the rotating machine, are in motion
S	Tested for harmful effects due to the ingress of water when the movable parts of the equipment, e.g., the rotor of the rotating machine, are stationary
W	Suitable for use under specified weather conditions and provided with additional protective features or process

Table 6.1.6 Application of Degree of Protection

Example of location	Condition of location	Switchboard, etc[1]	Generators	Motors	Transformers, Converters	Lighting fixtures	Heating appliances	Accessories[2]
Dry accommodation space	Danger of touching live parts only	IP 20	-	IP 20	IP 20	IP 20	IP 20	IP 20
Dry control rooms[4]		IP 20	-	IP 20	IP 20	IP 20	IP 20	IP 20
Control rooms	Danger of dripping water and(or) moderate mechanical damage	IP 22	-	IP 22	IP 22	IP 22	IP 22	IP 22
Engine rooms and boiler rooms above floor plates[5]		IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44
Steering gear rooms		IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44
Refrigerating machinery rooms		IP 22	-	IP 22	IP 22	IP 22	IP 22	IP 44
Emergency machinery rooms		IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44
General store rooms		IP 22	-	IP 22	IP 22	IP 22	IP 22	IP 22
Pantries		IP 22	-	IP 22	IP 22	IP 22	IP 22	IP 44
Provision rooms		IP 22	-	IP 22	IP 22	IP 22	IP 22	IP 22
Bathrooms and showers	Danger of spraying water and(or) increased danger of mechanical damage	-	-	-	-	IP 34	IP 44	IP 55
Engine rooms and boiler rooms below floor plates		-	-	IP 44	-	IP 34	IP 44	IP 55[3]
Closed fuel oil or lubricating oil separator rooms		IP 44	-	IP 44	-	IP 34	IP 44	IP 55[3]
Ballast pump rooms, bow thruster rooms and similar spaces below load line		IP 44	-	IP 44[6]	IP 44	IP 34	IP 44	IP 55
Refrigerated rooms		-	-	IP 44	-	IP 34	IP 44	IP 55
Galleys and laundries		IP 44	-	IP 44	IP 44	IP 34	IP 44	IP 44
Shaft or pipe tunnels in double bottom	Danger of jet water, existence of cargo dust particle, serious mechanical damage and(or) aggressive fumes	IP 55	-	IP 55	IP 55	IP 55	IP 55	IP 56
Holds for general cargo		-	-	-	-	IP 55	-	IP 55
Open decks	Exposure to heavy seas	IP 56	-	IP 56	-	IP 56	IP 56	IP 56
Bilge wells	Exposure to submersion	-	-	-	-	IP X8	-	IP X8

(NOTES)

(1) It contains distribution boards, motor control centers and controllers.

(2) Accessories include switches, detectors, junction boxes, etc.

(3) Socket outlets are not to be installed in engine rooms, boiler rooms below floor plates, enclosed fuel and lubricating oil separator rooms or spaces requiring certified safe equipment.

(4) Navigation bridge may be categorized as a "dry control room" and consequently, the installation of IP 20 equipment would suffice therein provided that : (a) the equipment is located at to preclude being exposed to stream, or dripping/spraying water emanating from pipe flanges, valves, ventilation ducts and outlets, etc., installed in its vicinity, and (b) the equipment is placed to preclude the possibility of being exposed to sea or rain.

(5) Where the equipment is located within areas protected by local fixed pressure water spraying or water-mist fire extinguishing system and its adjacent areas.

(6) Electric motors and starting transformers for thrusters shall be equipped with heating elements (space heater, etc) for standstill heating. Provided the space will not be used as pump room for ballast, fuel oil, etc., the thrusters motor may be accepted with IP 22 enclosure type.

* "-" marks indicate installation of electrical equipment is not recommended., selection for explosion-protected construction is to be in accordance with the relevant requirements of **Pt 6, Ch 1** of the Rules.

(2) Electrical equipment installed in paint stores and enclosed spaces giving access to the paint store is to be in accordance with the followings.

(A) Electrical equipment installed in paint stores and ventilating ducts for the paint store are to be of explosion-protected type and cables of armoured type or installed in metallic conduits are to be used.

(B) In the areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets, the following electrical equipment is to be installed:

(a) Electrical equipment with the type of protection as permitted in paint stores or

(b) Equipment of protection class Exn, or

(c) Appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature, or

(d) Appliances with simplified pressurized enclosures or vapour-proof enclosures (minimum class of protection IP55) whose surface does not reach unacceptably high temperature

(C) The enclosed spaces giving access to the paint store may be considered as non-hazardous spaces, provided that :

(a) The door to the paint store is a gastight door with self-closing devices without holding back arrangements.

(b) The paint store is provided with an acceptable, independent, natural ventilation system ventilated from a safe area.

(c) Warning notices are fitted adjacent to the paint store entrance stating that the store contains flammable liquids.

(D) Switches, protective devices, and motor control gear of electrical equipment installed in a paint store are to interrupt all poles or phases and preferably are to be located in non-hazardous space.

(3) Electrical equipment and relevant ventilation ducts installed in paint stores, battery rooms, acetylene stores are classified as "zone 1". Explosion protecting classes are to be higher than at least the followings in accordance with (KS C) IEC 60079.

(A) Paint store : Gas vapour group IIB, temperature class T3

(B) Battery room : Gas vapour group IIC, temperature class T1

(C) Acetylene store : Gas vapour group IIC, temperature class T2

(4) Electrical equipment installed in spaces on open deck within 1 m from ventilation openings of paint stores, battery rooms, acetylene stores or 3 m from outlets of mechanical ventilation equipments is classified as "zone 2".

3. In application to **103. 9** of the Rules, when current not more than rated values of electrical equipment and cables flows, deviation of magnetic compass needle not more than ±0.5° is not considered as a bad effect. And the excessive effect happened at the time of circuit on and off may not be considered, but the circuits switched on and off frequently are to be considered.

104. Earthing of electrical equipment

1. In application to **104. 2** of the Rules, the following exposed metal parts may not be earthen:

(1) Non-current-carrying metal parts of electrical equipment which are unlikely to be touched by persons during their service

(2) Lamp caps

(3) Shades, reflectors and guards, supported on lampholders or lighting fittings constructed of, or shrouded in non-conducting material

(4) Metal parts or screw separated by insulators from the current-carrying parts or from earthen non-current-carrying parts which are not charged or earthen under normal service condition

(5) Bearing housing insulated to prevent circulation of current in the bearing

(6) Clips of fluorescent lighting tube

(7) Equipment supplied at safety voltage

(8) Cable clips

2. Earthing may be made under the requirements as specified below:

(1) All earthing connections are to be made through copper or other corrosion resistance material and to be securely installed to hull structure. All earthing conductors are to be protected, where necessary, against mechanical damage and electrolytic corrosion.

(2) Where the metal frame or enclosure of electrical equipment is directly fitted to hull structure,

and the surface in contact are clean and free from rust, scales and paints, and bolted firmly, no earthing conductors may be provided.

(3) Under any circumstances, a lead cable sheath is not to be used as a sole earthing means.

(4) Nominal cross-sectional areas of all copper earthing conductors are to be as given in **Table 6.1.7** of the Guidance, In a case where earthing conductors other than copper are used, their conductances are to be of more than that of copper conductors given in **Table 6.1.7** of the Guidance.

(5) Connections between earthing conductors and hull structure are to be made in an accessible position, and to be secured by a screw of brass or other corrosion resistance material of diameter not less than 4 mm which is to be used for this purpose only. In any case, the contact faces are to have glossy metal surface when screws are tightened.

3. In a power distribution system where one line of the system is earthen and normally of non-current carrying line, the earthing connection is to be as specified in **2** above. However, the upper limit value 64 mm^2 of the cross-sectional area of the earthing conductor given in **Table 6.1.7** of the Guidance does not apply.

Table 6.1.7 Sizes of Earthing Conductor

<table>
<tr><th colspan="2">Kind of earthing conductor</th><th>Conductor's sectional area of current-carrying parts</th><th>Minimum sectional area of copper earthing conductor</th></tr>
<tr><td colspan="2" rowspan="2">1. Earthing conductor in flexible cables and flexible cords</td><td>16 mm^2 or less</td><td>100 % of conductor's sectional area of current-carrying parts</td></tr>
<tr><td>Over 16 mm^2</td><td>50 % of conductor's sectional area of current-carrying parts, but minimum 16 mm^2</td></tr>
<tr><td rowspan="4">2. Earthing conductor in cable runs secured</td><td rowspan="2">Insulated earthing conductor</td><td>16 mm^2 or less</td><td>100 % of conductor's sectional area of current-carrying parts, but minimum 1.5 mm^2</td></tr>
<tr><td>Over 16 mm^2</td><td>50 % of conductor's sectional area of current-carrying parts, but minimum 16 mm^2</td></tr>
<tr><td rowspan="2">Bared earthing conductor connected directly with lead sheath</td><td>2.5 mm^2 or less</td><td>1 mm^2</td></tr>
<tr><td>Over 2.5 mm^2 ~ 6 mm^2</td><td>1.5 mm^2</td></tr>
<tr><td colspan="2" rowspan="3">3. Single earthing conductor</td><td>(a) 3 mm^2 or less</td><td>100 % of conductor's sectional area of current-carrying parts, but minimum 1.5 mm^2 in case of lead wire, and minimum 3 mm^2 in case of the others</td></tr>
<tr><td>(b) Over 3 mm^2 ~ 125 mm^2</td><td>50 % of conductor's sectional area of current-carrying parts, but minimum 3 mm^2</td></tr>
<tr><td>(c) over 125 mm^2</td><td>64 mm^2</td></tr>
</table>

4. In application to **104. 3** of the Rules, portable electrical appliances are to be in accordance with the followings.

(1) The non-current-carrying metal parts of portable electrical appliances are to be earthed through plugs and receptacles by mean of earthing conductors provided in flexible cables or cords.

(2) Portable electrical appliances insulated doubly may not be earthed.

5. Aluminium superstructures Methods of securing aluminium superstructures to the steel hull of a ship often include insulation to prevent electrolytic corrosion between these materials. In such case, a separate bonding connection is to be provided between superstructure and the hull which should be made in such a manner that electrolytic corrosion is avoided and the points of connection may readily be inspected.

107. Ambient conditions

1. In application to **107. 1** of the Rules, "Ambient temperatures for electrical equipment installed in environmentally controlled spaces" are in accordance with the followings.

(1) Where electrical equipment is installed within environmentally controlled spaces the ambient temperature for which the equipment is to be suitable may be reduced from 45 °C and maintained at a value not less than 35 °C provided:

(A) The equipment is not for use for emergency services.

(B) Temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature.

(C) The equipment is able to be initially set to work safely within a 45 °C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45 °C ambient temperature.

(D) Audible and visual alarms are provided, at a continually manned control station, to indicate any malfunction of the cooling units.

(2) In accepting a lesser ambient temperature than 45 °C , it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

(3) The equipment used for cooling and maintaining the lesser ambient temperature is to be classified as a secondary essential service.

108. Clearance and creepage

1. Clearance and creepage are in accordance with **706. 2** of the Guidance.

109. Testing and inspection

1. The generators, switchboards and transformers used for cargo refrigerating installations and cargo handling arrangements specified in **Pt 9** of the Rules, are to be tested and inspected in accordance with the requirements in **109.** of the Rules.

2. The cables to be type approved by the requirements in **109. 1** (2) are in accordance with the followings.

(1) Cables used for supply and distribution circuits for power, lighting and internal communications

(2) Sheathed portable cords used for supplying and distribution circuits for power

(3) Polyvinylchloride insulated multi-core cables for 150 V electronic equipment

(4) Cables used for control circuit(insulation cables used for distribution boards and control gears)

(5) Cables used for communication such as optical fiber cables, coaxial cables and etc.

3. Type approval test for sheathed portable cords and Polyvinylchloride sheath cords other than cables specified in 4 above, may be carried out according to manufacturer's request.

4. Tests and inspections on type approved products

In application to **109. 6** of the Rules, it is to be in accordance with the followings.

(1) The inspections and tests in the presence of the Surveyor for individual product of followings among type-approved electrical equipment may be wholly omitted.

(A) Fuse

(B) Circuit breaker

(C) Magnetic contactor

(D) Cable trays/protective casings made of plastic materials

(E) Protection relay

(2) The individual products of followings among type-approved electrical equipment are to be tested in the presence of the Surveyor as follows:

(A) Explosion-proof type electrical equipment (rotating machinery only)

(a) Construction inspection (including dimension check for gab size, depth, etc.

(b) Temperature test

(c) Insulation resistance test

(d) High voltage test

(e) Water-proof test(sealing type only)

(B) Cables

(a) Construction inspection and dimension check
(b) Insulation resistance test
(c) High voltage test

5. "Where deemed appropriate by the Society " required in **109. 1** (1) (C), (D) of the Rules means "the cases approved by QA or others."

Section 2 Rotating Machinery

201. General

1. Main source of electrical power

(1) In application to **201. 2** (3) of the Rules, the shaft driven generator systems are to comply with following requirements.
(A) Forming part of the ship's main source of electrical power
(a) They are to be capable of operating under all weather conditions during sailing and during maneuvering, also when the vessel is stopped, within the specified limits for the voltage variation in **205. 4** and **206. 2** of the Rules and the frequency variation in **106. 3 Table 6.1.1** of the Rules.
(b) Their rated capacity is safeguarded during all operations given (a) above and is such that in the event of any other one of the generators failing, the essential services and services for habitability can be maintained.
(c) The short circuit current of the generator/generator system is sufficient to trip the generator/generator system circuit-breaker taking into account the selectivity of the protective devices for the distribution system. Protection is to be arranged in order to safeguard the generator/generator system in case of a short circuit in the main bus bar. The generator/generator system is to be suitable for further use after fault clearance.
(d) Standby generators are automatically started.
(B) Not forming part of the ship's main source of electrical power
Generators and generator systems, having the ship's propulsion machinery as their prime mover but not forming part of the ship's main source of electrical power may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that:
(a) There are sufficient and adequately rated additional generators fitted, which constitute the main source of electrical power required by **201. 2.** (1), (2) and (3).
(b) Arrangements are fitted to automatically start one or more of the generators, constituting the main source of electrical power required by **201. 2.** (1), (2) and (3) and also upon the frequency variations exceeding ±10% of the limits specified in (c) below.
(c) The specified limits for the voltage variations in **205. 4** and **206. 2** of the Rules and the frequency variation in **106. 3 Table 6.1.1** of the Rules can be met within the declared operating range of the generators and/or generator systems.
(d) The short circuit current of the generator and/or generator system is sufficient to trip the generator/generator system circuit-breaker taking into account the selectivity of the protective devices for the distribution system.
(e) Where considered appropriate, load shedding arrangements are fitted.
(f) On ships having remote control of the ship's propulsion machinery from the navigating bridge means are provided, or procedures be in place, so as to ensure that supplies to essential services are maintained during maneuvering conditions in order to avoid a blackout situation.

(2) Provisions for maintaining or immediately restoring the electrical supply to equipment propulsion and steering specified in **201. 2** (5) of the Rules are to comply with followings:
(A) Where the electrical power is normally supplied by more than one generator set simultaneously in parallel operation, provision of protection, including automatic disconnection of sufficient non-essential services and if necessary secondary essential services and those provided for habitability, is to be made to ensure that, in case of loss of any of these generating sets, the remaining ones are kept in operation to permit propulsion and steering and to ensure safety.
(B) Where the electrical power is normally be supplied by one generator, the following require-

ments are to be complied with.

(a) provision is to be made, upon loss of power, for automatic starting and connecting to the main switchboard of stand-by generator(s) of sufficient capacity with automatic re-starting of the essential auxiliaries, in sequential operation if required.

(b) The time for automatic starting and connecting to the main switchboard of a standby generator specified in (a) above is to be preferably within 30 seconds, but in any case not more than 45 seconds, after loss of power.

202. Prime movers for generators

For prime movers with a brake mean effective pressure of 1.35 MPa or more to which the application of the method of throwing on the rated load of a generator specified in **202. 2** (2) of the Rules is impossible, the throwing-on method in three or four steps in accordance with the formulae below is to be used notwithstanding the requirements of the Rules:

Total throw-on load at the 1st step(%) = 80/BMEP

Total throw-on load at the 2nd step(%) = 135/BMEP

Total throw-on load at the 3rd step(%) = 180/BMEP

Total throw-on load at the 4th step(%) = 100

Where, BMEP : Brake mean effective pressure(MPa)

However, in case where the above throwing-on method applies, the manufacturers or shipyards are requested to submit a throw-on power calculation sheet demonstrating that the thrown load and base load at each step of operation do not exceed the value determined by the formulae above under any circumstances, to the Society for approval.

(1) At the time of power restoration after blackout

(2) At the time of sequential starting

(3) At the time of starting with a large start-up load

(4) At the time of instantaneous load transfer when one set of the generators fails (during parallel running)

203. Rotating machinery shaft

1. Rotating machinery shaft

(1) In application to **203. 1** of the Rules, The fillet radius on edge part is to be 0.08 times the shaft's actual diameter to prevent the stress concentration. In a case where the filet radius is less than 0.08 times the shaft's actual diameter, the shaft diameter is to be increased proportionally according to the coefficient of stress concentration.

(2) “Where it is apprehended that the torque is remarkably greater than normal torque” means where the auto synchronizing device is not installed. In this case the value of F is to be 120 % of the value given in accordance with **Table 6.1.3** of the Rules.

204. Temperature rise

1. In application to **204. 1** of the Rules, temperature rising of bearing is to be in accordance with the followings.

(1) Temperature rising limit of bearing (self-cooling type) is 35℃ when it measures at the surface, and is 40℃ when it measures by keeping temperature sensor under the metal. However, where heat-proof lubricating oil is used, it is 50℃ when it measures at the surface.

(2) Where rotating machinery used heat-proof insulation material of up-grade than F-Grade is difficult to apply to (1) above, data for heat-proof temperature rising limit is to be submitted to the Society, and is to be approved by the Society.

2. Temperature measuring method for winding of rotating of machinery forced cooling type by air cooler is to be the method of keeping temperature sensor under the winding or bridge method.

3. When cooling water temperature of rotating machinery of forced cooling type by air cooler is over 32℃, the temperature limit is to be in accordance with the discretion of the Society.

205. Ship's service d.c. generator

1. Undervoltage protection (For a.c and d.c generators)

For generators arranged for parallel operation with one another or with shore power feeder, measures are to be taken to prevent the generator breaker from closing if the generator is not generating and to prevent the generator remaining connected to the busbars if voltage collapses.

In the case of an undervoltage release provided for this purpose, the operation is to be instantaneous when preventing closure of the braker, but is to be delayed for discrimination purposes when tripping a breaker.

208. Welding

1. The manufacturers are to submit the detailed data in connection with the welding work for examination of the Society if they plan to make coupling of generator shaft welded with flange for the first time. And fatigue test is to be included in the welding process qualification test.

2. The manufacturers are to submit the following data in connection with the welding work for examination of the Society if they plan to make generator shaft welded with rib, etc.

(1) Standard design stress and strength calculation data for rib, etc. attached to the shaft by welding
(2) Standard for welding workmanship and details for control standard
(3) Welding process qualification test record. The test results carried out by means of the test specimen manufactured according to the standard for welding workmanship specified in above (2), are to be included to the record, and macro test, micro test and hardness distribution measurement for welding parts are to be carried out.

3. The torque transmission parts such as spider(center of rotor), etc. with welded construction are to be in accordance with 2 above.

4. Welding for electric motor shaft is to be in accordance with the followings.

(1) The essential auxiliary driving motors having output of 100 kW or over are to be in accordance with **1** and **2** above.
(2) The motors having output less than 100 kW are to be in accordance with the followings.
 (A) Shaft coupling flanges with welded construction are to be applied with appropriate modification of (1) above.
 (B) For rib, etc. with welded construction, standard for welding workmanship only instead of (A) above may be submitted.

209. Testing and inspection

1. Temperature test

In application to **209. 3** of the Rules, temperature test of rotating machinery, as a general rule, is carried out at actual load. But, in an unavoidable case, the zero power factor method or the temperature deduction method may apply to synchronous machines, and the equivalent load method may apply to induction machinery, such as the followings.

(1) Synchronous machines
 (A) Zero power factor method
 The rotating machinery is to be over-excited at unload condition by generator or motor, and is to be tested by flowing current close to rated current of zero power factor at rated voltage and frequency. The zero power factor method is capable of applying to synchronous machines for compensating of power factor, but where the method applies to synchronous generator or motor, sufficient field current to get value close to rated output providing for the case a hard to get the rated output by short of field current, is to flow at the test, and the test result is to be corrected according to the followings.
 (a) Temperature test is to be carried out for each rated voltage and no-load (armature open circuit), and rising temperature t_0 of armature winding and rising temperature t_{c0} of iron core of armature are to be get from the test.
 (b) In zero power factor method
 t' = rising temperature of windings at voltage V', current I'

t'_c = rising temperature of iron cores at voltage V', current I'

t'_f = rising temperature of field windings at field current I'_f

(c) when rated voltage is V, Rising temperature can be calculated by the following formula.

Armature windings : $T = t_0 + (t' - t_0) \times \left(\frac{I}{T}\right)^2$

Iron core of armature : $T = t_{c0} + (t' - t_{c0}) \times \left(\frac{I}{T}\right)^2$

Field windings : $I_f = t'_f \times \left(\frac{I_f}{T_f}\right)^2$

The test voltage V', as far as possible, is to be rated voltage, but voltage over than 90 % of rated voltage.

(B) Temperature deduction

Whichever is available among the followings.

(a) The rising temperature of iron core at rated output is the rising temperature of iron core when rotating machinery is operated at unload condition of terminal voltage equivalent to 110 % of rated voltage, and the rising temperature of armature windings at rated output is the rising temperature of armature windings when rotating machinery is operated at short condition of all terminals carrying armature current equivalent to 125 % of rated output.

(b) Total rising temperature of iron cores and armature windings, in each case, measured final temperature of iron core and armature windings when rotating machinery is operated at unload condition of rated voltage or at short condition of all terminals carrying rated current, is each rising temperature for rated output.

(c) The circulation current equivalent to rated current armature at $d.c.$ or single phase source is to be transmitted at the condition of that windings are connected by ring shape(triangle) line connection type, and opened one side, the terminal voltage equivalent to rated voltage, rising temperature of armature iron cores and windings are almost same as rated output when rotating machinery operates at rated speed through exciting to generate voltage of terminals equivalent to rated voltage. The current of field is to be corrected by zero power factor method.

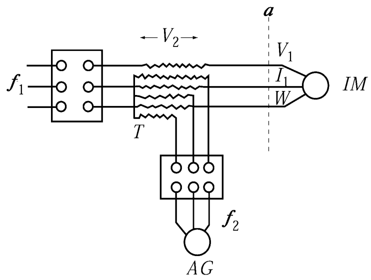
(2) Inductors

(A) First stage synthesizing equivalency load method

This method is test method carried out by increasing and decreasing the voltage and frequency after synthesizing the voltage of main source and low voltage having frequency different from the voltage of main source when the inductor for testing connected such as **Fig 6.1.1** of the Guidance operates at no-load condition, and in general, the method synthesizing first stage current and total load current (current standard method), is used. The method (loss standard method) that input is equalized with loss at rated load calculated from the circle diagram method for inductors of special squirrel cage, 2 pole machinery and large output.

(B) Second stage synthesizing load method

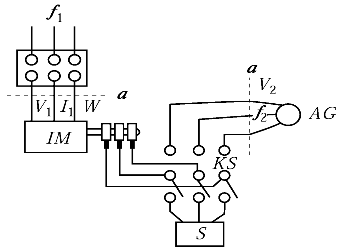
This method is test method transmitted full load current to first stage by increasing and decreasing the voltage and frequency after synthesizing the second stage voltage and low voltage having low frequency when the inductor for testing connected as **Fig 6.1.2** operates at no-load condition.



IM : Inductor for testing
a : Connection point of Volt-meter, Am-meter, Watt-meter
AG : Generator for auxiliary source
I_1 : First stage current of inductor
f_1 : Frequency of source (rated frequency)
T: Series transformer
f_2 : Synthesizing frequency
V_1 : Terminal voltage (rated voltage)
W : Input
V_2 : Synthesizing voltage

(NOTES)
1. The direction of phase circulation of auxiliary source is to be selected same as that of main source.
2. V_2 is to be exceedingly less than V_1.(about impedance voltage of inductor for testing)

Fig 6.1.1 First stage synthesizing equivalency load method



IM : Inductor for testing
I_1 : First stage current of inductor
a : Connection point of Volt-meter, Am-meter, Watt-meter
V_2 : Synthesizing voltage
f_2 : Synthesizing frequency
AG : Generator for auxiliary source
W : Input
V_1 : Terminal voltage (rated voltage)
S : Starting resistor
f_1 : Frequency of source (rated frequency)
KS : Change-over switch

(NOTES)
1. When inductor operates by auxiliary source after having a short-circuit of field, the direction of auxiliary source is to be selected direction same as that of rotator the case operated by main source.
2. It is recommended that, as far as possible, synthesizing frequency f_2 is not more than 1/2 f_1.

Fig 6.1.2 Second stage synthesizing load method

2. Over-current or excess torque test

In application to **209. 4** of the Rules, excess torque test of special type motor may be carried out as the following unless otherwise designated.

Single phase motor : excess torque of 33 % during 15 seconds

Motor used for deck machinery : excess torque of 50 % during 15 seconds

Synchronous induction motor : excess torque of 35 % during 15 seconds

3. Over speed test

In application to **209. 5** of the Rules, over speed test for 2 pole induction motor having 500 kW or over, is to be carried out at 120 % of synchronizing speed.

4. Voltage regulation test

(1) In application to **209. 8** of the Rules, voltage regulation test for generator, as a general rule, is to be carried out at the condition that the generator is connected directly with prime mover. Where the test is carried out by generator only, it is supposed that speed between no load and full load is changed in a straight line, and the voltage regulation rate is 3.5 % in the case of that there is no data about speed variation of prime mover.

(2) In application to **209. 8** (2) of the Rules, In the absence of precise information concerning the maximum values of the sudden loads, the following conditions may be assumed: 60 % of the rated current with a power factor of between 0.4 lagging and zero to be suddenly switched on with the generator running at no load, and then switched off after steady-state conditions have been reached.

5. Commutation test

(1) In application to **209. 10** of the Rules, grade of spark between commutator and brush of *d.c.* machinery is divided into 8 kinds specified in **Fig 6.1.3** of the Guidance, the sparks of No.5 through No.8 are considered as harmful spark.

(2) Nevertheless (1) above, when surface of commutator after the temperature test and over-load test becomes black or gets damaged depending on spark, or the brush wears down or gets damaged, the spark is considered harmful spark.

(3) The spark of No.2 or No.1 are recommended as spark at load of rated output or less.

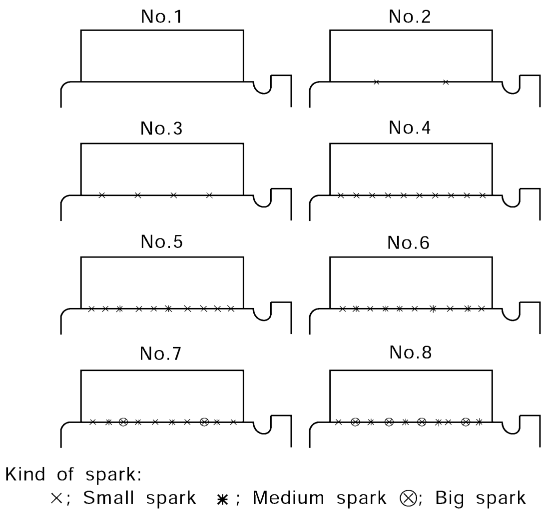


Fig 6.1.3 spark on surface of commutator

Section 3 Switchboards, Section Boards, Distribution Boards and Protective Equipment

301. General

1. Locations

In application to **301. 1** (1) of the Rules, in a case where steam pipes, water pipes, oil pipes, etc. are inevitably laid in the proximity of switchboards, flanges of these pipes are to be of welded joints or means are to be so provided that no detrimental effects would be exerted on switchboards if a leakage occurs.

2. In application **301. 1** (2) of the Rules, the followings are to be complied with.

(1) The main generating station is to be situated within the machinery space, i.e. within the extreme main transverse watertight bulkheads.

(2) Any bulkhead between the extreme main transverse watertight bulkheads is not regarded as separating the equipment in the main generating station provided that there is access between the spaces.

(3) The main switchboard is to be located as close as practicable to the main generating station, within the same machinery space and the same vertical and horizontal A-60 fire boundaries.

(4) Where essential services for steering and propulsion are supplied from section boards, these and any transformers, converters and similar appliances constituting an essential part of electrical supply system are also to satisfy the foregoing.

3. Safety spaces of operators

In application to **301. 2** of the Rules, the width of broken space to be provided in front of switchboards is to be 0.9 m or more as the standard. Furthermore, in case of emergency switchboard supplied from batteries or switchboards of small ships so constructed that necessary operation and maintenance can be done from their front, the passageway at the rear side of switchboards may be omitted.

4. Safety precautions to operators

In application to **301. 3** of the Rules, insulation mats have to get the type approval or product inspection by the Society and relevant requirements are to be in accordance with (KS C) IEC 61111.

302. Construction

1. Flame retardant test of insulation material is to be carried out at the normal temperature and the condition of that there is no wind, and round bar or thin steel plate having minimum length 120 mm, breadth 10 mm and thickness 3 mm is to be used as a standard for test specimen. The specimen is to be so tied up with a fine wire that breadth becomes an angle of about 45° vertically and length becomes horizontally. The test is to be used liquefied natural gas, and the flame is to be so adjusted vertically in air that the height of flame becomes about 125 mm and blue area of the flame becomes about 35 mm. The centerline of the flame is to become vertically, and the front of blue area of the flame is to be attached 5 times every 15 seconds intervals during 15 seconds at bottom of the specimen. It may be recognized that the specimen burns out after testing. Where the damaged length of the specimen is 60 mm or less, it is recognized as flame retardant material.

2. Flame retardant test of sealing compound for penetration of cables through fire-proof bulkheads and decks is to be applied with appropriate modifications of the requirements of **1** above. Where the damaged length of the specimen is 60 mm or less, the material is recognized as flame retardant compound (material equivalent to compound of non-combustible material).

3. The following may be regarded as the "other approved means" specified in **302. 1** (2) of the Rules.

(1) Circuit breaker without tripping mechanism
(2) Disconnecting link or switch by which busbars can be split easily and safely.

303. Busbars and equalizer connections

1. Busbars and the contact faces of busbars and linking conductors are to be protected against corrosion or oxidization by means of silver plating, tin plating or dipping in solder bath, etc.

2. Current rating of busbars may generally be determined by **Table 6.1.8** of the Guidance.

Table 6.1.8 Current Rating of Busbars

Type		Current rating
For Generator	In case where only one generator is feeding power to the busbars	100 % or more of the rated current of the generator
	In case where two or more generators are feeding power at their full capacities to the busbars	{(100 % of the rated current of one generator of the largest capacity) + (80 % of sum of the rated currents of the rest of generators)} or more
For Power Feeding	In case of general power feeding circuit	75 % of sum of the rated currents of the feeding circuits (including spare circuits) or more, but need be not more than the capacity of generator busbar
	In case where the feeding circuit has only one load circuit, or where power is fed to a group of motors under continuous service	The total rated current or more

304. Measuring instruments for switchboards

1. Instrument scales

In application to **304. 3** of the Rules, instrument scales mean effective measuring range. And where the scale of current meter for electrical motor needs to be extended for starting current, the extended scales do not apply with this requirement.

305. Protective devices

1. Protection against short-circuit

(1) In application to **305. 5** of the Rules, the circuit-breakers approved by the Society are recog-

nized as the circuit-breaker having the following making capacity, but the case specified in **305. 5** (3) of the Rules is excluded.

(A) d.c. circuit-breaker: value same as the rated short-circuit current

(B) a.c. circuit breaker: value specified in **Table 6.1.9** of the Guidance

(2) In a.c. circuit breaker, short-circuit test is to be carried out by test circuit having power factor different from the value specified in **Table 6.1.9** of the Guidance, the value calculated by the formula is to be used as a standard value for the making capacity of circuit-breaker passed the test.

$$I_{making} = I_{sy} \times n(A), \qquad n = \sqrt{2}\left\{1 + \sin\phi \times e^{-\frac{\frac{\pi}{2}+\phi}{\tan\phi}}\right\}$$

I_{making} : Making current

I_{sy} : Rated short-circuit current (effective value of short-circuit current in contrast to 1/2 cycle after shorting the circuit)

Table 6.1.9 Making Current of A.C. Circuit Breaker

Kind	Rated short-circuit current I_{sy} (A)	Making current I_{making} (A)	n I_{making}/I_{sy}	Power factor of circuit for short-circuit test $cos\phi$
Moduled-case circuit- breaker	2,500 5,000 7,500 10,000 14,000 18,000	4,250 8,500 12,750 17,000 23,800 30,600	1.7	0.5
	22,000 25,000 30,000 35,000 42,000 50,000 65,000 85,000 100,000	48,400 55,000 66,000 77,000 92,400 110,000 143,000 187,000 220,000	2.2	0.2
Air circuit- breaker	10,000 20,000 40,000 70,000 90,000	20,000 44,000 92,000 161,000 207,000	2.0 2.2 2.3 2.3 2.3	0.3 0.2 0.15 0.15 0.15

(3) In case where determination of cascade breaking capacity of breakers necessary for employing for short-circuit protection is intended in accordance with **305. 5** (2) of the Rules, the test method and criteria are to be as specified the followings.

(A) Test method

Back-up circuit breakers and fuses are to be connected in series with the circuit breakers on load side, and short-circuit tests under an operating duty of O - 2 minutes* - CO 1 time for one circuit breaker on load side are to be carried out.

Note: In case where the thermal trip reset time and fuse replacement time exceed 2 minutes, the time asterisked is the one deemed appropriate by the Society.

(B) Criteria after tests

The circuit breakers on load side are to satisfy the following requirements.

(a) No short-circuit is to be caused if the back-up circuit breaker is reclosed with the pow-

er supply being connected, and no voltage is to be applied on the terminals of the circuit breaker on load side.
(b) Circuit breaker can be safely and easily replaced with a spare.
(c) No damage is to be caused on the case body and cover.
(d) Maker and break of circuit is to be possible.
(e) High voltage test is to be carried out at a voltage 2 times the rated voltage, and to prove that it resists the voltage.
(f) Insulation resistance is to be 0.5 MΩ or over.

2. Protection of generator

In application to **305. 6** of the Rules, protection of generator is to be in accordance with the followings.

(1) The trip current scale adjusting value of over-current trip device, with time delay, for generator is to be selected as value protected at safety over-current according to heat capacity of generator and characteristics of over-current trip device, with time delay. And where kind and adjusting value of over-current trip device, with time delay (long delay and short delay), for short-circuit protection device are selected, cooperation between protection devices is to be considered.
(2) When parallel running of two sets or more of generators is capable, and selection trip device is provided, the adjusting value and characteristics of over-current trip device, with time delay, are so selected that over-current trip device of generator is not to operate with preference trip device at the same time. And when essential service motors are in danger of operating selection trip device at starting, the device may be interlocked during operating the motors.
(3) The following adjusting values for reverse power protection device are standard value.
(A) Generator driven by turbine : 2 ~ 6 %
(B) Generator driven by diesel engine : 6 ~ 15 %

3. Protection of feeder circuits

In application to **305. 9** of the Rules, rated current or trip current value of protection device used in single motor circuit excluding circuit for steering gear motors and small motors of rated current value 6A or less is, as possible as, to be not more than value specified in **Table 6.1.10** of the Guidance.

Table 6.1.10 Protection of feeder circuits

Kind of motor (starting method)		Rated current of fuse or moduled-case circuit-breaker
d.c. motor		150
Winding type induction motor		
Single phase, squirrel cage type, and synchronous motor (full voltage, reactor and resistor starting)		300
Squirrel cage type and synchronous motor (single winding transformer starting), special squirrel cage type motor	less than 30 A	250
	30 A or over	200

4. Protection of circuits

(1) In application to **305. 2** (2) of the Rules, “where the Society may exceptionally permit” means the followings.
(A) When it is impracticable, for example engine starting battery circuit
(B) For essential motors which are duplicated and thruster motor, the overload protection may be replaced by an overload alarm
(C) For exceptional permission according to **Pt 5, Ch 7, 207. 5** and **301. 2** (5) of the Rules

307. Testing and inspection

1. Switchboards of same type are those manufactured by same method at the same factory, and are to comply with the following.

(1) External dimension, internal capacity and ventilating method of generator panel having synchronizer panel are to be about the same.
(2) Type and rated values of generator circuit-breaker are to be same, and dimension, and arrangement of busbar and construction of terminal for connection are to be about the same.
(3) Load currents of busbar are to be about the same or less than the current.
(4) The arrangements of attached components in panels adjoined with heat source such as relay, fuse, resistor, etc. are to be about the same, and their total consumption power is to be about the same or less than the power.
(5) Construction and arrangement of terminals excluding maneuvering circuit, circuit for instrument, etc. are to be about the same.

2. Temperature test

In application to **307. 2** of the Rules, where coil is used with Class F insulation or Class H insulation, temperature rising limit of the coil is in accordance with the **Table 6.1.11** of the Guidance.

Table 6.1.11 Temperature Rising Limit of the Coil (°C) (Based on ambient temperature of 45°C)

Kind of insulation \ Test method	Thermometer method	Resistance method
Class F insulation	95	115
Class H insulation	120	140

3. High voltage test

(1) In **307. 4** of the Rules, auxiliary apparatus means connected indicating lamp, small transformer, relay, etc. between different poles or each phase
(2) When high voltage test for distribution boards is carried out according to **307. 4** of the Rules, instrument and auxiliary apparatus are to be removed. But the high voltage test for a unit of each apparatus is to be carried out for a unit of each apparatus and to comply with **307. 4** of the Rules.
(3) Electronic equipment or installations which is assembled within distribution boards, but are not connected directly with essential circuits of distribution boards or main circuits of supply and distribution on board, excluding special cases, do not apply to the Rules.

Section 4 Cables

401. General

1. In application to **401.** of the Rules, the term “consideration” means (KS C) IEC 60092 series, (KS C) IEC 60794, (KS C) IEC 60092-373 or standards considered as equivalent thereto.

2. Specifications including composition, dimension, property of composition material, test items, and for cables other than cables specified in **Par 1** above or **401.** of the Rules are to be submitted are to be approved by the Society.

402. Application of cables

1. In application to **402. 2** (3) of the Rules, "except where specially approved by the Society regarding mechanical damages" means that it is able to use un-armoured cables as long as the following tests are satisfied.

(1) **Tensile testing** is to be either of the followings.
(A) Tensile strength of inner sheath is to be 20 N/mm^2 and above, tensile strength of outer

sheath is to be 13 $\mathrm{N/mm^2}$ and above. Fracture elongation of inner or outer sheath is to be 250 % and above.

(B) Tensile strength of inner & outer sheath is to be 17 $\mathrm{N/mm^2}$ and above. Fracture elongation of inner or outer sheath is to be 400 % and above.

(2) **Impact testing and wear resistant testing**
Testing method and contents are to be approved by the Society.

(3) **Compression testing**
Insulation is not to be destructed by force of 1ton.

2. In application to **402. 3** of the Rules, flame retardant and fire resisting cables are to satisfy the followings;

(1) Flame retardant cable : (KS C) IEC 60332 series
(2) Fire resistant cable : (KS C) IEC 60331 series

403. Current rating of cable

1. Voltage drop In application to **403. 2** of the Rules, calculation of voltage drop is to complying with the following formulae as the standard :

(1) In the case of *d.c.* circuit

$$\text{Voltage drop}(\%) = \frac{R_{20} \times K \times 2L \times I \times 100}{V}$$

(2) In the case of *a.c.* circuit
Single phase *a.c.* circuit

$$\text{Voltage drop}(\%) = \left(\frac{R_{20} \times K \times 2L \times I \times 100}{V}\right) \times \delta(\%)$$

Three phase *a.c.* circuit

$$\text{Voltage drop}(\%) = \left(\frac{R_{20} \times K \times 2L \times I \times 100}{V}\right) \times \frac{1.73}{2} \times \delta(\%)$$

L : Length of cable for single passage (m)
I : Maximum load current (A)
V : Circuit voltage (V)
R_{20}: *d.c.* resistance at 20℃ (Ω/m)
K : Temperature factor at the maximum allowable temperature of conductor
(60℃ : 1.16, 75℃ : 1.22, 80℃ : 1.24, 85℃ : 1.26)
δ : Factor of voltage drop (Refer to **Table 6.1.12** and **Table 6.1.13** of the Guidance)

2. In circuits of electric motors, voltage drop is to be calculated by taking into account the starting current of an electric motor with the largest capacity. Further, in circuits of generators, approximately 115 % of the rated current is to be regarded as the maximum load thereby it is recommended that voltage drop is to be controlled to 1 % or less as far as practicable. Also, voltage drop in circuits of accumulator batteries, shore connection, etc. is to be controlled to 2 % or less as far as practicable.

Table 6.1.12 Factor of A.C. Voltage Drop in Rubber Insulated Cables (δ)

Nominal sectional area of conductor (mm^2)	Power factor (%)							Inductance (mH/km)	
	100	95	90	85	80	75	70	660 V	250 V
325	1.15	1.51	1.61	1.68	1.72	1.74	1.75	0.244	
250	1.10	1.37	1.45	1.49	1.51	1.52	1.52	0.246	
200	1.06	1.26	1.31	1.34	1.34	1.34	1.33	0.248	
150	1.04	1.19	1.22	1.22	1.22	1.21	1.18	0.249	
125	1.03	1.13	1.14	1.14	1.12	1.10	1.07	0.254	
100	1.02	1.10	1.09	1.08	1.06	1.03	1.00	0.254	
80	1.01	1.06	1.05	1.03	1.00	0.99	0.94	0.258	
60	1.01	1.04	1.02	1.00	0.97	0.93	0.90	0.262	
50	1.00	1.02	1.00	0.96	0.93	0.89	0.86	0.268	
38	1.00	1.00	0.98	0.94	0.90	0.87	0.82	0.272	0.217
30	1.00	0.99	0.96	0.92	0.88	0.84	0.80	0.276	0.221
22	1.00	0.98	0.94	0.90	0.86	0.82	0.77	0.280	0.227
14	1.00	0.97	0.93	0.89	0.84	0.80	0.75	0.294	0.239
8	1.00	0.96	0.92	0.87	0.83	0.78	0.73	0.312	0.255
5.5	1.00	0.96	0.91	0.87	0.82	0.77	0.72	0.330	0.265
3.5	1.00	0.96	0.91	0.86	0.81	0.76	0.72	0.354	0.279
2.0	1.00	0.95	0.91	0.86	0.81	0.76	0.71	0.388	0.309
1.25	1.00	0.95	0.90	0.85	0.81	0.76	0.71	0.428	0.343

Table 6.1.13 Factor of A.C. Voltage Drop in Mineral Insulated Cables (δ)

Nominal sectional area of conductor (mm^2)	Power factor (%)							Inductance (mH/km)
	100	95	90	85	80	75	70	
1.0	1.000	0.953	0.904	0.855	0.805	0.756	0.706	0.428
1.5	1.000	0.954	0.905	0.857	0.807	0.758	0.709	0.401
2.5	1.000	0.956	0.908	0.860	0.811	0.763	0.714	0.368
4	1.000	0.959	0.912	0.865	0.817	0.769	0.720	0.344
6	1.000	0.962	0.917	0.871	0.821	0.776	0.728	0.321
10	1.001	0.969	0.927	0.882	0.837	0.791	0.744	0.298
16	1.001	0.980	0.941	0.899	0.856	0.811	0.766	0.279
25	1.002	0.994	0.961	0.923	0.883	0.841	0.799	0.265
35	1.005	1.011	0.983	0.950	0.913	0.874	0.834	0.254
50	1.009	1.034	1.016	0.988	0.956	0.922	0.885	0.245
70	1.016	1.071	1.059	1.040	1.014	0.984	0.952	0.237
95	1.026	1.106	1.110	1.101	1.088	1.060	1.033	0.231
120	1.040	1.150	1.168	1.168	1.157	1.140	1.119	0.226
150	1.046	1.204	1.237	1.248	1.246	1.150	1.221	0.223

404. Installation of cables

1. Precaution against fire protection

(1) In application to **404. 3** (1) of the Rules, "special precautions" means the installation work of cables in the enclosed space or semi-enclosed space in ships meets either of the following requirements. However, the works (B) (iii) below are to be approved by the Society in accordance with the requirements in **Pt 3, Sec 22** of the「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」

(A) One cable is installed independently. Where the distance between those cables is to be of 5 times or more the diameter of the larger cable, the distance between one cable and bunched cables is to be of 5 times or more the diameter of the largest (the minimum value: the width of bunched cables or more), or an adequate fire stop is to be provided between one independently installed cable and others, they may be installed independently.

(B) In a case where bunched cables are installed, the following requirements are to be complied with:

(a) Flame retardant cables in a bunched condition which have passed the test of Category A, (KS C) IEC 60332-3-22(Test on electric cables under fire conditions - Part 3-22 : Test for vertical flame spread of vertically-mounted bunched wires or cable - Category A) in accordance with the requirements in **Pt 3, Sec 21 2108** of the「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」are to be used.

(b) In case where cables other than those specified in (i) above are used, the following means are to be taken (Refer to **Fig 6.1.4** of the Guidance).

(i) Fire stops having at least B-0 penetrations fitted as follows:
- cable entries at the main and emergency switchboard,
- where cables enter engine control rooms,
- cable entries at centralized control panels for propulsion machinery and essential auxiliaries,
- at each end of totally enclosed cable trunks (additional fire stops do not need to be installed inside totally enclosed cable trunks); and

(ii) Cable runs in non-totally-enclosed trunks and open cable runs are to comply with the following:
- to have fire protection coating applied to at least 1m in every 14m and to entire length of vertical runs, or
- to be fitted with fire stops having at least B-0 penetrations every second deck or approximately 6 m for vertical runs and at every 14 m for horizontal runs.

(iii)The cable penetrations are to be installed in steel plates of at least 3 mm thickness(see **Fig 6.1.4** (3)), but need not extend through ceilings, decks, bulkheads or solid sides of trunk. In cargo area, fire stops need only be fitted at the boundaries of the spaces.

(c) In case where the effect of the proposed means for preventing flame propagation are considered to be compatible with or better than that available with those specified in (b) above, such method may be used.

(2) In (1) above, in case where cables are taken additional measures, the additional measures are not to have a bad effect on the cables, and be of heat-resistance materials considered as equivalent to the cables.

(3) In application to **404. 3** (3) of the Rules, the followings are to be complied with.

(A) Electrical services required to be operable under fire conditions are as follows:

(a) Control and power systems to power-operated fire doors and status indication for all fire doors
(b) Control and power systems to power-operated watertight doors and their status indication
(c) Emergency fire pump
(d) Emergency lighting
(e) Fire and general alarms
(f) Fire detection systems
(g) Fire-extinguishing systems and fire-extinguishing media release alarms
(h) Low location lighting
(i) Public address systems
(j) Remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion

(B) In application to **404. 3** (3) of the Rules, the followings are to be complied with.

(a) Cables being of a fire resistant type complying with IEC 60331-31 for cables of greater than 20 mm overall diameter, otherwise 60331-21, are installed and run continuous to keep the fire integrity within the high fire risk area. (see **Fig 6.1.5**)

(b) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

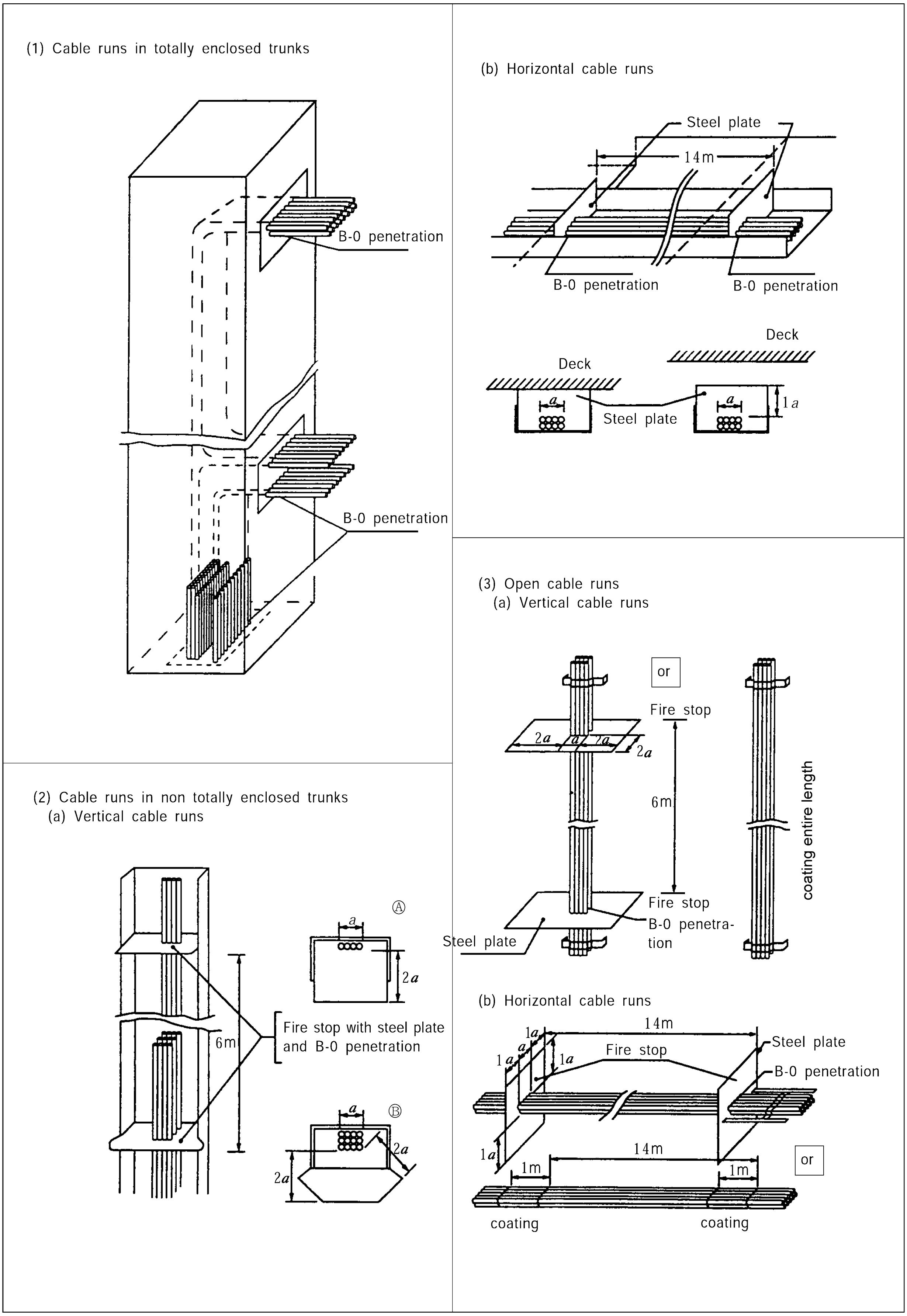


Fig 6.1.4 Flame propagation prevention measures

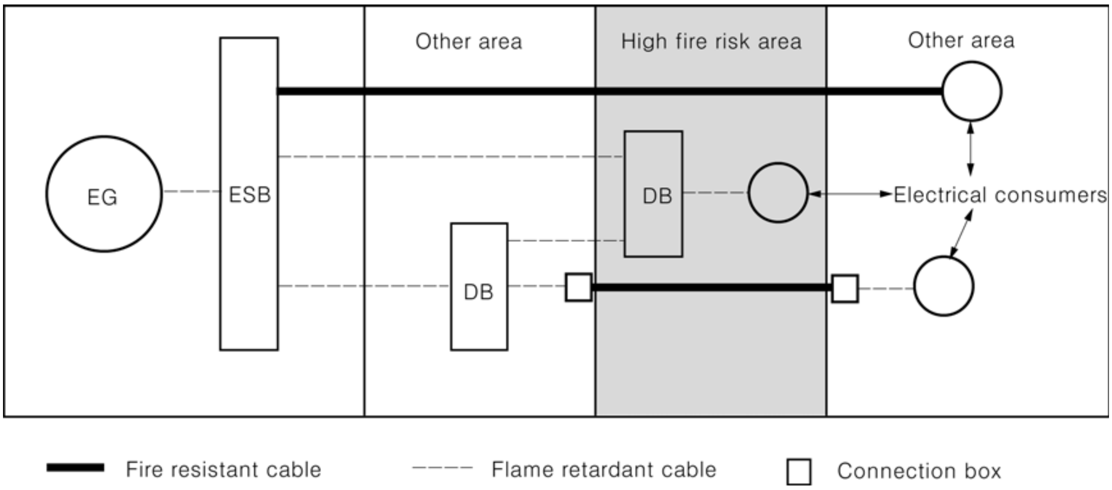


Fig 6.1.5 Example for Application of Fire Resistant Cables

(C) The definition for “high fire risk areas” is the following:
  (a) Machinery spaces as defined by Chap. II-2 / Reg. 3.30 of SOLAS
  (b) Spaces containing fuel treatment equipment and other highly flammable substances
  (c) Galley and Pantries containing cooking appliances
  (d) Laundry containing drying equipment
  (e) Spaces as defined by paragraphs (8), (12), and (14) of Chap. II-2 / Reg. 9.2.2.3.2.2 of SOLAS for ships carrying more than 36 passengers
(D) Fire resistant type cables are to be easily distinguishable.
(E) For special cables, requirements in the following standards may be used:
  (a) Electric data cables : (KS C) IEC 60331-23
  (b) Optical fibre cables : (KS C) IEC 60331-25

(4) The interconnecting cable between a generator and the main switchboard is to be routed clear fuel oil purifier spaces, above the other generator engines and fuel oil purifiers except the cables are;
(A) subdivided into at least two groups separated throughout their length as widely as practicable,
(B) fire resisting cables which have passed the test specified in (KS C) IEC 60331, or
(C) protected by means deemed appropriate by the Society.

2. The wording "a fire in an adjacent space" in **404. 3** (2) of the Rules generally means the fire from which standard time-temperature curves are obtainable in the standard fire test defined in regulation II-2/3.47 of Annex to SOLAS Convention.

3. The wording "high fire risk areas" in **403. 3** (2) of the Rules generally means spaces specified in **Pt 8, Ch 3, 301. 3** (3) ⑨ and **4** (2) ⑨ of the Rules excluding lockers.

4. Cables in refrigerated spaces In application to **404. 7** of the Rules, in case where non-metallic sheaths such as PVC or polychloroprene are used for cables installed in refrigerated spaces, materials which are not affected at the lowest temperature of refrigerated spaces are to be selected and the cables are to be installed in such a manner that they are not subjected to mechanical damage.

5. In case where installation of cables specified in **401. 1** of the Guidance in the space specified in **404. 3** of the Rules is unavoidable, these cables are to be installed in insulated steel pipes or steel ducts equivalent to A-60 or more, or fire resisting cables which have passed the test specified in (KS C) IEC 60331 are to be used.

6. Cables in dangerous spaces

Where cables are installed in dangerous spaces worried over fire or explosion due to electrical accident, the cable are to be protected properly.

(1) Dangerous spaces generally mean the following areas:
(A) Dangerous spaces specified in **Pt 7, Ch 1, Sec 11** of the Rules, Rules for Ships Carrying Liquefied Gases in Bulk (**Pt 7, Ch 5** of the Rules), and Rules for Ships Carrying

Dangerous Chemical in Bulk (**Pt 7, Ch 6** of the Rules).
(B) Cargo holds specified in **Pt 7, Ch 3, Sec 9** of the Rules
(C) Battery rooms, paint store and flammable gas bottle room such as acetylene gas bottle storage room

(2) Protections for cables to be installed in the dangerous spaces specified in (1) above are to comply with the following requirements:
(A) Cables to be installed in dangerous spaces specified in (1) (A) above may be regarded to have the protection by this requirement if the relevant requirements in **Pt 7, Ch 1, Sec 11** of the Rules, Rules for Ships Carrying Liquefied Gases in Bulk (**Pt 7, Ch 5** of the Rules), and Rules for Ships Carrying Dangerous Chemical in Bulk (**Pt 7, Ch 6** of the Rules) are complied with.
(B) Cables to be installed in cargo holds specified in (1) (B) above may be respectively regarded to have the protection by this requirement if the relevant requirements in **Pt 7, Ch 3, Sec 9** of the Rules are complied with.
(C) The protections for cables to be installed in each compartment specified in (1) (C) above are to comply with the following requirements:
(i) Cables are, in principle, to be of the metal armoured ones.
(ii) Protections for preventing mechanical damage to cables are to be provided as necessary.

406. Earthing

1. Earthing of Metallic Coverings

In application to **406. 1** of the Rules, earthing of metallic coverings of cables may comply with the requirements as specified below:

(1) Cable sheaths and armours may be earthen with earthing glands so designed as to allow effective earthing. Glands are to be installed in such a manner that they are securely fixed to the earthen metal structure with good electrical contact.
(2) Conduits may be earthen by being screwed into a metal enclosure, or by nuts on both sides of the wall of a metallic enclosure, provided the surfaces in contact are clean and free from rust, scale or paint and that the enclosure is securely earthen. The connection is to be painted immediately after assembly in order to inhibit corrosion.
(3) Cable sheaths and armour, and conduits may be earthen by means of clamps or clips of corrosion resistant materials making effective contact with sheath or armour and earth metal in lieu of the procedures specified in (1) and (2) above.
(4) All contacts of metal conduits, ducts and metal sheaths of cables used for earth continuity are to be soundly made and, where necessary, to be protected against corrosion.

407. Securing of cables

1. Clips, support and accessories

(1) In application to **407. 3** of the Rules, in case where non-metal cable bands and supports are used, their specification of material, dimension, property and manner is to be submitted to the society for obtaining approval. However, that those used for the interior of switchboards, etc. may be excluded from this requirement.
(2) In application to **407. 3** (4) of the Rules, the wording 'special considerations are to be given in order to prevent the release of the cable means the reinforcement by metal cable bands. Metal cable bands are to be arranged at intervals of 1 to 2 m considering the outside diameter of the cable.

408. Penetration of bulkheads and decks

1. Maintenance of the water-tightness and gas-tightness

In application to **408. 1** of the Rules, in maintenance of the water-tightness and gas-tightness at the cable penetrations, the construction and characteristics of materials of the cables are to be considered.

2. Penetration through fireproof bulkheads and decks

In application to **408. 2** of the Rules, penetration of bulkheads and decks is to be in accordance with the followings:

(1) The cable penetrations through A class bulkheads or decks are to be approved by the Society in accordance with the requirements of **Ch 3** of the「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」

(2) In case where cable glands are used those in the cable penetration through A class bulkheads or decks are to be filled with the non-combustible compound approved by the Society at least to a thickness of 25 mm or more may be accepted notwithstanding the requirements specified above. In this case, except A-0 class divisions, thermal insulation material is to be fitted additionally according to the class of fire protection as in other cases.

(3) The compound used in the cable penetrations through B class bulkheads or decks is to be of the non-combustible compound approved by the Society. In case where the compound is used to fill the sealing box or coaming, the length of the filled part is to be at least 50 mm or more.

(4) The compound approved to be used at the cable penetrations through A class bulkheads or decks under the requirements specified in (1) above may be regarded as the non-combustible compound meeting the requirements in (2) and (3) above.

409. Metallic pipes and conduits

1. In application to **409. 5** of the Rules, "where pipe arrangement is long" means not less than 30 m.

410. Cables for alternating current

1. In application to **410.** (5) of the Rules, distance between cable and steel bulkhead, as far as possible, is to be 50 mm or over.

2. "Large cross section" in **410.** (6) of the Rules means conductor having section area 185 mm^2 or over.

411. Joints and branch circuits

1. In application to **411. 2** of the Rules, "propulsion cable" means the cable of entire length between generators and electric motors for propulsion in electric propulsion ships.

412. Testing and inspection

1. For each product of cables passed type approval test according to **109. 1** (2) of the Rules, and each product of cables approved by **109. 6** of the Rules, material test for cable component may be omitted.

2. PVC sheathed cables to be installed in refrigerated spaces below -10℃ are to pass the cold bending test of cooling temperature which is -5℃ below the lowest temperature of a refrigerated space. A figure in an unit not exceed 5 is considered as 5 and that exceeding 5 is considered as 10 of the test temperature.

3. In case where the cables specified in 2 above are used with polychloroprene rubber sheath, the cables are to pass the cold bending test for PVC sheathed cables. But the test may be omitted in case where the lowest temperature of a refrigerated space is -30°C or over.

4. Cables are to be tested by **Ch 3, Sec 21** of the「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」, and are to be passed.

Section 5 Distribution

501. Methods of distribution

1. Insulation monitoring system

(1) Distribution system is the circuit such as the followings.

(A) First stage distribution circuit connected with circuit of electric generator

(B) Second stage distribution circuit connected by way of insulation transformer from the first stage distribution circuit in (A) above. But, as far as not specifying specially, second stage distribution circuit of specific equipment (for example, Suez canal search light, heater and lighting circuit for specific crane, etc.) is to be excluded.

(C) Lighting circuit using accumulator batteries as electrical source or main busbar of distribution boards connected to the circuit

(2) Alarm setting value of insulation monitoring device is used are 1/10 of insulation value at normal condition of electrical circuit as a standard.

(3) Where insulation monitoring device is used with earth lighting, interlocking device between them is to be provided.

2. Hull return distribution

The wording "special precautions taken to the satisfaction of the Society in **501. 4** (2) of the Rules" is the followings.

(1) All final sub-circuit is to consist of two insulated wires, and the hull return circuit is to be achieved by connecting directly to the hull one of the busbars of the distribution board from which they originate.

(2) Earth wires are to be installed in readily accessible locations to permit their examination and disconnection for testing of insulation.

503. Shore connections

1. Protector of connection box

In application to **503. 2** of the Rules, in case where portable means checking the phase sequence or polarity is provided on-board, means checking the phase sequence or polarity for shore connection may be omitted.

506. Navigation light circuits

1. Installation of navigation light indicator

In application to **506. 5** of the Rules, navigation light indicator is to be placed in both an accessible position on the navigation bridge and an easily accessible position for operating, and alarm is to be provided for power failure of navigation lights and in case that navigation lights are turned out due to short circuit, etc.

508. Feeder circuits for communication and signalling system, other lights

1. Daylight signalling lamp

In application to **508. 3** of the Rules, the power supply of the daylight signalling lamps is to comply with following requirements.

(1) Daylight signalling lamps are not to be solely dependent upon the ship's main or emergency sources of electrical energy.

(2) Daylight signalling lamps are to be provided with a portable battery with a complete weight of not more than 7.5 kg.

(3) The portable battery is to have sufficient capacity to operate the daylight signalling lamp for a period of not less than 2 hours.

(4) The portable battery is to be charged from the ship's main or emergency sources of electrical energy.

Section 6 Transformers for Power and Lighting

601. General

1. Capacity and number of transformer

(1) In application to **601. 2** of the Rules, where 3 sets of single phase transformer are arranged with Δ circuit connection at each first and second stage, and sufficient capacity necessary for

essential services can be supplied in spite of arranging *V* circuit connection due to failure of 1 set among them, a reserved transformer does not need to be installed specially. But, where 3 phase transformer of *Y*-*Δ* circuit connection is used, a reserved 3 phase transformer is to be installed.

(2) Arrangement of transformers are to be as follows. (see **Fig 6.1.6**)

(A) Each transformer is to be located as a separate unit with separate enclosure or equivalent thereto.

(B) Each transformer is to be served by separate circuits on the primary and secondary side.

(C) Each primary circuit is to be provided with switch-gear and protection devices in each phase.

(D) Each of the secondary circuits is to be provided with a multipole isolating switch.

(E) Transformers supplying bow thruster are excluded.

602. Construction

1. Transformer for accommodation

In application to **602. 1** of the Rules, the box and cover of dry type transformer are to be of metal and be of drip-proof type excluding where transformers are installed in switchboard or control panel having enclosure of appropriate construction. And the opening is to be of gab not more than 12 mm or to have grating not entered rounding bar of diameter 12 mm or over, and is to be of construction which a mouth, etc. cannot enter into the opening.

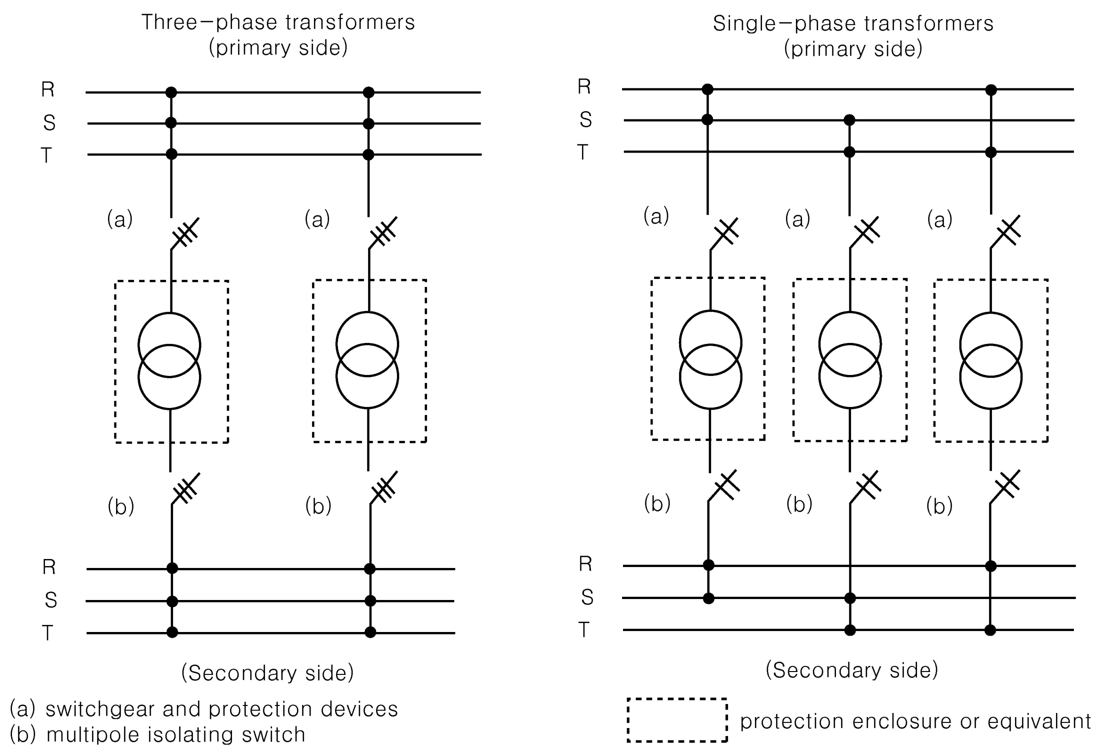


Fig 6.1.6 Arrangement of Transformers

605. Testing and inspection

1. General

In application to **605. 1** of the Rules, "transformer which is produced in series having identical type" is a transformer of identical capacity, voltage, current, major dimensions, cooling method and insulation grade, and manufactured by same manufacturing method at same factory.

2. Voltage variation test

In application to **605. 3** of the Rules, rate of voltage variation by calculation formula in is accordance with the following.

Rate of voltage variation = $q_r + \frac{q_z^2}{200}(\%)$

q_r : Voltage drop by resistance (%)

· In case of single phase : $q_r = \frac{P_{75}}{EI} \times 100$ or $q_r = \frac{P_{115}}{EI} \times 100$

· In case of 3 phase : $q_r = \frac{P_{75}}{\sqrt{3}\,EI} \times 100$ or $q_r = \frac{P_{115}}{\sqrt{3}\,EI} \times 100$

q_x : Voltage drop by reactance $= \frac{E_x}{E} \times 100(\%)$

P_t : Loss against rated capacity at t°C (W)

P_{75} : Loss against rated capacity calculated in terms of 75°C (W)

P_{115} : Loss against rated capacity calculated in terms of 115°C (W)

E_z : impedance voltage (V), i.e. voltage between first stage terminals when P_t is measured.

E_x : Reactance voltage (V)

· In case of single phase : $E_x = \sqrt{E_z^2 - \left(\frac{P_t}{I}\right)^2}$

· In case of 3 phase : $E_x = \sqrt{E_z^2 - \left(\frac{P_t}{\sqrt{3}\,I}\right)^2}$

E : Rated first stage voltage (V)

I : Rated first stage current (A)

And $P75$ in calculation formula above apply to A, E and B grade insulation, P_{115} apply to F and H grade insulation.

Section 7 Control-gears for Motors and Magnetic Brakes

701. Construction

1. Magnetic contactor and over-current relay for electric motor

In application to **701. 5** of the Rules, thermal relays or magnetic over-current relays for electric motor are to comply with the following at environmental temperature of 45℃.

(1) To be operated within 2~30 seconds under the condition of flowing the current of 600 % of the full load.

(2) To be operated within 4 minutes under the condition of flowing the current of 200 % of the current value after passing the current corresponding to the full load of electric motor until saturated temperature.

(3) To be not operated under the condition of flowing the current of 100 % of the full load, and to be operated within 2 hours under the condition of flowing the current of 125 % of the current value after saturated temperature.

703. Emergency stopping apparatus

In application to **703.** of the Rules, emergency stopping apparatus of equipments installed in machinery spaces are to be installed at the outside of machinery spaces.

706. Clearance and creepage distance of control appliances

1. The rated insulating voltage means the voltage having no difficulty in use as standard insulating voltage for design of control-gear, and the rated insulating voltage is the rated voltage or over.

2. Minimum creepage distances in **706.** (2) of the Rules are to be in accordance with **Table 6.1.15** and **Table 6.1.16** of the Guidance according to the grades specified in **Table 6.1.14** of the Guidance.

3. Clearance and creepage distance of control-gear is to be in accordance with the following (refer to **Table 6.1.17** of the Guidance). Grade C in the following means degree of protection and ambient condition specified in **706.** (1) of the Rules.

(1) Clearance is to be decided on the minimum distance between bare live parts, minimum value of Grade C is the value specified in **Table 6.1.16** of the Rules, and minimum value of Grade A and B is the value specified in **Table 6.1.15** and **6.1.16** of the Guidance.

(2) Creepage is to be decided on the minimum distance adjoining the surface of insulating material inserted between bare live parts, minimum value of Grade C is the value specified in **Table 6.1.16** of the Rules, and minimum value of Grade A and B is the value specified in **Table 6.1.15** and **6.1.16** of the Guidance. But the space such as the following existing in the surface of insulating material is to be decided to be no space.

(A) Breadth or depth of space less than 1 mm in Grade B rated insulating voltage 125 V over and Grade C rated insulating voltage 250 V or less

(B) Breadth or depth of space less than 2 mm in Grade C rated insulating voltage 250 V over

(3) In (1) and (2) above, where insulating material is divided by metal between bare live parts, creepage distance of control-gear is to comprise one of the followings.

(A) The maximum value among the divided insulation material is to be decided on, in case of Grade C, the value specified in **Table 6.1.16** of the Rules or more, and in case of Grade A and B, the each value specified in **Table 6.1.15** and **6.1.16** of the Guidance or more.

(B) The sum of two higher values among the divided insulation material is to be, in case of Grade C, the value specified in **Table 6.1.16** of the Rules or more, and in case of Grade A and B, the each value specified in **Table 6.1.15** and **6.1.16** of the Guidance or more. But the divided insulation materials less than 1mm in Grade B rated insulating voltage 125 V over and Grade C rated insulating voltage 250 V or less, and those less than 2 mm in Grade C rated insulating voltage 250 V or less are excluded.

Table 6.1.14 Class for Protection Condition and Environmental Condition

Class	Minimum value	Protection condition	Environmental condition
A	**Table 6.1.15**	Inside of control-gear protected enough to be not affected with environmental condition such as moisture, dust, etc. Example: Inside of dust-protection type relay, plated printing distribution board.	Control gear using at excellent environmental condition which has nothing to worry about pollution Example: Air-conditioning clean room
B	**Table 6.1.16**	Control-gear protected enough to be not affected with environmental condition such as moisture, dust, etc. Example: Small relay for control device, exclusive use socket, not plated printing distribution board.	Control gear using at good environmental condition Example: Clean electrical equipment room

Table 6.1.15 Minimum Clearance and Creepage Distance for Class A Control Appliances

Rated insulating voltage V	Class A			
	Clearance mm		Creepage [(3)(4)] mm	
(*d.c., a.c.*)	$L-L^{(1)}$	$L-A^{(2)}$	*a*	*b*
Not exceeding 12	0.2	0.2	0.2	0.2
Exceeding 12 to 30	0.4	0.4	0.4	0.4
Exceeding 30 to 60	0.5	0.5	0.5	0.5
Exceeding 60 to 125	0.5	0.5	0.5	1
Exceeding 125 to 250	1	1	1	1.5
Exceeding 250 to 380	1.5	1.5	1.5	2
Exceeding 380 to 500	2	2	2	3

Table 6.1.16 Minimum Clearance and Creepage Distance for Class B Control Appliances

Rated insulating voltage V	Class B			
	Clearance mm		Creepage [(3)(4)] mm	
(*d.c.*, *a.c.*)	$L-L$ [(1)]	$L-A$ [(2)]	a	b
Not exceeding 12	0.4	0.4	0.4	0.4
Exceeding 12 to 30	1	1	1	1.5
Exceeding 30 to 60	1	1	1	2
Exceeding 60 to 125	1.5	1.5	1.5	2.5
Exceeding 125 to 250	2	3	2	3
Exceeding 250 to 380	3	3	3	4
Exceeding 380 to 500	4	4	4	6

(NOTES)
(1) "$L-L$" applies to clearance between bare live parts, and between live part and earthen metal part.
(2) "$L-A$" applies to clearance between live part and metal part which accidently becomes dangerous.
(3) Creepage distance is to be determined by type and shape of insulation. a applies to ceramic insulator (steatite and porcelain), and comparable other insulator which is particularly safe against leaked electricity provided with ribbed construction or vertical partitions proved to be equally effective as ceramic insulator through experiments having a tracking index greater than 140 e.g., phenol resins formed items. "b" applies to other insulation materials.
(4) In case where "$L-A$" is greater than the corresponding creepage "a" or "b", the creepage distance between bare live parts and insulated metals which operator may readily touch and which becomes live parts by the deterioration of insulation are to be "$L-A$" or more.
(5) Current value is to be expressed by the rated current-carrying value.

Table 6.1.17 Selection of Clearance and Creepage Distance

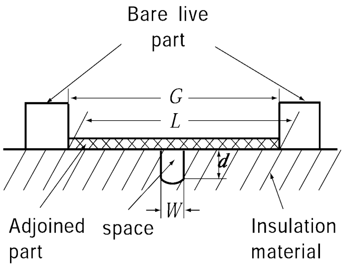
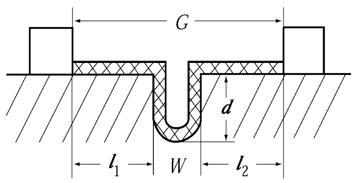
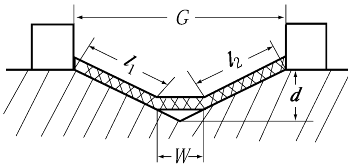
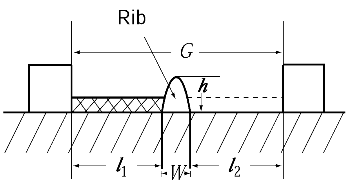
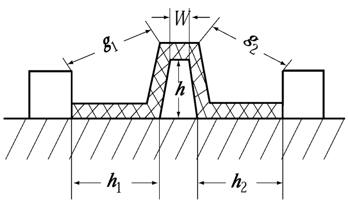
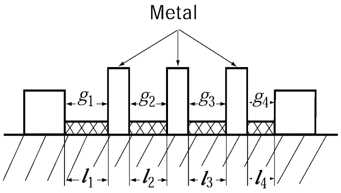
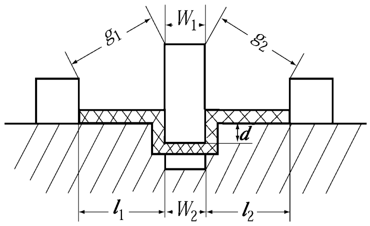
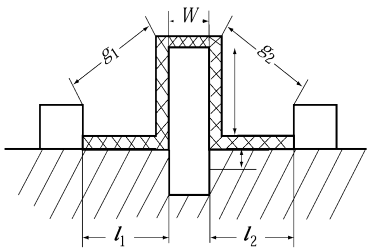
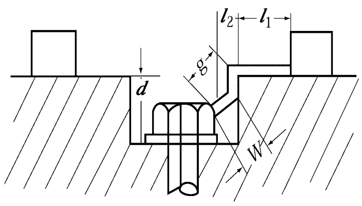
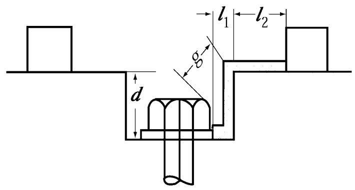
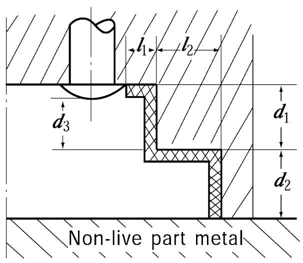
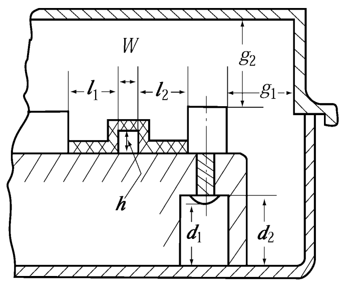
No.	Figure	Condition	Clearance (G)	Creepage (L)
1		For W or d<1mm Class B: Exeeding 125V Class C: 250V or under For W or d<2mm Class C: Exeeding 250V	G	L
2		For W or $d \geq$ 1mm Class B: Exeeding 125V Class C: 250V or under For W or $d \geq$ 2mm Class C: Exeeding 250V	G	$L = l_1+l_2+W+2d$
3		For W=1mm or $d \geq$ 1mm Class B: Exeeding 125V Class C: 250 V or under For W=2mm or $d \geq$ 2mm Class C: Exeeding 250V	G	$L = l_1+l_2+W$
4		For h<1mm Class B: Exeeding 125V Class C: 250V or under For h<2mm Class C: Exeeding 250V	G	$L = l_1+l_2+W$
5		For $h \geq$ 1mm Class B: Exeeding 125V Class C: 250V or under For $h \geq$ 2mm Class C: Exeeding 250V	$G=g_1+g_2+W$	$L=l_1+l_2+W+2h$
6		In case where metal exists between live parts Example: $g_1>g_2>g_3>g_4$ $l_1>l_2>l_3>l_4$ For g_2 and $l_2 \geq$ 1mm Class B: Exeeding 125V Class C: 250V or under For g_2 and l_2 $\geq$ 2mm Class C: Exeeding 250V	$g_1 \geq$ requirement value or $g_1 + g_2 \geq$ requirement value × 1.25	$l_1 \geq$ requirement value or $l_1 + l_2 \geq$ requirement value × 1.25

Table 6.1.17 Selection of Clearance and Creepage Distance (Continued)

No.	Figure	Condition	Clearance (G)	Creepage (L)
7		Where the depth of space of insulation material is deeper than inserting part.	$G = g_1+g_2+W_1$	$L = l_1+l_2+W_2+2d$
8		Where the insulation material and rib are so inserted as to be seen one body.	$G=g_1+g_2+W$	$L=l_1+l_2+W+2h$
9		For W=1mm or l_2<1mm Class B: Exeeding 125V Class C: 250V or under For W=2mm or $l_2 \geq$ 2mm Class C: Exeeding 250V	$G = g+l_1$	$L = l_1+d$
10		For $l_2 \geq$ 1mm Class B: Exeeding 125V Class C: 250V or under For $l_2 \geq$ 2mm Class C: Exeeding 250V	$G = g+l_1$	$L = l_1+l_2+d$
11		For $l_2 \geq$ 1mm Class B: Exeeding 125V Class C: 250V or under For $l_2 \geq$ 2mm Class C: Exeeding 250V	$G = d_2+d_3$	$L = l_1+l_2+d_1+d_2$
12		In case where there is in receptacle of metal	$G_1 = l_1+l_2+W$ (between bare live parts) $G_2 = g_1(g_1 < g_2 < d_1)$ (between ground)	$L_1 = l_1+l_2+W+2h$ (between bare live parts) $L_2 = d_2$ (between ground)

(4) In (1) and (2) above, where rib exists in the surface of insulating material inserted between bare live parts, the creepage and clearance are to be decided on the values excluded the height such as the followings.
  (A) Height of rib less than 1 mm in Grade B rated insulating voltage 125 V over and Grade C rated insulating voltage 250 V or less
  (B) Hight of rib less than 2 mm in Grade C rated insulating voltage 250 V over
(5) In (1) and (2) above, where the other rib inserted in insulating material between bare live parts, and the inserted distance is less than the depth of space of insulation material, creepage is to be decided on minimum distance along the line of the inserted rib.
(6) In (5) above, where the rib of material able to see as same insulating material is inserted, creepage and clearance are to be decided on minimum distance along the line of surface of the rib.
(7) Creepage to earth and clearance to earth are to be decided on minimum distance according to (1) and (2) above.
(8) The insulation distance of those having insulating metal which becomes bare live part by deterioration is to be decided according to (3) above.

707. Testing and inspection

1. General

In application to **707. 1** of the Rules, “control-gear which is produced in series having identical type” is a control-gear manufactured by same manufacturing method at same factory and complying with the followings.

(1) External dimension of panel, box, etc., internal capacity and ventilating method are to be about the same.
(2) Type and rated values of circuit-breaker, magnetic contactor of main circuit are same, and dimension and arrangement of main circuit conductor and construction of terminal for connection are to be about the same.
(3) Load currents of main circuit are to be about the same or less than the current.
(4) The arrangement of attached components in panel adjoined with heat source such as relay, fuse, resistor, etc. are to be about the same, and their total consumption power is to be about the same or less than the power.

2. High voltage test

In **707. 4** of the Rules, the high voltage test is to be in accordance with **307. 4** of the Rules.

Section 8 Fuses, Circuit-breakers and Electromagnetic Contactors

801. General

1. Korean Industrial Standards or equivalent are the followings. And where products made by manufacturer other than Korean flag, the standard established by the nation may apply according to the discretion of the Society. However, the standards are to be updated. And where these standards are not standard for ship's store, the products are to be considered with ship's environmental condition (to comply with **Pt 6, Ch 1, Sec 1** of the Rules).

(1) Fuse
  (KS C) IEC 60269 Low-voltage fuses
(2) Circuit breaker
  (KS C) IEC 60947-2 Low-voltage switchgear and controlgear - Part 2: Circuit-breakers
(3) Electromagnetic contactor
  (KS C) IEC 60947-4-1 Low-voltage switchgear & controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters

Section 9 Explosion-protected Electrical Equipment

901. General

1. Material

"Material which minimizes the risk of spark by friction" in **901. 3** (2) of the Rules means material which does not occur explosion owing to spark caused by friction or impact between metals. That means material identified anti-ignition tested by using the drop tester specified in KS E 3903 (Non-ignition Testing Methods for Non-sparking Beryllium Copper Alloy Tools).

2. Construction

Pressurized protected and intrinsically safe electrical equipment are to be indicated the followings in addition to requirements specified in **901. 4** (5) of the Rules.

(1) Pressurized protected electrical equipment
Ventilating type and sealing type are to be indicated the followings.
(A) Internal capacity of equipment
(B) Required wind pressure and wind capacity at the protection gas inlet of equipment
(C) Required wind pressure at the protection gas outlet of equipment (ventilating type only)
(D) Permissible maximum wind pressure of container

(2) Intrinsically safe electrical equipment
(A) The followings are to be indicated. But for detector, etc. the requirements (a) through (c) may be omitted.
(a) Rated value of intrinsically safe circuit
(b) Rated value of non-intrinsically safe circuit
(c) Useful condition
(B) Where a non-intrinsically safe circuit in incorporated equipment is not explosion- protected type, the followings are to be indicated in addition to (A) above.
(a) Caution for prohibition from installing in dangerous spaces
(b) Caution for prohibition from alteration, modification for component of equipment, wiring, etc.
(C) A intrinsically safe circuit in incorporated equipment is to be indicated clearly with the purport at terminals. Wiring diagram of equipment is to be attached and seen inside cover of equipment.

902. Special requirements

The wording “as deemed appropriate by the Society” in 902. of the Rules means the followings.

1. Flameproof type electrical equipment

(1) Where flameproof lighting fittings are fitted with bulkheads penetrated through, they are to be so installed as not to impair the integrity of the bulkheads.
(2) In case where a drain discharging devices is provided to the enclosure of flameproof construction, it is to be so constructed as not to impair the flameproof characteristics even with the device in the open position.
(3) In case where a waterproof packing is provided to the flameproof construction, it is to be so constructed as not to impair the flameproof joints, such as length of flame path and gaps etc., caused by the water intrusion.
(4) In case where a cable is connected to a terminal box by the cable pipe connecting method, sealing fittings are to be provided near the terminal box.

2. Intrinsically safe type electrical equipment

(1) Intrinsically safe electrical equipment is to be installed independently against general electrical equipment. Where the combined installation with general equipment is necessary, earthed metallic partitions are to be provided between these equipment.
(2) The wires for intrinsically safe circuits are to be measured to discriminate easily against those for other circuits. And the wires are also to be separated 50mm or more from those for other circuits and to be shielded electrically, if necessary.
(3) Connection terminal for intrinsically safe circuit and non-intrinsically safe circuit under the combined installation are to comply with either of the followings.

(A) Connection terminals for the both circuits are to be installed in individually circuit boards separated from 50mm each other.
(B) Earthed metallic partitions having efficient mechanical strength and insulation are to be provided between the connection terminals for the both circuits.

(4) Even if an electrical fault for general circuit other than intrinsically safe circuits is happened, the function of a safety barrier is to be kept operating.
(5) Safety barriers are to be located in non-hazardous areas.
(6) Safety barriers are to be structured by at least two same components unless one component specified below is used. In case where one of the components is broken, an explosion protecting performance is to be maintained.

(A) Power Transformers
The insulation between first and second field windings is to be ensured by earthed partitions made by copper. And each field winding is to have an efficient insulation performance.
(B) Current Limitation Resistors
The surface of the resistors is to be covered by a synthetic resin or the resistors are to be embedded in a formed resin.
(C) Blocking Condensers
The condenser is to be structured by two solid dielectric type capacitors connected with each other in series which have high reliability. Electrolytic capacitors including tantalum type are not to be used.

3. Increased safety type electrical equipment

(1) Enclosures of increased safety lighting fittings are to be of a robust construction made of non-hygroscopic flame-retardant or incombustible material, and also they are to be of watertight construction or equivalent thereto.
(2) In case where an increased safety type motor or transformer is used, the efficient protection for overload and overheat is to be provided. Especially for a squirrel cage induction motor, the additional protection is to be provided not so as to use it over an allowable restraint time and abnormal temperature rise is not to be occurred under the restraint condition of the rotor.
(3) In case where there is a limitation for use in order to maintain an explosion protecting performance, the approval for use by the Society is to be necessary.

4. Pressurized protected type electrical equipment

(1) When air is used as the pressurized medium, the air inlet is to be located in a safe space.
(2) Where air or inert gas is used as the pressurized medium, an interlock device is to be provided to ensure a displacement of air within the apparatus of at least 10 times the free volume of its enclosure and thus to obtain the required pressure before it can be energized.
(3) Pressurized protected electrical equipment is to be automatically disconnected from the source of electrical power in the event of the loss of pressure within its enclosure. However, if this arrangement increases the hazard to the ship, it may be permitted for loss of pressure to operate an alarm device only.

5. Powder filling type electrical equipment

(1) The enclosure is to be at least IP54 or higher. If it is IP55 or higher grade, a breathing device is to be provided.
(2) A powder material filled in the enclosure is to be quartz or solid glass particles and have an efficient insulation performance.
(3) The total stored energy of all capacitors in an enclosure is not to exceed 20J in normal operation.
(4) In case where there is a limitation for use in order to maintain an explosion protecting performance, the approval for use by the Society is to be necessary.

6. Oil immersion type electrical equipment

(1) The oil level indicating device is to be provided so that the liquid level can easily checked in service.
(2) Live parts of the electrical equipment are to be immersed to a depth of not less than 25mm below the surface of protective liquid.
(3) Where connecting cables are dipped into protective liquid, they are to be of oil resistant type.
(4) In case where there is a limitation for use in order to maintain an explosion protecting perform-

ance, the approval for use by the Society is to be necessary.

7. Encapsulation type electrical equipment

(1) Where some protection components are installed in order to limit a temperature rise, the setting value is not to be changed.
(2) In case where there is a limitation for use in order to maintain an explosion protecting performance, the approval for use by the Society is to be necessary.

8. Non-sparking type electrical equipment

(1) Non-sparking type electrical equipment applied to electrical equipment such that, in normal operation and in certain specified regular expected occurrences, it is not capable of igniting a surrounding explosive gas atmosphere.
(2) It shall not produce an operational arc or spark unless that arc or spark is prevented from causing ignition of a surrounding explosive gas atmosphere separately.
(3) Degree of protection is to be more than either of the followings
 (A) IP 54 where there are bare live parts, or IP 44 where there are insulated live parts
 (B) IP 4X where there are bare live parts, or IP 2X where there are insulated live parts where the equipment is intended for installation only in locations providing adequate protection against the entry of solid foreign objects or water capable of impairing safety.

Section 10 Lighting Fittings, Heating Appliances and Wiring Accessories

1001. General

Lighting fitting, heating appliances, etc., as a rule, are to comply with Korean Industrial Standard or equivalent thereto.

1002. Lighting fittings

1. Construction and location

In application to **1002. 1** (3) of the Rules, a guard for globes made by materials other than glass materials may be omitted according to the discretion of the Society.

2. In application to **1002. 2** (4) and **3** of the Rules, the following requirements shall be complied with. However type approval may be omitted subject to the Society's permission, in this case, they are to comply with KS or equivalent thereto.

(1) Application standard
 (A) (KS C) IEC 60092-306 (electrical installations in ships, equipment, luminaries and accessories)
 (B) KS C8100 (electronic ballast stabilizer for fluorescent lighting)
 (C) KS standard or equivalent thereto for safety and function requirements of LED lighting in ships.
 (D) In application to the above (A) and (B), in case that there are different contents about the same requirements, (KS C) IEC 60092-306 shall be complied with.
 (E) Other equivalent KS or IEC standard
(2) Test
 Test is to be carried out in accordance with **Table 3.23.1** of **Ch 3, Sec 23** of **Guidance for Approval of Manufacturing Process and Type Approval, etc** and (KS X) IEC 60945 (maritime navigation and radiocommunication equipment and systems - general requirements - methods of testing and required test results) are to be complied with. However, test may be partly exempted when the Society considers necessary.

1003. Heating appliances

1. Protection guard for heating elements is to be fixed firmly and to be prevented from touching the live parts, and an opening parts of protection guard are to be minimized for preventing standard test finger from touching the heating elements.

2. Live parts of cooking heater are to be prevented cooking appliances from touching cooking appliances.

3. Where the heating element is employed in liquid, it is to be protected by anti-corrosive metal sheath.

4. In case of heating appliance used for a bath, heating elements are to be arranged to avoid electrical shock in bath, and operating switches are to be of multi pole connection type and to be provided with indicating lamp and name plate.

5. Portable cooking heaters are to be of construction not falling over sideways.

Section 11 Internal Communications

1102. Essential internal communication systems

1. Essential internal communication and signal systems are to be inclusive of the followings.

(1) Navigation lights, signalling lamps and signal alarms required in International Convention
(2) Internal communications
  (A) Communications between the following
    (a) Between navigation bridge and main engine control station
    (b) Between navigation bridge and steering gear room
    (c) Engineer's alarm
    (d) Available communications between navigation bridge, centralized control room, engine control station and engineer's accommodation at failure of main power.
(3) Internal signal alarms
  (A) General emergency alarm
  (B) Fire alarm
  (C) CO_2 release alarm
(4) Steering gear control system and rudder angle indicator
(5) Navigation equipment required in International Convention as deemed necessary by the Society
(6) Other internal communications, signal alarms and navigation equipment

1105. General emergency alarm system

Where circuit breakers for overcurrent protection are provided for feeder circuits of general emergency alarm system, the notice of "To be always kept 'ON'" is to be posted. It is, however, not necessary to post the notice if protected by fuses.

1106. Public address system

1. A public address system is not be required in the spaces such as under deck passage way, bosun's locker, hospital and pump room.

2. Where an individual loudspeaker has a device for local silencing, an override arrangement from the control stations, including the navigating bridge, shall be in place

3. In application to **1106. 6** (1) of the Rules, the sound pressure levels for cabin and state rooms shall be attained as required, during sea trials.

4. In application to **1106. 7** of the Rules, the method to minimize the effect of a single failure is as follows :

(1) The use of segregated cable routes to public rooms, alleyways, stairways and control stations
(2) The use of multiple amplifiers
(3) The use of more than one device for generating electronic sound signals
(4) The use of electrical protection for individual loudspeakers against short circuits.

Section 12 Semi-Conductor Rectifiers for Power

1205. Testing and inspection

1. Temperature test

In application to **1205. 2** of the Rules, the appropriateness for requirements in **1203. 2** of the Rules may be identified by temperature measuring of cooling pin, case, refrigerant, etc. But, where the temperature rising limit for cooling pin, case, refrigerant, etc. is in the limit, it is presumed the temperature of joining parts as the designated case not exceeded the allowable maximum temperature.

2. Operation test

In application to **1205. 3** of the Rules, operation test for protection devices means interlocking test between cooling fan and switch, and destructive test such as protection fuse test for rectifier elements may be omitted.

Section 13 Accumulator Batteries

1301. Applicable Standards

1. Accumulator batteries are to comply with Korean Industrial Standards.

2. In case where accumulator batteries are made by foreign manufacturer, the accumulator batteries are to comply with the standards recognized by the nation and to comply with ship's stores.

3. Accumulator batteries of an adequate discharge rate are to be selected according to their application.

4. In case where alkali batteries are used, the specification including the construction, performance, method of installation, etc. is to be submitted at each time to the Society for obtaining approval.

5. In application to **1301. 2** of the Rules, a valve-regulated sealed battery is the one in which the cells are closed but have an arrangement(valve) that allows the emission of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced. Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the following ventilation requirements are complied with.

(1) The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 percent of that given in **1306. 1**.
(2) Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.
(3) Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas emission in excess of the manufacturer's design quantity.
(4) Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected when the battery compartment ventilation system fail.

1303. Location

1. In application to **1304. 4** of the Rules, the term "large batteries" means the accumulator batteries connected to battery charging facilities with an output of 2 kW or more. The output of battery charging facilities is to be the product of the rated current of the rectifier and nominal voltage of battery group.

2. Accumulator batteries connected to battery charging facilities with a capacity in a range from 0.5 kW to 2 kW are to be placed in a battery box installed within a battery compartment or on the upper deck or upward.

3. Accumulator batteries connected to battery charging facilities with a capacity in a range 0.5 kW or less may be installed as followings:

(1) To be placed in a storage box or locker installed at an adequate area.

(2) To be placed in an open state within the machinery space.
(3) To be placed in a compartment with good air ventilation.

1304. Electrical installation in battery compartment

In application to **1304. 1** of the Rules, the explosion-protected electrical equipment may be things used in explosible mixture gas or equivalent.

1306. Ventilation

1. The capacity of exhaust ventilation of a battery compartment is to be of the value obtained by the following formula or more:

$Q = 110 \times I \times n$ (l/h)

Q : Exhaust capacity

I : Maximum charging current at end (where no specific limitation is specified, the charging current in 10 hours is to be regarded as the standard)

n : Number of batteries

2. It is recommended that the ventilation system for a compartment containing accumulator batteries connected to battery charging facilities with an output of 2 kW or more is to be of the mechanical exhaust-ventilation.

Section 14 Emergency Electrical Equipment

1401. Application

1. In application to **1401. 4** of the Rules, "exceptionally" whilst the vessel is at sea, means the following:

(1) Blackout situation
(2) Dead-ship situation
(3) Routine use for testing
(4) Short-term parallel operation with the main source of electrical power for the purpose of load transfer

2. The emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements as per items (1) and (2) below are complied with.

(1) Requirements
(A) To prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation.
(B) The prime mover is to be arranged with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as required for the prime mover for main power generation and for unattended operation.
(C) The fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required by SOLAS.
(D) The prime mover is to be designed and built for continuous operation and should be subjected to a planned maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea.
(E) Fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed.
(F) Means are to be provided to readily change over to emergency operation.
(G) Control, monitoring and supply circuits, for the purpose of the use of the emergency generator in port are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services. When necessary for the safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits.

(2) Instructions are to be provided on board to ensure that when the vessel is under way all control

devices(e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard. These instructions are also to contain information on required fuel oil tank level, position of harbour/sea mode switch if fitted, ventilation openings, etc.

1402. Capacity of emergency source of power

1. The power supply period for the navigation lights (masthead lights, side lights and stern lights) specified in **1402. 2** (3) of the Rules, may be reduces to 3 hours under the acceptance of the domestic regulations of flag state of the ship.

2. In application to **1402. 2** (5) (A) of the Rules, "Internal communication equipment" means the following:

(1) Engine telegraph
(2) Communication equipment between the navigation bridge and the main engine control stations other than main control station
(3) Engineers´ alarm
(4) Communication other than general telephone between the navigation bridge and the steering gear compartment
(5) Other internal communication equipment as deemed necessary by the Society
(A) In case of passenger ships, the following requirements are to be complied with.
(a) The means of communication which is provided between the officer of the watch and the person responsible for closing any watertight door which is not capable of being closed from a central control station.
(b) The public address system or other effective means of communication which is provided throughout the accommodation, public and service spaces.
(c) The means of communication which is provided between the navigating bridge and the main fire control station.

3. In application to **1402. 2** (5) (B) of the Rules, in case where domestic regulations of flag of the ship accept, the capacity of emergency source of power may be in accordance with the following:

(1) Ships having gross tonnage 5000 tons or more may be reduced to the service period of rudder angle indicator specified in **Pt 5, Ch 7, 206.** (2) of the Rules.
(2) Ships having gross tonnage less than 5000 tons are to be in accordance with the followings:
(A) It is not required to supply emergency source the following navigation equipment.
(a) Gyro-compass
(b) Echo-sounding device
(c) Device to indicate speed and distance through the water
(d) Rudder angle indicator, revolution meter of each propeller, propellers and the pitch and operational mode of controllable pitch propellers
(B) Service period for navigation radar may be reduced to the period by domestic regulations of flag of the ship (until 3 hours in case of having Korean flag ship).

4. In case where domestic rules of flag of ship are accepted, the service period of the load in **1402. 2** (5) (d) and fire alarm system in **1402. 2** (5) (c) of the Rules may be reduced until 30 minutes.

1403. Kind and performance of emergency source of electrical power

1. In application to **1403.** (2) (A) of the Rules, where the inverter or converter is connected to the output circuit of the batteries (consumer side), the maximum permitted voltage fluctuations may be taken as those specified in **Table 6.1.1** (a) or (b) in **106.** of the Rules respectively, notwithstanding the voltage drop on the battery.

2. The requirements of uninterruptible power system(UPS) units

In application to **1403.** (3) of the Rules, the requirements which the Society considers appropriate are to be as follows;

(1) Application
These requirements are to apply to interruptible power system (hereinafter referred to as “UPS”) units installed in ships as an emergency source of electrical power.
(2) Definitions

(A) UPS means a source of electrical power with converters, switches and batteries, constituting for maintaining continuity of load power in case of input power failure.
(B) Off-line UPS unit means an electrical power where under normal operation the output load is powered from the bypass line and only transferred to the inverter if the bypass supply fails or goes outside preset limits.
(C) Line interactive UPS unit means a system specified in (B) above where the bypass line switch to stored energy power when the input power goes outside the preset voltage and frequency limits.
(D) On-line UPS unit means a system where under normal operation the output load is powered from the inverter, and will therefore continue to operate without break in the event of the supply input failing or going outside preset limits.

(3) Design and Construction
(A) UPS units are to be constructed in accordance with (KS C) IEC 62040 or an acceptable and relevant national or international standard.
(B) The operation of the UPS units is not to depend on external services.
(C) The type of UPS unit (off-line, line-interactive, on-line) is to be appropriate to the power supply requirements of the connected load equipment.
(D) UPS units are to have an external bypass circuit.
(E) UPS units are to have a self-monitoring function, and audible and visual alarms are to be activated in the space where crews normally attend in the following cases.
(a) Power supply failure (abnormal voltage or frequency)
(b) Earth fault
(c) Operation of battery protective device
(d) Discharge of battery
(e) Operation of bypass circuit for on-line UPS units

(4) Arrangement
(A) UPS units are to be suitably located for use in an emergency condition.
(B) UPS units utilizing valve regulated sealed batteries may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of (KS C) IEC 62040 or an acceptable and relevant national or international standard.

(5) Performance
(A) The output power is to be maintained for the duration time required for the connected equipment as specified in 1402 of the Rules.
(B) No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity. The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in the regulations.
(C) On restoration of the input power, the rating of the charge unit shall be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

(6) Testing and inspection
(A) UPS units of 50 kVA and over are to be tested by this Society at the manufacturer's works or at other works.
(B) Appropriate test is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:
(a) Functionality, including operation of alarms
(b) Temperature rise
(c) Ventilation rate
(d) Battery capacity
(C) In case where input power failure of UPS is happened, if the continuous power supply is necessary without power interruption, this operation condition is to be verified after installation by practical test.

3. Starting from dead ship condition

In application to **1403.** (4) of the Rules, the followings are to be complied with.

(1) The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition. Emergency generator stored starting energy is not to be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries(emergency generator excluded).

(2) For steam ships, the 30 minute time limit can be interpreted as time from blackout/dead ship condition defined above to light-off of the first boiler.

1404. Transitional source of emergency electrical power

In application to **1404.** (1) of the Rules, where the inverter or converter is connected to the output circuit of the batteries(consumer side), the requirements specified in **1403. 1** may be applied.

1406. Starting arrangements for emergency generating sets

1. The starting devices specified in **1406. 2** of the Rules are to be comply with the following requirements:

(1) The source of stored energy is to be capable of starting the prime mover at least six times.
(2) In case where the automatic starting system is of the consecutive starts, the number of starts is to be three or less.
(3) For the automatic starting system, means are to be provided to hold such an allowance of source of energy capable of starting the prime mover three times further after making the initial consecutive starts.

Section 16 High Voltage Electrical Installations

1601. General

1. The supply voltages and frequency specified in the followings are recognized as a standard.

System nominal voltage (kV)	Commercial frequency (Hz)
3(3.3)	50 or 60
6(6.6)	50 or 60
10(11)	50 or 60
15	50 or 60

1602. System design

1. Standards applied to high voltage equipment

The following equipment is to comply with the relevant IEC Pub. or equivalent and above.

(A) Circuit breakers : IEC 62271-100
(B) Switches : (KS C) IEC 60265
(C) Fuses : (KS C) IEC 60282
(D) Contactors : IEC 60470
(E) Current transformers for instruments : (KS C) IEC 60044
(F) Voltage transformers for instruments : (KS C) IEC 60044
(G) Relays : (KS C) IEC 60255
(H) Rotating machinery : (KS C) IEC 60529 and 60034-5

1605. Cables

1. Application

In application to **1605** of the Rules, (KS C) IEC 60183 may apply.

1606. Switchgear and controlgear assemblies

1. In application to **1606. 4**, the high voltage test procedure is to be in accordance with the IEC 62271-200, or equivalent and above, data proving that the assembly will withstand an internal arc is to be submitted to the Society for information service.(e.g. testing in accordance with Appendix A of IEC 62271-200)

1607. Installation

In application to **1607. 1** (3) of the Rules, “safe and effective measures” means the followings.
(1) Pressure-release flaps are to be installed.
(2) Ducts of sufficient cross-section are to be provided.
(3) Combustible materials and electrical equipments are not admissible in the area of coming out gases.

Section 19 Spare Parts, Tools and Instruments

1901. Spare parts

1. For the electric or electro-hydraulic steering gears equipped with two or more steering gear motors or motor generators, the spare armature or stator specified in **1901. 1** (4) of the Rules may be omitted.

2. The requirements in **1901. 1** (4) of the Rules do not apply to electric motors for steering control systems. ⚓

CHAPTER 2 CONTROL SYSTEMS

Section 2 System and Control

201. System design

1. In application to **201. 7** (1) of the Rules, examples of computer-based systems are shown in the **Table 6.2.1**. Where independent effective backup or other means of averting danger is provided, the system category Ⅲ may be downgraded to category Ⅱ.

Table 6.2.1 Example of computer based system

Category	Examples
Ⅰ	- Maintenance support systems - Information and diagnostic systems
Ⅱ	- Alarm and monitoring equipment - Tank capacity measuring equipment - Control systems for auxiliary machinery - Main propulsion remote control systems - Fire detection systems - Fire extinguishing systems - Bilge systems - Governor control systems - Other systems considered necessary by the Society
Ⅲ	- Machinery protection systems/equipment - Burner control systems - Electronic fuel injection for diesel engines - Control systems for propulsion and steering - Synchronising units for switchboards - Other systems considered necessary by the Society

202. Automatic and remote control of main engines or controllable pitch propellers

1. Application

In case where the local control handle fitted to main propulsion machinery is moved to the main control station, the requirements in **202.** of the Rules may not apply except the following case:

(1) when the main control station is provided outside the space where main propulsion machinery is installed.

(2) When the main control station is provided inside the space where main propulsion machinery is installed, and environmental enclosure.

2. Remote control devices for main engines or controllable pitch propellers

(1) At the remote control station for the main propulsion machinery, alarm devices which come into action on the following cases is to be provided.

(A) Lubricating oil low pressure

(B) Cooling fresh water low pressure (or high temperature, cooling water pump stop, etc.)

(C) Low pressure of hydraulic oil or air for remote control system, or failure of electrical source

(D) Starting of emergency stopping devices.

(2) For the remote control station for propulsion motors, alarm devices activating on the following cases are to be provided in addition to those specified in (1) above:

(A) Insulation resistance drop of supply circuits

(B) An abnormal stopping of cooling fan for semi-conductor electric power converter

(C) Pressure drop of cooling water for semi-conductor electric power converter (temperature rising or stopping of cooling water pump)

(D) Starting of semi-conductor safety devices for semi-conductor electric power converter

(3) Visual alarm specified in (1) and (2) above is to be capable of identifying kind of abnormal conditions and the related equipment. However, in case of ships remote-controlled in bridge and the other space, visual alarm installed in bridge does not apply this requirement. And visual alarms discriminated easily by the other gauges and meters in engine room do not apply this requirement.

(4) For the remote control system of main propulsion steam turbine, means for automatic opening of astern intermediate valves at the operation into astern maneuvering are to be provided.

(5) In case where control devices specified in above (2) are installed, the local control equipment for the main engine can be omitted. However, in case where control equipment is installed in main control station, it is recommended that the emergency local control equipment for main propulsion machinery be installed.

(6) Countermeasure for the event of failure of the source (electric power, pneumatic pressure and hydraulic pressure) for remote control system due to the failure of main engine remote control system is to be provided.

(7) Main engine starting by remote control system for main propulsion machinery and starting air low pressure alarm are in accordance with the followings:

(A) In case where the low pressure alarm activate after satisfying the number of starting specified in **Pt 5, Ch 6, 1101. 1** of the Rules, startings after this are be controlled at the main control station.

(B) In case where the low pressure alarm activate before satisfying the number of starting specified in **Pt 5, Ch 6 1101. 1** of the Rules, the next startings is to be capable at the remote control station and the number of starting is to be satisfied in the requirements.

3. Bridge Control Devices

(1) It is recommended that the operating handle (or button) of the bridge control devices is linked with the engine room telegraph.

(2) In application to **202. 3** (3) of the Rules, where override may result in total failure of the engine and/or propulsion equipment within a short time is as followings.

(A) All diesel engines
(a) Overspeed
(b) Failure of lubricating oil system
(c) Crankcase explosive condition

(B) All steam turbine
(a) Failure of lubricating oil system
(b) Overspeed
(c) Back-pressure for auxiliary turbines

(C) All boiler
(a) Failure of flame
(b) Failure of flame scanner
(c) Low water level
(d) Failure of forced draft pressure
(e) Failure of control power

(D) All reduction gears
Shutdown prime movers upon failure of reduction gear lubricating oil system

(E) Generators
For generators fitted with forced lubrication system only: shutdown prime movers upon failure of generator lubricating oil system

4. Safety Measures

For the remote control devices for the main propulsion machinery, inter-locking devices are to be provided so as not to allow main propulsion machinery to start on the following conditions:

(1) When the turning gear is engaged.
(2) When the lubricating oil pressure is low.

Section 3 Tests

301. Shop tests

1. Type approval

(1) In application to **301. 1** of the Rules, "automatic equipment" to be type-approved are , in principle, as follows:
(A) Alarm and monitoring systems
(B) Control systems for, main engine, generators, boilers and essential auxiliary machinery, etc.
(C) Computer-based systems
(D) Fire detection systems
(E) Gas detection systems
(F) Electronic governor systems
(G) Speed and shaft horsepower sensing equipment
(H) Controller
(I) Flow, level, limit, pressure, temperature switches
(J) Oil mist detectors
(K) UPS
(L) Electrical and electronic indicators
(M) Electric power converters for electric propulsion unit
(N) Optical sensors and optical application device applied to the above (A) ~ (M)
(O) Those considered necessary by the Society

(2) "Test methods approved by the Society" specified in **301. 1** of the Rules means the requirements specified in **Ch 3, Sec 23** of the「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」

2. Shop tests of automation system

In application to **301. 2** (1) (C) of the Rules, test products including the circuits (electronic products or PCB card, etc), for which applying test voltage is undesirable, are allowed to be tested after isolating the relevant circuits. However, in case that the relevant circuits' construction is difficult to be isolated, insulation resistance test and high voltage test may be exempted by admitting the record of type approval test. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 6 Electrical Equipment and Control Systems

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Rules for the Classification of Steel Ships

Part 7 Ships of Special Service

Rules

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APPLICATION OF PART 7 "SHIPS OF SPECIAL SERVICE"

1. Unless expressly specified otherwise, the requirements in these Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date : 1 July 2011

CHAPTER 3 BULK CARRIERS

Section 16 Electrical Equipment of Coal Carriers

- 1602. has been newly added.
- 1603. 2 (2) has been deleted.

CHAPTER 4 CONTAINER SHIPS

Section 8 Welding

- 801. and 802. have been newly added.

CONTENTS

CHAPTER 1 OIL TANKERS

Section 1 General

101. Application

1. The requirements in this Chapter apply to oil tankers which were contracted for construction after 1 April 2006, excluding the vessels which should be applied **Pt 12** (Common Structural Rules for Double Hull Oil Tankers) and **Pt 7, Ch 10** (Double Hull Tanker). However, **Sec 10** (Piping Systems and Venting Systems for Oil Tankers) and **Sec 11** (Electrical Equipment) apply to oil tankers including the vessels which should be applied **Pt 12** (Common Structural Rules for Double Hull Oil Tankers) and **Pt 7, Ch 10** (Double Hull Tanker).

2. The construction and equipment of ships intended to be registered and classed as tanker are to be in accordance with the requirements in this Chapter, where a tanker means a ship intended to carry crude oil, petroleum products having a vapour pressure (absolute pressure) less than 0.28 MPa at 37.8℃ or other similar liquid cargoes in bulk.

3. Except where specifically required in this Chapter, the general requirements for steel ships are to be applied.

4. The requirements in this Chapter are framed for tankers with machinery aft, having one or more rows of longitudinal bulkheads, single decks, single bottoms and longitudinal framing.

5. In tankers intended to carry liquid cargoes other than crude oil and petroleum products, having a vapour pressure (absolute pressure) less than 0.28 MPa at 37.8 ℃ and having no hazard as poisonous, corrosive, etc. and moreover less inflammability than that of crude oil and petroleum products, the structural arrangements and scantlings are to be to the satisfaction of the Society, having regard to the properties of the cargoes to be carried.

102. Arrangement of bulkheads

In cargo oil tanks, longitudinal and transverse oiltight bulkheads and wash bulkheads are to be arranged suitably.

103. Cofferdams

1. Cofferdams of airtight construction and having sufficient width as required for ready access are to be provided at the forward and after ends of cargo oil spaces and between cargo oil spaces and accommodation spaces. In tankers intended to carry oils having a flash point exceeding 60℃, however, the preceding requirements may be modified.

2. The cofferdams described in the preceding Paragraph may be used as pump rooms.

3. Ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

4. Fuel oil or ballast water tanks may be concurrently used as the cofferdams to be provided between cargo oil tanks and fuel oil or ballast water tanks, subject to the approval by the Society.

5. Location and separation of spaces in tankers of 500 tons gross and above carrying oils having a flash point not exceeding 60℃ are to be in accordance with the requirements in **Pt 8, Ch 2, 104.**

104. Airtight bulkheads

Airtight bulkheads are to be provided for the isolation of all cargo oil pumps and pipings from spaces containing stoves, boilers, propelling machinery, electric installations other than those of explosion-proof type specified in **Pt 6, Ch 1, Sec 9** or machinery space where source of ignition is normally present. In tankers carrying oils having a flash point exceeding 60℃, however, the preceding requirements may be modified.

105. Ventilation

1. Efficient ventilation is to be provided in spaces adjacent to cargo oil tanks. Air holes are to be cut in every part of the structure where there might be a chance of gases being pocketed.

2. Efficient means are to be provided for clearing oil tanks and pump rooms of dangerous vapours by means of mechanical ventilation or by steam.

3. In tankers carrying oils having a flash point exceeding 60℃ the capacity of ventilation in the pump rooms specified in **1004.** may be modified.

4. The requirements in **1004.** are applied to the ventilation fans and wire mesh screens for the spaces adjacent to the cargo oil tank specified in **Par 1**.

106. Openings for ventilation

Ventilation inlets and outlets are to be arranged so as to minimize the possibilities of vapours of cargoes being admitted to an enclosed space containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. Especially, openings of ventilation for machinery spaces are to be situated as far afterwards apart from the cargo spaces as practicable.

107. Openings of superstructure and deckhouse

The arrangement of openings on the boundaries of superstructure and deckhouse are to be such as to minimize the possibility of accumulation of vapours of cargoes. Due consideration in this regard is to be given when the ship is equipped to load or unload at the stern. Side scuttles to the poop front or other similar walls are to be of fixed type. Such openings of tankers of 500 tons gross and above carrying oils having a flash point not exceeding 60℃ are to be in accordance with the requirements in **Pt 8, Ch 2, 104.2.**

108. Thickness of structural members in cargo oil spaces

The thickness of structural members in cargo oil spaces is to be in accordance with the following:

(1) The thickness of shell plating is not to be less than that obtained from the formulae in **Pt 3, Ch 4, 302., 304., 305.** and **404.** using 2.0 in lieu of 1.5 in the formulae.

(2) The thickness of deck plating of freeboard deck is not to be less than that obtained from the formulae in **Pt 3, Ch 5, 301**. using 2.0 in lieu of 1.5 in the formulae.

(3) Where frames, beams, stiffeners and other members for which the scantlings are specified by the section modulus only consist of flanged plates, special sections or web and face plates, the thickness of web plates is not to be less than that obtained from the following formula. Where the depth of web plates, however, is specially made deeper due to the reason from other than strength, the preceding requirements may be modified.

$$t = 0.015 k_0 d_0 + 2.5 \quad \text{(mm)}$$

where:

d_0 = depth of web plates (mm)

k_0 = as given in the following formulae. However, value of f_B and f_D is not to be less than 1.0.

Longitudinals located not more than 0.25D above top of keel : $k_0 = \sqrt{\frac{1}{4}\left(3f_B + \frac{1}{K}\right)}$

Longitudinals located not less than 0.25D below deck : $k_0 = \sqrt{\frac{1}{4}\left(3f_D + \frac{1}{K}\right)}$

Other members : $k_0 = \sqrt{\frac{1}{4}\left(3 + \frac{1}{K}\right)}$

(4) Various girders, longitudinal, transverse, vertical or horizontal, the cross ties and end connecting brackets thereof and various bulkhead platings are not to be of less thickness than determined from **Table 7.1.1** according to the length of ship.

Table 7.1.1 Minimum Thickness

Length of ship (m)	Thickness (mm)
$L < 105$	8.0
$105 \le L < 120$	8.5
$120 \le L < 135$	9.0
$135 \le L < 150$	9.5
$150 \le L < 165$	10.0
$165 \le L < 180$	10.5
$180 \le L < 195$	11.0
$195 \le L < 225$	11.5
$225 \le L < 275$	12.0
$275 \le L < 325$	12.5
$325 \le L < 375$	13.0
$375 \le L$	13.5

(5) The thickness of flat bar and tripping bracket, etc. fitted up on web of longitudinal girders, transverses and girders of bulkheads is not to be less than that obtained from the following formula. The thickness need not, however, exceed that of web plates to which they are connected.

$$t = 0.5\sqrt{L} + 2.5 \quad (\text{mm})$$

(6) In no case is the thickness of structural members to be less than 7 mm.

109. Direct strength calculation

Where approved by the Society, the scantlings of structural members may be determined basing upon direct strength calculation defined in **Pt 3, Ch 1, 206.**

Section 2 Hatchways, Gangways and Freeing Arrangements

201. Ships having unusually large freeboard

Relaxation from the requirements specified hereunder will be considered to ships having an extra-ordinarily large freeboard.

202. Hatchways to cargo oil tanks

1. The thickness of coaming plates is not to be less than 10 mm. Where the length and coaming height of a hatchway exceed 1.25 m and 760 mm respectively, vertical stiffeners are to be provided to the side or end coamings and the upper edge of coamings is to be suitably stiffened.

2. Hatchway covers are to be of steel or other approved materials. The construction of steel hatchway covers is to comply with the following requirements. The construction of hatchway covers of materials other than steel is to be in accordance with the discretion of the Society.

(1) The thickness of cover plates is not to be less than 12 mm. In ships not more than 60 m in length, however, the requirement may be modified.
(2) Where the area of a hatchway exceeds 1 m^2 but does not exceed 2.5 m^2, cover plates are to be stiffened by flat bars of 100 mm in depth spaced not more than 610 mm apart. Where, however, the cover plates are 15 mm or more in thickness, the stiffeners may be dispensed with.
(3) Where the area of a hatchway exceeds 2.5 m^2, cover plates are to be stiffened by flat bars of 125 mm in depth spaced not more than 610 mm apart.
(4) Covers are to be secured oiltight by fastenings spaced not more than 457 mm apart in circular hatchways or 380 mm apart and not more than 230 mm far from the corners in rectangular hatchways.

3. In small ships, the requirements in the preceding Paragraph may be suitably modified.

4. The cover is to be provided with an opening at least 150 mm in diameter which is to be so constructed as to be capable of being closed oiltight by means of a screw plug or a cover of peep hole.

5. Hatchway coamings are to be provided with gas cocks or other suitable exhausting devices.

203. Hatchways to spaces other than for cargo oil tanks

In exposed positions on the freeboard and forecastle decks or on the tops of expansion trunks, hatchways serving spaces other than cargo oil tanks are to be provided with steel watertight covers having scantlings complying with the requirements in **Pt 4, Ch 2, Sec 2.**

204. Permanent gangway and passage

1. A fore and aft permanent gangway complying with the requirements of **Pt 4, Ch 4, 503.** is to be provided at the level of the superstructure deck between the midship bridge or deck house and the poop or aft deck house, or equivalent means of access is to be provided to carry out the purpose of the gangway, such as passage below deck. Elsewhere and in ships without midship bridge or deck house, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

2. Safe and satisfactory access from the gangway level is to be available between crew accommodations and machinery space or between separated crew accommodations.

205. Freeing arrangements

1. Ships with bulwarks are to have open rails fitted for at least a half of the length of the exposed part of the freeboard deck or other effective freeing arrangements. The upper edge of sheer strake is to be kept as low as practicable.

2. Where superstructures are connected by trunks, open rails are to be provided for the whole length of the exposed parts of the freeboard deck.

Section 3 Longitudinal Frames and Beams in Cargo Oil Spaces

301. General

Longitudinal frames and beams provided in permanent ballast water tanks and cargo oil spaces including void spaces and pump rooms are to be in accordance with the requirements stated hereunder.

302. Scantlings

1. The section modulus of bottom longitudinals and side longitudinals including bilge frames is not to be less than that obtained from the formulae given in **Table 7.1.2.**

Table 7.1.2 Section modulus of bottom and side longitudinals

Position	Section modulus (cm^3)	
	Bottom longitudinals	Side longitudinals including bilge frames
Midship part and between a point $0.15L$ from the fore end and the collision bulkhead	$Z = 110 C_1 C_2 KShl^2$	$Z = 110 C_1 C_2 KShl^2$ $Z_{min} = 3.2K\sqrt{L}Sl^2$
Forward and afterward end parts	$Z = 93.5 C_1 C_2 KShl^2$	$Z = 93.5 C_1 C_2 KShl^2$ $Z_{min} = 2.72K\sqrt{L}Sl^2$

l = spacing of bottom transverses (m).
S = spacing of longitudinals (m).
h = distance from the bottom longitudinal under consideration to the point h' above the top of keel given in the following table (m).
C_1, h', C_2 = as given by the following table.

	C_1	h' (m)	C_2
Bottom longitudinals	$\frac{1}{24 - 15.0 f_B K}$	$h' = d + 0.026L'$	1.0 : Where L is 230 m and under. 1.07 : Where L exceeds 400 m. For the intermediate values of L, C_2 is to be obtained by linear interpolati
Side longitudinals including bilge frames	$\frac{1}{24 - \alpha K}$	$h' = d + 0.038L'$	

L' = length of ship (m). Where, however, L exceeds 230 m. L' is to be taken as 230 m.
α = either α_1 or α_2 according to value of y. However, value of α is not to be less than β.

$$\alpha_1 = 15.0 f_D \left(\frac{y - y_B}{Y'} \right) \quad \text{for} \quad y \geq y_B$$

$$\alpha_2 = 15.0 f_B \left(\frac{y_B - y}{y_B} \right) \quad \text{for} \quad y < y_B$$

β = coefficient determined according to values of L as specified below :
$\beta = 6/a$ when L is 230 m and under
$\beta = 10.5/a$ when L is 400 m and above
For intermediate values of L, β is to be obtained by linear interpolation.
y = vertical distance (m) from the top of keel to the lower edge of plating when the platings under consideration are under y_B and to the upper edge of plating when the platings under consideration are above y_B, respectively.
Y' = the greater of the value specified in **Pt 3, Ch 3, 203.,** (5) (a) or (b).
a = $\sqrt{K}$, when high tensile steels are used for not less than 80 % of side shell plating at the transverse section amidship and 1.0 for other parts.

2. The section modulus of longitudinal beams is not to be less than 1.1 times that obtained from the formula in **Pt 3, Ch 10, 303.**

3. Notwithstanding the provisions in **Pars 1** and **2,** the section modulus of longitudinal frames and beams is not to be less than that obtained assuming them as stiffeners on deep tank bulkhead and taking the distance up to the top of hatchway as h.

4. Longitudinal beams and side longitudinals attached to sheer strake are to be of such dimensions as to have slenderness ratio not exceeding 60 at the midship part as far as practicable. This requirement, however, may be suitably modified for small vessels.

5. As for flat bars used for longitudinal beams and frames, the ratio of depth to thickness is not to exceed 15.

6. The extreme width of face plates of longitudinal beams and frames is not to be less than that obtained from the following formula:

$$b = 2.2\sqrt{d_0 l} \quad (\text{mm})$$

where:

d_0 = depth of web of longitudinal beams or frames (mm).

l = spacing of transverses (m).

303. Attachment

Longitudinal frames and beams are to be continuous or to be attached at their ends in such a manner as to effectively develop the sectional area and the resistance to bending.

Section 4 Girders, Transverses and Cross Ties in Cargo Oil Spaces

401. General

1. The requirements specified hereunder are intended to be applied to structures consisting of two to five transverses arranged at approximately equal intervals between transverse bulkheads or between the transverse bulkhead and the wash bulkhead.

2. Girders or transverses in the same plane are to be so arranged that abrupt change in the strength and rigidity is avoided; they are to have brackets of sufficient scantling and with properly rounded corners at their ends.

3. The depth of girders or transverses is not to be less than 2.5 times that of slots for frames, beams and stiffeners.

4. As for the face plates composing girders, the thickness is not to be less than that of web plates and the width of the face plates is not to be less than that obtained from the following formula:

$$b = 2.7\sqrt{d_0 l} \quad (\text{mm})$$

where:

d_0 = depth of girder (mm). In case where it is a balanced girder, d_0 is the depth from the surface of plate to the face plate (mm).

l = distance between supports of girder (m). Where, however, effective tripping brackets are provided, they may be taken as supports.

5. The requirements of **401.** to **406.** are also to be applied to pump rooms, ballast water tanks or void spaces in the midship part so far as practicable.

402. Transverses and girders provided in centre or side tanks in ships having two or more longitudinal bulkheads

1. Bottom transverses and bottom girders:

(1) The depth, web thickness and section modulus of bottom transverses and the web thickness and section modulus of bottom girders provided in the middle between longitudinal bulkheads are not to be less than those obtained from the given in **Table 7.1.3** respectively.

(2) Where one or two intercostal side girders are provided between longitudinal bulkhead and bottom girders provided at mid-distance of longitudinal bulkheads, and the bottom transverses are

of the reduced scantlings in accordance with (3) below, the sectional area of web plates and moment of inertia of side girders are not to be less than those obtained from the following formulae:

Sectional area of web plates : $A = \alpha_1 \dfrac{L_0}{B_0} d_0 t_0 \quad (\mathrm{cm}^2)$

Moment of inertia : $I = \alpha_2 \left(\dfrac{L_0}{B_0}\right)^3 I_0 \quad (\mathrm{cm}^4)$

where:

α_1, α_2 = coefficients given in **Table 7.1.4.**

I_0 = moment of inertia of bottom transverses (cm^4).

L_0, B_0, d_0, t_0 = as specified in **Table 7.1.3.**

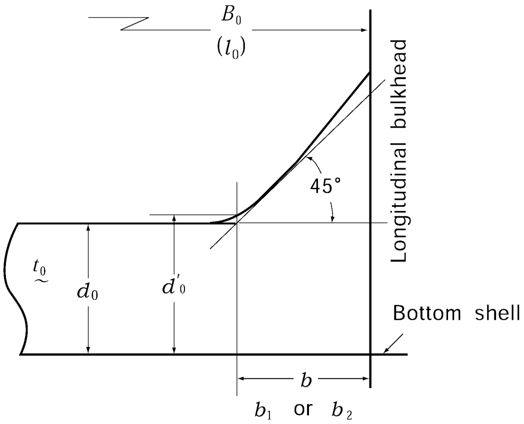


Fig 7.1.1 Measurement of b, d_0, d'_0 etc.

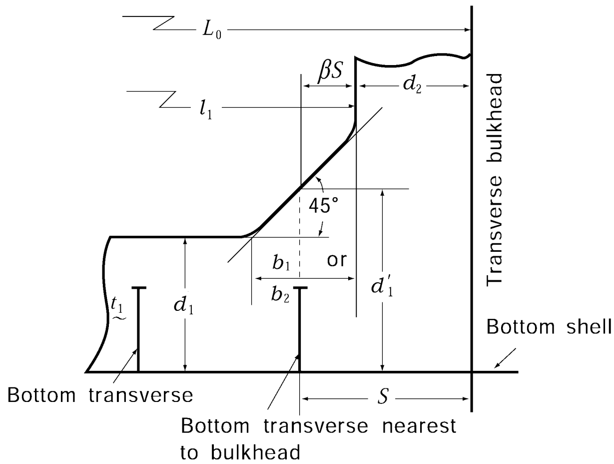


Fig 7.1.2 Measurement of d_1, d'_1, d_2, S etc.

Table.7.1.4 Coefficients α_1 and α_2

Number of side girders	Coefficient	
	α_1	α_2
1	0.0085	0.67
2	0.0045	0.42

(3) Where intercostal side girders are provided in accordance with (2), the bottom transverses and girders may be of the scantlings obtained from the formulae in (1), using coefficients C_0, C_1, C_2, C_3 and C_4 reduced by 10 % where two transverses are provided and 5 % where three transverses are provided.

(4) In ships without longitudinal centre line bulk heads, a centre girder with brackets at proper intervals is to be provided so as to maintain sufficient strength where the ship is drydocked on keel blocks.

Table 7.1.3 Scantlings of bottom transverses and bottom girders

	Depth (mm)	Web thickness (mm)	Section modulus (cm^3)
Bottom transverses	$d = C_0 l_0$	Thickness at the inner edge of bracket attached to longitudinal bulkhead $t = \left(C_1 - 87\frac{b}{l_0}\right)\frac{KQ}{d_0' - a} + 2.5$	$Z = C_2 K k^2 Q l_0$
Bottom girders	-	$t = C_3 \frac{\eta KQ}{d_1} + 2.5$	$Z = C_4 K k Q l_1$

Q = $\alpha S h_1 l_0$
α = 1.0 where L is 230 m and under
1.2 where L exceeds 400 m.
For the intermediate values of L, a is to be obtained by linear interpolation.
h_1 = as given by the following formula:
$d + 0.026L'$ (m).
L' = length of ship (m). Where, however, L exceeds 230 m, L is to be taken as 230 m.
S = spacing of transverses (m), (see **Fig 7.1.2**)
l_0 = overall length of transverses (m). Which is equal to B_0 or $(B_0 - d_3)$ where d_3 depth of vertical web attached to the centre line bulkhead (m).
b = length of horizontal arm of bracket connecting transverse to longitudinal bulkhead (m). (see **Fig 7.1.1**)
d_0' = depth of transverse at the inner edge of the above mentioned bracket (mm). (see **Fig 7.1.1**)
a = depth of slot (mm). Where, however, the slots near the inner edge of brackets are provided with collar plates, a may be taken as zero.
d_1' = depth of girder including bracket at the transverse nearest to the bulkhead (mm). (see **Fig 7.1.2**)
l_1 = overall length of girder, which is equal to $(L_0 - d_2)$(m), where d_2 is depth of vertical web on transverse bulkhead (m). (see **Fig 7.12**)
k = correction factor due to bracket given by the following formula:

$$k = 1 - \frac{0.65(b_1 + b_2)}{l}$$

b_1, b_2 = arm length of brackets at both ends of girders and transverses respectively (m).
l = overall length of girders and transverses (m), which is equal to l_0 or l_1.
η = as given by the following table.

Number of transverses	$\beta = \frac{S - d_2}{S}$	η
Two rows	$0 \leq \beta < \frac{2}{3}$ (See **Fig 7.1.2**)	$\eta = 2 - 1.5\beta$
	$\frac{2}{3} \leq \beta$	$\eta = 1.0$
Three to five rows	$0 \leq \beta < 0.5$	$\eta = 1.6 - 1.2\beta$
	$0.5 \leq \beta$	$\eta = 1.0$

d_0, t_0 = depth (mm) and web thickness (mm) of transverses respectively.
d_1, t_1 = depth (mm) and web thickness (mm) of girders respectively.
B_0 = distance between longitudinal bulkheads (m).
L_0 = distance between transverse bulkheads (m).
C_0, C_1, C_2, C_3, C_4 = as obtained from the following table according to K_0 respectively.

Table 7.1.3 Scantlings of bottom transverses and bottom girders (continued)

Number of transverses	Coef-ficient	$K_0 = \frac{d_0 t_0}{d_1 t_1} \times \frac{L_0}{B_0}$									
		$K_0 \leq 0.2$	$0.2 < K_0 \leq 0.3$	$0.3 < K_0 \leq 0.4$	$0.4 < K_0 \leq 0.5$	$0.5 < K_0 \leq 0.6$	$0.6 < K_0 \leq 0.7$	$0.7 < K_0 \leq 0.8$	$0.8 < K_0 \leq 1.0$	$1.0 < K_0 \leq 1.2$	Where no girder is provided
Two rows	C_0	0.090	0.095	0.100	0.105	0.115	0.115	0.120	0.125	0.135	0.160
	C_1	23.6	24.3	25.5	26.7	27.8	29.0	30.1	31.8	34.0	43.7
	C_2	1.44	1.47	1.54	1.63	1.77	1.94	2.12	2.43	2.87	5.69
	C_3	36.8	34.5	32.3	30.5	28.5	26.6	24.8	22.2	18.8	-
	C_4	8.08	7.65	7.04	6.51	6.25	5.73	5.21	4.09	4.17	-
Three rows	C_0	0.090	0.095	0.100	0.105	0.110	0.115	0.120	0.125	0.135	0.160
	C_1	24.0	25.5	26.7	27.8	29.4	30.5	31.7	33.6	36.3	43.7
	C_2	1.47	1.54	1.63	1.79	1.96	2.19	2.43	2.84	3.41	5.69
	C_3	57.2	54.0	50.9	47.5	44.6	42.3	39.9	36.0	31.3	-
	C_4	10.42	9.65	8.97	8.34	7.67	7.06	6.51	5.73	4.69	-
Four rows	C_0	0.090	0.095	0.100	0.105	0.110	0.115	0.120	0.125	0.135	0.160
	C_1	24.4	25.9	27.1	28.6	30.0	31.3	32.7	34.8	37.5	43.7
	C_2	1.47	1.54	1.70	1.87	2.03	2.28	2.52	3.01	3.73	5.69
	C_3	76.0	68.1	64.2	60.3	56.4	52.5	48.5	43.5	36.8	-
	C_4	10.69	9.65	88.6	8.08	7.34	6.80	5.99	5.27	4.17	-
Five rows	C_0	0.095	0.100	0.105	0.110	0.115	0.120	0.125	0.135	0.145	0.160
	C_1	24.7	26.3	27.4	29.4	30.9	32.5	34.0	36.7	40.2	43.7
	C_2	1.54	1.63	1.79	2.03	2.28	2.52	2.83	3.50	4.46	5.69
	C_3	94.0	83.8	78.3	72.8	67.5	62.6	57.2	49.5	39.2	-
	C_4	15.64	13.56	12.50	11.46	10.16	9.12	8.08	6.78	4.69	-

NOTES :
1. Where strong vertical girders are provided on transverse bulkheads at one side only in case of four or five transverses, coefficient C_4 is to be increased appropriately.
2. Where the depth of centre line bottom girder is of extremely large depth, coefficient, coefficient C_4 may be suitably modified.

2. Deck transverses and girders

(1) The depth and section modulus of deck transverses are not to be less than those obtained from the following formulae:

Depth of transverses : $d = C_0 l_0$ (m)

Section modulus of transverses : $Z = CKk^2\sqrt{L}Sl_0^2$ (cm^3)

where:

C_0, C = coefficients given in **Table 7.1.5** respectively.

d_0, t_0 = depth (mm) and web thickness (mm) of transverses respectively.

d_1, t_1 = depth (mm) and web thickness (mm) of girders respectively.

L_0, B_0, S, k = as specified in **Table 7.1.3.**

l_0 = overall length of transverses (m), which is equal to B_0 or $(B_0 - d_3)$, where d_3 is depth of vertical web on centre line bulkhead (m).

Table 7.1.5 Coefficients C_0 and C

Number of transverses	$K_0 = \frac{d_0 t_0}{d_1 t_1} \times \frac{L_0}{B_0}$	C_0	C
Two and three	$K_0 \leq 0.5$	0.07	0.79
	$K_0 \geq 1.5$	0.10	1.82
Four	$K_0 \leq 0.4$	0.07	0.79
	$K_0 \geq 1.4$	0.10	1.82
Five	$K_0 \leq 0.3$	0.07	0.79
	$K_0 \geq 1.3$	0.10	1.82
NOTE: For intermediate values of K_0, C_0 and C are to be obtained by linear interpolation.			

(2) Deck girders provided at the mid-distance of longitudinal bulkheads may be of scantlings determined in relation to those of deck transverse specified in (1). Where deck girders from a ring system together with strong vertical webs on transverse bulkheads as specified in **505.,** the depth of girders is not to be less than that obtained from the following formula.

$$d = \frac{L_0 D}{9B_0} \quad (\mathrm{m})$$

where:

B_0, L_0 = as specified in **Table 7.1.3.**

3. Transverses provided on longitudinal centre line bulkheads are not to be of less scantling than determined in accordance with **403. 2**(2) for transverses on longitudinal bulkheads in wing tanks.

403. Transverses and girders provided in wing tanks in ships having two or more longitudinal bulkheads

1. Side transverses

(1) Symbols used in this Paragraph are defined as follows:

$$Q = \alpha S h l_0$$

α = 1.0 where L is 230 m and under,
1.2 where L exceeds 400 m
For intermediate values of L, α is to be obtained by linear interpolation.

h = distance from the mid-point of l_0 to the point H_2 above the top of keel (m).

h_s = distance from the mid-point of b_s to the point H_2 above the top of keel (m).

$$H_2 = d + 0.038L' \quad (\mathrm{m})$$

L' = length of ship (m). Where L' exceeds 230 m, L' is to be taken as 230 m.

l_0 = overall length of side transverses (m), which is equal to the distance between the inner surfaces of face plates of bottom transverses and deck transverses. (See **Fig 7.1.3**)

S = spacing of transverses (m).

S' = spacing of stiffeners provided depthwise on the web plates of transverses at the portion where cross ties are connected (m).

k = as specified in **Table 7.1.3.**

b = length of arm of the lowest bracket (m). (See **Fig 7.1.3**)

b_s = width of the area supported by cross ties (m). (See **Fig 7.1.3**)

d_0' = depth of side transverses at the inner edge of the lowest bracket (mm). (See **Fig 7.1.3**)

a = depth of slot in the vicinity of inner edge of the lowest bracket. Where, however, the slots are provided with collar plates, a may be taken as zero.

A = section area effective to support the axial force from cross tie (cm^2), which is to be taken as follows:

(a) Where the face plates of cross ties are continuous to the face plates of transverses in an arc form or a similar form, A is the total sum of the sectional area of the web plate of transverse at the portion between the contact points of the tangents to the arc or the similar curve making an angle of 45° to the direction of cross tie, that of the stiffener provided in the axial direction of cross tie on the web plate between the contact points, and 0.50 times that of the face plates at the contact points. (See **Fig 7.1.4** (a))

(b) Where the face plates of cross ties are continuous to the face plates of transverses in the form of straight line with rounded corners, A is the total sum of the sectional area of the web plate of transverse at the portion between the midpoints of the intersections of the extensions of the lines of inner surface of face plates of both cross tie and transverse with the lines making an angle of 45° to the direction of cross tie in contact with the inner surface of face plates at the transforming parts, that of the stiffener provided in the axial direction of cross tie on the web plate between the above mentioned mid-points and 0.50 times that of the face plates at the mid-points. (See **Fig 7.1.4** (b))

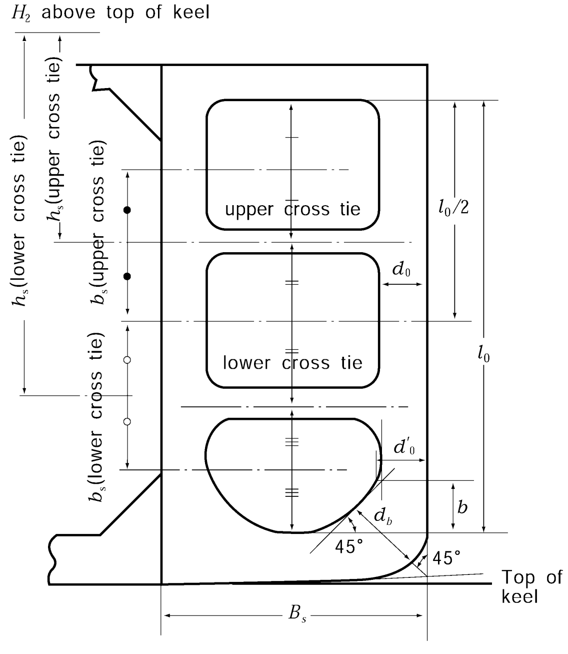


Fig 7.1.3 Measurement of l_0, d'_0, b, b_s, etc.

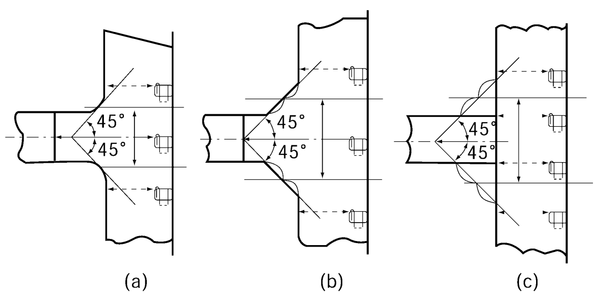


Fig 7.1.4 Extent for total sectional area

(c) Where the face plates of cross ties are joined directly to the face plates of transverses with a right or nearly right angle and both face plates are connected with brackets and further, stiffeners are provided on the web plate of transverses on the extended lines of face plates of cross tie, A is the total sum of the sectional area of the web plate of transverse at the portion between the mid-points of the intersections of the extensions of lines of inner surface of face plates of both cross tie and transverse with the lines making an angle of 45° to the direction of cross tie in contact with the free edge lines of brackets, and that of the stiffeners provided as mentioned above. (See **Fig 7.1.4** (c))

C_0, C_1, C_2 = coefficients given in **Table 7.1.6** according to the number of cross ties respectively.

Table 7.1.6 Coefficients C_0, C_1, C_2 and C_2'

Number of cross ties	C_0	C_1	C_2	C_2'
0	0.150	55.7	5.07	7.14
1	0.110	44.8	2.70	4.42
2	0.100	39.4	2.28	3.74
3	0.095	36.2	2.12	3.49

(2) The depth of transverses is not to be less than $C_0 l_0$ (m) at the mid-point of l_0. Where the transverses are of tapered form, the reduction in depth at the upper end is not to exceed 10 % of the depth at the mid-point of l_0, and the rate of increase in depth at the lower end is not to be less than that of reduction at the upper end.

(3) The web thickness of transverses at the inner edge of brackets at the lower ends is not to be less than that obtained from the following formula. Where, however, bottom transverses and longitudinal bulkheads in centre tanks or inner tanks are connected with large brackets extending to the lowest cross ties, the web thickness of side transverses may be properly reduced.

$$t = \left(C_1 - 148\frac{b}{l_0}\right)\frac{KQ}{d_0' - a} + 2.5 \quad \text{(mm)}$$

(4) The web thickness of transverses at the portion where cross ties are connected is not to be less than that obtained from the following formula. Where slots are provided in the web at the portion where cross ties are connected, the slots are to be effectively covered with collar plates.

$$t = 16\sqrt{\frac{\alpha S b_s h_s}{A}} \times S' \quad \text{(mm)}$$

(5) The section modulus of transverses at the span is not to be less than that obtained from the following formula :

$$Z = C_2 K k^2 Q l_0 \quad (\text{cm}^3)$$

2. Vertical webs on longitudinal bulkheads

(1) Vertical webs on longitudinal bulkheads connected to side transverses with effective cross ties are to be of the scantlings required in **Par 1** for side transverses with cross ties.

(2) Vertical webs on longitudinal bulkheads without cross ties are generally to be of the scantlings required in **Par 1** for side transverses without cross ties. However, h is to be the distance from the mid-point of l_0 to the top of hatches of inner tanks or centre tanks (m).

3. Bottom transverses

(1) The rigidity of bottom transverses is to be well balanced with that of side transverses.

(2) The section modulus of bottom transverses at the span is not to be less than that obtained from the following formula:

$$Z = 9.3 K \alpha k^2 S h_1 l_1^2 \quad (\mathrm{cm}^3)$$

where:

α, k, S = as specified in **Par 1** (1).

h_1 = as specified in **Table 7.1.3.**

l_1 = overall length of bottom transverses (m), which is equal to the distance between the inner surface of face plates of bottom transverses and that of vertical webs on longitudinal bulkheads.

(3) The section modulus of transverses at bilge and at the lower end of longitudinal bulkheads is not to be less than that obtained from the following formula. Where, however, bottom transverses and vertical webs on longitudinal bulkheads in centre tanks or inner tanks are connected with large brackets extending to the lowest cross ties, the section modulus of transverses specified above may be properly reduced. In calculating the section modulus, the neutral axis of section is to be taken as located at the middle of the depth d_b (See **Fig 7.1.3**) of transverses.

$$Z = C_2' K Q l_0 \quad (\mathrm{cm}^3)$$

where:

Q, l_0 = as specified in **Par 1** (1) respectively.

C_2' = coefficient given in **Table 7.1.6** according to the number of cross ties.

4. Deck transverses

(1) The rigidity of deck transverses is to be well balanced with that of side transverses.

(2) The section modulus of deck transverses is not to be less than that obtained from the following formula:

$$Z = 3 K k^2 S \sqrt{L}\, l_2^{\,2} \quad (\mathrm{cm}^3)$$

where:

k, S = as specified in **Par** 1(1) respectively.

l_2 = overall length of deck transverses (m), which is equal to the distance between the inner edges of face plates of side transverses and that of vertical webs on longitudinal bulkheads.

5. Transverses and girders where longitudinal girders are provided on ship's side and on longitudinal bulkheads

The requirements in this Paragraph are intended to be applied to the structures consisting of one, two or three side stringers or horizontal girders and three transverses in association with cross ties provided only at the crossing point of middle transverses and side stringers to connect ships sides to longitudinal bulkheads.

(1) The scantlings of side transverses and the section modulus of transverses at bilge are not to be less than those obtained from the formulae given in **Pars 1** and **3** respectively, using C_0, C_1, C_2, and C_2' as given in **Table 7.1.7** according to the value of K given by the following formula:

$$K = \frac{d_0}{d_1}\left(\frac{l_1}{l_0}\right)^2$$

where:

d_0 = mean depth of side transverses (mm).

l_0 = as specified in **Par 1**(1).

d_1 = mean depth of side stringers (mm).

l_1 = overall length of side stringers (m), which is equal to the distance between transverse bulkheads minus the depth of horizontal girders on transverse bulkheads.

Table 7.1.7 Coefficients C_0, C_1, C_2, C_2', C_3 and C_4

Number of girders	Coefficient	$K=\frac{d_0}{d_1}\left(\frac{l_1}{l_0}\right)^2$											
		$K \le 0.2$	$0.2 < K \le 0.3$	$0.3 < K \le 0.4$	$0.4 < K \le 0.5$	$0.5 < K \le 0.6$	$0.6 < K \le 0.7$	$0.7 < K \le 0.8$	$0.8 < K \le 0.9$	$0.9 < K \le 1.0$	$1.0 < K \le 1.2$	$1.2 < K \le 1.4$	$1.4 < K \le 1.6$
one	C_0	0.070	0.080	0.085	0.090	0.095	0.095	0.100	0.100	0.100	0.105	0.105	0.110
	C_1	36.9	37.8	39.0	40.0	41.1	41.8	42.5	42.9	43.2	43.6	43.9	44.3
	C_2	1.44	1.60	1.77	1.89	2.03	2.11	2.22	2.29	2.37	2.45	2.53	2.63
	C_2'	2.89	3.06	3.23	3.40	3.55	3.69	3.81	3.91	4.00	4.08	4.18	4.24
	C_3	45.0	39.6	36.9	34.5	32.4	30.6	28.9	27.4	26.1	24.3	22.0	19.8
	C_4	4.06	3.55	3.26	3.03	2.81	2.61	2.44	2.30	2.16	2.00	1.85	1.70
Two	C_0	0.060	0.072	0.075	0.080	0.085	0.085	0.090	0.090	0.090	0.095	0.095	0.100
	C_1	27.2	29.1	30.8	32.4	33.4	34.3	35.1	35.7	36.3	37.1	38.0	38.9
	C_2	0.76	0.93	1.10	1.25	1.40	1.51	1.61	1.70	1.81	1.94	2.11	2.19
	C_2'	1.62	1.87	2.13	2.34	2.55	2.72	2.89	30.4	3.13	3.31	3.46	3.57
	C_3	30.6	27.9	26.0	24.3	23.0	21.8	20.7	19.7	18.7	17.3	15.3	13.5
	C_4	2.96	2.66	2.48	2.30	2.14	1.98	1.85	1.72	1.62	1.48	1.33	1.18
Three	C_0	1.050	0.060	0.065	0.070	0.075	0.080	0.080	0.085	0.085	0.090	0.090	0.095
	C_1	23.2	25.1	26.8	28.1	29.2	30.2	31.1	32.0	32.9	33.9	34.8	35.7
	C_2	0.050	0.68	0.84	0.98	1.11	1.24	1.35	1.44	1.53	1.69	1.86	2.03
	C_2'	1.19	1.45	1.70	1.87	2.10	2.30	2.47	2.64	2.78	2.98	3.15	3.32
	C_3	26.1	24.3	23.4	22.5	21.6	20.7	19.8	18.9	18.0	16.7	15.0	13.2
	C_4	2.52	2.22	2.07	1.92	1.78	1.66	1.56	1.47	1.39	1.26	1.11	0.96

NOTE:

1. Where two side stringers are provided, $1.2C_3$ and $1.2C_4$ are to be used for the lower stringer, and $0.8C_3$ and $0.8\ C_4$ for the upper stringer, in place of C_3 and C_4 respectively.
2. Where three side stringers are provided, $1.3C_4$ is to be used for the lowest stringer, and $0.7C_4$ for the uppermost stringer, in place of C_4 respectively.

(2) The section modulus of side stringers and the web thickness of side stringers in the span from the end of side stringer to the crossing point of side stringer and side transverse at the end are not to be less than those obtained from the following formulae respectively. Where three side stringers are provided, the web thickness of the uppermost stringers may be properly reduced.

Web thickness : $t = C_3 K \frac{Q}{d_1} + 2.5$ (mm)

Section modulus of side stringer : $Z = C_4 K k Q l_1$ (cm^3)

where:

Q, k = as specified in **Par 1** (1) respectively.

d_1, l_1 = as specified in (1) respectively.

C_3, C_4 = coefficients given in **Table 7.1.7** according to the value of K.

(3) The web thickness of transverses and side stringers at the portion where cross ties are connected is not to be less than that determined in accordance with **Par 1** (4). However, in the formula therein:

S = a half of l_1 specified in (1).

S' = spacing of stiffeners provided in depthwise on webs of side transverses and vertical webs on longitudinal bulkheads, or on side stringers and stringers on longitudinal bulkheads respectively at the portion where the cross ties are connected (m).

A = effective sectional area to support the axial force from cross ties (cm^2). Where cross ties consist of the members provided both on web plate of transverses and stringers, the area is equal to the total sectional area of these members which are to be determined in general as required in **Par 1** (1).

(4) Vertical webs and horizontal girders on longitudinal bulkheads are not to be of less scantlings than determined in accordance with (1) and (2).

(5) Where n tiers of horizontal girders are provided, the distances between the girders, the girder and the deck, and the girder and the top of keel are not to be less than 0.85 $D/(n+1)$ nor more than 1.15 $D/(n+1)$ as far as practicable.

(6) Where two or more horizontal girders are provided, the uppermost girder may, if properly arranged, be of the depth reduced by not more than 10% from the mean depth of the girders.

404. Cross ties

1. In ships having two or more longitudinal bulkheads where side transverses and vertical webs on longitudinal bulkheads in wing tanks are connected with cross ties and where the structural arrangements are as given in **403. 5,** the cross ties are to be in accordance with the following requirements.

2. As regards the spacing of cross ties, the requirements in **403. 5** (5) are to be applied in general.

3. The sectional area of cross ties connecting side transverses to vertical webs on longitudinal bulkheads in wing tanks is not to be of less than section area obtained from the formula given in **Table 7.1.8.**

4. (1) Brackets are to be provided at the ends of cross ties to connect to transverses or girders.
(2) Transverses are to be provided with tripping brackets at the junction with cross ties.
(3) Where the breadth of face plates forming cross ties exceeds 150 mm on one side of the web, stiffeners connected to web and face plates are to be fitted at proper intervals.

Table 7.1.8 Section area of cross tie and thickness of web

Section area (cm^2)	Thickness of web (mm)
Whichever is the greater : $A=\dfrac{0.77K\alpha Sb_s h_s}{1-0.5\dfrac{l}{k\sqrt{K}}}$, $A=1.1K\alpha Sb_s h_s$	$t=16\sqrt{\dfrac{\alpha Sb_s h_s}{A}}\times d_0$

α = as specified in **403. 1** (1).
S = spacing of transverses (m). Where, however, constructed as specified in **403. 5,** S is to be taken as a half of l_1 specified in **403. 5** (1) (m).
b_s = width of the area supported by cross ties (m). (See **Fig 7.1.3**).
h_s = distance from the mid-point of b_s to the point H_2 specified in **403. 1** (1) above the top of keel (m).
l = length of cross ties measured between the inner edges of the side transverses (or stringers) and the vertical webs (or horizontal girders) on longitudinal bulkheads (m).
k = $\sqrt{I/A}$ (cm)
I = the least moment of inertia of cross ties (cm^4).
A = sectional area of cross ties (cm^2).
d_0 = depth of web plates (mm). Where, however, stiffeners are provided lengthwise on the web plates, the depth may be considered to be divided by the stiffeners.

405. Minimum thickness of web plates, scantling of stiffeners

1. (1) The web thickness of girders situated below the position of approximately $0.25D$ above the top of keel is not to be less than that required by **108.** (4) or that obtained from the following formula, whichever is the greater.

$$t=13.2\frac{Cd_0}{\sqrt{K}}+2.5 \quad (\mathrm{mm})$$

where:

d_0 = depth of web plates (m). Where stiffeners are provided horizontally on the midpart of web plates, distance between the stiffener and shell plating or face plate (m), or between the stiffeners (m).

C = coefficient which is determined from **Table 7.1.9** according to the ratio of S to d_0 where S is the spacing of stiffeners provided on web plates in the depthwise (m).

Table 7.1.9 Coefficient C

S/d_0	C
$\dfrac{S}{d_0}\geq 1.0$	1.0
$\dfrac{S}{d_0}< 1.0$	$\sqrt{\dfrac{S}{d_0}}$

(2) The web thickness of girders situated above the position of approximately $0.25D$ below the lower edge of deck at ships sides is not to be less than that required by **108.** (4) or that obtained from the following formula, whichever is the greater:

$$t = 11.0\frac{Cd_0}{\sqrt{K}} + 2.5 \quad (\text{mm})$$

where:

d_0, C = as specified in (1).

(3) The web thickness of transverse girders and longitudinal girders other than those specified in the above (1) and (2) is not to be less than that required by **108.** (4) or that obtained from the following formula, whichever is the greater. The girders situated higher than $D/3$ above the top of keel or the lower edge of face plate at the lower side of the second cross ties from deck, whichever is the lower, may have the web thickness as obtained from the formula with its first term multiplied by 0.85, subject to the requirements of (i) and (ii) in this Sub-paragraph (b).

$$t = \frac{Cd_0}{\sqrt{K}} + 2.5 \quad (\text{mm})$$

where:

d_0 = as specified in (1).

C = coefficient determined from **Table 7.1.10,** according to the ratio of S to d_0 and the stiffened panel arrangement, where S is the spacing of stiffeners provided on web plates in the depthwise (m). For the intermediate value of S/d_0, C is to be obtained by linear interpolation.

Table 7.1.10 Coefficients C_1, C_2 and C_3

S/d_0	C_1	C_2	C_3
0.2 or less	2.6	2.1	3.7
0.4	4.5	3.7	6.7
0.6	5.6	4.9	8.6
0.8	6.4	5.8	9.6
1.0	7.1	6.6	9.9
1.5	7.8	7.4	10.3
2.0	8.2	7.8	10.4
2.5 or more	8.4	8.0	10.4

(a) Where no stiffener is provided in parallel with face plates ...... C_1
Where, however, slots are provided, C_2 is to be used and the web thickness is not to be less than that obtained by applying the requirements of (i) in this sub-paragraph.

(b) Where stiffeners are provided in parallel with face plates,
For panel between face plate and stiffener or between stiffeners ...... C_3
However, the thickness need not exceed the value obtained by using coefficient C_1, Subject to no stiffener in parallel to face plate and no slot being provided. For panel between stiffener and shell plating ...... C_2

(i) Where slots are provided on webs with no reinforcement, the first term of the formula is to be multiplied by the following factor:

$$\sqrt{4.0\frac{d_1}{S}-1.0}$$

where d_1/S is 0.5 or less, the multiplier is to be taken as 1.0.

where:

d_1 = depth of slots (m).

(ii) Where openings are provided on webs with no reinforcement, the first term of the formula is to be multiplied by the following factor:

$$1+0.5\frac{\phi}{a}$$

where:

a = length at the longer side of the panel surrounded by the web stiffeners (m).

ϕ = diameter of openings (m). Where openings are of oblong, ϕ is to be the length of the longer diameter (m).

(4) The depth of flat bar stiffeners provided on girders and transverses is not to be less than 0.08 d_0. Where, however, the stiffeners are fitted to the full depth of girders, d_0 is to be taken as the depth of girders, and where the stiffeners are fitted to the length from the top of longitudinal frames which penetrate girders to the face plate of girders, d_0 is to be taken as the depth of girders minus the height of longitudinal frames, and where the stiffeners are fitted in parallel with face plates, d_0 is to be taken as the spacing of tripping brackets.

(5) Tripping brackets are to be provided on the web plate of transverses at the inner edge of end brackets and at the connecting part of crossties, etc. and also at the proper intervals in order to support transverses effectively. Where the breadth of face plates exceeds 180 mm on one side of the web, the tripping brackets are to be connected to face plates as well.

2. Where horizontal flat bar stiffeners are provided on bottom and deck girders, the stiffeners are not to be of less depth than 0.06 l, notwithstanding the requirements in **Par 1** (4). For strong bottom girders supporting bottom transverses, however, the horizontal stiffeners are not to be of less depth than 0.08 l, where l is the spacing of transverses (m), except that where brackets extending for the full depth of girders are provided at the midpoint of l, l may be taken as a half of the spacing of transverses.

3. Where flat bar stiffeners are connected at their ends to face plates, tripping brackets, etc., the depth of stiffeners as specified in **Par 1** (4) and **Par 2** may be properly reduced.

406. Special consideration on stiffening girders, webs and end connection brackets

Connecting brackets of bottom transverses to web plates on longitudinal bulkheads and the web plates in the vicinity of the inner edge of connecting brackets, and connecting brackets of bottom girders to web plates on transverse bulkheads (oiltight, watertight and wash) and the web plates in the vicinity of the inner edge of connecting brackets which are respectively situated in centre tanks or inner tanks, and side transverses and connecting brackets at the lower end of vertical webs on longitudinal bulkheads and the web plates in the vicinity of the inner edge of connecting brackets, and connecting brackets of side stringers to web plates on transverse bulkheads and the web plates in the vicinity of the inner edge of connecting brackets which are respectively situated in wing tanks, are to be specially provided with stiffeners in a close spacing. Further, on the web plates at the portions specified above is to be given a special consideration to prevent buckling, where the plates are unavoidably lap jointed.

Section 5 Bulkheads in Cargo Oil Spaces

501. Sectional area of transverse bulkhead plating in centre tanks

The sectional area of transverse bulkhead plating in the depthwise direction of ship in centre tanks is not to be less than that obtained from the following formula :

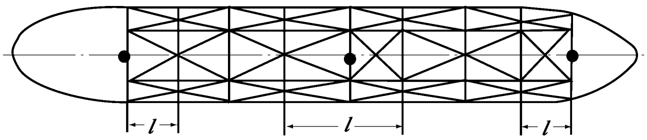
$$A = 0.95KS(h - 0.32d)(l - S)\left(C + \frac{Y}{l - S}\right) \quad (\mathrm{cm}^2)$$

where:

S = spacing of bottom transverses (m).

h = distance from the top of keel to the top of hatches in centre tanks (m).

l = distance between two bulkheads of watertight, oiltight or wash, which are situated respectively forward and afterward of the bulkhead concerned (m). Where the bulkhead concerned, however, is situated at the fore or after end of cargo oil spaces, l is to be the distance from such end bulkhead to the bulkhead of watertight, oiltight or wash, which is situated forward or afterward of the bulkhead respectively (m). (See **Fig 7.1.5**)



● marks show the bulkheads concerned

Fig 7.1.5 Measurement of l

Y = distance measured athwartship from ship's centre line (m).

C = coefficient which is to be taken as zero where no centre line girder is provided in the bottom structure of centre tanks, and to be obtained from the following formula where centre line girder is provided :

$$C = \frac{0.175}{1 + 131.0\dfrac{a}{D}\left(\dfrac{1.5K_b^3}{1 + 15.6K_b^2} + \dfrac{K_d^3}{1 + 15.6K_d^2}\right)} \times \frac{a}{S}$$

where:

a = half-breadth of centre tanks (m).

K_b, K_d = ratio of h_b/l and h_d/l, respectively, where h_b is the height of centre line bottom girder (m) and h_d is the height of centre line deck girder (m).

502. Thickness of bulkhead plating

1. The thickness of bulkhead plating is not to be less than that obtained from the formula in Pt 3, **Ch 15, 202.** for deep tank bulkhead plating, using h measured from the lower edge of plating to the top of hatches (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

2. The breadth of the uppermost and lowest strakes of longitudinal bulkhead plating is not to be less than $0.1D$ and the thickness of these is not to be less than that obtained from the following formulae :

For lowest strakes : $t = 1.1S\sqrt{KL} + 2.5$ (mm)

For uppermost strakes : $t = 0.85S\sqrt{KL} + 2.5$ (mm)

where:

S = spacing of stiffeners (m).

3. The thickness of longitudinal bulkhead plating is to comply with the requirements of **Pt 3, Ch 3, Secs 3** and **4.**

503. Stiffeners

1. The section modulus of stiffeners is not to be less than that obtained from the formula in **Pt 3, Ch 15, 203.** and **207.** for deep tank bulkhead stiffeners, using h measured from the midpoint of l in case of vertical stiffeners or from the centre of the width of plating supported by the stiffener in case of horizontal stiffeners to the top of hatches (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

2. Horizontal stiffeners provided on upper and lower parts of longitudinal bulkhead plating are to be of increased scantling above those specified in the preceding Paragraph.

3. The full width of face plates of horizontal stiffeners on longitudinal bulkhead is not to be less than that required in **302. 6.**

504. Strong vertical webs

Where strong vertical webs are provided in support of horizontal girders on transverse bulkheads at the mid-distance of longitudinal bulkheads, the vertical webs are to be in accordance with the following requirements, according to the case where transverse bulkhead is of vertical stiffener system or horizontal stiffener system.

(1) In the case of vertical stiffener system, the depth, web thickness and section modulus of strong vertical webs supporting horizontal girders are not to be less than those obtained from the following formulae respectively. (See **Fig 7.1.6**)

Depth of webs : $d = 3\left(\frac{l_1}{B_0}\right)^2 d_0$ (mm)

Web thickness :

Web thickness of vertical webs in the portion between the top of face plate of bottom girder and the horizontal girder just above the bottom girder, and web thickness of vertical webs in the portion between the said horizontal girder and the horizontal girder just above it in case where the said horizontal girder is provided within 1/3 length of vertical arm of bracket at the lower end of vertical webs above the face plate of bottom girder:

In case of one horizontal girder :

$$t_1 = \frac{87}{d_l} KW_1 \left(\frac{a_1}{l_1}\right)^2 \left(1 + \frac{2a_2}{l_1}\right) + 2.5 \quad \text{(mm)}$$

In case of two horizontal girders :

$$t_2=\frac{87}{d_l}K\left[W_1\left(\frac{a_1}{l_1}\right)^2\left\{1+\frac{2(a_2+a_3)}{l_1}\right\}\right]$$

In case of three horizontal girders :

$$t_3=\frac{87}{d_l}K\left[W_1\left(\frac{a_1}{l_1}\right)^2\left\{1+\frac{2(a_2+a_3+a_4)}{l_1}\right\}+W_2\left(\frac{a_1+a_2}{l_1}\right)^2\left\{1+\frac{2(a_3+a_4)}{l_1}\right\}\right.$$
$$\left.+W_3\left(\frac{a_1+a_2+a_3}{l_1}\right)^2\left(1+\frac{2a_4}{l_1}\right)\right]+2.5\quad(\mathrm{mm})$$

In case of n horizontal girders : $t_n=\frac{87}{d_l}K\left[\sum_{i=1}^{n}W_i\left(\sum_{j=1}^{i}\frac{a_j}{l_1}\right)^2\left(1+2\sum_{k=i+1}^{n+1}\frac{a_k}{l_1}\right)\right]+2.5\quad(\mathrm{mm})$

Thickness of vertical webs in the portion between the lower surface of face plate of deck girders and the horizontal girder just below the said face plate.

In case of one horizontal girder : $t_1=\frac{87}{d_u}KW\left(\frac{a_2}{l_1}\right)^2\left(1+\frac{2a_1}{l_1}\right)+2.5\quad(\mathrm{mm})$

In case of two horizontal girders :

$$t_2=\frac{87}{d_u}K\left[W_1\left(\frac{a_1+a_2}{l_1}\right)^2\left(1+\frac{2a_1}{l_1}\right)+W_2\left(\frac{a_3}{l_1}\right)^2\left\{1+\frac{2(a_1+a_2)}{l_1}\right\}\right]+2.5\quad(\mathrm{mm})$$

In case of three horizontal girders :

$$t_3=\frac{87}{d_u}K\left[W_1\left(\frac{a_2+a_3+a_4}{l_1}\right)^2\left(1+\frac{2a_1}{l_1}\right)+W_2\left(\frac{a_3+a_4}{l_1}\right)^2\left\{1+\frac{2(a_1+a_2)}{l_1}\right\}\right.$$
$$\left.+W_3\left(\frac{a_4}{l_1}\right)^2\left\{1+\frac{2(a_1+a_2+a_3)}{l_1}\right\}\right]+2.5\quad(\mathrm{mm})$$

In case of n horizontal girders : $t_n=\frac{87}{d_u}K\left[\sum_{i=1}^{n}W_i\left(\sum_{j=i+1}^{n+1}\frac{a_j}{l_1}\right)^2\left(1+2\sum_{k=1}^{i}\frac{a_k}{l_1}\right)\right]+2.5\quad(\mathrm{mm})$

Section modulus of webs : $Z=4Kk^2B_0hl_1^2\quad(\mathrm{cm}^3)$

where:

l_1 = overall length of vertical webs (m), which is equal to the distance between the inner surface of face plates of bottom and deck girders. In case where horizontal girder is provided within 1/3 of the length of vertical arm of bracket at the lower end of vertical webs above the top of bottom girders, l_1 is to be the distance between the said horizontal girder and the inner surface of face plate of deck girders (m).

B_0 = distance between longitudinal bulkheads (m)

d_0 = mean depth of horizontal girders (m).

d_l = depth of webs at the lower portion of vertical webs considered (mm).

d_u = depth of webs at the upper portion of vertical webs considered (mm).

n = number of horizontal girders provided within the length of l_1.

W_i (i = 1, 2,...n) = load which vertical webs receive from the number n horizontal girder counting from the top of l_1 and which is obtained from the following formulae :

In case of one horizontal girder : $W_1 = \frac{B_0}{4}(a'_1 + a'_2)\left(h' + \frac{3}{4}a'_1 + \frac{1}{4}a'_2\right)$ (t)

In case of two horizontal girders :

$$W_1 = \frac{B_0}{4}(a'_1 + a_2)\left(h' + \frac{3}{4}a'_1 + \frac{1}{4}a_2\right) \quad \text{(t)}$$

$$W_2 = \frac{B_0}{4}(a_2 + a'_3)\left(h' + a'_1 + \frac{3}{4}a_2 + \frac{1}{4}a'_3\right) \quad \text{(t)}$$

In the case of three horizontal girders :

$$W_1 = \frac{B_0}{4}(a'_1 + a_2)\left(h' + \frac{3}{4}a'_1 + \frac{1}{4}a_2\right) \quad \text{(t)}$$

$$W_2 = \frac{B_0}{4}(a_2 + a_3)\left(h' + a'_1 + \frac{3}{4}a_2 + \frac{1}{4}a_3\right) \quad \text{(t)}$$

$$W_3 = \frac{B_0}{4}(a_3 + a'_4)\left(h' + a'_1 + a_2 + \frac{3}{4}a_3 + \frac{1}{4}a'_4\right) \quad \text{(t)}$$

In case of n horizontal girders :

$$W_1 = \frac{B_0}{4}(a'_1 + a_2)\left(h' + \frac{3}{4}a'_1 + \frac{1}{4}a_2\right) \quad \text{(t)}$$

$$W_i = \frac{B_0}{4}(a_i + a_{i+1})\left(h' + \sum_{j=1}^{i-1}a_j + \frac{3}{4}a_i + \frac{1}{4}a_{i+1}\right) \quad \text{(t)} \qquad (i = 2, 3 \ldots\ldots, n\text{-}1)$$

$$W_n = \frac{B_0}{4}(a_n + a'_{n+1})\left(h' + \sum_{j=1}^{n-1}a_j + \frac{3}{4}a_n + \frac{1}{4}a'_{n+1}\right) \quad \text{(t)}$$

Where

j = 1 in the above formulae for W_i and W_n, a_i is to be taken as a'_1.

where :

a_i (i = 1, 2, ..., n) = distance between the top of l_1 and the horizontal girder just below the top, distance between the adjacent horizontal girders or distance between the bottom of l_1 and the horizontal girder just above the bottom (m). (i is to be counted from the top.)

a'_1 = distance between the lower surface of deck longitudinals and the uppermost horizontal girder (m).

a'_{n+1} = distance from the lowest horizontal girder within the length of l_1 to the horizontal girder just below it or to the upper surface of bottom longitudinals (m).

h = distance from the mid-point of l_1 to the top of hatchways in centre tanks (m).

h' = distance from the lower surface of deck longitudinals to the top of hatchways in centre tanks (m).

k = correspondingly as specified in **Table 7.1.3.**

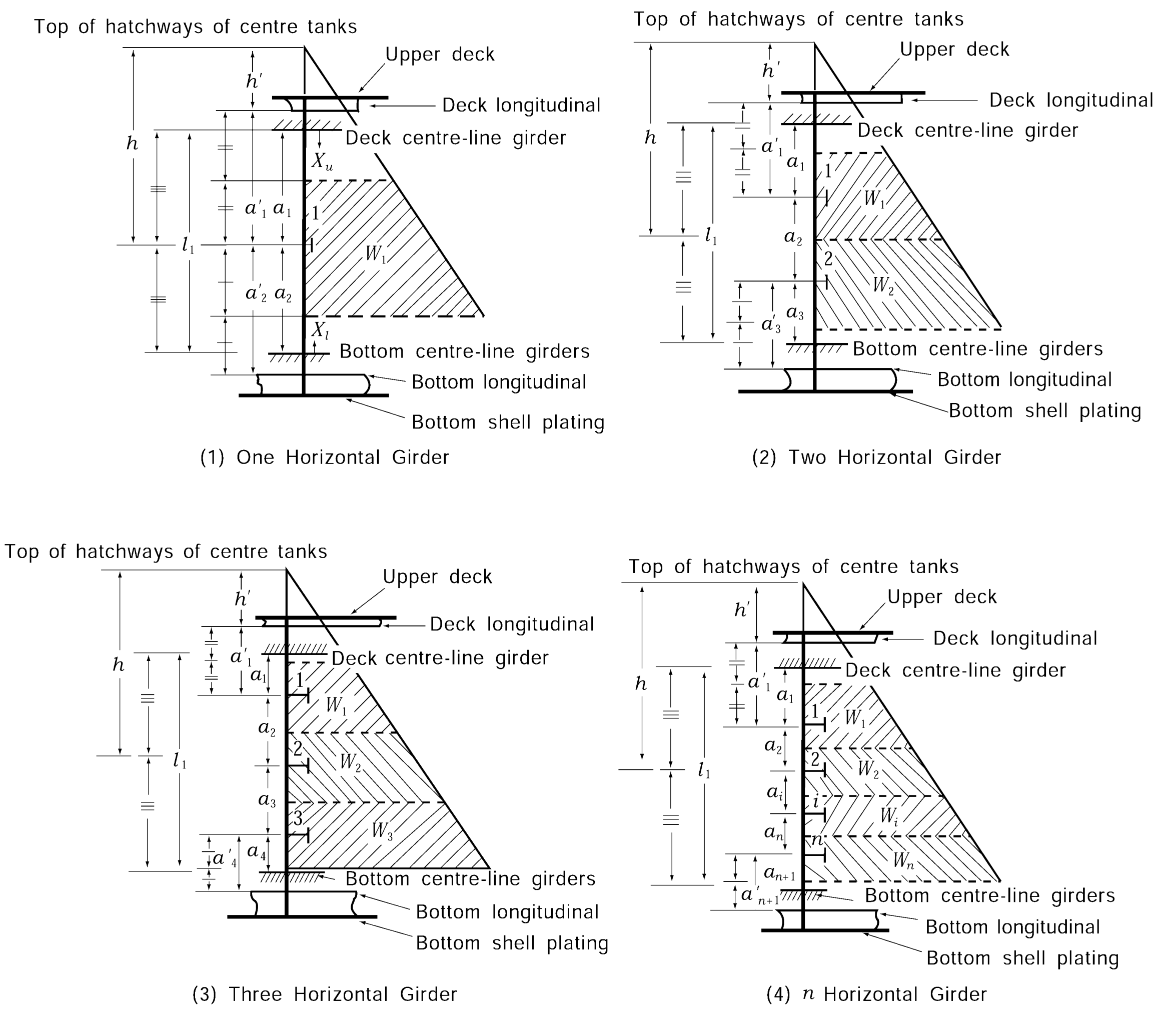


Fig 7.1.6 Measurement of each dimension and load

(2) In case where one horizontal girder is provided, the depth, web thickness and section modulus of strong vertical webs supporting the horizontal girder are not to be less than those obtained from the following formulae respectively:

Depth of webs : $d = 3\left(\frac{l_1}{B_0}\right)^2 d_0$ (mm)

Web thickness :

Web thickness of vertical webs in the portion between the top of face plates of bottom girders and the horizontal girders :

$$t_1 = \frac{87}{d_l - a} K\left[\frac{1}{4} B_0 h l_1 \left\{\frac{1}{2} - \frac{X_l}{l_1} + \frac{l_1}{2h}\left(\frac{1}{5} - \frac{X_l}{l_1} + \frac{X_l^2}{l_1^2}\right)\right\} + W_1\left(\frac{a_1}{l_1}\right)^2\left(1 + \frac{2a_2}{l_1}\right)\right] + 2.5 \quad \text{(mm)}$$

Web thickness of vertical webs in the portion between the lower surface of face plates of deck girders and the horizontal girders :

$$t_2=\frac{87}{d_u-a}K\left[\frac{1}{4}B_0hl_1\left\{\frac{1}{2}-\frac{X_u}{l_1}-\frac{l_1}{2h}\left(\frac{1}{5}-\frac{X_u}{l_1}+\frac{X_u^2}{l_1^2}\right)\right\}+W_1\left(\frac{a_2}{l_1}\right)^2\left(1+\frac{2a_1}{l_1}\right)\right]+2.5 \quad (\mathrm{mm})$$

Section modulus of webs : $Z=5.2Kk^2B_0hl_1^2 \quad (\mathrm{cm}^3)$

where :

X_l = distance measured upward from the top of face plates of bottom girders (m).

X_u = distance measured downward from the lower surface of face plates of deck girders (m).

$$W_1=\frac{B_0}{8}(a'_1+a'_2)\left(h'+\frac{3}{4}a'_1+\frac{1}{4}a'_2\right) \quad (\mathrm{t})$$

l_1, B_0, d_0, d_l, d_u, a_1, a_2, a_1', a'_2, h, h', k = as specified in (1) respectively.

a = depth of slot (m). Where, however, the slots are effectively covered by collar plates, a may be taken as zero.

505. Vertical webs supported by horizontal girders

Where vertical webs provided on transverse bulkhead are supported by the horizontal girders specified in **506.**, the depth, web thickness and section modulus of vertical webs are not to be less than those obtained from the following formulae respectively.

Depth of webs : $d=143l \quad (\mathrm{mm})$ or $2.5a \quad (\mathrm{mm})$, whichever is the greater.

Web thickness : $t=C_1K\frac{Shl}{d_0-a}+2.5 \quad (\mathrm{mm})$

Section modulus of webs : $Z=C_2Kk^2Shl^2 \quad (\mathrm{cm}^3)$

where :

a = depth of slots (mm).

l = overall length between the points of support of vertical webs (m), which is equal to the distance from the inner surface of face plates of bottom girders to the horizontal girder just above it, that between the horizontal girders, or that from the inner surface of face plates of deck girders to the horizontal girders just below it.

S = spacing of vertical webs (m).

h = distance from the mid-point of l to the top of hatchways of the tanks concerned (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

d_0 = depth of webs at the point under consideration (mm).

k = correspondingly as specified in **Table 7.1.3.**

C_1, C_2 = coefficients given by the following formulae respectively:

$$C_1 = 87\left\{\frac{1}{2} - \frac{X}{l} + \frac{1}{2}\,\frac{l}{h}\left(\frac{1}{5} - \frac{X}{l} + \frac{X^2}{l^2}\right)\right\},$$

$$C_2 = 8\left(1 + \frac{l}{10h}\right)$$

X = distance measured upward from the lower end of l (m).

506. Horizontal girders supporting vertical webs

Where vertical webs are supported by horizontal girders provided on transverse bulkheads, the depth, web thickness and section modulus of horizontal girders are not to be less than those obtained from the following formulae respectively. The section modulus, however, is not to be less than that obtained from the formulae taking the starting point of a_i each end of the girders, whichever is the greater. (See **Fig 7.1.7**)

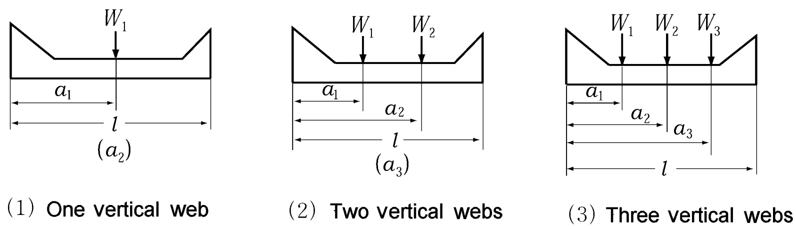


Fig 7.1.7 Measurement of l, a_1, a_2, etc.

Depth of girders : $d = 143l$ (mm)

Web thickness in the portion between the ends of horizontal girders and the vertical webs at ends :

In case of one vertical web : $t_1 = \frac{87}{d_0} K W_1 \left(1 - \frac{a_1}{l}\right)^2 \left(1 + \frac{2a_1}{l}\right) + 2.5$ (mm)

In case of two vertical webs :

$$t_2 = \frac{87}{d_0} K \left[W_1 \left(1 - \frac{a_1}{l}\right)^2 \left(1 + \frac{2a_1}{l}\right) + W_2 \left(1 - \frac{a_2}{l}\right)^2 \left(1 + \frac{2a_2}{l}\right)\right] + 2.5 \quad \text{(mm)}$$

In case of three vertical webs :

$$t_3 = \frac{87}{d_0} K \left\{ W_1 \left(1 - \frac{a_1}{l}\right)^2 \left(1 + \frac{2a_1}{l}\right) + W_2 \left(1 - \frac{a_2}{l}\right)^2 \left(1 + \frac{2a_2}{l}\right) + W_3 \left(1 - \frac{a_3}{l}\right)^2 \left(1 + \frac{2a_3}{l}\right)\right\} + 2.5 \quad \text{(mm)}$$

Section modulus of girders :

In case of one vertical web : $Z_1 = 85.5Kk\, W_1 a_1 \left(1 - \frac{a_1}{l}\right)^2$ (cm^3)

In case of two vertical webs : $Z_2 = 85.5Kk \left\{ W_1 a_1 \left(1 - \frac{a_1}{l}\right)^2 + W_2 a_2 \left(1 - \frac{a_2}{l}\right)^2 \right\}$ (cm^3)

In case of three vertical webs :

$$Z_3 = 85.5Kk \left\{ W_1 a_1 \left(1 - \frac{a_1}{l}\right)^2 + W_2 a_2 \left(1 - \frac{a_2}{l}\right)^2 + W_3 a_3 \left(1 - \frac{a_3}{l}\right)^2 \right\} \quad (\text{cm}^3)$$

where:

l = overall length between the points of support of horizontal girders (m), which is equal to the distance between side shell plating and longitudinal bulkhead or that between the longitudinal bulkheads (m). Where, however, side stringers and longitudinal girders on longitudinal bulkheads are provided, the distance between the face plates of longitudinal girders is to be taken as l and where the strong vertical webs specified in **504.** are provided in the middle between the longitudinal bulkheads, a half of the distance between the longitudinal bulkheads is to be taken as l.

W_i (i = 1,2,3) = load which horizontal girders receive from the vertical web of number i counting from the end of l, which is given by the following formulae :

$$W_1 = \frac{1}{2} a_2 \, b \, h \quad (\mathrm{t})$$

$$W_2 = \frac{1}{2} (a_3 - a_1) \, b h \quad (\mathrm{t})$$

$$W_3 = \frac{1}{2} (l - a_2) bh \quad (\mathrm{t})$$

b = width of the area to be supported by horizontal girders (m).

h = distance from the mid-point of b to the top of hatchways of the tanks concerned (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

a_i (i = 1,2,3) = distance from the end of l to the vertical web of number i counting from the end of l (m).

k = correspondingly as specified in **Table 7.1.3.**

507. Horizontal girders supporting vertical stiffeners

Where vertical stiffeners are supported by horizontal girders provided on transverse bulkheads, the depth, web thickness and section modulus of horizontal girders are not to be less than those obtained from the following formulae respectively :

Depth of girders : $d = 143\, l$ (mm) or $2.5\, a$ (mm), whichever is the greater.

Web thickness : $t = CK \dfrac{S h l}{d_1 - a} + 2.5 \quad (\mathrm{mm})$

Section modulus of girders : $Z = C' K k^2 S h l^2$

where :

a = depth of slots (mm).

l = overall length between points of support of horizontal girders (m), which is equal to the distance between side shell plating and longitudinal bulkhead or that between longitudinal bulkheads. Where, however, side stringers and longitudinal girders on longitudinal bulkhead are provided, the distance between the face plates of longitudinal girders is to be taken as l.

S = width of area to be supported by girders (m).

h = distance from the mid-point of S to the top of hatchways of the tanks concerned (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

d_1 = depth of girders at the point under consideration (mm).
k = correspondingly as specified in **Table 7.1.3.**
C = coefficient given by the following formula:

$$C = \left| 87\left(\frac{1}{2} - \frac{X}{l}\right) \right|$$

X = distance measured from the end of l (m).
C' = coefficient given in **Table 7.1.11.**

Table 7.1.11 Coefficient C'

	Where side stringers and vertical webs on longitudinal bulkheads are provided	Others
Wing tank	7	10
Centre tank	7	$10\frac{B_S}{B_C}$

NOTES:
B_S = width of wing tanks (m), Which is equal to the distance between side shell plating and longitudinal bulkhead.
B_C = width of centre tanks (m), which is equal to the distance between longitudinal bulkheads. Where, however, B_S/B_C exceed 1.0, B_S/B_C is to be taken as 1.0 and where less than 0.7, to be taken as 0.7.

508. Web plates, face plates and stiffeners of girders

1. The thickness of vertical webs and horizontal girders provided on transverse bulkheads is not to be less than that required by the following:

(1) The web thickness of strong vertical webs specified in **504.** is to be as required in **405. 1** (1) in general. However, for the upper 2/3 of l_1, excluding the portion nearby the top of vertical arm of lower bracket of vertical webs, the formula may have its first term multiplied by 0.85.

(2) The web thickness of those webs and girders specified in **505.** to **507.** is to be as required in **405. 1** (3) in general.

2. The thickness and breadth of face plates forming vertical webs and horizontal girders specified in **Par 1** is not to be of less scantlings than required in **401. 4.** However, the depth of girders of corrugated bulkheads is to be measured from the middle of the depth of corrugation.

3. The girders specified in **Par 1** are to be provided with flat bar stiffeners, applying the requirements of **405.**

509. Special stiffening of web plates and end connection brackets

As regards the strong vertical webs specified in **504.** the lower brackets and the web plates between the top of face plate of bottom girders and the horizontal girders situated directly above the bottom girders, including the web plates up to the horizontal girder situated directly above the said horizontal girder in case where the said girder is situated within 1/3 the length of vertical arm of brackets above face plate of bottom girders, are to be provided with stiffeners specially in close spacing. Regarding the horizontal girders specified in **506.** and **507.,** the end brackets and the web plates in the vicinity of the inner edge of brackets are also to be provided with stiffeners in close spacing. Further, a special consideration is to be given to the web plates at the portion specified above to be protected from buckling, in case where the said plates are unavoidably lap jointed.

510. Additional strengthening of bulkhead in large tanks

As for large tank boundaries, the scantlings of bulkhead plates, stiffeners, vertical and horizontal girders are not to be less than those obtained from relevant formulae in **501.** to **507.,** where the value of h or h' is the one specified in each requirement or that given by the following formula, whichever is the greater.

$$H = 0.85(h + \Delta h) \quad (\mathrm{m})$$

where:

h = h or h' as specified in each requirement.

Δh = as specified in **Pt 3, Ch 15,105.**

511. Wash bulkheads

1. Stiffeners and girders are to be of adequate strength in conformity with the size and opening ratio of tanks.

2. The sectional area of wash bulkhead plating to the depthwise direction of the ship in centre tanks is not to be less than that required in **501.** as far as practicable.

3. The thickness of bulkhead plating is not to be less than that required by **108.** (4) or that obtained from the following formula, whichever is the greater. The thickness of the lowest strake of transverse wash bulkheads is to be properly increased.

$$t = 0.3S\sqrt{(L+150)K} + 2.5 \quad (\mathrm{mm})$$

where:

S = spacing of stiffeners (m).

4. The breadth and thickness of the uppermost and the lowest strakes in centre line wash bulkheads are to be as required in **502. 2** as far as practicable.

5. It is recommended that a special consideration be given to the thickness of wash bulkhead plating to prevent the plating from shear buckling.

Section 6 Relative Deformation of Wing Tanks

601. Relative deformation of wing tanks

As regards wing tanks, where the value obtained from the following formula exceeds 0.15, a special consideration is to be given to the structure of wing tanks.

$$\delta = \frac{h - 0.32d}{n_b K_b + n_s \eta_s K_S + n_t \eta_t K_t} \times \frac{a}{b} l$$

where:

a = half-breadth of centre tanks (m).

b = breadth of wing tanks (m).

h = distance from the top of keel to the top of hatches of centre tanks (m).

l = length of one tank situated between oil-and/or water-tight bulkheads in centre tanks (m).

n_b, n_s, n_t = number of transverse bulkheads, wash bulkheads and transverse rings in wing tanks located within l, respectively. The bulkheads at the fore and aft ends of l are to be counted 1/2, respectively.

η_s, η_t = values given in **Table 7.1.12** in accordance with the opening ratio. For intermediate value of opening ratio, η_s and η_t are to be obtained by linear interpolation.

Table 7.1.12 Coefficients η_s and η_t

Opening ratio (%)	η_s and η_t
0	1.00
5	0.95
10	0.80
20	0.55
30	0.35
40	0.23
50	0.15
60	0.10
70	0.06

K_b, K_s, K_t = values obtained from the following formula : $81.0\dfrac{Dt}{\alpha b}$ (t/cm)

where:

t = mean thickness of transverse bulkhead plating in wing tanks (mm), in obtaining K_b value.
mean thickness of wash bulkhead plating in wing tanks (mm), in obtaining K_s value.
mean thickness of transverse rings in wing tanks (mm), in obtaining K_t value.

α = value obtained from the following formulae, in case where transverse bulkheads or wash bulkheads in wing tanks are of corrugated form, in accordance with the case where the corrugation is vertical or horizontal:

For vertical corrugation : $\dfrac{Girth\ length\ of\ ship\ in\ athwartships\ (\mathrm{m})}{b}$

For horizontal corrugation : $\dfrac{Girth\ length\ of\ ship\ in\ depthwise\ (\mathrm{m})}{D}$

For the case other than above, the value is to be 1.0.

Section 7 Welding

701. Welding

1. The welding in tankers is to be in accordance with the requirements given in **Pt 3, Ch 1, Table 3.1.6** except where specially prescribed in this Article for cargo oil tanks.
2. The application of the fillet welding is to be as given in **Table 7.1.13.**

Table 7.1.13 Fillet welding

<table>
<tr><th>Column</th><th colspan="2">Item</th><th>Where applied</th><th>Kind of weld</th></tr>
<tr><td>1</td><td rowspan="6">Transverse girders and webs</td><td rowspan="3">Web plates</td><td>Shell, deck or longitudinal bulkhead plating</td><td>$F1$</td></tr>
<tr><td>2</td><td>Web plates</td><td>$F1$</td></tr>
<tr><td>3</td><td>Face plates</td><td>$F2$</td></tr>
<tr><td>4</td><td>Slots in web plates</td><td>Web plates longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads</td><td>$F2$</td></tr>
<tr><td>5</td><td rowspan="2">Tripping brackets and stiffeners provided on web plates</td><td>Web plates</td><td>$F3$</td></tr>
<tr><td>6</td><td>Web plates of longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads</td><td>$F1$</td></tr>
<tr><td>7</td><td colspan="2">Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads</td><td>Shell, deck or longitudinal bulkhead plating</td><td>$F3$</td></tr>
<tr><td>8</td><td colspan="2" rowspan="2">Cross ties</td><td>Members forming cross ties (web plates to face plates)</td><td>$F3$</td></tr>
<tr><td>9</td><td>Face plates of transverses, side stringers or longitudinal girders</td><td>$F1$</td></tr>
<tr><td colspan="5">NOTE:
Where the radius at the toe of end brackets is small, it is recommended that $F1$ be used for appropriate length at the toe of bracket.</td></tr>
</table>

Section 8 Supplementary Provisions for Tankers Having Longitudinal Bulkhead at Centre Line Only

801. Application

The requirements specified hereunder apply to tankers not exceeding 120 m in length having longitudinal bulkhead at the centre line only. As regards the matters not specially provided in these requirements, the requirements in each previous Articles concerned are to be applied. Application of **406.** and **509.**, however, may be dispensed with.

802. Trunks

1. The thickness of trunk top and side plating is not to be less than that obtained from the following formula :

$$t = 6.5\frac{S}{\sqrt{K}} + 2.0 \quad (\mathrm{mm})$$

where:

S = spacing of longitudinal stiffeners (m).

2. The section modulus of longitudinal stiffeners provided on trunks is not to be less than that obtained from the following formula :

$$Z = 2K\sqrt{L}Sl^2 \quad (\mathrm{cm}^3)$$

where:

l = spacing of transverses (m).

S = spacing of longitudinal stiffeners (m).

803. Transverses in cargo oil spaces

1. Transverses in cargo oil spaces are to be in accordance with the requirements of **401.** to **406.** except those specially specified in this Article. In small ships, however, the brackets at ends of transverses may be dispensed with, subject to the approval by the Society.

2. The depth and section modulus of bottom transverses are not to be less than those obtained from the following formulae respectively :

Depth of transverses : $d = 0.16 l_0$ (m)

Section modulus of transverses : $Z = 9.7Kk^2(d + 0.026L')Sl_0^2$ (cm^3)

where:

l_0 = overall length of transverses (m), which is equal to the distance from the inner surface of face plates of side transverses to the inner surface of face plates of vertical webs on centre line bulkhead.

S = spacing of transverses (m).

k = correspondingly as specified in **Table 7.1.3.**

3. The depth and section modulus of side transverses are not to be less than those obtained from the following formulae respectively. Where the transverses are of tapered from, the requirements in **403. 1** (2) are to be applied.

Depth of transverses : $d = 0.15 l_0$ (m)

Section modulus of transverses : $Z = 8.7Kk^2Shl_0^2$ (cm^3)

where:

l_0 = overall length of side transverses (m), which is equal to the distance between the inner surfaces of face plates of bottom transverses and deck transverses. (See **Fig 7.1.3**)

S = spacing of transverses (m).

h = distance from the mid-point of l0 to the point high as given by the following formula above the top of keel (m):

$h = d + 0.038L$ (m)

k = correspondingly as specified in **Table 7.1.3.**

4. The section modulus of transverses at bilge is not to be less than that obtained from the following formula. However, in calculating the section modulus of transverses, the neutral axis of section is to be assumed as to situate at the mid-point of the depth of transverses d_b. (See **Fig 7.1.3**)

$$Z = 7.8KShl_0^2 \quad (\text{cm}^3)$$

where:

S, h, l_0 = as specified in **Par 3** respectively.

5. Deck transverses

(1) The depth and section modulus of deck transverses in ships having no trunk are not to be less than those determined correspondingly in accordance with the requirements in **402. 2** (1).

(2) In trunk ships, it is a standard arrangement that transverses extending from side to side of the ship across the trunk are provided In this case, the depth of deck transverses regarded as being supported by trunks may be $0.03B$.

6. As for vertical webs provided on the centre line bulkhead, the requirements in **Par 3** for side transverses are to be correspondingly applied, but the depth and section modulus of deck transverses are not to be less than those obtained from the formulae with each coefficient multiplied by 0.8 respectively.

804. Stiffening transverse

Trunks are to be provided with stiffening transverses in line with the deck transverses. The section modulus of stiffening transverses is not to be less than that obtained from the following formula :

$$Z = 1.4K\sqrt{L}Sl^2 \quad (\text{cm}^3)$$

where:

l = half-breadth of trunks (m).

S = spacing of stiffening transverses (m).

Section 9 Special Requirements for Wing Tanks at Fore Parts

901. Application

In case of oil tankers of 200 *metres* and over in length, the members provided in wing tanks not being ballasted at full load condition which are located between $0.15L$ from the bow and the collision bulkhead are to comply with the requirements specified hereunder as well as the requirements in each previous Articles concerned.

902. Side longitudinal frames

1. The section modulus of side longitudinal frames is not to be less than that obtained from the following formula :

$$Z = 9KShl^2 \quad (\text{cm}^3)$$

where:

l = spacing of transverses (m).

S = spacing of longitudinal frames (m).

h = distance measured from the frame concerned to the point of the height which is to be obtained from the following formula above the top of keel : $h' = 0.7d + 0.05L$ (m)
In any case, however, the distance is not to be less than that obtained from the following formula : $h = 0.2\sqrt{L} + 0.03L$ (m)

2. Where side longitudinal frames are connected to transverse by brackets, the section modulus may be taken as the value obtained from the formula in the preceding Paragraph multiplied by the following factor :

Where C is obtained from the following formulae : $(1-C)^2$

In case where brackets are provided at both ends : $C=\frac{b_1+b_2-0.3}{l}$

In case where a bracket is provided at one end : $C=\frac{b-0.15}{l}$

b, b_1, b_2 = arm length of brackets on longitudinal frames respectively (m). In case, C is negative, C is to be taken as zero. (See **Fig 7.1.8**)

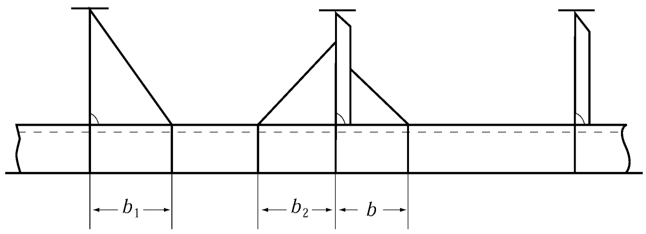


Fig. 7.1.8 Measurement of *b*, *b*$_1$ and *b*$_2$

903. Side transverses

1. The section modulus of side transverses is to be in accordance with the requirement in **403. 1** (5). In applying the formula, however, h is the distance from the mid-point of l_0 to $0.1L$ above the top of keel (m).

2. The thickness of webs of side transverses at inner edge of brackets at lower ends is to be in accordance with the requirements in **403. 1** (3). In applying the formula, however, h is the distance from the midpoint of l_0 to $0.1L$ above the top of keel (m).

3. The thickness of webs between cross ties is not to be less than that obtained from the following formula :

$$t=43.5\,CK\frac{Sh_il_i}{d_i-a_i}+2.5 \quad (\text{mm})$$

where:

S = spacing of transverses (m).

d_i = depth of web at the mid-point of each span (mm).

a_i = maximum depth of slots in each span (mm). The depth, however, may be taken as zero where the slots are provided with collar plates.

l_i = span of each transverse (m). However, for the part between cross ties and bottom or deck transverses. l_i is the distance between the centre of cross ties and the face plate of bottom or deck transverses; for the part between cross ties, the distance between centres of cross ties. (See **Fig 7.1.9**)

h_i = distance from the mid-point of each l_i to the point $0.1L$ above the top of keel. Where, however, the distance is less than $0.06L$(m), h_i is to be taken as $0.06L$(m).

C = coefficient given by the following formula :

$$C=1.2-\frac{2b_i-0.3}{l_i}$$

b_i = arm length of brackets at both ends of span, whichever is the smaller (m). (See **Fig 7.1.9**)

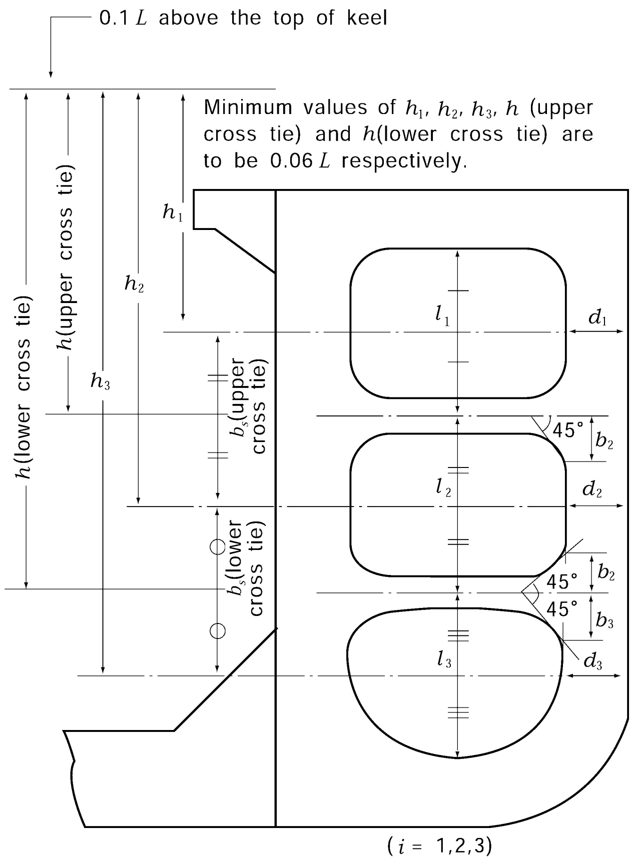


Fig. 7.1.9 Measurement of l, b, etc.

4. The thickness of web at the portion where cross ties are connected is to be as required in **403. 1** (4). In applying the formula, however, h is the distance from the mid-point of b_s to the point 0.1 L above the top of keel (m), except that h is to be taken as $0.06L$(m) where the distance is less than $0.06L$(m).

904. Special stiffening of web plates at ends of transverses

The upper and lower end brackets connected to side transverses and vertical webs on longitudinal bulkheads, and the web plates of transverses at the inner edge of the brackets and in the vicinity of the portion where cross ties are connected, are to be provided with stiffeners in specially close spacing.

905. Cross ties

The cross sectional area of cross ties and web thickness are to be in accordance with the requirements in **404.** In applying the formula, however, h is the distance from the mid-point of b_s to the point $0.1L$ above the top of keel (m), except that h is to be taken as $0.06\ L$(m), where the distance is less than $0.06L$(m).

906. Vertical webs on longitudinal bulkheads

The scantlings of vertical webs on longitudinal bulkheads are not to be less than generally those determined in accordance with the requirements for side transverses.

Section 10 Piping Systems and Venting Systems for Oil Tankers

1001. General

1. Application

(1) The requirements in this Section apply to the piping systems and venting systems for ships intended to be registered as oil tankers.
(2) The requirements in this Section apply to oil tankers which have all the following features. The piping systems and venting systems for other types of oil tankers will be considered by the Society in each case.
  (a) Tankers carrying crude oil, petroleum products having a flash point not exceeding 60°C (closed cup test) or other similar liquid cargoes
  (b) Tankers of which the machinery spaces and cargo oil tanks (including slop tanks, the same being referred hereinafter in this Section) are arranged in accordance with the requirements in **Pt 8, Ch 2, 104.**
  (c) Tankers of which the cargoes are loaded by land facilities and unloaded by cargo pumps on board ship.
(3) In addition to the requirements in this section, the requirements in **Pt 8, Ch 2, 104.** and **Pt 8, Ch 3, 505.** are to be complied with.

2. Drawings and Data

Drawings and data to be submitted are generally as follows.

(1) Drawings and data for approval (with materials, dimensions, design pressures, etc. of pipes, valves, etc. and the arrangement of devices to prevent the passage of flame)
  (a) Piping diagram of cargo oil pipes and instrumentation
  (b) General arrangement of bilge systems and ventilation systems of a cargo oil pump room
  (c) General arrangement of venting systems for cargo vapours, etc.
  (d) Other drawings and data considered necessary by the Society
(2) Drawings and data for reference
  (a) Capacity calculation sheet for pressure/ vacuum valves and overpressure protective device of cargo oil tanks
  (b) Other drawings and data considered necessary by the Society

3. Special type

Where ships are equipped with new types of pumps and/or piping systems, specifications and detailed drawings are to be submitted to the Society for approval. The Society may require additional detailed investigations or tests of their own, where deemed necessary by the Society.

1002. Cargo oil pumps and piping systems

1. Cargo oil pumps

(1) Cargo oil pumps are to comply with the following (a) to (e).
  (a) Each pump is to be so designed as to minimize the risk of sparking and oil leakage at the seal.
  (b) Where machinery is driven by shafting passing through a bulkhead or deck, shafting is to be provided with flexible couplings, and gastight seals with efficient lubrication or other means of ensuring the permanence of the gastight seal are to be fitted in way of the bulkhead or deck. If a bellows piece is incorporated in the design, it is to be pressure tested before fitting. The gastight seals or other means are to be so designed as to minimize the risk of sparking, and the sealing parts contacted with the shafting are to be material that will not initiate sparks.
  (c) Cargo oil pumps are to comply with the requirements in **Pt 8, Ch 2, 104. 10**(1).
  (d) A stop valve is to be provided on the delivery side of the pump. However, such stop valve may be omitted, provided that the cargo oil pipe on the delivery side of the pump is provided with a stop valve in a proper position.
  (e) Where a relief valve is provided on the delivery side of the pump, the arrangement is to be such that the escaped oil is led to the suction side of the pump.

(f) A pressure measuring device is to be fitted on the delivery side of each pump. Where the pump is driven by a prime mover which is installed in the space other than the pump room, an additional pressure measuring device is to be fitted at a suitable position visible from the controlling position.

(2) Where prime movers, other than steam engines or hydraulic motors, for driving the cargo oil pumps are installed in the cargo oil pump room, descriptions and construction of the prime movers and the driving system are to be submitted for the approval by the Society.

(3) Where deep well pumps, submerged pumps, etc. are installed, construction of the pumps and driving systems are to be submitted for approval by the Society.

(4) In general, cargo oil pumps are not to be used for other purposes than transferring cargo oil or ballast in cargo oil tanks, transferring tank cleaning water for cargo oil tanks, discharging bilge as specified in **1003. 1**(2), or discharging ballast as specified in **1003. 2** (2).

2. Arrangement of cargo oil piping systems

(1) Cargo oil pipes are classified into Class Ⅲ, except where considered necessary by the Society.

(2) Each cargo oil tank is to be provided with a cargo oil suction pipe(s) so arranged that cargo unloading can be carried out with one of the cargo oil pumps out of use.

(3) Cargo oil pipes are to be so arranged as to be capable of loading cargo oil to cargo oil tanks without passing through cargo oil pumps. Where loading pipes are led directly to the tanks from above the deck, the opening ends of these pipe are to be led to the lower part of the tanks as far as practicable to prevent the accident caused by the generation of static electricity.

(4) Where sea suction pipes for ballasting purpose are connected to cargo oil pipes, stop valves are to be provided between the sea suction valves and the cargo piping.

(5) Slip joints used in the cargo oil pipes are to be in compliance with **Pt 5, Ch 6, 104. 5.**

(6) Sea suction pipes and discharge pipes for permanent ballast tanks are not to be connected to the sea suction pipes and discharge pipes for cargo oil tanks.

3. Alternative use of tanks

Where cargo oil tanks are so designed that they can also be used as ballast tanks or fuel oil tanks, the tanks are to be provided with devices which the Society requires, and approved drawings or documents having descriptions on a detailed operating manual for the alternative use are to be provided on board the ship.

4. Separation of cargo oil pumps and cargo oil pipes

(1) Cargo oil pipes are to be entirely separated from other pipes, except where permitted in **1002. 2** (2) and **1003. 1** and **2.**

(2) Cargo oil pipes are not to be led through fuel oil tanks nor engine room and accommodation spaces where sources of vapour ignition are normally present. In addition, these pipes are not to be led to spaces forward the collision bulkhead or after the front bulkhead of the engine room.

(3) Cargo oil pipes on the weather deck are to be arranged sufficiently apart from the accommodation spaces.

(4) Where a ship is equipped with bow and/or stern loading and unloading of cargo oil outside the cargo area, the connections of the cargo lines leading to the cargo hose connection therein are to be of welded joints except valve connections and the cargo lines are to be clearly identified and segregated by following means of (A) or (B) situated in the cargo area. The open ends of the cargo lines are to be provided with a blank flange at the bow and/or stern end connections.

(A) Two valves which can be secured in the closed position and provided that the efficiency of the segregation can be checked

(B) One valve together with another closing appliances providing an equivalent standard of segregation such as a removable spool piece or spectacle flange

(5) Cargo oil pipes and similar pipes to cargo oil tanks are not to pass through ballast tanks. However, these pipes may pass through the ballast tanks provided that these pipes in ballast tanks are of short length and the connections of these pipes are of welded joints or flanged joints which have no risk of leakage.

(6) Notwithstanding preceeding (5), for oil tankers other than double hull tankers, cargo oil pipes may pass through the ballast tanks provided that the connections of these pipes are of welded joints or flanged joints which have no risk of leakage. Expansion bends only, not glands, are permitted in these lines within ballast tanks.

5. Bulkhead valves of cargo oil piping systems

(1) Cargo oil pipes passing through oiltight bulkheads between cargo oil tanks and pump rooms are to be provided with stop valves as close to the bulkhead as practicable.
(2) Where the valves prescribed in (1) are located inside the pump room, they are to be made of steel or cast iron products with an elongation of 12 % and above. These values are to be capable of being closed at the position of the valves and from a readily accessible position outside the compartment in which they are located. However, if the valves operated at a position above the deck are fitted on each cargo oil branch pipe, the valves located inside the pump room may be of cast iron products with an elongation of less than 12 % without remote control device.
(3) Where the valves prescribed in (1) are located inside the tank, the valves may be of cast iron and need not be capable of being closed at the position of the valves, but they are to be provided with remote control devices, and the pipes are to be provided with another valve in the pump room.
(4) Where the valves are required to be remote controlled according to the requirements in (2) and (3), means are to be provided to show whether they are open or closed.

6. Valve operation rod penetrating through decks

Stuffing boxes are to be provided at positions at which operating rods from cargo valves pass through gastight or oiltight decks.

7. Piping in cargo oil tanks

(1) Pipes other than cargo oil pipes, cargo oil heating pipes, ballast pipes of cargo tanks and pipes permitted in (2) to (4) are not to pass through cargo oil tanks nor to have any connection to these spaces.
(2) Pipes for remote control of cargo oil piping systems, and vapour discharge pipes, tank cleaning pipes and sounding devices of cargo oil tanks may be led to cargo oil tanks.
(3) Scupper pipes, sanitary pipes, etc. may be led through cargo oil tanks subject to the approval by the Society.
(4) Ballast pipes and other pipes such as sounding and vent pipes to ballast tanks are not to pass through cargo oil tanks. However, these pipes may pass through the cargo oil tanks provided that these pipes in cargo oil tanks are of short length and the connections of these pipes are of welded joints or flanged joints which have no risk of leakage.
(5) Notwithstanding preceeding (4), for oil tankers other than double hull tankers, ballast pipes of ballast tanks adjacent to a cargo oil tanks may pass through cargo oil tanks provided that the connections of these pipes are of welded joints or flanged joints which have no risk of leakage. Expansion bends only, not glands, are permitted in these lines within cargo oil tanks.

8. Sounding devices of cargo oil tanks

A suitable sounding device approved by the Society is to be fitted onto any cargo oil tank. The sounding device is to be designed or arranged to prevent any outflow of flammable gases into spaces such as engine room, accommodation spaces, etc. where sources of vapour ignition are normally present.

9. Steam pipes

(1) The cargo oil heating steam supply and return pipes are not to penetrate the cargo oil tank plating, other than at the top of the tank, and the main supply pipes are to be run above the weather deck.
(2) Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank.
(3) The cargo oil heating steam return pipes are to be led to an observation tank or other oil detectors in a position well-ventilated and well-lighted part of the space as apart as possible from hot surfaces such as boilers and ignition sources for the detection of contaminated oil in steam drain.
(4) The steam temperature in steam pipes arranged in cargo oil pump rooms and cargo oil heating steam pipes is not to exceed 220℃.
(5) In the cargo oil pump rooms, drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the bilge wells.
(6) Each branch connection of cleaning steam pipes of cargo oil tanks or other tanks to which a cargo oil pipe is led is to be provided with a screw-down non-return valve or two stop valves.

10. Thermal oil pipes

(1) The thermal oil piping arrangement for the cargo oil tanks is to comply with following requirements:
  (A) All joints in the cargo oil tanks are to be of butt-welded type.
  (B) Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the cargo oil tanks. Where the thermal oil pipe penetrates the oiltight bulkhead between a cargo oil tank and the pump room, shut-off valves or cocks may be installed as close to the bulkhead as practicable.
  (C) The system is to be so arranged that the pressure in the coil is at least 3 m water head above the static head of the cargo when the circulating pump is not operating.
  (D) For the ships only carrying oils having a flash point not exceeding 60 ℃, the requirement in **Pt 5, Ch 6, 1004.** is to be applied.
(2) The thermal oil temperature in the cargo area is not to exceed 220 ℃.

11. Heating plants for asphalts cargo

(1) Heating plants for asphalt tanks are to be arranged.
(2) Heating coils in asphalt tanks are to be sufficient thickness with fully welded joint.
(3) Pumps and valve systems are to be suitable for the type of cargo to be transported.
(4) Heating system for cargo pumps and cargo lines is to be arranged.
(5) Temperature gauges are to be arranged in each cargo tanks enabling the recording of temperatures at bottom, midway between bottom and deck and at deck level in order to prevent overheating of cargo.

12. Integrated cargo oil and ballast driving systems

Emergency stopping devices and control systems of integrated hydraulic and/or electric system used to drive both cargo oil and ballast pumps including active control and safety systems(hereinafter referred to as「integrated cargo oil and ballast driving system」) are to comply with following requirements.

(1) Emergency stopping devices of integrated cargo oil and ballast driving system are to be independent from control systems. A single failure in the emergency stopping devices or the control systems is not to render the integrated cargo oil and ballast driving system inoperative.
(2) Manual emergency stops of cargo oil pumps are to be arranged in a way that they are not to cause the stop of the hydraulic power source.
(3) The control systems are to be provided with backup power supply, which may be satisfied by a duplicate power supply from the main switch board.
The failure of any power supply is to provide audible and visible alarm activation at each location where the control panel is fitted.
(4) Manual overriding or redundant arrangements are to be provided within the control systems to be made available for the operation of the integrated cargo oil and ballast driving system in the event of failure of the automatic or remote control systems.

1003. Piping systems for cargo oil pump rooms, cofferdams and tanks adjacent to cargo oil tanks

1. Bilge piping systems, etc. for cargo oil pump rooms and cofferdams adjacent to cargo oil tanks

(1) Bilge piping system consisting of a power driven pump or eductor is to be provided to discharge bilge in the cargo oil pump room and cofferdams adjacent to a cargo oil tank. The bilge in these spaces is not to be led to the engine room.
(2) Cargo oil pumps may be used for bilge drainage purpose specified in (1), provided that each bilge suction is provided with a screw-down non-return valve, and a stop valve or cock is fitted on the suction side of the pump and, in addition, a stop valve is fitted between the cargo oil pipe and the overboard discharge valve.
(3) Bilge pipes for a cofferdam adjacent to a cargo oil tank are to be entirely separate from those for spaces not adjacent to a cargo oil tank. However, a common bilge pump (except cargo oil pump) may be used for bilge drainage purpose of these spaces subject to the approval by the Society, provided that the bilge pipe for spaces not adjacent to a cargo oil tank has a non-return valve.

(4) Sounding pipes of cofferdams adjacent to a cargo oil tank is not to be less than 38 mm in internal diameter and unless otherwise approved by the Society to be led to above the weather deck.
(5) The bilge system serving the cargo oil pump room is to be operable from outside the cargo oil pump room.
(6) Intrinsically safe type bilge level alarm devices are to be provided in the bilge well of the cargo oil pump room so as to activate an audible and visible alarm in the cargo control room and on the navigation bridge.
(7) The cargo oil pump room is to comply with the requirements in **Pt 8, Ch 2, 104. 10** (3).

2. Ballast tanks adjacent to cargo oil tanks

(1) The requirements in this Paragraph are also applied to ballast tanks used as cofferdams at the fore and after ends of cargo oil tanks in accordance with the requirements in **103. 4.**
(2) Ballast pipes of ballast tanks adjacent to a cargo oil tank are to be separated from other pipes and are not to be led to the engine room. For this purpose, an exclusive pump for ballasting and deballasting these tanks is, generally, to be provided in the pump room. However, where specially approved by the Society, the cargo pumps may be used for the purpose of only de-ballasting in an emergency. In case ballast tanks are not adjacent to cargo oil tank and qualified as being safe, other requirements by the Society will be applied.
(3) Each air pipe to ballast tanks adjacent to a cargo oil tank is to be provided with an easily renewable flame screen at their outlets. In case where approved by the Society, the requirement in **Pt 5, Ch 6, 201. 4** (1) for the dimension of the air pipes will be properly modified.
(4) Sounding pipes of ballast tanks adjacent to a cargo oil tank are to be led to above the weather deck, unless otherwise approved by the Society.

3. Fore peak ballast tank

The fore peak ballast tank ballasted with the system serving other ballast tanks within the cargo area are to be meet the following requirements:

(1) The vent pipe openings are to be located on open deck 3 m away from sources of ignition.
(2) Means are to be provided on the open deck to allow measurement of flammable gas concentrations within the fore peak tank by a suitable portable instrument.
(3) The sounding arrangement to the fore peak tank is to be direct from open deck.
(4) The access to the fore peak tank is to be direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that :
  (A) In case the enclosed space is separated from cargo tanks by cofferdams, the access is to be through a gas tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole stating that the fore peak tank may only be opened after;
    (a) it has been proven to be gas free; or
    (b) any electrical equipment which is not certified safe in the enclosed space is isolated.
  (B) In case the enclosed space has a common boundary with the cargo tanks and is therefore hazardous, the enclosed space is to be well ventilated.

4. Fuel oil tanks adjacent to cargo oil tanks

Sounding pipes of fuel oil tanks adjacent to a cargo oil tank are to be led to above the weather deck, unless otherwise approved by the Society.

5. Pump arrangement for forward compartment

A pump used for bilge drainage or transfer of ballast water or fuel oil in a compartment forward of the cargo oil tanks is to be exclusive and unless otherwise approved by the Society to be installed in the forward part of the ship. However, where approved by the Society, other suitable pumps than specified above may be used for the bilge drainage or transfer of ballast water in a compartment forward of the cargo oil tanks.

1004. Ventilation systems in cargo oil pump rooms

1. The capacity, structure and etc. of ventilation systems are to comply with the requirements in **Pt 8, Ch 2, 104. 4**(1).

2. The ducts are to be arranged, to permit ventilation from the vicinity of the pump room bilge, above the transverse floor plate or bottom longitudinals. An emergency intake located nearly 2 m above the pump room lower grating is to be arranged to the ducts, and this emergency intake is to have a damper which is capable of being opened or closed from the weather deck and lower grating level.

3. The foregoing exhaust system is to be in association with open grating floor plates to allow the free flow of air.

1005. Venting systems of cofferdams adjacent to cargo oil tanks

Effective venting systems are to be provided to cofferdams adjacent to a cargo oil tank. Where air pipes are provided for this purpose, each air pipe is to be provided with an easily renewable flame screen at their outlets, and they are not to be less than 50 mm in internal diameter. Where ventilation system is provided, the construction of the ventilation fan and the wire mesh screens fitted on the exhaust ducts are to comply with the requirements in **1004.** Air holes are to be cut in every part of the structure where there might be a change of gases being pocketed.

1006. Positions of openings of machinery spaces, deck houses, etc. and electrical equipment, etc.

The arrangement of ventilation inlets and outlets and other deckhouse and superstructure boundary space openings is to be such as to complement the requirements in **Pt 8, Ch 2, 104. 3.** Such vents especially for machinery spaces are to be situated as far aft as practicable. Due consideration in this regard is to be given when the ship is equipped to load or discharge at the stern. Sources of ignition such as electrical equipment are to be so arranged as to avoid an explosion hazard.

1007. Tankers carrying only oils having a flash point exceeding 60 °C

For tankers intended only for the carriage of oils having a flash point exceeding 60 ℃ the requirements in this Section applies as follows;

1. The requirements in **1001. 2** to **1002. 9, 1003. 1**(3) to (7), **1003. 2**(1), **1003. 3** & **5, 1005.** to **1006.** may be properly modified.

2. The requirements in **1002. 11, 12** & **1003. 1**(2) are to be satisfied.

3. Bilges of the cargo oil pump room and cofferdams adjacent to a cargo oil tank may be led to the engine room (See **1003. 2**(1)).

4. Ballast pipes of ballast tanks adjacent to a cargo oil tank may be led to the engine room (See **1003. 2**(2)). The wire gauze to prevent the passage of flame required for the outlets of the air pipes to the ballast tanks may be omitted (See **1003. 2**(3)). The sounding pipes of these tanks may be arranged to have openings below the weather deck (See **1003. 2**(4)).

5. The sounding pipes of fuel oil tanks adjacent to a cargo oil tank may not be led to above the weather deck (See **1003. 4**).

6. The requirements in **1004.** are to be satisfied. However, The capacity and structure of fan are to be in accordance with the guidance considered by the Society.

1008. Testing and inspection

After the manufacture of piping systems and ventilating systems of oil carriers, the following tests are to be conducted in addition to the requirements in **Pt 5, Ch 6, Sec 12.**

1. Tests on board

(1) Cargo oil pipes, after the completion of their piping, are to be subjected to a leak test at a pressure of 1.25 times the design pressure or greater.

(2) Heating pipes inside cargo oil tanks are to be subjected to a leak test at a pressure of 1.5 times the design pressure or greater.

2. After installation inboard, auxiliaries and piping systems are to be subjected to the following tests :

(1) A test on the functioning of cargo oil pumps.
(2) A test on the functioning of ventilating systems.
(3) A test on the functioning of various systems concerning safety measures specified in this Section.

Section 11 Electrical Equipment

1101. General

1. Application

Electrical equipment for ships carrying crude oil, petroleum products or other similar liquid cargoes is to comply with the requirements in this Section, (KS C) IEC 60092-502 and all applicable requirements in **Pt 6, Ch 1.**

2. Dangerous spaces

(1) In tankers carrying flammable liquids having a flash point not exceeding 60°C(closed cup test), the following spaces and zones are to be considered as dangerous spaces.
- (A) Zone 0
  - (a) Cargo tanks
  - (b) Slop tanks
  - (c) Interior of pipes for pressure-relief or venting systems for cargo and slop tanks
  - (d) Interior of cargo pipes
- (B) Zone 1
  - (a) Void spaces adjacent to integral cargo tanks
  - (b) Hold spaces containing independent cargo tanks
  - (c) Cofferdams and segregated ballast tanks adjacent to cargo tanks
  - (d) Cargo pump rooms
  - (e) Enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tank bulkheads
  - (f) Spaces, other than cofferdam, adjacent to and below the top of a cargo tank(for example, trunks, passageways and hold)
  - (g) Areas on open deck or semi-enclosed spaces on open deck, within a sphere of 3m radius from any ventilation outlets, cargo tank openings, gas or vapour outlets(for example, cargo tank hatches, sight ports, tank cleaning openings, sounding pipe openings, etc., the same being referred hereinafter), cargo manifold valve, cargo valve, cargo pipe flange and cargo pump-room ventilation outlets for pressure release which permits the flow of small volumes of gas or vapour caused by thermal variation.
  - (h) Areas on open deck or semi-enclosed spaces on open deck, within a vertical cylinder of unlimited height and 6m radius from the outlet centre, and within a hemisphere of 6m radius below the outlet which permits the flow of large volumes of gas or vapour during loading, discharging or ballasting
  - (i) Areas on open deck or semi-enclosed spaces on open deck, within 1.5m from cargo pump room entrances, within a sphere of 1.5m radius from of cargo pump room ventilation inlet and openings specified (B) Zone 1
  - (j) Areas on open deck within spillage coamings surrounding cargo manifold valves and 3m beyond these, up to a height of 2.4m above the deck
  - (k) Areas on open deck over all cargo tanks(including all ballast tanks within the cargo tank block) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3m fore and aft on open deck, up to a height of 2.4m above the deck
  - (l) Compartments for cargo hoses
  - (m) Enclosed or semi-enclosed spaces in which pipes containing cargoes are located
- (C) Zone 2
  - (a) Areas on open deck or semi-enclosed spaces on open deck, within 1.5m surrounding the areas specified in (B)
  - (b) Spaces within 4m surrounding the areas specified in (B) (h)
  - (c) Spaces forming an air-lock between the areas specified in (B) and non-hazardous areas

(d) Areas on open deck within spillage coamings intended to keep spillages clear of accommodation and service spaces and 3m beyond these, up to a height of 2.4m above the deck
(e) Areas on open deck over all cargo tanks where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3m fore and aft on open deck, up to a height of 2.4m above the deck surrounding open or semi-enclosed spaces of (B)
(f) Spaces forward of the open deck specified in (e) and (B) (k), below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5m above the main deck, unless ;
(i) the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5m from the foremost cargo tank and at least 10m measured horizontally from any cargo tank outlet or gas or vapour outlet ; and
(ii) the spaces are mechanically ventilated
(g) Ballast pump room adjacent to cargo tanks

(2) In tankers carrying flammable liquids having a flash point exceeding 60°C(closed cup test), the following spaces and zones are to be considered as dangerous spaces.
(A) In tankers carrying cargoes that are heated more than temperature which is 15°C lower than the flash point, the classification of hazardous areas and spaces are the same as the requirements specified in (1)
(B) In tankers carrying cargoes that are heated less than temperature which is 15°C lower than the flash point or cargoes that are not heated, the hazardous areas are classified in Zone 2 as follows
(a) Cargo tanks
(b) Slop tanks
(c) Interior of pipes for pressure-relief or venting systems for cargo and slop tanks
(d) Interior of cargo pipes

3. System of supply

(1) The system of power supply is to be one of the following systems:
Two-wire insulated for *d.c.*
Two-wire insulated for single-phase *a.c.*,
Three-wire insulated for three-phase *a.c.*,
(2) Generator circuits, power supply and distribution circuits are not to be earthed, nor to depend on hull return system except the following:
(a) Impressed current cathodic protection system for outer hull protection only,
(b) Earth indication devices or other alternative means, however, in no case the circulation current to exceed 30 mA,
(c) Limited and locally earthed systems, such as starting and ignition systems of internal combustion engines,
(d) Electrical circuits having no fear of causing hull current in the dangerous spaces, subjected to the approval of the Society.

4. Isolating means

Distribution circuits for the electrical equipments installed in dangerous spaces are to be provided on each circuit with multipole linked isolation switches in a safe space. In addition, the isolation switches are to be clearly labelled to identify the electrical equipment to be connected with, and further effective means are to be provided to avoid danger due to unauthorized operation of the isolation switches.

5. Earth detection

Excluding intrinsically safe circuits, the feeders and distribution circuits to be connected to the electrical equipments in the dangerous spaces or to run through the dangerous spaces are to be provided with such devices that keep monitoring the insulation levels and will give an alarm in case of abnormally low level.

1102. Wirings in dangerous spaces

1. General

Cables are generally not to be installed in the dangerous spaces specified in **1101. 2.** Where installation of cables in such spaces is unavoidable, it is to comply with the following requirements.

2. Selection of cables

Cables are to be one of the following. Where corrosion may be expected, a non-metallic impervious sheath is to be applied over metallic sheath or armour of cables for corrosion protection.

(1) Mineral insulated and metallic sheathed.
(2) Lead sheathed and armoured.
(3) Non-metallic impervious sheathed and armoured.

3. Installation of cables

(1) Cables are to be installed as close to the hull center line as practicable.
(2) Cables are to be installed sufficiently distant from decks, bulkheads, tanks and various kinds of pipes.
(3) Cables which are installed on the fore and aft gangways and the decks are to be protected against mechanical damage. Further, the cables and their supports are to be fitted in such a manner as to withstand expansion and contraction and other effects of the hull structure.
(4) The penetration part of the cables or cable pipes through decks and bulkheads of the dangerous spaces is to be constructed so as to maintain gastightness and liquid-tightness as the case may require.
(5) When mineral insulated cables are used, special precautions are to be taken to ensure sound terminations.

4. Earthing of cables

All metallic protective coverings of power and lighting cables passing through dangerous spaces, or connected to equipment in such spaces, are to be earthed at least at each end.

5. Intrinsically safe circuits

(1) The cables for intrinsically safe circuits associated with intrinsically safe type electrical equipment are to be of exclusive use, being installed separately from cables for general circuits.
(2) Intrinsically safe circuits associated with different kinds of intrinsically safe type electrical equipment are generally to be wired individually using different cables. Where it is necessary to use a multi-core cable in common, a cable which has shields by each core or each pair of cores is to be used, having such shields earthed effectively.

1103. Electrical equipment in dangerous spaces

1. General

(1) Electrical equipment is generally not to be installed in the dangerous spaces specified in **1101. 2.** Where installation of electrical equipment is unavoidable, it is to comply with the following requirements.
(2) Explosion-protected electrical equipment is to comply with the requirements in **Pt 6, Ch 1, Sec 9.**
(3) Electrical measuring, monitoring, control and communication apparatus are to be of intrinsically safe type.
(4) Portable lamps are to be of intrinsically safe or flameproof type with self-contained battery or of air-driven type with pressurized enclosure.
(5) Lighting fittings of increased safety type are to be of a type accepted by the Society for oil tankers.

2. All dangerous spaces specified in 1101. 2

Intrinsically safe type electrical equipment may be installed.

3. Cathodic protection

(1) Impressed current systems are not to be permitted in oil cargo tanks.

(2) Magnesium or magnesium alloy anodes are not to be permitted in oil tanks.
(3) Aluminium anodes are only permitted in cargo tanks of tankers in locations where the potential energy does not exceed 275 N-m. Aluminium anodes are not to be located under tank hatches or Butterworth openings in order to avoid any metal parts falling on the fitted anodes, unless protected by adjacent structure.
(4) There is no restriction on the position of zinc anodes.
(5) The anodes are to have steel cores and these are to be sufficiently rigid to avoid resonance in the anode support and be designed so that they retain the anode even when it is wasted.
(6) The steel inserts are to be attached to the structure by means of a continuous weld of adequate section. Alternatively they may be attached to separate supports by bolting, provided a minimum of two bolts with locknuts are used. However, approved mechanical means of clamping will be accepted.
(7) The supports at each end of an anode are not to be attached to separate items which are likely to move independently.
(8) When anode inserts or supports are welded to the structure, they are to be arranged so that the welds are clear of stress raisers.

4. Cofferdams, double bottoms and duct-keels adjoining cargo tanks

(1) The transducers of navigation instruments such as electric depth sounding devices may be installed. The transducers are to be of totally-enclosed type and to be housed in a gastight enclosure clear of the cargo tank. The cables to the transducers are to be installed in heavy gauge galvanized steel pipes with gastight joints up to the main deck.
(2) Where the anodes or electrodes and the cables of an impressed current cathodic protection system for outer hull protection are installed in such spaces, the requirements in the preceding (1) are to be applied.
(3) Lighting fittings of flameproof type or of air-driven type with pressurized enclosure may be installed in double bottoms and ductkeels equipped with machinery which is to be manned for operation and watch. The lighting fittings are to be arranged on at least two independent circuits.

5. Dangerous spaces specified in 1101. 2 (1) (B) (e)

(1) Lighting fittings of flameproof type or of air-driven type with pressurized enclosure may be installed. Lighting fittings in the spaces which are normally attended by the personnel are to be supplied by at least two independent circuits.
(2) Cables may be run through in these spaces.

6. Dangerous spaces specified in 1101. 2 (1) (B) (f) and ballast tanks adjoining cargo tanks

(1) Electrical equipment specified in **Par 3** may be installed.
(2) Lighting fittings of flameproof type or air-driven type with pressurized enclosure may be installed in the spaces equipped with machinery which is to be manned for operation and watch.
(3) Through-runs of cables are to be subjected to the approval of the Society.

7. Dangerous spaces specified in 1101. 2 (1) (B) (d)

(1) Electrical equipment specified in **Par 3** may be installed.
(2) Lighting fittings of flameproof type of air-driven type with pressurized enclosure may be installed. Lighting fittings are to be arranged on at least two independent circuits.
(3) Where cables are run through cargo pump room entrances, they are to be installed in heavy gauge steel pipes or steel ducts with gastight joints.

8. Dangerous spaces specified in 1101. 2 (1) (B) (m), (l)

(1) Lighting fittings of flameproof type or air-driven type with pressurized enclosure may be installed.
(2) Where cables are run through these spaces, they are to be installed in heavy gauge steel pipes or steel ducts with gastight joints.

9. Dangerous spaces specified in 1101. 2 (1) (B) (g), (h), (k) and (1) (C) (b), (e)

(1) Electrical equipment of flameproof type, pressurized protected type and increased safety type may be installed.
(2) Cables may be run through the spaces. However, no cable expansion bends are to be provided in the spaces specified in **1101. 2** (8) as far as practicable.

10. Enclosed and semi-enclosed spaces having a direct opening in 1101. 2

These spaces are to be taken as equivalent to the adjacent dangerous spaces having direct openings, and the electrical installations are to be in compliance with the corresponding requirements in the preceding **Pars 1** to **8.**

11. Electric motors driving equipment in cargo pump room

Electric motors driving equipment located in cargo pump room spaces are to be installed in the space partitioned from these spaces by a gastight bulkhead and deck. In addition, suitable stuffing boxes are to be fitted where shafts pass through gastight bulkheads and decks.

12. Lighting in dangerous spaces

(1) Where dangerous spaces are illuminated through glazed ports, these are to be effectively protected from mechanical damage and are to have strong covers secured from the side of the safe spaces. Glazed ports are to be so constructed that glass and sealing will not be impaired by the working of the ship.
(2) The glass and the protection of the light fitting in the preceding (1) are not to impair the integrity of the bulkhead and are to be of equivalent strength. The fitting is to have the same resistance to fire and smoke as the unpierced bulkhead.
(3) To discourage personnel from entering the cargo pump room when the ventilation is not in operation, one of the following means is to be applied.
 (A) Lightings in cargo pump room are to be interlocked with ventilation system such that ventilation systems are to be in operation to energize the lighting. Failure of the ventilation systems should not cause the lighting to go out. Emergency lighting, if fitted, is not to be interlocked.
 (B) Audible and visible alarms located at the door to the cargo pump room are to provide a warning if the door is opened when the cargo pump room ventilation is not in operation. A notice is to be prominently displayed on or adjacent to the pump room door to the effect that the alarms indicate that the pump room ventilation is not in operation, that the pump room atmosphere may therefore be hazardous, and that the pump room is not to be entered until verified safe. The audible alarm is also to sound on the navigation bridge. Reset of the alarm is to be provided from the navigation bridge only.

13. Electric motors driving ventilators for dangerous spaces

Electric motors driving the ventilators for cargo pump rooms and the exhaust ventilators for other dangerous spaces are not to be installed in the ventilation ducts.

1104. Earthing and bonding of cargo tanks, process plant and piping systems for the control of static electricity

1. Bonding straps are required for cargo tanks and process plant, piping systems which are not permanently connected to the hull of the ship as the followings.

(1) Independent cargo tanks
(2) Cargo tanks and piping systems which are electrically separated from the hull of the ship
(3) Pipe connections arranged for the removal of spool pieces

2. Where bonding straps are required, they are to comply with the followings.

(1) The bonding straps are to be clearly visible so that any shortcomings can be clearly detected.
(2) The bonding straps are to be designed and sited so that they are protected against mechanical damage and, as far as possible, they are not affected by high resistivity contamination(corrosive products or paint).
(3) The bonding straps are to be easy to install and replace. ⚓

CHAPTER 2 ORE CARRIERS

Section 1 General

101. Application

1. The construction and equipment of ships intended to be registered and classed as "Ore Carriers" are to be in accordance with the requirements in this Chapter or equivalent thereto.

2. Except where specially required in this Chapter, the general requirements for the construction and equipment of steel ships are to be applied.

3. The requirements in this Chapter are framed for ships not less than 120 m and up to 230 m in length and of usual form, having single deck, machinery aft, two rows of longitudinal watertight bulkheads, and also having double bottoms under ore holds, decks and bottoms with longitudinal framing.

4. Ore carriers which are different construction from the scope of application given above or the length of which exceeds 230 m and the requirements in this Chapter are considered to be not applicable, matters are to be determined as deemed appropriate by the Society.

5. Except where specially required in this Chapter, the requirements in Chapter 3 are to be applied.

102. Direct strength calculation

When the scantlings of each members are determined based upon direct calculations defined **Pt 3, Ch 1, 206.** of the Rules, concerned members, load cases, the scope of strength calculation and permissible stresses are to be at the discretion of the Society.

103. Drainage

1. In general, one bilge suction opening is to be provided on each side of the ship at the after end of the each hold. Where the length of ore hold in ships having only one hold exceeds 66 meters, additional bilge suction opening is to be arranged in a suitable position in the forward half-length of the hold.

2. Bilge wells are to be provided at suitable positions so as to protect the cover plates from the direct strike of ore and to be provided with rose boxes or other suitable means so that the suction openings may not be choked by ore dust, etc.

3. Where bilge pipes are led through double bottoms, side tanks or void spaces, non-return valves, or stop valves capable of being closed from a readily accessible position, are to be provided at their open ends.

4. Bilge suction branch pipes may be of inside diameter obtained from the formula in **Pt 5, Ch 6, 404. 2,** taking B as the mean breadth of the ore hold.

Section 2 Construction and Dimension

201. Subdivision

1. The distance between longitudinal watertight bulkheads and ship's side is not to be less than that obtained from the following formula even at the narrow parts at the ends of the ship:

$$l = 4L + 500 \quad (\text{mm})$$

2. At least one transverse watertight bulkhead is to be provided between longitudinal watertight bulkheads at a position somewhat forward of the middle of the length of the ore cargo space, except where the Society is satisfied with the omission of such bulkhead.

202. Double bottoms

1. The height of double bottoms is to be determined in such a manner that the centre of gravity of the ship is sufficiently high in full load condition. The standard height is to be $0.2D$ (m).

2. The thickness of centre girders is not to be less than that obtained from the following formula :

$$t = 0.04L + 6.0 \quad (\text{mm})$$

3. Floor plates or bottom transverses are to be arranged at the positions of bulkheads or transverses in side tanks or void spaces.

4. Where longitudinal framing is adopted in the inner bottom, the thickness of the floor plates is not to be less than that obtained from the following formula. The sum of the depth of lightening holes, slots, etc. is not to exceed a half of the depth of the floor at the part $b/4$ or more from the ends of the floor and a quarter of the depth of the floor at $b/8$ from the ends of the floor. Where suitable reinforcement is provided, lightening holes over the preceding limits may be permitted.

$$t = 62.5K\frac{SbH}{d_0} + 1.5 \quad (\text{mm})$$

where:

S = spacing of floor plates (m).

b = breadth of floor plates (m).

H = value obtained from the following formulae :

Where floor plates only are arranged : $H = 2h - d$ (m)

Where one transverse is ar ranged between adjacent floor plates to support inner bottom longitudinals : $H = 1.6h - d$ (m)

h = vertical distance from the upper surface of inner bottom plates to the upper deck measured at the centre line of the ship (m).

d_0 = depth of floor plates (mm).

5. Stiffeners are to be provided on the centre girder plates and floor plates in the spacing not greater than that obtained from the following formula :

$$l = 100t - 250 \quad (\text{mm})$$

where:

t = thickness of centre girders or floor plates (mm).

6. The thickness of inner bottom plates is not to be less than that obtained from the following formulae, whichever is the greater :

$$t_1 = CS\sqrt{Kh} + 4 \quad (\text{mm})$$
$$t_2 = 0.28(M_{GR} + 50)\sqrt{SK} + 5 \quad (\text{mm})$$

where:

C = coefficient obtained from the following formulae, depending on the value of l/S

$\left(0.46\dfrac{l}{S}+2.64\right)\sqrt{\gamma}$: for $1 \le \dfrac{l}{S} < 3.5$

$4.25\sqrt{\gamma}$: for $3.5 \le \dfrac{l}{S}$

l = spacing of solid floor(m)

γ = specific gravity of cargoes

$$\gamma = \frac{W}{V}$$

W = mass of cargoes for the hold under consideration (ton)

V = volume of the hold excluding its hatchway(m^3)

However, the value of γ is not to be less than 1.2 times the ratio of the designed deadweight(t) to the total capacity(m^3) of all holds

S = spacing of inner bottom longitudinals (m).

h = as specified in **Par 4.**

M_{GR} = mass of grab (t)

7. The section modulus of inner bottom longitudinals is not to be less than that obtained from the following formula :

$$Z = \frac{2KShl^2}{1.2\sigma_y - \sigma_x K} \times 10^3 \quad (cm^3)$$

where:

S = spacing of inner bottom longitudinals (m).

h = as specified in **Par 4.**

l = spacing of floor plates or transverses (m).

σ_y = 235 (N/mm^2)

$$\sigma_x = \frac{(M_s + M_w)y}{I} \times 10^5 \quad (N/mm^2)$$

M_s, M_w, I = as specified in **Pt 3, Ch 3, Table 3.3.1**

y = vertical distance from top of the inner bottom to neutral axis at centre line (m)

203. Construction and scantlings of wing tanks or void spaces

1. Longitudinal frames and beams are to be as required in the provisions of **Pt 10, Sec 3** and **Sec 7.**

2. Construction and scantlings of transverses, girders, webs and cross ties are to be as required in the following provisions.

(1) The thickness of transverses, girders, webs and cross ties are not to be less than those given by **Ch 10, Table 7.10.1** according to the length of the ship.

(2) Girders and transverses in the same plane are to be so arranged that abrupt change in the strength and rigidity is avoided. They are to have brackets of sufficient scantlings and with properly rounded corners at their ends.

(3) The depth of girders and transverses is not to be less than 2.5 times that of slots for frames, beams and stiffeners.

(4) As for the face plates composing girders, the thickness is not to be less than that of web plates and the full width is not to be less than that obtained from the following formula.

$$85.4\sqrt{d_0 l} \qquad (\mathrm{mm})$$

Where,

d_0 : Depth of girder(m). In case where the girder is a balanced girder, d_0 is the depth from the surface of plate to the face plate(m).

l : Distance between supports of girder(m). Where, however, effective tripping brackets are provided, they may be taken as supports.

(5) Transverses are to be effectively stiffened according to the **Ch 1, 405. 1** (4) and (5), and lower brackets of transverses on longitudinal bulkheads and side shell and web plates in the vicinity of the edge of the brackets are to be provided stiffeners in a closer spacing.

(6) The scantlings of transverses are to be as required in the provisions of **Ch 1, 403. 1**. (Refer to **Fig 7.2.1**)

(7) The scantlings of transverses on longitudinal bulkheads are to be as required in the provisions of **Ch 1, 403. 2**.

(8) The scantlings of bottom transverses are to be as required in the provisions of **Ch 1, 403. 3**. (Refer to **Fig 7.2.1**)

(9) The scantlings of deck transverses are to be as required in the provisions of **Ch 1, 403. 4**.

(10) The web thickness of transverse is not to be less than that obtained from the formula for t_3 given in **Ch 10, 405. 3**.

(11) Where side transverses and transverses on longitudinal bulkheads are connected with cross ties, the cross ties are to be as required in the following provisions.

(A) The construction of cross ties is to be as required in the following provisions.

(i) Brackets are to be provided at the ends of cross ties to connect cross ties with transverses.

(ii) Where the breadth of face plates forming cross ties exceeds 150 mm on one side of the web, stiffeners are to be provided at proper intervals to support the face plates as well.

3. The construction and scantlings of bulkheads are to comply with the requirements in **Ch 10, 103.** and **Sec 2**. When applying the requirements in **Ch 10, Sec 2**, h_1, h_2 and h_3 are to be substituted for those applicable to deep tank bulkhead.

4. The thickness of longitudinal watertight bulkhead plating at the lower part of the ore hold is to be properly increased in relation to the thickness of inner bottom plating.

5. The thickness of longitudinal watertight bulkheads is to be in accordance with the requirements in **Pt 3, Ch 3, 302., 303.** as well as **Sec 4.**

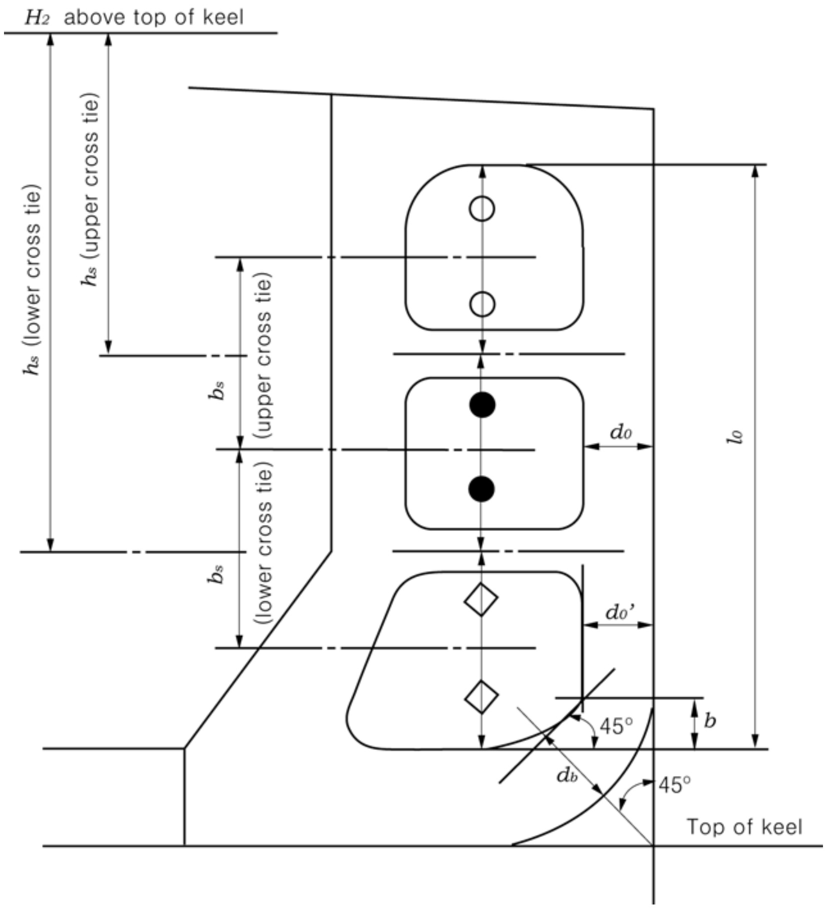


Fig 7.2.2 Measurement of l_0, d_0, b, b_s

204. Transverse bulkheads in ore holds

1. The scantlings of the members of the transverse bulkheads in ore holds are to be in accordance with the requirements in **Pt 3, Ch 15, Sec 2.** Where, however, in application of these requirements, h in the formula is to be substituted for $0.72h'$, h' is to be in accordance with the following.

(1) Bulkhead platings:
Vertical distance (m) from the lower edge of the bulkhead plate to the upper deck at the centre line of the ship.

(2) Stiffeners:
Vertical distance (m) from the midpoint of l for vertical stiffeners or from the midpoint of distance between the adjacent stiffeners for horizontal stiffeners to the upper deck at centre line. Where, however, the distance is less than 6 metres, h' is to be at least 0.8 times the distance plus 1.2 m, l is as specified in **Pt 3, Ch 15, 203.**

(3) Girders:
Vertical distance (m) from the mid-point of l for vertical girders or from the mid-point of S for horizontal girders, to the upper deck at centre line. Where, however, the distance is less than 6 metres, h' is to be at least 0.8 times the distance plus 1.2 m, l and S are as specified in **Pt 3, Ch 15, 204.**

2. Notwithstanding the requirements in **Par 1**, the thickness of the transverse bulkhead platings is not to be less than 7 mm.

3. The thickness of the lowest strake of bulkhead plating is to be appropriately increased referring to the thickness of inner bottom plating.

205. Relative deformation of wing tanks

As for wing tanks, where the value obtained from the following formula exceeds 0.18, a special consideration is to be given to the structure of the wing tanks :

$$\delta = \frac{2h - 0.65d}{n_b K_b + n_s \eta_s K_s + n_t \eta_t K_t} \cdot \frac{a}{b} l$$

where:

h = vertical distance between the top of inner bottom plating and the upper deck at the centre line of the ship (m).

l = length of one ore hold (m).

$a, b, n_b, n_s, n_t, \eta_s, \eta_t, K_b, K_s, K_t$ = values to be obtained by applying the requirements in **Ch 1, 601,** respectively.

206. Ore/Oil carriers

1. Such ore carriers as intended to carry oils in the ore holds and/or wing tanks (hereinafter referred to as “ore/oil carriers”) are to comply with the relevant requirements in **Ch 1,** in addition to those in this Section.

2. In addition to the requirements in this Section, special requirements may be given as deemed necessary for ore/oil carriers by the Society.

207. Slop tanks in ore/oil carriers

1. Cofferdams are to be provided between slop tanks and machinery spaces in accordance with the requirements of **Ch 1, 103.** In addition, cofferdams are to be provided between slop tanks and ore holds, except where the slop tanks are cleaned and gas freed at any time prior to loading ore cargoes.

2. The cofferdams specified in **Par 1** are to be capable of being flooded, except where the cofferdams are used concurrently as pump rooms, fuel oil tanks or water ballast tanks, or cargo oil tanks (in case of cofferdams between slop tanks and ore holds only).

3. Adequate ventilation is to be provided for the spaces surrounding the slop tanks.

4. Notice boards are to be errected at suitable points detailing the precautions to be observed prior to loading or unloading, or whilst carrying ore cargo with oily water in the slop tanks.

5. It is recommended to provide an inert gas system for the slop tanks. ⚓

CHAPTER 3 BULK CARRIERS

Section 1 General

101. Application

1. The requirements in this Chapter apply to bulk carriers which were contracted for construction after 1 April 2006, excluding the vessels which should be applied **Pt.11** (IACS Common Structural Rules for Bulk Carriers). However, the requirements in **Sec 14** and **Sec 16** apply to bulk carriers including the vessels which should be applied **Pt 11**.

2. The construction and equipment of ships intended to be registered as "Bulk Carriers" are to be in accordance with the requirements in this Chapter or equivalent thereto.

3. Except where specially required in this Chapter, the general requirements for the construction and equipment of steel ships are to be applied.

4. The requirements in this Chapter are framed for ships not less than 100 m and up to 250 m in length and of usual form, having single deck, machinery aft, bilge hopper tanks and topside tanks, and also double bottoms under cargo holds, and decks and bottoms with longitudinal framing.

5. Ships with different construction from the scope of application given above or larger ships to which the requirements in this Chapter are not applicable, are to be at the discretion of the Society.

6. Bulk carriers, which were contracted for construction before 1 July 1998, and the keels of which were laid or which were at a similar stage of construction before 1 July 1999, are to be determined at the discretion of the Society.

102. Plans and documents for approval

Plans and documents submitted for approval are to indicate kinds of cargo and/or ballast, loading capacity, level of liquid, etc in each of the holds at service.

103. Direct strength calculation

Where approved by the Society, the scantlings of structural members may be determined based upon direct strength calculation specified in **Pt 3, Ch 1, 206.**

104. Drainage of bulk holds

1. In general, one bilge suction opening is to be arranged on each side of the ship at the after end of the each hold.

2. Bilge wells are to be arranged at suitable positions so as to protect the cover plates from the direct strike of bulk cargoes and to be provided with mud boxes or other suitable means so that the suction openings may not be choked by bulk dust, etc.

3. Where bilge pipes are led through double bottoms, side tanks or void spaces, non-return valves or stop valves capable of being closed from a readily accessible position, are to be provided at their open ends.

4. Where scupper pipes on topside tanks are led over board, stop valves capable of being operated at deck and automatic non-return valves attached to shell plating are to be provided.

105. Coal transportation

For ships intended for transport of coal, care is to be taken to the following:
(1) Structure between holds and other compartments is to be airtight.
(2) Trimming hatches are recommended to be provided outside superstructures and deckhouses.
(3) Ventilation of holds is to be made by a ventilation system provided on the weather part.

106. Minimum thickness

1. The thickness of inner bottom plating, bulkhead plates, floor plates, girders and bracket plates in double bottom bilge hopper tanks, topside tanks, side tanks, hold tanks etc. are not to be less than those required by **Table 7.3.1** according to the length of ships.

Table 7.3.1 Minimum thickness

Length of ships(m)	Minimum thickness(mm)
$L < 105$	8.0
$105 \leq L < 120$	8.5
$120 \leq L < 135$	9.0
$135 \leq L < 150$	9.5
$150 \leq L < 165$	10.0
$165 \leq L < 180$	10.5
$180 \leq L < 195$	11.0
$195 \leq L < 225$	11.5
$225 \leq L < 275$	12.0
$275 \leq L < 325$	12.5
$325 \leq L < 375$	13.0
$375 \leq L$	13.5

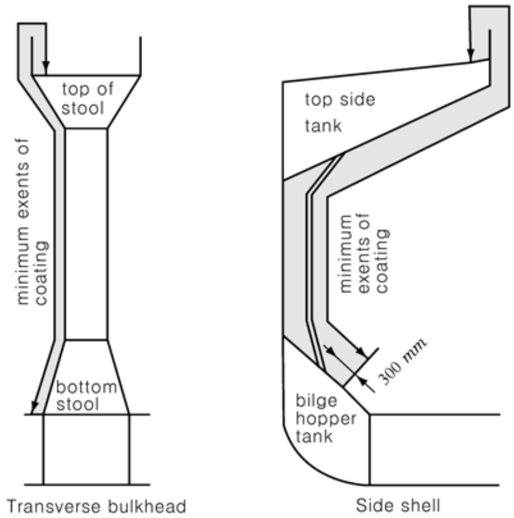


Fig 7.3.1 Minimum extent of corrosion protection coating for cargo hold

2. The minimum thickness of side shell plating located between hopper and upper wing tanks is not to be less than t_{min} in mm, given by :

$$t_{min} = \sqrt{L} \quad (mm)$$

3. The minimum thickness of frame webs within the cargo area except the foremost cargo hold is not to be less than :

$$t_{min} = 0.03L + 7 \quad (mm)$$

Where L is the length of ships in meters, but need not be taken greater than 200 m. The thickness of the frame lower bracket is not to be less than the greater of the fitted thickness of the side frame web and $t_{min} + 2$ (mm). The thickness of the frame upper bracket is not to be less than the greater of the fitted thickness of the side frame web and t_{min}.

4. The minimum thickness of frame webs in way of the foremost hold is not to be less than 1.15 times of thickness as specified in **Par 3.** The thickness of the frame lower bracket in way of the foremost hold is not to be less than the greater of the fitted thickness of the side frame web and $1.15\, t_{min} + 2$ (mm). The thickness of the frame upper bracket is not to be less than the greater of the fitted thickness of the side frame web and $1.15\, t_{min}$.

107. Corrosion protection coatings for cargo hold spaces

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of the cargo holds, excluding the flat tank top areas and the hopper tankers sloping plating approximately 300 mm below the side shell frame and brackets, are to have an efficient protective coating (epoxy coating or equivalent) applied in accordance with the manufacturers recommendation.(See **Fig 7.3.1**)

108. Longitudinal Strength

1. The longitudinal strength of bulk carriers is to comply with the requirements in **Pt 3, Ch 3.**

2. In addition to the requirements in **Par 1**, all bulk carriers of 150 m in length and above, intending to carry cargoes having bulk density of 1.0 t/m^3, or above are to be in accordance with the requirements in **Sec 10.**

Section 2 Harmonised Notations and Corresponding Design Loading Conditions

201. General

1. General

A bulk carrier may in actual operation be loaded differently from the design loading conditions specified in the loading manual, provided limitations for longitudinal and local strength as defined in the loading manual and loading instrument onboard and applicable stability requirements are not exceeded.

2. Application

(1) The requirements are applicable to "Bulk Carrier" of usual form, having single deck, machinery aft, bilge hopper tanks and topside tanks, and also double bottoms under cargo holds, and deck and bottoms with longitudinal framing, and length as defined in **Pt. 3, Ch 1, 102.** of 150 m or above and contracted for new construction on or after 1 July 2003.
(2) The loading conditions listed under **Par 4**. are to be used for the checking of rules criteria regarding longitudinal strength, local strength, capacity and disposition of ballast tanks and stability.
(3) The loading conditions listed under **Par 5.** are to be used for the checking of rule criteria regarding local strength. The local strength is to be in accordance with the requirements of **Pt 3, Annex 3-2 Guidance for the Direct Strength Assessment.**
(4) For the purpose of applying the conditions given in the requirement, maximum draught is to be taken as moulded summer load line draught.

3. Harmonised notations and annotations

Bulk Carriers are to be assigned one of the following notations:

BC-A : for bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions.
BC-B : for bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to BC-C conditions.
BC-C : for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

The following additional notations and annotations are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

(1) additional notations;
(max cargo density ... t/m^3) for notations BC-A and BC-B if the maximum cargo density is less than 3.0 t/m^3
(no MP) for all notations when the vessel has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in **Par 5.** (3)
(2) annotations;
(allowed combination of specified empty holds) for notation BC-A.

4. Design loading conditions (General)

(1) BC-C
Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at maximum draught with all ballast tanks empty.
(2) BC-B

As required for BC-C, plus:
Homogeneous cargo loaded condition with cargo density 3.0 t/m^3, and the same filling rate (cargo mass/hold cubic capacity) in all cargo holds at maximum draught with all ballast tanks empty.
In cases where the cargo density applied for this design loading condition is less than 3.0 t/m^3, the maximum density of the cargo that the vessel is allowed to carry is to be indicated with the additional notation (max cargo density ... t/m^3).

(3) BC-A
As required for BC-B, plus:
At least one cargo loaded condition with specified holds empty, with cargo density 3.0 t/m^3, and the same filling rate (cargo mass/hold cubic capacity) in all loaded cargo holds at maximum draught with all ballast tanks empty.
The combination of specified empty holds shall be indicated with the annotation (Holds Nos. ... may be empty).
In such cases where the design cargo density applied is less than 3.0 t/m^3, the maximum density of the cargo that the vessel is allowed to carry shall be indicated within the annotation, e.g. (Holds Nos. ... may be empty, with max cargo density ... t/m^3).

(4) Ballast conditions (applicable to all notations)
(A) Ballast tank capacity and disposition
All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements:
(a) Normal ballast condition
Normal ballast condition for the purpose of this requirement is a ballast (no cargo) condition where :
(i) the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in the last paragraph of **Pt 3, Annex 3-1 3.** (1) (G) of the Guidance are to be complied with.
(ii) any cargo hold or holds adapted for the carriage of water ballast at sea are to be empty.
(iii) the propeller is to be fully immersed, and
(iv) the trim is to be by the stern and is not to exceed $0.015L$, where L is the length between perpendiculars of the ship.
In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.
(b) Heavy ballast condition
Heavy ballast condition for the purpose of this Requirement is a ballast (no cargo) condition where :
(i) the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in the last paragraph of **Pt 3, Annex 3-1 3.** (1) (G) of the Guidance are to be complied with.
(ii) at least one cargo hold adapted for carriage of water ballast at sea, where required or provided, is to be full,
(iii) the propeller immersion I/D is to be at least 60%, where
I = the distance from propeller centerline to the waterline
D = propeller diameter, and
(iv) the trim is to be by the stern and is not to exceed $0.015L$, where L is the length between perpendiculars of the ship.
(v) the moulded forward draught in the heavy ballast condition is not to be less than the smaller of $0.03L$ or 8 m
(B) Strength requirements
All bulk carriers are to meet the following strength requirements :
(a) Normal ballast condition
(i) the structures of bottom forward are to be strengthened in accordance with the **Pt 3, Ch 4, Sec. 4 404.** against slamming for the condition of (A) (a) at the lightest forward draught.
(ii) the longitudinal strength requirements are to be met for the condition of (A) (a) and
(iii) in addition, the longitudinal strength requirements are to be met with all ballast tanks 100% full.

(b) Heavy ballast condition
(i) the longitudinal strength requirements are to be met for the condition of (A) (b)
(ii) in addition to the condition in (B) (b) (i), the longitudinal strength requirements are to be met under a condition with all ballast tanks 100% full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100% full, and
(iii) where more than one hold is adapted and designated for carriage of water ballast at sea, it will not be required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

(5) Departure and arrival conditions
Unless otherwise specified, each of the design loading conditions defined in **4.** (1) to **4.** (4) is to be investigated for the arrival and departure conditions as defined below:
- Departure condition : with bunker tanks not less than 95% full and other consumables 100%
- Arrival condition : with 10% of consumables.

5. Design loading conditions (for local strength)

(1) Definitions
The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.
The following definitions apply:
M_H : the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught.
M_{Full} : the cargo mass in a cargo hold corresponding to cargo with virtual density (homogeneous mass/hold cubic capacity, minimum 1.0 t/m^3) filled to the top of the hatch coaming. M_{Full} is in no case to be less than M_H.
M_{HD} : the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draft.

(2) General conditions applicable for all notations
(A) Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.
(B) Any cargo hold is to be capable of carrying minimum 50% of M_H, with all double bottom tanks in way of the cargo hold being empty, at maximum draught.
(C) Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

(3) Conditions applicable for all notations, except when notation {no MP} is assigned
(A) Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught.
(B) Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83% of maximum draught.
(C) Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the maximum draught. The requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast, if applicable.
(D) Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75% of maximum draught.

(4) Additional conditions applicable for BC-A notation only
(A) Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty.
(B) Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying M_{HD} plus 10% of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty

in way of the cargo hold, at maximum draught. In operation the maximum allowable cargo mass shall be limited to M_{HD}.

(C) Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

In operation the maximum allowable mass shall be limited to the maximum cargo load according to the design loading conditions.

(5) Additional conditions applicable for ballast hold(s) only Cargo holds, which are designed as ballast water holds, are to be capable of being 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.

(6) Additional conditions applicable during loading and unloading in harbour only

(A) Any single cargo hold is to be capable of holding the maximum allowable sea-going mass at 67% of maximum draught, in harbour condition.

(B) Any two adjacent cargo holds are to be capable of carrying M_{Full}, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in he double bottom in way of the cargo hold being empty, at 67% of maximum draught, in harbour condition.

(C) A reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the maximum draught in sea-going condition, but shall not exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

(7) Hold mass curves

Based on the design loading criteria for local strength, as given in preceding **5.** (2) to **5.** (6) (except **5.** (5)), hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught, in seagoing condition as well as during loading and unloading in harbour.

At other draughts than those specified in the preceding design loading conditions, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught. Hold mass curves for each single hold, as well as for any two adjacent holds, are to be included.

Section 3 Double Bottoms

301. General

1. Except where required in this Section, the requirements in **Pt 3, Ch 7** are to be applied.

2. The scantlings of structural members in double bottom tanks intended to be deep tanks are to be correspondingly in accordance with the requirements in **Pt 3, Ch 7,** as well as the requirements in this Section. However, the thickness of inner bottom plating need not be increased by 1 mm as given in **Pt 3, Ch 15, 208.** for the top plating of deep tanks.

3. Specific gravity of cargoes described in this Section is as defined by the following formula :

$$\gamma = \frac{W}{V}$$

where:

W = mass of cargoes for the hold under consideration (t).

V = volume of the hold excluding its hatchway (m^3)

4. The coefficient specified in **302.** to **304.** is to be obtained from the following formula. Where, however, the angle between hopper plate and horizontal plane, β, is very large, the value of k is to be at the discretion of the Society. (See **Fig 7.3.2**)

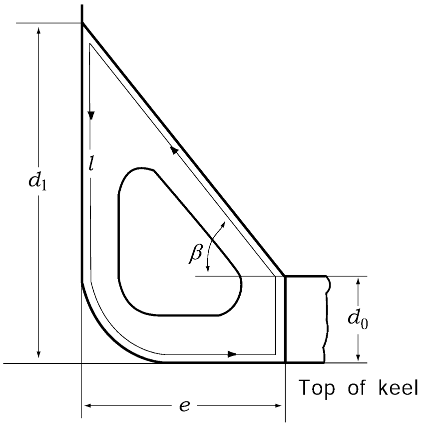


Fig 7.3.2 Measurement of l, e, d_0, d_1 etc.

$$k = 2.1 \frac{l\, l_h}{e^2 \left(1 + \frac{d_1}{d_0}\right)^2}$$

where:

l_h = length of hold (m). Where stools are provided at transverse bulkheads, l_h may be reduced to the distance between the toes.

l = total girth length of hopper plate, side girder and shell plating composing the bilge hopper (m).

e = width of bilge hopper (m)

d_1 = distance from the top of keel to the top of bilge hopper (m).

d_0 = depth of centre girder (m).

5. In addition to the requirements in this **Sec**, all single side skin bulk carriers of 150 m in length and above, intending to carry cargoes having bulk density of 1.0 t/m^3 or above, are to be in accordance with the requirements in **Sec 11.**

302. Centre girders and side girders

1. Side girders are to be provided at the toes of bilge hoppers. In addition, side girders are to be arranged between the centre girder and the side girder at the toe of bilge hoppers at intervals approximately not exceeding the distance obtained from the given in **Table 7.3.2.** Where, however, the value given by the formula exceeds 4.6 metres, the distance is to be taken as 4.6 metres.

2. Except where specially approved by the Society, the thickness and depth of centre girders are not to be less than those obtained from the formula given in **Table 7.3.2.** In any case, however, the depth is not to be less than $B/20$.

3. Where duct keels are provided, their spacing is not to be larger than 1.8 m. Sufficient consideration is to be paid to strength continuity of solid floors and stiffness of shell plating and inner bottom plating between duct keels.

4. Where the distance from the top of inner bottom plating to the top of overflow pipes is more than 15 m, brackets are to be provided at both ends of vertical stiffeners on watertight side girders and to be connected with inner bottom plating and bottom longitudinals.

303. Floor plates

1. Solid floors are to be provided with spacing not more than that obtained from the formulae given in **Table 7.3.3.** However, the spacing is to be 3.65 m even if the value obtained exceeds 3.65 m, and the spacing may be 2.5 m where the value obtained is less than 2.5 m. Solid floors are to be provided at the foot of the sloping plates of lower stools attached to transverse bulkhead.

2. The thickness of solid floors is not to be less than that obtained from the formula given in **Table 7.3.3.**

304. Inner bottom plating

1. The thickness of inner bottom plating is not to be less than that obtained from the following formulae, whichever is the greater :

$$t_1 = C_3 \frac{KB^2 d}{d_0} + 1.5 \quad (\mathrm{mm})$$

$$t_2 = C_3' S \sqrt{hK} + 1.5 \quad (\mathrm{mm})$$

where:

d_0 = height of centre girders (mm).

S = spacing of inner bottom longitudinals (m).

h = vertical distance from the top of inner bottom plating to the upper deck at centre line (m).

C_3 = coefficient given by the following formula. However, for adjacent holds simultaneously loaded or empty, and specially short holds, the value obtained from the following formula is to be multiplied by 1.2 :

$$C_3 = ab$$

a = as specified in **Table 7.3.2.**

b = b_0 or αb_1 given below according to the value of B/l_h.

b_0 for $\frac{B}{l_h} < 0.8$

b_0 or αb_1, whichever is the greater for $0.8 \leq \frac{B}{l_h} < 1.2$

αb_1 for $1.2 \leq \frac{B}{l_h}$

b_0, b_1 = as given in **Table 7.3.4** according to the values of k and B/l_h.

k, l_h = as specified in **301. 4** respectively.

α = as given by the following formula :

$$\alpha = \frac{13.8}{24 - 10.6 f_B K}$$

C_3' = coefficient obtained from the following formulae, depending on the value of l/S :

$\left(0.46\frac{l}{S}+2.64\right)\sqrt{\gamma}$ for $1 \leq \frac{l}{S} < 3.5$

$4.25\sqrt{\gamma}$ for $3.5 \leq \frac{l}{S}$

l = distance between floors (m).

γ = as specified in **301. 3.** However, the value of γ is not to be less than 1.2 times the ratio of the designed deadweight (t) to the total capacity of all holds (m^3).

2. The thickness of inner bottom plating under hatchway, where no ceiling is provided, is to be 2 mm greater than that obtained from the second formula in **Par 1,** except where **Par 3** is applied.

3. In ships in which cargoes are handled by grabs or similar mechanical appliances, thickness of inner bottom plating is to be 2.5 mm greater than that specified in **Par 1,** except where ceiling is provided.

305. Longitudinals

The section modulus of bottom and inner bottom longitudinals is not to be less than that obtained from the formulae given in **Table 7.3.5,** respectively.

Table 7.3.2 Dimension of centre girders and side girders

Item	Scantlings
(1) Spacing of side girders	(a) For loaded holds $l = 5.7 - 1.6\gamma$ (m)
	(b) For empty holds when the ship is fully loaded $l = 3.5$ (m)
(2) Depth of centre girders	$H = 15\sqrt{\frac{L_h BD}{m}}$ (mm)
(3) Thickness of centre girders and side girders	The thickness obtained from the following formula according to the location in the hold, whichever is the greater : $t_1 = \frac{C_1 KSBd}{d_0 - d_1}\left(2.6\frac{x}{l_h} - 0.17\right)\left\{1 - 4\left(\frac{y}{B}\right)^2\right\} + 1.5$ (mm) $t_2 = \frac{C_1' d_2}{1000\sqrt{K}} + 1.5$ (mm)

γ = as specified in **301. 3.**
L_h = total length of all cargo holds, excluding pump rooms and cofferdams (m).
m = number of holds
S = distance between the centres of two adjacent spaces from the centre or side girder under consideration to the adjacent longitudinal girders (m).
d_0 = depth of the centre or side girder under consideration (mm).
d_1 = depth of the opening at the point under consideration (mm).
d_2 = depth of the girder at the point under consideration (mm). Where, however, horizontal stiffeners are provided in way of the depth of girder, d_0 is the distance from the horizontal stiffener to the bottom shell plating or inner bottom plating or the distance between the horizontal stiffeners (mm).
l_h = length defined in **301. 4.**
x = longitudinal distance between the centre of l_h of each hold and the point under consideration (m). Where, however, x is less than $0.2\,l_h$, x is to be taken as $0.2\,l_h$, and where x exceeds $0.45\,l_h$, x may be taken as $0.45\,l_h$.
y = transverse distance from the centre line of ship to the longitudinal girder (m).
S_1 = spacing of the brackets or stiffeners provided on the centre girders or the side girders under consideration (m).
C_1' = coefficient given in the following table according to S_1/d_2. For intermediate values of S_1/d_2, C_1' is to be obtained by linear interpolation.

S_1/d_2	C_1'	
	Centre girder	Side girder
0.3 and under	4.4	3.6
0.4	5.4	4.4
0.5	6.3	5.1
0.6	7.1	5.8
0.7	7.7	6.3
0.8	8.2	6.7
0.9	8.6	7.0
1.0	8.9	7.3
1.2	9.3	7.6
1.4	9.6	7.9
1.6 and over	9.7	8.0

Table 7.3.2 Dimension of centre girders and side girders (continued)

$C_1 = nab$

n : coefficient given by the following table.

Location	n
For adjacent holds simultaneously loaded or empty, and specially short holds such as pump room located in the area of cargo holds	$\frac{1}{3}\left(7-2\frac{B}{l_h}\right)^{(*1)}$
For other holds	1.0

(*1) B/l_h exceeds 1.8, B/l_h is to be taken as 1.8, and where B/l_h is under 0.5, B/l_h is to be taken as 0.5.

a = coefficient given by the following table.

Position	$h\gamma/d$	a
For loaded holds	$\frac{h\gamma}{d} < 0.55$	$0.026\frac{L'}{d} - \frac{h\gamma}{d} + 1$
	$0.55 \le \frac{h\gamma}{d} \le 1.45$	$0.026\frac{L'}{d} + 0.45$
	$\frac{h\gamma}{d} > 1.45$	$0.026\frac{L'}{d} + \frac{h\gamma}{d} - 1$
For empty holds under full load condition		$0.026\frac{L'}{d} + 1$

h = vertical distance from the top of inner bottom plating to the upper deck at centre line (m).
L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.
b = value given in the following table, depending on k and B/l_h specified in **301. 4.** For intermediate values of k, b is to be obtained by linear interpolation.

k \ B/l_h	and over less than 1.4	1.4 1.6	1.6 1.8	1.8 2.0	2.0 2.2	2.2 2.4	2.4
10.0 and over	17	16	15	14	13	12	11
5.0	16	15	14	13	12	11	11
2.0	15	15	14	13	12	11	11
1.0	14	14	14	13	12	11	11
0	13	13	13	12	12	11	11

NOTE :
Where a partial intermediate side girder with suitable thickness is provided at a location between a transverse bulkhead, or a stool in case where it is provided at the lower part of a bulkhead and the solid floor located at a position 20 % or more of the hold length far from the end of the hold, 35 % each of its sectional area of the intermediate side girder may be added to the sectional area of the adjacent girders respectively. Where a stool is provided at the lower part of a transverse bulkhead, a side girder is to be provided under the stool to counter-balance this partial intermediate side girder.

Table 7.3.3 Spacing and thickness of floor plates

Item	Scantlings
(1) Spacing of floor plates	(a) For loaded holds $l = 5.6 - 2.8\gamma$ (m)
	(b) For empty holds under full loaded condition $l = 2.5$ (m)
(2) Thickness of solid floors	The thickness obtained from the following formula according to the location in the hold, whichever is the greater: $t_1 = \frac{C_2 K S B' d}{d_0 - d_1}\left(\frac{2y}{B''}\right)\left\{1 - 2\left(\frac{x}{l_h}\right)^2\right\} + 1.5$ (mm) $t_2 = 0.086\sqrt[3]{\frac{H^2 d_0^2}{C_2' K}(t_1 - 1.5)} + 1.5$ (mm)

γ = as specified in **301. 3.**
S = spacing of solid floors (m).
B' = distance between the lines of bilge hoppers at the top of inner bottom plating at the midship part (m).
B'' = distance between the lines of toes of bilge hoppers at the top of inner bottom plating at the position of the solid floor under consideration (m).
l_h = length defined in **301. 4.**
y = transverse distance from the centre line of ship to the point under consideration at the position of the solid floor under consideration (m). Where, however, y is less than $B''/4$, y is to be taken as $B''/4$, and where y exceeds $B''/2$, y may be taken as $B''/2$.
x = longitudinal distance from the middle of l_h of the respective hold to the floor under consideration (m).
d_0 = depth of the solid floor at the point under consideration (mm).
d_1 = depth of the opening at the point under consideration (mm).
C_2 = coefficient obtained from the following table.

Position	C_2
For cargo hold	ab
For adjacent holds simultaneously loaded or empty	0.9 ab

a = coefficient specified in **Table 7.3.2.**
b = value given in the following table, according to k and B/l_h which are defined in **301. 4.** For intermediate values of k, the value of b is to be determined by linear interpolation

k \ B/l_h	and over less than 0.4	0.4 0.6	0.6 0.8	0.8 1.0	1.0 1.2	1.2 1.4	1.4 1.6	1.6 1.8	1.8 2.0	2.0 2.2	2.2 2.4	2.4
10.0 and over	40	38	34	31	26	23	21	18	16	15	14	12
5.0	40	40	37	33	30	26	24	22	18	18	16	15
2.0	41	40	38	35	33	30	28	25	23	21	18	17
1.0	41	40	40	39	37	34	32	29	26	24	23	21
0	41	41	41	41	41	40	37	33	32	30	26	25

C_2' = coefficient given in the following table, according to the ratio of the spacing of stiffeners S_1 (mm) to d_0. For intermediate values of S_1/d_0, C_2' is to be determined by linear interpolation.

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

Table 7.3.3 Spacing and thickness of floor plates (continued)

H : value obtained from the following table.

Kinds	H
(a) Where slots without reinforcement are provided on solid floors	$\sqrt{4.0\frac{d_2}{S_1}-1.0}^{(*1)}$
(b) Where openings without reinforcement are provided on solid floors	$0.5\frac{\phi}{d_0}+1$
(c) Where slots and openings without reinforcement are provided on solid floors	Product of the values given by (a) and (b).
(d) Except for (a), (b) and (c)	1.0

(*1) Where d_2/S_1 is less than 0.5, H is to be taken as 1.0.

d_2 = depth of slots without reinforcement provided at the upper and lower parts of solid floors (mm), whichever is the greater.
ϕ = major diameter of the openings (mm).

NOTE :
Where a partial intermediate solid floor with suitable thickness is provided between the outermost side girder and the side girder located not less than 20% of B'' far from the former, 35% each of its sectional area may be added to the sectional area of the adjacent solid floors respectively. In this case, diaphragms, girders or brackets are to be provided in the bilge hopper tank to counter-balance this partial intermediate solid floor.

Table 7.3.4 Coefficient b_0 or b_1

B/l_h (and over)	B/l_h (less than)	k / b_0 or b_1	10.0 and over	5.0	2.0	1.0	0
	0.4	b_0	4.6	3.9	3.3	2.7	2.0
0.4	0.6	b_0	4.1	3.5	3.0	2.4	2.0
0.6	0.8	b_0	3.4	2.9	2.4	2.1	1.9
0.8	1.0	b_0	2.3	2.1	1.9	1.7	1.5
		b_1	2.3	2.0	1.7	1.4	1.4
1.0	1.2	b_0	1.7	1.5	1.5	1.4	1.3
		b_1	2.2	1.9	1.7	1.6	1.3
1.2	1.4	b_1	2.0	1.8	1.6	1.4	1.3
1.4	1.6	b_1	1.8	1.6	1.5	1.4	1.2
1.6	1.8	b_1	1.5	1.4	1.4	1.3	1.2
1.8	2.0	b_1	1.3	1.2	1.2	1.2	1.2
2.0	2.2	b_1	1.1	1.1	1.1	1.1	1.1
2.2		b_1	1.0	1.0	1.0	1.0	1.0

NOTE:
For intermediate values of k, b_0 and b_1 are to be obtained by linear interpolation.

Table 7.3.5 Section modulus of bottom and inner

Longitudinals	Section modulus (cm^3)
Bottom longitudinals	$Z_b = \frac{CKSl^2}{24-15.0f_B K}(d+0.026L')$
Inner bottom longitudinals	$Z_i = \frac{CKShl^2}{24-11.4f_B K}$ (However, $Z_{min} = 0.75Z_b$)

γ = as specified in **301. 3.**
l = spacing of solid floors (m).
S = spacing of bottom longitudinals or inner bottom longitudinals (m).
L' = length of ship (m). Where, however, L exceeds 230 m, L is to be taken as 230 m.
h = as specified in **304.1.**
C = coefficient given in the following table.

<table>
<tr><th rowspan="2">Case</th><th colspan="2">C</th></tr>
<tr><th>Bottom longitudinals</th><th>Inner bottom longitudinals</th></tr>
<tr><td>In case where no strut specified in 307. is provided midway between floors</td><td>100</td><td>100 γ
(However, $C \geq 90$)</td></tr>
<tr><td rowspan="3">In case where a strut specified in 307. is provided midway between floors</td><td>a) Lower part of the holds which be-come empty in a fully loaded condition and that of deep tanks: 62.5</td><td rowspan="2">60 γ
(However, $C \geq 54$)</td></tr>
<tr><td>b) Elsewhere: 30 γ + 20 (However, $C \geq 50$)</td></tr>
<tr><td colspan="2">And further, where the width of vertical stiffeners provided on floors and that of struts are specially large, the coefficient may be properly reduced.</td></tr>
</table>

306. Vertical struts

1. Where vertical struts are provided, they are to be rolled sections other than flat bars or bulb plates and to be well overlapped with the webs of bottom and inner bottom longitudinals.

2. The sectional area of the above-mentioned vertical struts is not to be less than that obtained from the following formula. Where the double bottom is deep, sufficient care is to be taken against buckling.

$$A = 1.8\,CKSbh \quad (cm^2)$$

where:

S = spacing of longitudinals (m).

b = breadth of the area supported by the strut (m).

h = as obtained from the following formula. In no case is h to be less than d.

$$h = \frac{d + 0.026L' + h_i}{2} \quad (\mathrm{m})$$

L' = as specified in **Table 7.3.2.**

h_i = γ times the value of h specified in **304. 1** (m). However, under deep tanks, h is not to be less than the vertical distance from the upper surface of inner bottom to the mid-point between the top of overflow pipe and the top of inner bottom or 0.7 times the vertical distance from the upper surface of inner bottom to the point of 2.0 metres above the top of overflow pipe, whichever is the greater (m).

γ = as specified in **301. 3.**

C = coefficient obtained from the following formula. In no case is the value of coefficient to be less than 1.43.

$$C = \frac{1}{1 - 0.5\dfrac{l_s}{k\sqrt{K}}}$$

l_s = length of strut (m).

k = minimum radius of gyration of vertical struts, obtained from the following formula (cm).

$$k = \sqrt{\frac{I}{A}}$$

I = the least moment of inertia of the strut (cm^4).

A = sectional area of the strut (cm^2).

307. Double bottom structure under lower stools at bulkheads

The inner bottom plating, centre girders, side girders and bottom longitudinals under lower stools at bulkheads are to be connected with those of holds just before and behind the bulkheads properly extending them. The floors are to be equivalent to those of holds.

Section 4 Hopper Tanks

401. General

1. Compartments of hopper tanks are to be in coincidence with those of holds as far as practicable.

2. Special care is to be taken for the continuity of strength at fore and aft ends of hopper tank structure.

3. The scantlings of structural members in hopper tanks are to be in accordance with the requirements in this Section and also those in **Pt 3, Ch 15.**

402. Thickness of hopper plates

1. The thickness of hopper plates of hopper tanks is not to be less than that obtained from the following formula.

$t = CS\sqrt{hK} + 1.5$ (mm)

where:

S = length of the shorter side of the panel enclosed by stiffeners, etc. (m)

h = vertical distance from the lower end of the hopper plate to the upper deck at centre line (m).

C = coefficient obtained from the following formula. However, in no case is it to be less than 3.2.

$$C = 4.25\, C_1\, C_2 \sqrt{\gamma}$$

C_1 = coefficient obtained from the following formula

where $1 \le \frac{l}{S} < 3.5$ $C_1 = \left(0.11\frac{l}{S} + 0.615\right)$

where $3.5 \le \frac{l}{S}$ $C_1 = 1$

l = length of the longer side of the panel enclosed by stiffeners, etc. (m)

C_2 = coefficient obtained from the formula in **Table 7.3.6.**

Table 7.3.6 Coefficient C_2

Angle β (degree)	C_2
$\beta \le 40°$	1.0
$40° < \beta < 80°$	1.4 - 0.01 β
$\beta \ge 80°$	0.6

γ = as specified in **301. 3.** However, in no case is the value of γ to be less than 1.2 times the ratio of the designed total cargo mass (t) to the total volume of all cargo holds (including hatchways) (m^3).

2. In ships in which cargoes are handled by grabs or similar mechanical appliances, the thickness of hopper plate is to be increased by following thickness above that determined in the preceding **1.** or determined by **401. 3,** whichever is the grater.

Hopper plate under hatchway------------- 2.5 mm

Hopper plate other than the above------ 1.0 mm

3. Where transverse stiffeners are provided on the hopper plates is to be sufficient against buckling.

403. Stiffeners

1. The section modulus of longitudinal stiffeners provided on the hopper plates is not to be less than that obtained from the following formula :

$Z = CKShl^2$ (cm^3)

where:

S = spacing of stiffeners (m).

h = vertical distance from the stiffener to the upper deck at centre line (m).

l = length of longitudinal stiffener between transverse webs (m).

C = coefficient obtained from the following formula:

$$C=\frac{\alpha}{24-15.0f_B K\frac{y}{y_B}}$$

α = coefficient obtained from the formula given in **Table 7.3.7** according to β, acute angle between the hopper plate and the horizontal plate and γ specified in **301. 3.**

Table 7.3.7 Coefficient α

Angle β (degree)	α
$\beta \leq 40^\circ$	130 γ
$40^\circ < \beta < 80^\circ$	(214-2.1 β)γ
$\beta \geq 80^\circ$	46 γ

y = vertical distance from the neutral axis of transverse section of hull to the longitudinal stiffener concerned (m).

y_B = vertical distance from the neutral axis of transverse section of hull to the top of keel (m).

2. The section modulus of transverse stiffeners provided on hopper plates is not to be less than that obtained from the following formula :

$$Z = CKShl^2 \quad (\text{cm}^3)$$

where:

S = spacing of transverse stiffeners (m).

l = distance between the supports of stiffeners (m).

h = vertical distance from the mid-point of l to the upper deck at centre line (m).

C = coefficient obtained from the formula given in **Table 7.3.8.** according to b, acute angle between the hopper plate and the horizontal plate and γ specified in **301. 3.**

Table 7.3.8 Coefficient C

Angle β (degree)	C
$\beta \leq 40^\circ$	7.8 γ
$40^\circ < \beta < 80^\circ$	(12.8 - 0.125β) γ
$\beta \geq 80^\circ$	2.8 γ

3. Bottom longitudinals in bilge hopper tanks are to be in accordance with the requirements in **Pt 3, Ch 7, 403.** Side longitudinals are to be in accordance with the requirements in **Pt 3, Ch 8, 401. 1,** in which case l in the formula is to be taken as the distance between transverse webs in meters. The section modulus of bilge longitudinals need not exceed that specified for bottom longitudinals.

404. Transverse webs

1. In hopper tanks, a transverse web or diaphragm is to be provided at every solid floor.

2. The scantlings of transverse webs provided on hopper plates are not to be less than those obtained from the formulae given in **Table 7.3.9.**

3. Flat bar stiffeners are to be provided on transverse webs or diaphragms at the positions through which longitudinals pass and tripping brackets are to be provided at a spacing of approximately 3 meters as well.

Table 7.3.9 Scantlings of transverse webs

Transverse webs		Scantlings
(1) Webs	Depth	l/5 or 2.5 times the depth of slot for longitudinal stiffener, whichever is the greater.
	Thickness	The thickness obtained from the following formulae, whichever is the greater. $t_1 = 0.01 d_0 + 1.5 \quad (\mathrm{mm})$ $t_2 = \dfrac{C_1 K S h l}{d_0 - a} + 1.5 \quad (\mathrm{mm})$ within 0.2 l from ends $t_3 = 0.0502 \sqrt[3]{\dfrac{C_1 S h l S_1^2}{d_0 - a}} + 1.5 \quad (\mathrm{mm})$
(2) Section modulus		$Z = C_2 K S h l^2 \quad (\mathrm{cm}^3)$
(3) Face bars	Breadth	$d = 2.7 \sqrt{d_0 l_1} \quad (\mathrm{mm})$
	Thickness	Above formulae t_1 or t_2, whichever is the greater.

d_0 = depth of transverse web s (mm).
a = depth of slots (mm). Where effective collar plates are provided within 0.25 l from each end of l, a may be modified depending on the size of collar plates, a may be taken as zero for 0.5 l at the middle part of l.
S = breadth of the area supported by transverse webs (m).
h = vertical distance from the mid-point of l to the upper deck at centre line (m).
l = overall length of transverse web (m). Where the transverse webs are connected with effective brackets at ends. l may be modified in accordance with the requirements in **Pt 3, Ch 1, 605.**
l_1 = distance between supports of transverse web (m). Where, however, effective tripping brackets are provided, they may be taken as supports.
S_1 = the spacing of stiffeners of transverse webs or depth of web(m), whichever is smaller.
C_1, C_2 = coefficient obtained from the formulae given in the following table according to β, acute angle between the hopper plate and the horizontal plane and γ specified in **301. 3.** Where γ is less than 0.7, γ is to be taken as 0.7.

Angle (β)	C_1 (*1)	C_2 (*2)
$\beta \leq 40^\circ$	41.7 γ	7.1 γ
$40^\circ < \beta < 80^\circ$	(68.5 - 0.67 β) γ	(11.5 - 0.11 β) γ
$\beta \geq 80^\circ$	14.9 γ	2.7 γ

(*1) Where the value, C_1, obtained from the above formula is less than 27.8, C_1 is to be taken as 27.8.
(*2) Where the value, C_2, obtained from the above formula is less than 4.75, C_2 is to be taken as 4.75. Where an effective support is provided at the mid-point of girder, one-half of C_2 obtained from the above formula may be taken as C_2.

Section 5 Topside Tanks

501. General

1. Compartments of topside tanks are to be in coincidence with those of holds as fas as practicable. Except for the foremost hold, however, adjacent two compartments may be made one compartment.

2. Special care is to be taken for the continuity of strength at the fore and after ends of topside tank structure.

3. The scantlings of members in topside tanks are not to be less than those specified in **Pt 3, Ch 15,** where h is not to be less than a half of the breadth of tanks at midship section.

4. As for the flat bars used for longitudinal stiffeners, the ratio of the depth to the thickness is not to be greater than 15. As for longitudinals near the strength deck, the slenderness ratio is not to exceed 60 as far as possible at the midship part of the ships.

502. Thickness of sloping plates

1. The thickness of sloping plates of topside tanks is not to be less than that obtained from the following formula :

$$t = 4.6S\sqrt{Kh} + 1.5 \quad (\mathrm{mm})$$

where:

S = spacing of longitudinal or transverse stiffeners (m).

h = distance from the lower edge of sloping plate to the top of over-flow pipe or a half of the breadth of topside tank at midship part, whichever is the greater (m).

2. Where transverse stiffeners are provided on the sloping plates of topside tanks, the thickness of sloping plates is to be sufficient against buckling.

503. Stiffeners provided on sloping plates

1. The section modulus of longitudinal stiffeners provided on the sloping plates of topside tanks is not to be less than that obtained from the following formula :

$$Z = CKShl^2 \quad (\mathrm{cm}^3)$$

where:

S = spacing of longitudinal stiffeners (m).

h = vertical distance from the stiffener to the top of overflow pipe or one-half of the breadth of topside tank at midship part, whichever is the greater (m).

l = length of longitudinal stiffeners between transverse webs (m).

C = coefficient obtained from the following formula :

$$C = \frac{100}{24 - 15 f_D K \frac{y}{y_D}}$$

y_D = vertical distance from the neutral axis of transverse section of hull to the top of beams at side (m).

y = vertical distance from the neutral axis of transverse section of hull to the longitudinal stiffener concerned (m).

2. The section modulus of transverse stiffeners provided on the sloping plates of topside tanks is not to be less than that obtained from the following formula :

$$Z = 6.8 K S h l^2 \quad (\text{cm}^3)$$

where:

S = spacing of transverse stiffeners (m).

l = unsupported length of stiffener (m).

h = vertical distance from the mid-point of l to the top of overflow pipe or one-half of the breadth of topside tank at midship part, whichever is the greater (m).

504. Longitudinal beams

The section modulus of longitudinal beams in topside tanks is not to be less than that obtained from the requirement in **Pt 3, Ch 10, 303.** Where, h is the deck load (kN/m^2) specified in **Pt 3, Ch 10, Sec 2** or one-half of the breadth of topside tank at midship part multiplied by 9.81, whichever is the greater (m).

505. Side frames

1. The section modulus of side longitudinals in topside tanks is not to be less than that obtained from the formula in **Pt 3, Ch 8, 401. 1,** taking l and h as follows :

l = distance between transverse webs (m).

h = as specified in **Pt 3, Ch 8, 401. 1,** but is not to be less than one-half of the breadth of topside tank at midship part (m).

2. Where transverse frames are provided on the side shell plating in way of topside tanks, the section modulus is not to be less than that obtained from the following formula :

$$Z = 6 K S h l^2 \quad (\text{cm}^3)$$

where:

S = spacing of frames (m).

l = vertical distance from the bottom of sloping plate of topside tank to the upper deck at side (m).

h = vertical distance from the mid-point of l to the point $d + 0.038L'$ above the top of keel, or one-half of the breadth of topside tank at midship part, whichever is the greater (m). Where, however, the value is less than $0.3\sqrt{L}$ (m), h is to be taken as $0.3\sqrt{L}$ (m).

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.

506. Transverse webs

1. Transverse webs or diaphragms are to be provided at a spacing not exceeding 5 m in topside tanks.

2. The scantlings of transverse webs are not to be less than those obtained from the formulae in **Table 7.3.10.**

Table 7.3.10 Scantlings of transverse webs

Transverse webs		Scantlings
(1) Webs	Depth	(a) Where struts are provided at an intermediate position of transverse webs : $l/6$ (b) Elsewhere : $l/5$ or 2.5 times the depth of slots through which longitudinals pass, whichever is the greater.
	Thickness	The thickness obtained from the following formulae, whichever is the greater: $t_1 = 0.01 d_0 + 1.5$ (mm) $t_2 = 41.7 K \frac{Shl}{d_0 - a} + 1.5$ (mm) within 0.2 l from ends $t_3 = 0.174 \sqrt[3]{\frac{Shl S_1^2}{d_0 - a}} + 1.5$ (mm)
(2) Section modulus		(a) Where struts are provided at an intermediate position of transverse webs: $Z = 3.57 KShl^2$ (cm^3) (b) Elsewhere : $Z = 7.14 KShl^2$ (cm^3)
(3) Face bars	Breadth	$b = 2.7 \sqrt{d_0 l_1}$ (mm)
	Thickness	Above formulae t_1 or t_2, whichever is the greater.

d_0 = depth of transverse webs (mm).
a = depth of slots (mm). Where effective collar plates are provided within 0.25 l from each end of l, a may be modified depending on the size of collar plates. a may be taken as zero for 0.5 l at the middle part of l.
S = breadth of the area supported by transverse webs (m).
h = vertical distance from the midpoint of l to the top of overflow pipe, or a half of the breadth of topside tank, whichever is the greater (m)
l = overall length of transverse webs (m). Where a longitudinal diaphragm is provided at an intermediate position of transverse webs, l is to be the distance from the longitudinal diaphragm to the heel of bracket provided at the end of transverse webs (m). In any case where effective brackets are provided, l may be modified as specified in **Pt 3, Ch 1, 605.**
l_1 = distance between supports of transverse web (m). Where, however, effective tripping brackets are provided, they may be taken as supports.
S_1 = the spacing of stiffeners of transverse webs or depth of web (m), whichever is smaller.

3. Flat bar stiffeners are to be provided on transverse webs or diaphragms at the positions through which longitudinal frames or longitudinal stiffeners pass and brackets are to be provided at a spacing of approximately 3 metres as well.

4. Where heavy cargoes are loaded on the deck, web plates or diaphragms are to be suitably reinforced.

507. Large topside tanks

1. Where topside tanks are large, special consideration is to be given to the structure such as providing longitudinal diaphragms at around the midpoint of the breadth of topside tanks.

2. The thickness of longitudinal diaphragms, where provided, is not to be less than that specified in **106.,** or that obtained from the following formula, whichever is the greater. However, value of f_D is not to be less 1.0.

$$t = 19.8 S \sqrt{\frac{y f_D}{D}} + 1.5 \quad (\mathrm{mm})$$

where:

S = spacing of longitudinals (m).

y = vertical distance from $D/2$ at midship section to the mid-point of panel between the stiffeners under consideration (m).

3. Where longitudinal stiffeners are provided on longitudinal diaphragms, depth of stiffeners is not to be less than 0.06 l, where l is the distance between the girders provided on the longitudinal diaphragms. Where longitudinal stiffeners are connected with tripping brackets at ends, depth of the stiffeners may be properly reduced.

4. Where transverse stiffeners are provided on longitudinal diaphragms, the thickness of longitudinal diaphragms is to be sufficient against buckling. The scantlings of the stiffeners are to be equivalent to those specified in **Pt 3.**

Section 6 Transverse Bulkheads and Stools

601. Transverse bulkheads

1. The scantlings of structural members of transverse bulkheads are to be in accordance with the requirements in **Pt 3, Ch 15, Sec 2.** Where, however, in application of these requirements, h in the formulae is to be substituted by $0.36\gamma h'$, where γ is as specified in **301. 3.** Where, however, γ is less than 1.5, γ is to be taken as 1.5, and h' is to be in accordance with the following :

(1) In case of bulkhead platings, vertical distance from the lower edge of bulkhead plate to the upper deck at centre line of ship (m).

(2) Vertical distance from the mid-point of l for vertical stiffeners on bulkhead or from the mid-point of distance between the adjacent stiffeners for horizontal stiffeners to the upper deck at centre line of ship (m). l is as specified in **Pt 3, Ch 15, 203.**

(3) Vertical distance from the mid-point of l for vertical webs supporting stiffeners or from the midpoint of S for horizontal girders to the upper deck at centre line of ship (m). l and S are as specified in **Pt 3, Ch 15, 204.**

2. Notwithstanding the requirements in **Par 1**, the scantlings of structural members of transverse bulkheads are not to be less than those specified in **Pt 3, Ch 14.**

3. For transverse bulkhead without lower stool, the thickness of the lowest strake of bulkhead plating is to be appropriately increased referring to the thickness of inner bottom plating.

4. Plating of transverse bulkheads to which the sloping plates of topside tanks are connected, is to be properly strengthened, by increasing its thickness, or by any other means.

5. In addition to the requirements in this **Sec,** any cargo hold of bulk carriers of 150 m in length(L_f) and above, with single deck, topside tanks and hopper tanks, and of single side or double side skin construction, intending to carry solid bulk cargoes having a density of 1.0 t/m^3, or above, with vertically corrugated transverse watertight bulkheads, which are contracted for construction on or after 1 July 2006 is to be in accordance with the requirements in **Sec 12.**

602. Lower and upper stools at transverse bulkheads

1. The thickness of hopper plate of the lower stool of transverse bulkhead is not to be less than that obtained from the formula in **402. 1.** using the value of coefficient C reduced by 10 %. In ships in which cargoes are handled by grabs or similar mechanical appliances, the thickness is to be increased by 1 mm.

2. The section modulus of horizontal stiffeners provided on sloping plates of lower stool is not to be less than that obtained from the formula for stiffeners or hopper plates given in **403. 1,** where the coefficient C of the first term is to be reduced by 10 %. Where vertical stiffeners are provided, the section modulus is not to be less than that specified in **403. 2.**

3. Girders are to be provided in lower stools in the positions of centre girders and side girders in double bottoms. Scantlings of girders are not to be less than those specified in **404.**

4. Where holds are so designed as to be loaded with ballast water, cargo oil or heavy cargo, girders specified in the preceding Paragraph are to be sufficient against shear, for instance, by adopting diaphragms.

5. The scantlings of the members of upper stools are not to be less than those specified in **Pt 3, Ch 14.**

6. In addition to the requirements in this **Sec,** any cargo hold of bulk carriers of 150 m in length(L_f) and above, with single deck, topside tanks and hopper tanks, and of single side or double side skin construction, intending to carry solid bulk cargoes having a density of 1.0 t/m^3, or above, with vertically corrugated transverse watertight bulkheads, which are contracted for construction on or after 1 July 2006 is to be in accordance with the requirements in **Sec 12.**

Section 7 Hold Frames

701. Hold frames

1. The section modulus of hold frames is not to be less than that obtained from the formulae given in **Table 7.3.11.**

2. The thickness of webs near the top and bottom end connections of hold frames is to be sufficient against shearing.

3. For holds loaded with cargoes of specially large specific gravity, special care is to be taken such as increasing scantlings of hold frames specified in **Pars 1** and **2.**

4. Frames are to be fabricated symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

5. In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

6. The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than r, given by : (See, **Fig 7.3.4**)

$$r = \frac{0.4 b_f^2}{t_f} \quad (\mathrm{mm})$$

b_f = flange width of the brackets (mm).

t_f = thickness of the brackets (mm).

7. The web depth to thickness ratio of frames is not to exceed the following values.

(1) Symmetrical flanged frames : $60\sqrt{K}$

(2) Asymmetrical flanged frames : $50\sqrt{K}$

K is the material factor, as specified in **Pt 3, Ch 1, Sec 4, Table 3.1.2.**

8. The outstanding flange is not to be exceed $10\sqrt{K}$ times the flange thickness.

7.3.11 Section modulus of hold frames

Location	Section modulus (cm^3)
Between 0.15L from the fore end and the after peak bulkhead	$Z = CKShl^2$
Between 0.15L from the fore end and the collision bulkhead	$Z = 1.25KCShl^2$

S = spacing of frames (m).
h = vertical distance from a point $d + 0.038L'$ above the top of keel to the top of bilge hopper at side (m).
L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.
l = distance between the top of bilge hopper at side and the bottom of top side tank (m). (See **Fig 7.3.3**).
C = coefficient obtained from the following formula:

$$C = \left(3.3 - 2.5\frac{l}{h}\right) + (25.7\lambda_1 + 44.5)\alpha\frac{d}{h}$$

$$\lambda_1 = \frac{l_1}{l}$$

l_1 = vertical distance from the mid-point of depth of centre girder to the top of bilge hopper at side (m). (See **Fig 7.3.3**)
α = coefficient given in the following table. For intermediate values of B/l_h the values of α are to be determined by linear interpolation. For the holds which are empty in fully loaded condition, the value of α is to be 1.8 times the value determined from the table.

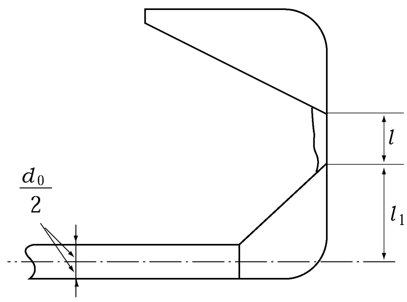


Fig 7.3.3 Measurement of l, l_1, etc

B/l_h	α
0.4 and under	0.0288
0.6	0.0207
0.8	0.0144
1.0	0.0099
1.2	0.0069
1.4	0.0048
1.6	0.0034
1.8 and over	0.0025

702. Top and bottom end connections of frames

1. The toes of brackets connecting frames with hopper plates and topside tank sloping plates are not to coincide with bracket ends in the tanks.
2. The section modulus of the frame and bracket or integral bracket, and associate shell plating, at the locations shown in **Fig 7.3.4,** is not to be less than twice the section modulus required for the frame midspan area. The dimensions of the lower and upper brackets are not to be less than those shown in **Fig 7.3.6.**
3. Structural continuity with the upper and lower end connection of side frames is to be ensured within topside and hopper tanks by connecting brackets as shown in **Fig 7.3.5.** The brackets are to be stiffened against buckling.

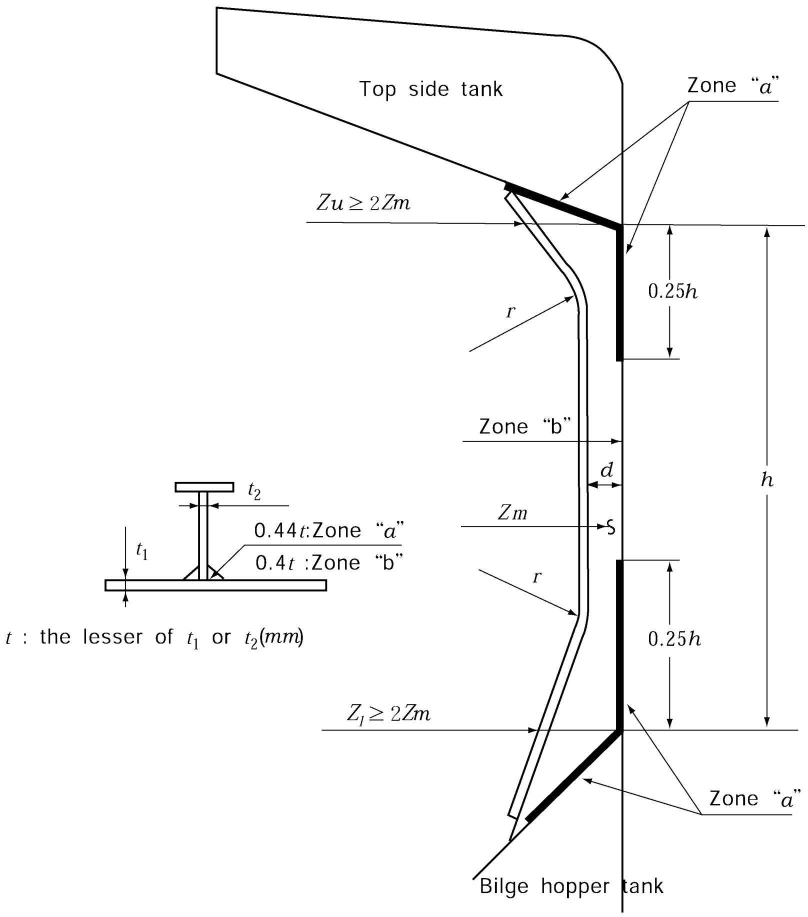


Fig 7.3.4 Figure of frame and bracket

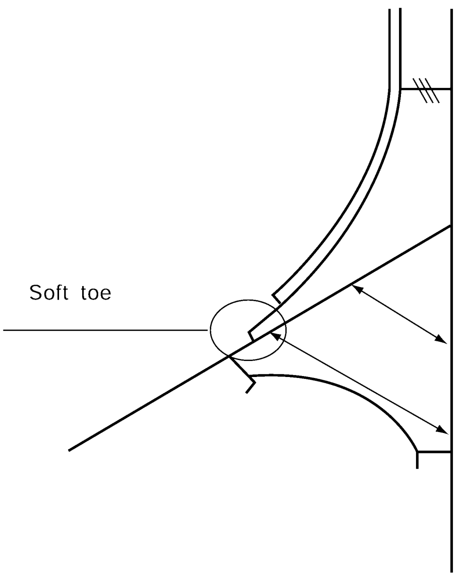
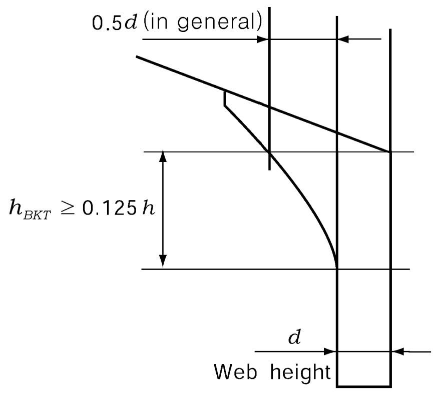


Fig 7.3.5 Bracket



h : As shown in **Fig 7.3.4**

Fig 7.3.6 The dimension of the lower and upper brackets.

4. Double continuous welding is to be adopted for the connections of frames and brackets to side shell, hopper and hopper wing tank plating and web to face plate. For this purpose, the weld throat is to be : (See, **Fig 7.3.4**)

Zone "a" : 0.44 t, Zone "b" : 0.4 t,

Where, t is the thinner of the two connected members.

5. Where the hull form is such to prohibit an effective fillet weld, edge preparation of the web of frame and bracket may be required, in order to ensure the same efficiency as the weld connection stated in **Par. 4.**

703. Side structure in the foremost hold

The scantlings of side hold frames immediately adjacent to the collision bulkhead are to be increased in order to prevent excessive imposed deformation on the shell plating. As an alternative, supporting structures are to be fitted which maintain the continuity of forepeak stringers within the foremost hold.

704. Tripping brackets

In way of the foremost hold, side frames of asymmetrical section art to be fitted with tripping brackets at every two frames, as shown in **Fig 7.3.7.**

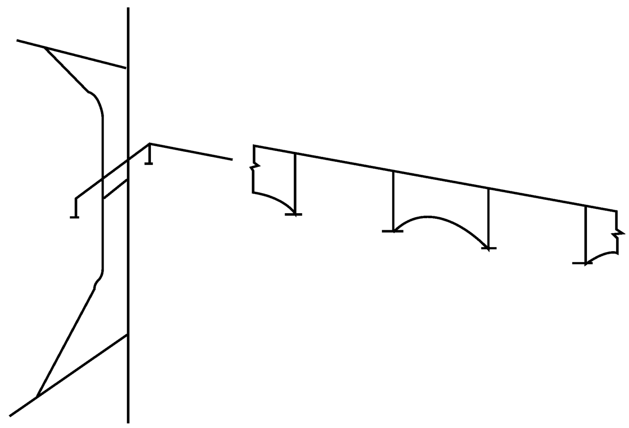


Fig 7.3.7 Tripping brackets to be fitted in way of foremost hold

Section 8 Decks and Shell Platings

801. Deck plating outside the line of openings

The cross sectional area of deck plating outside the line of openings, where topside tanks are not provided, is to determined in consideration of the continuity of longitudinal strength.

802. Deck plating inside the line of openings

1. Hatch end coamings are to be provided in coincidence with the positions of girders in topside tanks. If not coincident, sufficient care is to be taken for the continuity of strength at the connection of hatch end coamings with topside tanks.

2. Deck plating inside the line of openings is recommended to be provided with transverse beams. Where longitudinal beams are provided, special care is to be taken against buckling.

803. Side shell plating

Where a loaded hold and an empty hold are adjacent to each other across a transverse bulkhead, the thickness of side shell plating may be properly reduced from that specified in **Pt 3, Ch 3, 301.** considering that the transverse bulkhead under consideration withstands a part of shear forces on ship s hull in still water.

804. Bottom shell plating

The thickness of bottom shell plating of cargo holds in way of double bottom is not to be less than that obtained from the formula in **Pt 3, Ch 4, 304.** or from the first formula in **304. 1,** whichever is the greater. However, in application of the latter formula, α is to be as given by the following formula :

$$\alpha = \frac{13.8}{24 - 15.0 f_B K}$$

Section 9 Hatch Covers and Hatch Coamings of Cargo Holds

901. Application and definitions

1. These requirements apply to all bulk carriers, ore carriers and combination carriers, and are for all cargo hatch covers and hatch forward and side coamings on exposed decks in position Ⅰ, as defined in **Pt 4, Ch 2, Sec. 1 101.** These requirements applies to ships contracted for construction on or after 1 January 2004.

2. The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction.

3. The secondary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

4. The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting members. The secondary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

5. These requirements are in addition to the requirements of the ICLL.

6. The net minimum scantlings of hatch covers are to fulfil the strength criteria of the followings where adopting the load model given in **902.** :

(1) **903. 3**, for plating,
(2) **903. 4**, for secondary stiffeners,
(3) **903. 5** for primary supporting members,
(4) **903. 6** the critical buckling stress,
(5) **903. 7** the rigidity criteria.

7. The net minimum scantlings of hatch coamings are to fulfil the strength criteria of the followings where adopting the load model given in **904. 1**:

(1) **904. 2** for plating,
(2) **904. 3** for secondary stiffeners,
(3) **904. 4** for coaming stays,

8. The net thicknesses, t_{net}, are the member thicknesses necessary to obtain the minimum net scantlings required by **903.** and **904.**

The required gross thicknesses are obtained by adding the corrosion additions, t_s, given in **906.** to t_{net}.

9. Material for the hatch covers and coamings is to be steel according to **Pt 3, Ch 1, Sec. 4.**

10. Where t_{net} are used for member scantlings, they are to be noted on the drawings.

902. Hatch cover load model

1. The pressure P, in kN/m^2, on the hatch covers panels is given as follows.

Table 4.2.3 Wave pressures on hatch covers

Ware Pressure P (kN/m^2)			
Length for freeboard, L_f	Location	Position I	Position II
$L_f \geq 100$ m	$0.75 < x/L_f < 1$	$34.3 + (14.8 + a(L_f - 100))(4\frac{x}{L_f} - 3)$	
	$0 \leq x/L_f \leq 0.75$	34.3	25.5
$L_f < 100$ m	$0.75 < x/L_f < 1$	$12.2 + \frac{L_f}{9}(5\frac{x}{L_f} - 2) + 3.6\frac{x}{L_f}$	
	$0 \leq x/L_f \leq 0.75$	$14.9 + 0.195L_f$	$11.3 + 0.142L_f$

Note
(1) a : coefficient taken equal to :
a = 0.0726 for Type B freeboard ships
a = 0.356 for Type B-60 or Type B-100 freeboard ships.
(2) L_f : Length for freeboard defined in **Pt 3 Ch 1 Sec 1** (m). But need not be taken greater than 340 m.
(3) x(m) : Distance from the end of stern to the center of hatch cover that should be considered.
(4) Where two or more panels are connected by hinges, each individual panel is to be considered separately.

903. Hatch cover strength criteria

1. Allowable stress checks

(1) The normal and shear stresses σ and τ in the hatch cover structures are not to exceed the allowable values, σ_a and τ_a , in N/mm^2, given by:

$$\sigma_a = 0.80\sigma_y$$
$$\tau_a = 0.46\sigma_y$$

where,

σ_y = being the minimum upper yield stress, in N/mm^2, of the material.

(2) The normal stress in compression of the attached flange of primary supporting members is not to exceed 0.8 times the critical buckling stress of the structure according to the buckling check as given in **903. 6.**

(3) The stresses in hatch covers that are designed as a grillage of longitudinal and transverse primary supporting members are to be determined by a grillage or a FEM analysis.

(4) When a beam or a grillage analysis is used, the secondary stiffeners are not to be included in the attached flange area of the primary members.

(5) When calculating the stresses σ and τ, the net scantlings are to be used.

2. Effective cross-sectional area of panel flanges for primary supporting members

The effective flange area A_f, in cm^2, of the attached plating, to be considered for the yielding and buckling checks of primary supporting members, when calculated by means of a beam or grillage model, is obtained as the sum of the effective flange areas of each side of the girder web as appropriate:

$$A_f = \sum_{nf}(10 b_{ef} t) \quad (cm^2)$$

where,

nf = 2 if attached plate flange extends on both sides of girder web
= 1 if attached plate flange extends on one side of girder web only

t = net thickness of considered attached plate, in mm

b_{ef} = effective breadth, in m, of attached plate flange on each side of girder web
= b_p, but not to be taken greater than 0.165 l

b_p = half distance, in m, between the considered primary supporting member and the adjacent one

l = span, in m, of primary supporting members

3. Local net plate thickness

The local net plate thickness t, in mm, of the hatch cover top plating is not to be less than:

$$t = 15.8 F_p S \sqrt{\frac{P}{0.95\sigma_y}} \quad (mm)$$

but to be not less than 1% of the spacing of the stiffener or 6 mm if that be greater.

where,

F_P = factor for combined membrane and bending response
= 1.50 in general
= $1.90\ \sigma/\sigma_a$, for $\sigma/\sigma_a \geq 0.8$, for the attached plate flange of primary supporting members

S = stiffener spacing, in m

p = pressure, in kN/m^2, as defined in **902.**

σ = as defined in **903. 5.**

σ_a = as defined in **903.1**.

σ_y = as defined in **903.1**.

4. Net scantlings of secondary stiffeners

(1) The required minimum section modulus, Z, in cm^3, of secondary stiffeners of the hatch cover top plate, based on stiffener net member thickness, are given by:

$$Z = \frac{1000\, l^2 SP}{12\sigma_a} \quad (cm^3)$$

where,

l = secondary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

S = secondary stiffener spacing, in m

p = pressure, in kN/m^2, as defined in **902.**

σ_a= as defined in **903.1**

(2) The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

5. Net scantlings of primary supporting members

(1) The section modulus and web thickness of primary supporting members, based on member net thickness, are to be such that the normal stress σ in both flanges and the shear stress τ, in the web, do not exceed the allowable values σ_a and τ_a, respectively, defined in **903.1.**

(2) The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(3) The flange outstand is not to exceed 15 times the flange thickness.

6. Critical buckling stress check

(1) Hatch cover plating

(A) The compressive stress σ in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{C1}, to be evaluated as defined below:

$$\sigma_{C1} = \sigma_{E1} \qquad \text{when } \sigma_{E1} \le \frac{\sigma_y}{2}$$

$$= \sigma_y\left[1 - \frac{\sigma_y}{4\sigma_{E1}}\right] \qquad \text{when } \sigma_{E1} > \frac{\sigma_y}{2}$$

where,

σ_y = minimum upper yield stress, in N/mm^2, of the material

$\sigma_{E1} = 3.6E\left(\frac{t}{1000S}\right)^2$

E = modulus of elasticity, in N/mm^2

= 2.06 x 10^5 (N/mm^2) for steel

t = net thickness, in mm, of plate panel

S = spacing, in m, of secondary stiffeners

(B) The mean compressive stress, σ, in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{C2}, to be evaluated as defined below:

$$\sigma_{C2} = \sigma_{E2} \qquad \text{when } \sigma_{E2} \le \frac{\sigma_y}{2}$$

$$= \sigma_y\left[1 - \frac{\sigma_y}{4\sigma_y}\right] \qquad \text{when } \sigma_{E2} > \frac{\sigma_y}{2}$$

where,

σ_y = minimum upper yield stress, in N/mm^2, of the material

$\sigma_{E2} = 0.9\, m\, E\left(\frac{t}{1000\, S_s}\right)^2$

$m = c\left[1 + \left(\frac{S_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$

E = modulus of elasticity, in N/mm^2

= 2.06×10^5 for steel

t = net thickness, in mm, of plate panel

S_s = length, in m, of the shorter side of the plate panel

l_s = length, in m, of the longer side of the plate panel

ψ = ratio between smallest and largest compressive stress

c = 1.3 when plating is stiffened by primary supporting members

= 1.21 when plating is stiffened by secondary stiffeners of angle or T type

= 1.1 when plating is stiffened by secondary stiffeners of bulb type

= 1.05 when plating is stiffened by flat bar

(C) The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with the satisfaction of the Society as deemed equivalent to the above criteria.

(2) Hatch cover secondary stiffeners

(A) The compressive stress σ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{CS}, to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \qquad \text{when} \quad \sigma_{ES} \le \frac{\sigma_y}{2}$$

$$= \sigma_y \left[1 - \frac{\sigma_y}{4\sigma_{ES}}\right] \qquad \text{when} \quad \sigma_{ES} > \frac{\sigma_y}{2}$$

where,

σ_y = minimum upper yield stress, in N/mm^2, of the material

σ_{ES} = ideal elastic buckling stress, in N/mm^2, of the secondary stiffener

= minimum between σ_{E3} and σ_{E4}

$$\sigma_{E3} = \frac{0.001 E I_a}{A l^2}$$

E = modulus of elasticity, in N/mm^2

= 2.06×10^5 for steel

I_a = moment of inertia, in cm^4, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

A = cross-sectional area, in cm^2, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

l = span, in m, of the secondary stiffener

$$\sigma_{E4} = \frac{\pi^2 E I_w}{10^4 I_p l^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385 E \frac{I_t}{I_p}$$

$$K = \frac{C l^4}{\pi^4 E I_w} \times 10^6$$

m = number of half waves, given by the following table:

	$0 < K < 4$	$4 < K < 36$	$36 < K < 144$	$(m-1)^2 m^2 < K \le m^2 (m+1)^2$
m	1	2	3	m

I_w = sectorial moment of inertia, in cm^6, of the secondary stiffener about its connection with the plating

= $\frac{h_w^3\ t_w^3}{36} \times 10^{-6}$ for flat bar secondary stiffeners

= $\frac{t_f\ b_f^3\ h_w^2}{12} \times 10^{-6}$ for "Tee" secondary stiffeners

= $\frac{b_f^3\ h_w^2}{12(b_f + h_w)^2}\left[t_f\,(b_f^2 + 2b_f\ h_w + 4h_w^2) + 3t_w\ b_f\ h_w\right] \times 10^{-6}$ for angles and bulb secondary stiffener

I_p = polar moment of inertia, in cm^4, of the secondary stiffener about its connection with the plating

= $\frac{h_w^3\ t_w}{3} \times 10^{-4}$ for flat bar secondary stiffeners

= $\left(\frac{h_w^3\ t_w}{3} + h_w^2\ b_f\ t_f\right) \times 10^{-4}$ for flanged secondary stiffeners

I_t = St Venant's moment of inertia, in cm^4, of the secondary stiffener without top flange

= $\frac{h_w\ t_w^3}{3} \times 10^{-4}$ for flat bar secondary stiffeners

= $\frac{1}{3}\left[h_w\ t_w^3 + b_f\ t_f^3\left(1 - 0.63\frac{t_f}{b_f}\right)\right] \times 10^{-4}$ for flanged secondary stiffeners

h_w , t_w = height and net thickness, in mm, of the secondary stiffener, respectively

b_f , t_f = width and net thickness, in mm, of the secondary stiffener bottom flange, respectively

C = spring stiffness exerted by the hatch cover top plating

$$= \frac{k_p\ E\ t_p^3}{3S\left(1 + \frac{1.33k_p\ h_w\ t_p^3}{1000\,St_w^3}\right)} \times 10^{-3}$$

S = spacing, in m, of secondary stiffeners

k_p = $1 - \eta_p$, to be taken not less than zero

for flanged secondary stiffeners, k_p need not be taken less than 0.1

η_p = $\frac{\sigma}{\sigma_{E1}}$

σ = as defined in **903. 5**

σ_{E1} = as defined in **903. 6.** (1)

t_p = net thickness, in mm, of the hatch cover plate panel

(B) For flat bar secondary stiffeners and buckling stiffeners, the ratio h / t_w is to be not greater than $15\ k^{0.5}$,

where:

h / t_w = height and net thickness of the stiffener, respectively

k = $235/\sigma_y$

σ_y = minimum upper yield stress, in $\mathrm{N/mm^2}$, of the material.

(3) Web panels of hatch cover primary supporting members

(A) This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

(B) The shear stress τ in the hatch cover primary supporting members web panels is not to exceed 0.8 times the critical buckling stress τ_C, to be evaluated as defined below:

$$\tau_C = \tau_E \qquad \text{when } \tau_E \le \frac{\tau_F}{2}$$

$$= \tau_F\left[1 - \frac{\tau_F}{4\tau_E}\right] \qquad \text{when } \tau_E > \frac{\tau_F}{2}$$

where,

$\tau_F = \dfrac{\sigma_y}{\sqrt{3}}$

σ_y = minimum upper yield stress, in N/mm^2, of the material

$\tau_E = 0.9\, k_t\, E \left[\dfrac{t_{pr,n}}{1000\, d}\right]^2$

E = modulus of elasticity, in N/mm^2

= 2.06×10^5 for steel

$t_{pr,n}$ = net thickness, in mm, of primary supporting member

$k_t = 5.35 + \dfrac{4.0}{(a/d)^2}$

a = greater dimension, in m, of web panel of primary supporting member

d = smaller dimension, in m, of web panel of primary supporting member.

(C) For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

(D) For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

7. Deflection limit and connections between hatch cover panels

(1) Load bearing connections between the hatch cover panels are to be fitted with the purpose of restricting the relative vertical displacements.

(2) The vertical deflection of primary supporting members is to be not more than 0.0056 l, where l is the greatest span of primary supporting members.

8. Primary supporting members of variable cross-section

The net section modulus of primary supporting members with a variable cross-section is to be not less than the greater of the value obtained from the following formulae and the use of these formulae is limited to the determination of the strength of primary supporting members in which abrupt changes in the cross-section do not occur along their length. :

$$Z = Z_{CS} \quad (cm^3)$$

$$Z = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) Z_{CS} \quad (cm^3)$$

Z_{CS} : Net section modulus calculated with considering the net thickness, in cm^3, for a constant cross-section, complying with the checking criteria in **903. 6 (3)**.

$$\alpha = \frac{l_1}{l_0}$$

$$\psi = \frac{Z_1}{Z_0}$$

l_1 : Length of the variable section part, in m (see the following figure.)

l_0 : Span measured, in m, between end supports (see the following figure.)

Z_1 : Net section modulus calculated with considering the net thickness at end, in cm^3 (see the following figure.)

Z_0 : Net section modulus calculated with considering the net thickness at mid-span, in cm^3 (see the following figure.)

Moreover, the net moment of inertia of primary supporting members with a variable cross-section calculated with considering it's net thickness is to be not less than the greater of the values obtained, in cm^4, from the following formulae :

$$I = I_{CS} \quad (\text{cm}^4)$$

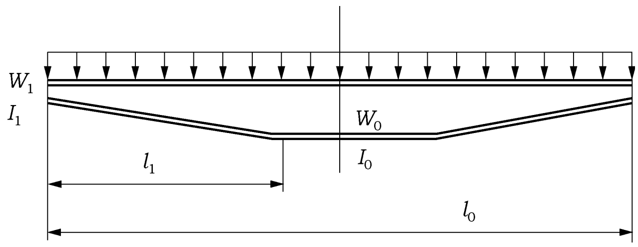
$$I = \left\{1 + 8\alpha^3\left(\frac{1-\phi}{0.2+3\sqrt{\phi}}\right)\right\} I_{CS} \quad (\text{cm}^4)$$

I_{CS} : Net moment of inertia with a constant cross-section calculated with considering the net thickness, in cm^4, complying with **903. 7** (2)

$$\phi = \frac{I_1}{I_0}$$

I_1 : Net moment of inertia calculated with considering the net thickness at end with considering the net thickness, in cm^4 (see the following figure.)

I_0 : Net moment of inertia calculated with considering the net thickness at mid-span with considering the net thickness, in cm^4 (see the following figure.)



Variable cross-section stiffener

9. Buckling stiffeners on webs of primary supporting members

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formulae :

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{\sigma_y}}$$

h_w : Web height of the stiffener (mm)
t_w : Net thickness of the stiffener (mm)

904. Hatch coamings and local details

1. Load model

The pressure P_{coam}, in kN/m^2, on the No. 1 forward transverse hatch coaming is given by:

$P_{coam} = 220$, when a forecastle is fitted in accordance with **Pt 7, Ch 3, Sec. 13**
$= 290$ in the other cases

The pressure P_{coam}, in kN/m^2, on the other coamings is given by:

$P_{coam} = 220$

2. Local net plate thickness

(1) The local net plate thickness t, in mm, of the hatch coaming plating is given by:

$$t = 14.9\,S\sqrt{\frac{P_{coam}}{\sigma_{a,coam}}S_{coam}}$$

where,

S = secondary stiffener spacing, in m
P_{coam} = pressure, in kN/m^2, as defined in **904. 1**
S_{coam} = safety factor to be taken equal to 1.15
$\sigma_{a,coam} = 0.95\sigma_y$

(2) The local net plate thickness is to be not less than 9.5 mm.

3. Net scantlings of longitudinal and transverse secondary stiffeners

The required section modulus Z, in cm^3, of the longitudinal or transverse secondary stiffeners of the hatch coamings, based on net member thickness, is given by:

$$Z = \frac{1000\,S_{coam}\,l^2\,S P_{coam}}{m\,c_P\,\sigma_{a,coam}}$$

where,

m = 16 in general
= 12 for the end spans of stiffeners sniped at the coaming corners
S_{coam} = safety factor to be taken equal to 1.15
l = span, in m, of secondary stiffeners
S = spacing, in m, of secondary stiffeners
P_{coam} = pressure in kN/m^2 as defined in **904.1**
c_P = ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth, in mm, equal to 40 t, where t is the plate net thickness
= 1.16 in the absence of more precise evaluation,
$\sigma_{a,coam} = 0.95\sigma_y$

4. Net scantlings of coaming stays

(1) The required minimum section modulus, Z, in cm^3, and web thickness, t_w, in mm, of coamings stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (see **Fig 7.3.8** and **7.3.9**) at their connection with the deck, based on member net thickness, are given by:

$$Z = \frac{1000 H_C^2 S P_{coam}}{2 \sigma_{a,coam}}$$

$$t_w = \frac{1000 H_C S P_{coam}}{h \ \tau_{a,coam}}$$

where,

H_C = stay height, in m

S = stay spacing, in m

h = stay depth, in mm, at the connection with the deck

P_{coam} = pressure, in $\mathrm{kN/m^2}$, as defined in **904. 1**

$\sigma_{a,coam} = 0.95 \sigma_y$

$\tau_{a,coam} = 0.5 \sigma_y$

(2) For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

(3) For other designs of coaming stays, such as, for examples, those shown in **Fig 7.3.10** and **7.3.11**, the stress levels in **903. 1** are to be applied and checked at the highest stressed locations.

5. Local details

(1) The design of local details is to be determined at the discretion of with the Society for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below.

(2) Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

(3) Underdeck structures are to be checked against the load transmitted by the stays, adopting the same allowable stresses specified in **904. 4**

(4) Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society requirements.

(5) Double continuous welding is to be adopted for the connections of stay webs with deck plating and the weld throat is to be not less than 0.44 t_w, where t_w is the gross thickness of the stay web.

(6) Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

905. Closing arrangements

1. Securing devices

The strength of securing devices is to comply with the following requirements:

(1) Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

(2) Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

(3) The net sectional area of each securing device is not to be less than:

$$A = 1.4 a / f \quad (\mathrm{cm}^2)$$

where,

a = spacing, in m, of securing devices, not being taken less than 2 m

$f = (\sigma_y / 235)^e$

σ_y = specified minimum upper yield stress, in N/mm^2, of the steel used for fabrication, not to be taken greater than 70% of the ultimate tensile strength.

$e = 0.75$ for $\sigma_y > 235 (N/mm^2)$

$= 1.0$ for $\sigma_y \leq 235 (N/mm^2)$

(4) Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

(5) Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weather tightness is to be maintained by the securing devices.

(6) For packing line pressures exceeding 5 N/mm, the cross section area is to be increased in direct proportion. The packing line pressure is to be specified.

(7) The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, I, of edge elements is not to be less than:

$$I = 6pa^4 \quad (cm^4)$$

where:

p = packing line pressure in N/mm, minimum 5 N/mm

a = spacing in m of securing devices.

(8) Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

(9) Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

(10) Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

2. Stoppers

(1) Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

(2) With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

(3) No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2, but this pressure may be reduced to 175 kN/m^2 when a forecastle is fitted in accordance with **Pt 7, Ch 3, Sec. 13.**

(4) The equivalent stresses in stoppers and their supporting structures, and calculated in the throat of the stopper welds are not to exceed the allowable value of $0.8\sigma_y$.

3. Materials and welding

Stoppers or securing devices are to be manufactured of materials, including welding electrodes, meeting this class requirements.

906. Corrosion addition and steel renewal

1. Hatch covers

(1) For all the structure (plating and secondary stiffeners) of single skin hatch covers, the corrosion addition t_s is to be 2.0 mm.

(2) For pontoon hatch covers, the corrosion addition is to be:

2.0 mm for the top and bottom plating
1.5 mm for the internal structures.

(3) For single skin hatch covers and for the plating of pontoon hatch covers, steel renewal is required where the gauged thickness is less than $t_{net}+0.5\text{mm}$.
(4) Where the gauged thickness is within the range $t_{net}+0.5\text{mm}$ and $t_{net}+1.0\text{mm}$, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.
(5) Coating is to be maintained in GOOD condition, as defined in **Pt 1, Ch 2, Sec. 1. 16.**
(6) For the internal structure of pontoon hatch covers, thickness gauging is required when plating renewal is to be carried out or when this is deemed necessary, at the discretion of the Society's Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net}.

2. Hatch coamings

(1) For the structure of hatch coamings and coaming stays, the corrosion addition t_s is to be 1.5 mm
(2) Steel renewal is required where the gauged thickness is less than $t_{net}+0.5\text{mm}$.
(3) Where the gauged thickness is within the range $t_{net}+0.5\text{mm}$ and $t_{net}+1.0\text{mm}$, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.
(4) Coating is to be maintained in GOOD condition, as defined in **Pt 1, Ch 2, Sec. 1, 16.**

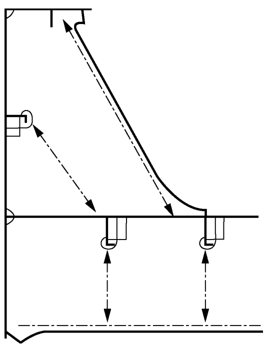


Fig 7.3.8

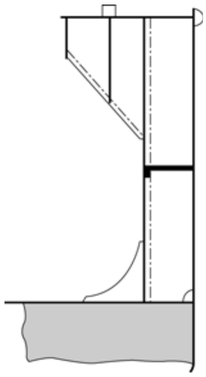


Fig 7.3.9

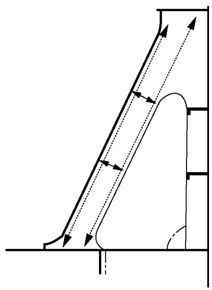


Fig 7.3.10

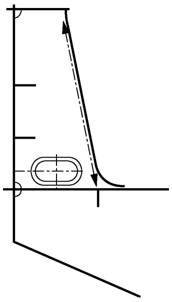


Fig 7.3.11

Section 10 Longitudinal Strength of Hull Girder in Flooded Condition for Bulk Carriers

1001. Application

1. These requirements are to be complied with in respect of the flooding of any cargo hold of bulk carriers, as defined **Pt 1, Annex 1-1, Remarks (11-2)**, with notation BC-A and BC-B, as defined in **Pt 7, Ch 3, Sec. 2,** which are contracted for construction on or after 1 July 2006.

Such ships are to have their hull girder strength checked for specified flooded conditions, in each of the cargo and ballast loading conditions defined in **Pt 3, Annex 3-1** of the Guidance and in every condition considered in the intact longitudinal strength calculations, including those and unloading transitory conditions in port and loading conditions encountered during ballast water exchange need not be considered. (Refer to the **Annex 7-7**)

1002. Flooding criteria

1. To calculating the weight of ingressed water, the following assumptions are to be made.
(1) The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.
(2) Appropriate permeabilities and bulk densities are to be used for any cargo carried.

(a) Iron ore : bulk density = 3.0 t/m^3, permeability = 0.3
(b) Cement : bulk density = 1.3 t/m^3, permeability = 0.3

(3) permeability for solid cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of the cargo, to the gross volume of the bulk cargo.

2. For packed cargo conditions (such as steel mill products), the actual density of the cargo should be used with a permeability of zero.

1003. Flooding conditions

1. Floodable holds

Each cargo hold is to be considered individually flooded up to the equilibrium waterline.

2. Loads

The still water loads in flooded conditions are to be calculated for the above cargo and ballast loading conditions.
The wave loads in the flooded conditions are assumed to be equal to 80% of those given in **Pt 3, Ch 3, Sec. 2 Table 3.3.1** and **Sec. 3 301. 1.**

1004. Stress assessment

1. The actual hull girder bending stress σ_{fld} at any location is given by :

$$\sigma_{fld} = \frac{M_{sf} + 0.8M_w}{Z} \times 10^3 \quad (\mathrm{N/mm^2})$$

where,

M_{sf} = still water bending moment in the flooded conditions for the section under consideration (kN-m).

M_w = wave bending moment as given in **Pt 3, Ch 3, Table 3.3.1.**

Z = section modulus for the corresponding location in the hull girder ($\mathrm{cm^3}$).

2. The shear strength of the side shell and the inner hull(longitudinal bulkhead) if any, at any location of the ship, is to be checked according to the requirements specified in **Pt 3, Ch 3, 301.** and **302.** in which F_s and F_w are to be replaced respectively by F_{SF} and F_{WF}, where :

F_{SF} = still water shear force, in kN, in the flooded conditions for the section under construction

F_{WF} = 0.8 F_w

F_w = wave shear force, in kN, as given in **Pt 3, Ch 3, 301.** for the section under construction

1005. Strength criteria

The damaged structure is assumed to remain fully effective in resisting the applied loading. Permissible stress and axial stress buckling strength are to be in accordance with **Pt 3, Ch 3, Table 3.3.1** and **Pt 3, Ch 3, 301.**

Section 11 Evaluation of Allowable Hold Loading for Bulk Carriers Considering Hold Flooding

1101. Application

1. These requirements are to be complied with in respect of the flooding of any cargo hold of bulk carriers of 150 m in length(L_f) and above, with single deck, topside tanks and hopper tanks, and of single side or double side skin construction intending to carry solid bulk cargoes t/m^3 having a density of 1.0 , or above, on or after 1 July 2006. (Refer to the **Annex 7-7**)

2. The loading in each hold is not to exceed the allowable hold loading in flooded condition, calculated as per **1104.,** using the loads given in **1102.** and the shear capacity of the double bottom given in **1103.**

3. In no case is the allowable hold loading, considering flooding, to be taken greater than the design hold loading in intact condition.

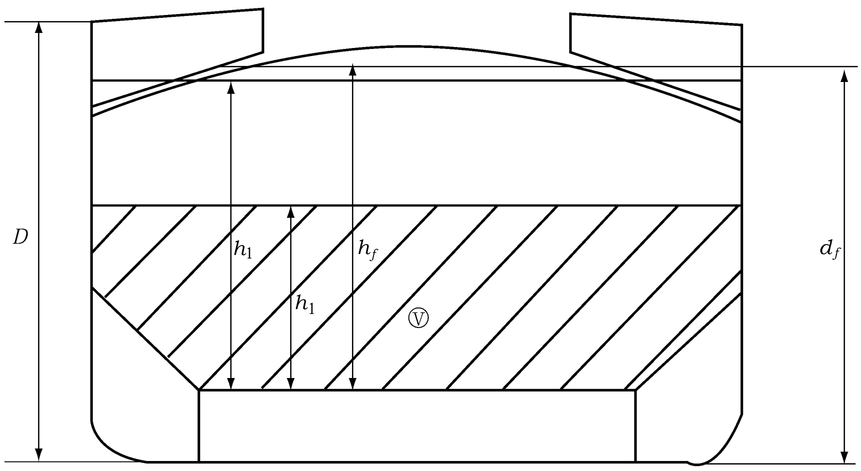
1102. Loading model

1. General

(1) The loads to be considered as acting on the double bottom are those given by follows.
  (a) External sea pressures
  (b) Combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.
(2) The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual :
  (a) Homogeneous loading condition.
  (b) Non-homogeneous loading condition.
  (c) Packed cargo conditions (such as steel mill products).
(3) For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold loading limit.

2. Inner bottom flooding head

The flooding head h_f is the distance measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f(m) from the baseline equal to :
(1) For ships less than 50,000 tonnes deadweight with Type B freeboard :
  (a) For the foremost hold : d_f = 0.95D
  (b) For the other holds : d_f = 0.85D
(2) In general
  (a) For the foremost hold : d_f = 1.0D
  (b) For the other holds : d_f = 0.9D



V : Volume of cargo

Fig. 7.3.12 Measurement of d_1, d_f, h_1 and h_f

1103. Shear capacity of the double bottom

1. The shear capacity C of the double bottom is defined as the sum of the shear strength at each end of :

(1) All floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool or transverse bulkhead if no stool is fitted (See **Fig 7.3.13**).

(2) All double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

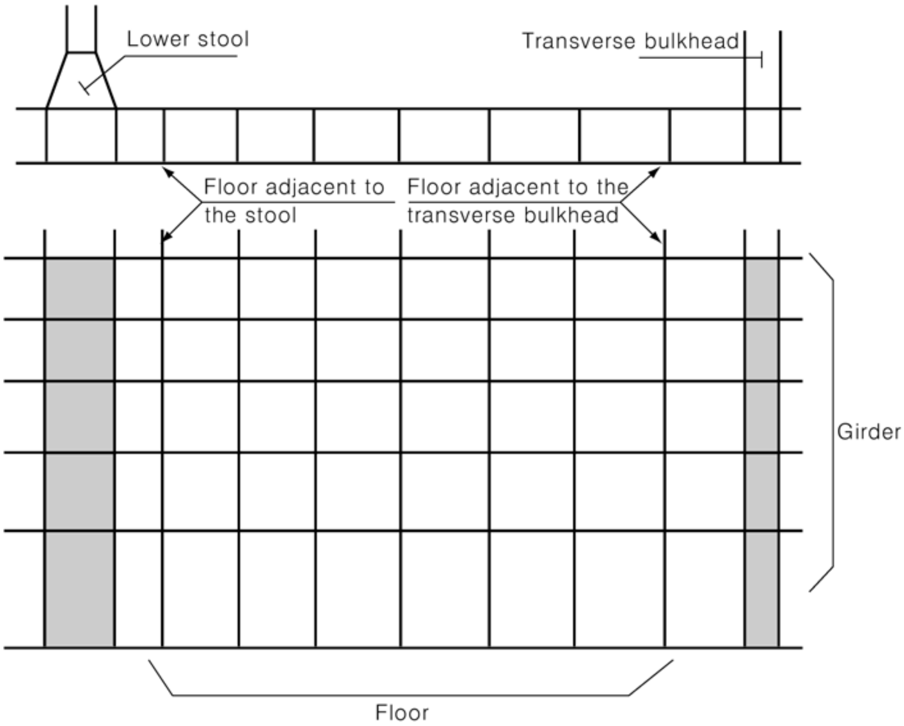


Fig 7.3.13 Floor and girder

2. Where in the end holds, girders or floors run out and are not directly attached to the boundary stool or hopper girder, their strength is to be evaluated for the one end only.

3. Note that the floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

4. When the geometry and/or the structural arrangement of the double bottom are such to make the above assumptions inadequate, the shear capacity C of double bottom is to be calculated according to the Society's discretion.

5. In calculating the shear strength, the net thickness of floors and girders is to be used. The net thickness $t_{\neq t}$ is given by :

$$t_{\neq t} = t - 2.5 \quad (\mathrm{mm})$$

t = thickness of floors and girders (mm).

6. Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1}(kN) and the floor shear strength in way of the openings in the outmost bay (i.e. that bay which is closer to hopper) S_{f2}(kN), are given by :

$$S_{f1} = A_f \frac{\tau_a}{\eta_1} \times 10^{-3} \quad \text{(kN)}$$

$$S_{f2} = A_{f,h} \frac{\tau_a}{\eta_2} \times 10^{-3} \quad \text{(kN)}$$

A_f = sectional area of the floor panel adjacent to hoppers (mm^2).

$A_{f,h}$ = net sectional area of the floor panels in way of the openings in the outmost bay (i.e. that bay which is closer to hopper) (mm^2).

τ_a = the allowable shear stress to be taken equal to the lesser of following formulae (N/mm^2).

$$\tau_{a1} = \frac{162\sigma_y^{0.6}}{(S/t_{\neq t})^{0.8}} \quad (N/mm^2), \qquad \tau_{a2} = \frac{\sigma_y}{\sqrt{3}} \quad (N/mm^2)$$

For floors adjacent to the stools or transverse bulkheads, τ_a may be taken as $\sigma_y / \sqrt{3}$

σ_y = minimum upper yield stress of the material (N/mm^2).

S = spacing of stiffening members of panel under consideration (mm).

η_1 = 1.1

η_2 = 1.2, may be reduced, to the Society's discretion, down to 1.1, where appropriate reinforcements are fitted to the Society's satisfaction.

7. Girder shear strength

The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) S_{g1}, and the girder shear strength in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted) S_{g2} are given by :

$$S_{g1} = A_g \frac{\tau_a}{\eta_1} \times 10^{-3} \quad \text{(kN)}$$

$$S_{g2} = A_{g,h} \frac{\tau_a}{\eta_2} \times 10^{-3} \quad \text{(kN)}$$

A_g = minimum sectional area of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) (mm^2).

$A_{g,h}$ = net sectional area of the girder panel in way of the largest opening in the outmost bay (i. e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted) (mm^2).

τ_a = allowable shear stress as given in **Par 6** (N/mm^2).

η_1 = 1.1

η_2 = 1.15, may be reduced, to the Society's discretion, down to 1.1 where appropriate reinforcements are fitted to the Society's satisfaction.

1104. Allowable hold loading

The allowable hold loading W is given by :

$$W = \rho_c V \frac{1}{F} \quad \text{(ton)}$$

F = 1.1 in general, and may be 1.05 for steel mill products.
ρ_c = Bulk cargo density (t/m^3).
V = Volume (m^3), occupied by cargo at a level h_1.

$$h_1 = \frac{X}{\rho_c g}$$

X = for bulk cargoes, the lesser of X_1 and X_2 given by :

$$X_1 = \frac{Z + \rho g(E - h_f)}{1 + \frac{\rho}{\rho_c}(perm - 1)}$$

$$X_2 = Z + \rho g(E - h_f\, perm)$$

X = X_1 using $perm = 0$, for steel products
ρ = sea water density (t/m^3).
g = gravity acceleration (= 9.81 m/s^2).
E = ship immersion (m), for flooded hold condition
= d_f - 0.1D
d_f = as given in **1102. Par 2.**
h_f = flooding head as defined in **1102. Par 2** (m).
$perm$ = cargo permeability, defined in **1002. Par 1.** it needs not be taken greater than 0.3 and is to be taken equal to zero for steel mill products.
Z = the lesser of Z_1 and Z_2 given by :

$$Z_1 = \frac{C_h}{A_{DB,h}}$$

$$Z_2 = \frac{C_e}{A_{DB,e}}$$

C_h = shear capacity of the double bottom, as defined in **1103.** considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (See **1103. Par 6**) and for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (See **1103. Par 7**) (kN).
C_e = shear capacity of the double bottom as defined in **1103.** considering, for each floor, the shear strength S_{f1} (See **1103. Par 6**) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (See **1103. Par 7**) (kN).

$$A_{DB,h} = \sum_{i=1}^{n} S_i B_{DB,i}$$

$$A_{DB,e} = \sum_{i=1}^{n} S_i (B_{DB} - S_l)$$

n = number of floors between stools (or transverse bulkheads, if no stool is fitted)
S_i = spacing of i th-floor (m).
$B_{DB,i}$ = $B_{DB} - S_l$, for floors whose shear strength is given by S_{f1}.

= $B_{DB,h}$, for floors whose shear strength is given by S_{f2}

B_{DB} = breadth of double bottom between hoppers (m) (See **Fig 7.3.14**).

$B_{DB,h}$ = distance between the two considered opening (m) (See **Fig 7.3.14**).

S_l = spacing of double bottom longitudinals adjacent to hoppers (m).

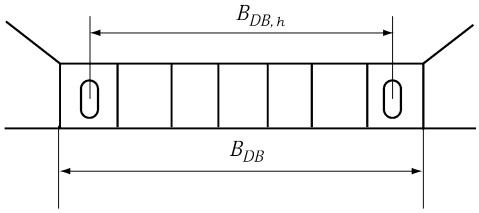


Fig. 7.3.14 Measurement $B_{DB,h}$ and B_{DB}

Section 12 Evaluation of Scantlings of Corrugated Transverse Watertight Bulkheads in Bulk Carriers Considering Hold Flooding

1201. Application and definitions

1. These requirements are to be complied with in respect of the flooding of any cargo hold of bulk carriers of 150 m in length(L_f) and above, with single deck, topside tanks and hopper tanks, and of single side or double side skin construction, intending to carry solid bulk cargoes having a density of 1.0 t/m^3, or above, with vertically corrugated transverse watertight bulkheads, which are contracted for construction on or after 1 July 2006. (Refer to the **Annex 7-7**)

2. The net thickness t_{net} is the thickness obtained by applying the strength criteria given in **1204.**

3. The required thickness is obtained by adding the corrosion addition t_s, given in **1206.** to the net thickness t_{net}.

4. In this requirement homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, does not exceed 1.2 to be corrected for different cargo densities (See, **Fig 7.3.15**).

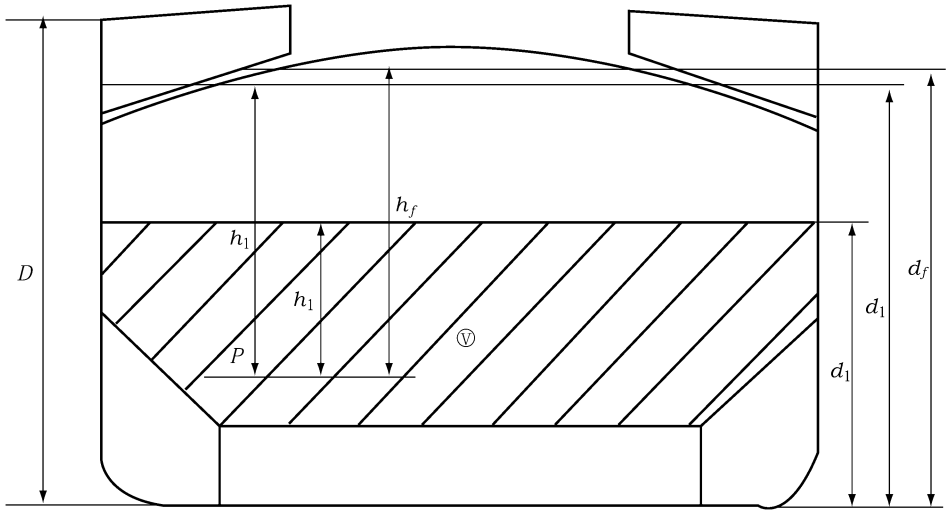


Fig 7.3.15 Measurement of d_1, d_f, h_1 and h_f

1202. Load model

1. General

(1) The loads to be considered as acting on the bulkheads are those given by the combination of the cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered.

(2) The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual :

(a) homogeneous loading conditions;

(b) non-homogeneous loading conditions(considering the individual flooding of both loaded and empty holds);

(3) The specified design load limits for the cargo holds are to be represented by loading conditions defined by the Designer in the loading manual.

(4) Non-homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements.

(5) Holds carrying packed cargoes are to be considered as empty holds for this application.

(6) Unless the ship is intended to carry, in non homogeneous conditions, only iron ore or cargo having bulk density equal or greater than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold shall also be considered to fill that hold volume up to the upper deck level at centreline.

2. Bulkhead corrugation flooding head

The flooding head h_f (See **Fig 7.3.15**) is the distance (m) measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f(m) from the baseline equal to :

(1) For ships less than 50,000 tonnes deadweight with Type B freeboard

(a) for the foremost transverse corrugated bulkhead : $d_f = 0.95D$

(b) for the other bulkheads : $d_f = 0.85D$

(2) For ships less than 50,000 tonnes deadweight with Type B freeboard and the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions.

(a) for the foremost transverse corrugated bulkhead : $d_f = 0.9D$

(b) for the other bulkheads : d_f = 0.8D

(3) In general

(a) for the foremost transverse corrugated bulkhead : d_f = D

(b) for the other bulkheads : d_f = 0.9D

(4) In (3), where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions.

(a) for the foremost transverse corrugated bulkhead : d_f = 0.95D

(b) for the other bulkheads : d_f = 0.85D

3. Pressure in the non-flooded bulk cargo loaded holds

(1) At each point of the bulkhead, the pressure P_c is given by :

$$P_c = \rho_c g h_1 \tan^2\gamma \quad (\mathrm{kN/m^2})$$

ρ_c = bulk cargo density ($\mathrm{t/m^3}$).

g = gravity acceleration (=9,81 $\mathrm{m/s^2}$).

h_1 = vertical distance (m), from the calculation point to horizontal plane corresponding to the level height of the cargo (See **Fig 7.3.15**), located at a distance d_1 (m) from the baseline.

γ = 45° - (ϕ / 2)

ϕ = angle of repose of the cargo, that may generally be taken as 35° for iron ore and 25° for cement.

(2) The force F_c acting on a corrugation is given by :

$$F_c = \rho_c g S_1 \frac{(d_1 - h_{DB} - h_{LS})^2}{2} \tan^2\gamma \quad (\mathrm{kN})$$

ρ_c, d_1, g and γ = as given above (1).

S_1 = spacing of corrugations (m) (See **Fig 7.3.16**).

h_{LS} = mean height of the lower stool from the inner bottom (m).

h_{DB} = height of the double bottom (m).

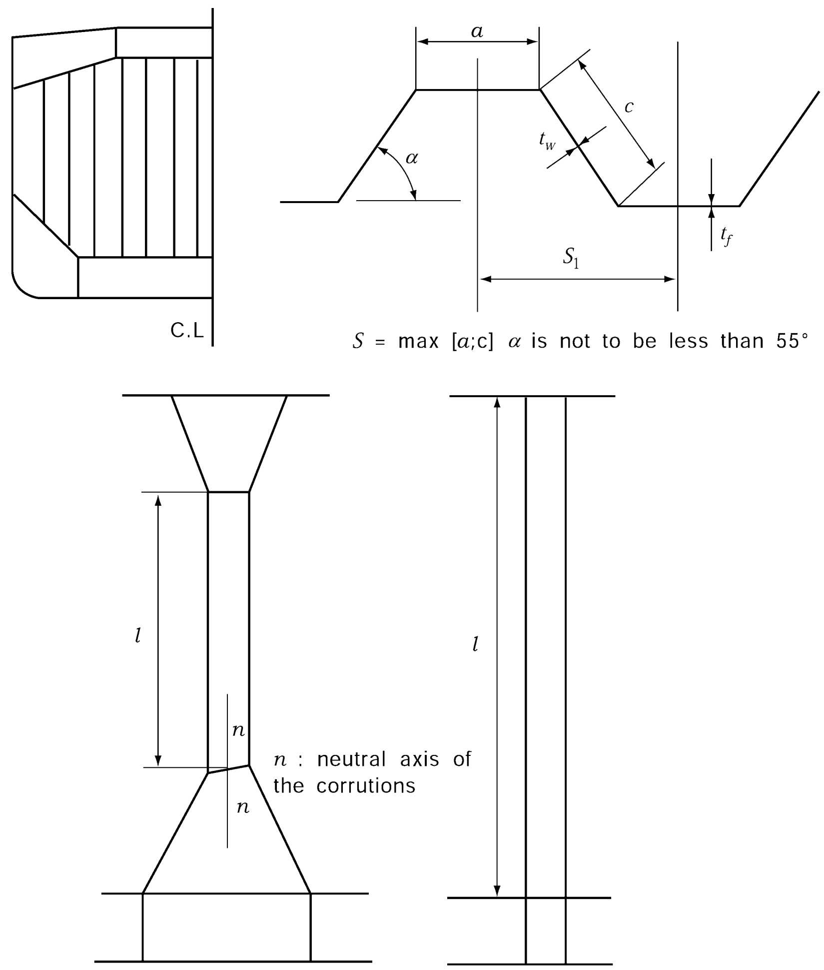


Fig 7.3.16 Measurement of S and l

4. Pressure in the flooded holds

(1) Bulk cargo holds

Two cases are to be considered, depending on the values of d_1 and d_f.

(a) $d_f \geq d_1$

(i) At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure P_{cf} is given :

$$P_{cf} = \rho g h_f \quad (\mathrm{kN/m^2})$$

ρ = sea water density $(\mathrm{t/m^3})$.
g = as defined in **1202. Par 3.** (1).
h_f = flooding head as defined in **1202. Par 2.**

(ii) At each point of the bulkhead located at a distance lower than d_1 from the baseline, the pressure P_{cf} is given by :

$$P_{cf} = \rho g h_f + [\rho_c - \rho(1 - perm)]\, g h_1 \tan^2\gamma \quad (\mathrm{kN/m^2})$$

ρ and h_f = as defined in above (i).

ρ_c, g, h_1 and γ = as defined in **1202. Par 3.**

$perm$ = permeability of cargo, as defined in **1202. Par 1.**

(iii) The force F_{cf} acting on a corrugation is given by :

$$F_{cf} = S_1 \left[\frac{\rho g (d_f - d_1)^2}{2} + \frac{\rho g (d_f - d_1) + (P_{cf})_{le}}{2} (d_1 - h_{DB} - h_{LS}) \right] \quad (\mathrm{kN})$$

where,

ρ = as defined in (i).

S_1, g, d_1, h_{LS} and h_{DB} = as given in **Par 3.**

d_f = as given in **Par 2.**

$(P_{cf})_{le}$ = pressure at the lower end of the corrugation ($\mathrm{kN/m^2}$).

(b) $d_f < d_1$

(i) At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure P_{cf} is given by :

$$P_{cf} = \rho_c g h_1 \tan^2 \gamma \quad (\mathrm{kN/m^2})$$

ρ_c, g, h_1 and γ = as given in above **Par 3.**

(ii) At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure, P_{cf}, is given by :

$$P_{cf} = \rho g h_f + [\rho_c h_1 - \rho (1 - perm) h_f] g \tan^2 \gamma \quad (\mathrm{kN/m^2})$$

where,

ρ, h_f and $perm$ = as given in above (a).

ρ_c, g, h_1 and γ = as given in above **Par 3.**

(iii) The force, F_{cf}, acting on a corrugation is given by :

$$F_{cf} = S_1 \left[\frac{\rho_c g (d_1 - d_f)^2}{2} \tan^2 \gamma + \frac{\rho_c g (d_1 - d_f) \tan^2 \gamma + (P_{cf})_{le}}{2} (d_f - h_{DB} - h_{LS}) \right] \quad (\mathrm{kN})$$

where,

ρ_c, S_1, g, d_1, γ, h_{DB} and h_{LS} = as given by above **Par 3.**

d_f = as given by above **Par 2.**

$(P_{cf})_{le}$ = pressure, at the lower end of the corrugation ($\mathrm{kN/m^2}$)

(2) Pressure in empty holds due to flooding water alone

At each point of the bulkhead, the hydrostatic pressure, P_f, induced by the flooding head, h_f, is to be considered. The force, F_f, acting on a corrugation is given by :

$$F_f = S_1 \rho g \frac{(d_f - h_{DB} - h_{LS})^2}{2} \quad (\mathrm{kN})$$

where,

ρ = as given by (1), (a), (i).

S_1, g, h_{DB} and h_{LS} = as given by **Par 3.**

d_f = as given by **Par 2.**

5. Resultant pressure and force

(1) Homogeneous loading conditions

(a) At each point of the bulkhead structures, the resultant pressure, P, to be considered for the scantlings of the bulkhead is given by ;

$$P = P_{cf} - 0.8P_c \quad (\mathrm{kN/m^2})$$

(b) The resultant force F, acting on a corrugation is given by ;

$$F = F_{cf} - 0.8F_c \quad (\mathrm{kN})$$

(2) Non-homogeneous loading conditions

(a) At each point of the bulkhead structures, the resultant pressure P, to be considered for the scantlings of the bulkhead is given by :

$$P = P_{cf} \quad (\mathrm{kN/m^2})$$

(b) The resultant force F, acting on a corrugation is given by :

$$F = F_{cf} \quad (kN)$$

1203. Bending moment and shear force in the bulkhead corrugations

The bending moment M and the shear force Q in the bulkhead corrugations are given by:

1. Bending moment

$$M = \frac{Fl}{8} \quad (\mathrm{kN\text{-}m})$$

F = resultant force, as given in **1202. Par 5.** (kN).

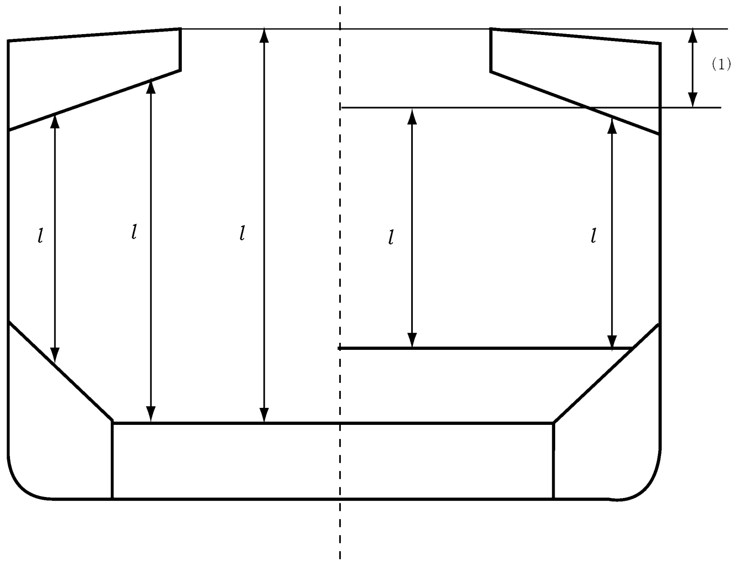
l = span of the corrugation (m) (See, **Fig 7.3.16** and **Fig 7.3.17**).

2. Shear force

The shear force Q, at the lower end of the bulkhead corrugations is given by :

$$Q = 0.8F \quad (\mathrm{kN})$$

F = as given in above **Par 1.**



(Note) (1) For the definition of l, the internal end of the upper stool is not to be taken more than a distance from the deck at the centerline equal to:
(1) For rectangular stool : 2 times the depth of corrugations.
(2) In general : 3 times the depth of corrugations.

Fig 7.3.17 Measurement of span l

1204. Strength criteria

1. General

The following criteria are applicable to transverse bulkheads with vertical corrugations (See **Fig 7.3.16**).

(1) For ships of 190 m of length and above, these bulkheads are to be fitted with a bottom stool, and generally with a top stool below deck. For smaller ships, corrugations may extend from inner bottom to deck.
(2) The corrugation angle(α) shown in **Fig 7.3.16** is not to be less than 55°.
(3) Requirements for local net plate thickness, $t_{\neq t}$ are given in **Par 7.** In addition, the criteria given in **Par 2** and **5** are to be complied with.
(4) The thicknesses of the lower part of corrugations considered in the application of **Par 2** and **3** are to be maintained for a distance from the inner bottom(if no lower stool is fitted) or the top of the lower stool not less than 0.15 l.
(5) The thicknesses of the middle part of corrugations as considered in the application of **Par 2** and **4** are to be maintained to a distance from the deck or the bottom of the upper stool not greater than 0.3 l.
(6) The section modulus of the corrugation in the remaining upper part of the bulkhead is not to be less than 75 % of that required for the middle part, corrected for different yield stresses.
(7) Lower stool
  (A) The height of the lower stool is generally to be not less than 3 times the depth of the corrugations. The thickness and material of the stool top plate is not to be less than those required for the bulkhead plating above.
  (B) The thickness and material of the upper portion of vertical or sloping stool side plating within the depth equal to the corrugation flange width from the stool top is not to be less than the required flange plate thickness and material to meet the bulkhead stiffness requirement at lower end of corrugation.
  (C) The thickness of the stool side plating and the section modulus of the stool side stiffeners is not to be less than the value given by the following formulae.
    (a) The thickness of the stool side plating

(i) $d_f \geq d_1$

$$t = CS\sqrt{h_1' K} + 2.5 \quad (\text{mm})$$

(ii) $d_f < d_1$

$$t = CS\sqrt{h_2' K} + 2.5 \quad (\text{mm})$$

where,

C = coefficient given by the following formula.

$$C = 3.825 C_1$$

C_1 = coefficient given by the following formula according to the value l/S.

$$1 \leq \frac{l}{S} < 3.5 \quad : \left(0.11\frac{l}{S} + 0.615\right)$$

$$3.5 \leq \frac{l}{S} \quad : 1.0$$

S = length of the shorter side of the panel enclosed by stiffeners, etc.
l = length of the longer side of the panel enclosed by stiffeners, etc.
h_1' and h_2' = as given in following formulae.

$$h_1' = h_f + \left\{\frac{\rho_c}{\rho} - (1 - perm)\right\} h_1 (\sin^2\beta \tan^2\gamma + \cos^2\beta)$$

$$h_2' = h_f + \left\{\frac{\rho_c}{\rho} h_1 - (1 - perm) h_f\right\} (\sin^2\beta \tan^2\gamma + \cos^2\beta)$$

β = slope angle of stool side plate (deg).
h_f = as given in **1202. Par 2.**
ρ_c, h_1 and γ = as given in **1202. Par 3.**
ρ = as given in **1202. Par 4.**
$perm$ = permeability of cargo, as defined in **1002. Par 1,** (3).

(b) The section modulus of the stool side vertical stiffeners

(i) $d_f \geq d_1$

$$Z = 7.8 KSh_1' l^2 \quad (\text{cm}^3)$$

(ii) $d_f < d_1$

$$Z = 7.8 KSh_2' l^2 \quad (\text{cm}^3)$$

where,

S = spacing of stiffeners (m).
l = unsupported length of stiffener (m).
h_1' and h_2' = as given in (a).

(D) The distance from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with **Fig 7.3.18.**

(E) The stool bottom is to be installed in line with double bottom floors and is to have a width not less than 2.5 times the mean depth of the corrugation. The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

(F) Where corrugations are cut at the bottom stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds.(See **Fig 7.3.20**) The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds.(See **Fig 7.3.20**)

(G) The plating of the lower stool and supporting floors is generally to be connected to the inner bottom by full penetration welds.

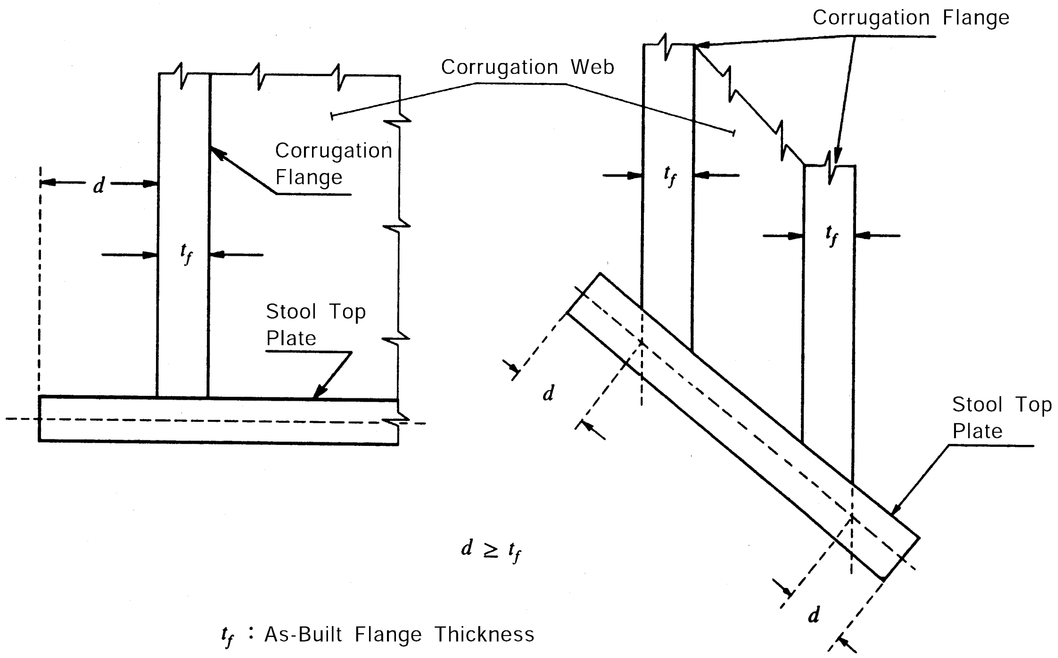


Fig 7.3.18 Permitted distance, d, from edge of stool top plate to surface of corrugation flange

(8) Upper stool

(A) The upper stool, where fitted, is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to 2 times the depth of corrugations, measured from the deck level and at hatch side girder.

(B) The upper stool is to be properly supported by girders or deep brackets between the adjacent hatch-end beams.

(C) The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non rectangular stools is to have a width not less then 2 times the depth of corrugations. The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below.

(D) The thickness of the lower portion of stool side plating is not to be less than 80 % of that required for the upper part of the bulkhead plating where the same material is used.

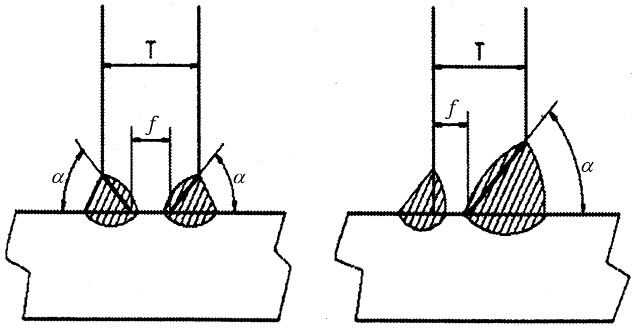
(E) The thickness of the stool side plating and the section modulus of the stool side stiffeners is not to be less than those required by the Society on the basis of the load model in (7), (C). The ends of stool side stiffener are to be attached to brackets at upper and lower end of the stool.

(F) Diaphragms are to be fitted inside the stool in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

(9) Alignment

(A) At deck, if no stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

(B) At bottom, if no stool is fitted, the corrugation flanges are to be in line with the supporting floors. Corrugated bulkhead plating is to be connected to the inner bottom plating by full penetration welds. The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds. (See **Fig 7.3.20**)



Root face (f) : 3 mm ~ T/3 mm
Groove Angle (α) : 40° ~ 60°

Fig 7.3.20 Welding methods

(C) The thickness and material properties of the supporting floors are to be at least equal to those provided for the corrugation flanges. Moreover, the cut-outs for connections of the inner bottom longitudinal to double bottom floors are to be closed by collar plates.

(D) The supporting floors are to be connected to each other by suitably designed shear plates, as deemed appropriate by the Society.

(E) Stool side plating is to align with the corrugation flanges and stool side vertical stiffeners and their brackets in lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. Stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top.

2. Bending capacity and shear stress

(1) The bending capacity is to be comply with the following relationship :

$$\frac{M}{0.5Z_{le}\sigma_{a,le}+Z_m\sigma_{a,m}}\times 10^3 \leq 0.95$$

M = bending moment, as given in **1203. Par 1** (kN-m).

Z_{le} = section modulus of one half pitch corrugation, at the lower end of corrugations, as given in **Par 3** (cm^3).

Z_m = section modulus of one half pitch corrugation, at the mid-span of corrugations, as given in **Par 4** (cm^3).

$\sigma_{a,le}$ = allowable stress, as given in **Par 5,** for the lower end of corrugations (N/mm^2).

$\sigma_{a,m}$ = allowable stress, as given in **Par 5,** for the mid-span of corrugations (N/mm^2).

(A) In no case Z_m is to be taken greater than the lesser of 1.15 Z_{le} and 1.15 Z'_{le} for calculation of the bending capacity, Z'_{le} being defined below.

(a) In case shedder plates are fitted which :
- are not knuckled;
- are welded to the corrugations and the top of the lower stool by one side penetration weld or equivalent;
- are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating;

- have thicknesses not less than 75 % of that provided by the corrugation flange ;
- and material properties at least equal to those provided by the flanges.

(b) Or gusset plates are fitted which:
- are in combination with shedder plates having thickness, material properties and welded connections in accordance with the above requirements;
- have a height not less than half of the flange width;
- are fitted in line with the stool side plating;
- are generally welded to the top of the lower stool by full penetration welds, and to the corrugations and shedder plates by one side penetration welds or equivalent.
- have thickness and material properties at least equal to those provided for the flanges.

(B) The section modulus Z_{le}, is to be taken not larger than the value Z'_{le}, given by :

$$Z'_{le} = Z_g + \frac{Qh_g - 0.5\,h_g^2 S_1 P_g}{\sigma_a} \times 10^3 \quad (\text{cm}^3)$$

Z_g = section modulus of one half pitch corrugation calculated, according to **Par 4.** in way of the upper end of shedder or gusset plates, as applicable (cm^3).

Q = shear force, as given in **1203. Par 2.** (kN).

h_g = height of shedder or gusset plates (m), as applicable (See **Fig 7.3.19** (1), (2), (3) and (4)).

S_1 = as given in **1202. Par 3.**

P_g = resultant pressure, as defined in **1202. Par 5.** calculated in way of the middle of the shedder or gusset plates (kN/m^2), as applicable.

σ_a = allowable stress, as given in **Par 5.** (kN/m^2).

(2) Shear stress τ is obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by ($\sin\alpha$), α being the angle between the web and the flange.

(3) When calculating the section modulus and the shear area, the $t_{\neq t}$ plate thicknesses are to be used.

(4) The section modulus of corrugations are to be calculated on the basis of the following requirements given in **Par 3** and **4.**

3. Section modulus at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef}, not larger than as given in **Par 6.** If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30 % effective.

(1) Provided that effective shedder plates, as defined in above **Par 2** are fitted (See **Fig 7.3.19** (1) and (2)), when calculating the section modulus of corrugations at the lower end (cross-section ① in **Fig 7.3.19** (1) and (2)), the area of flange plates may be increased by $2.5a\sqrt{t_f t_{sh}}$ (not to be taken greater than $2.5\,at_f$).

a = width of the corrugation flange (m) (See **Fig 7.3.12**).

t_{sh} = net shedder plate thickness (mm).

t_f = net flange thickness (mm).

(2) Provided that effective gusset plates, as defined in above **Par 2** are fitted (See **Fig 7.3.19** (3) and (4)), when calculating the section modulus of corrugations at the lower end (cross-section ① in **Fig 7.3.19** (3) and (4)), the area of flange plates may be increased by $7\,h_g t_f$.

h_g = height of gusset plate (m), see **Fig 7.3.19** (3) and (4), not to be taken greater than

$\frac{10}{7} S_{gu}$

S_{gu} = width of the gusset plates (m).

t_f = net flange thickness based on the as built condition (mm).

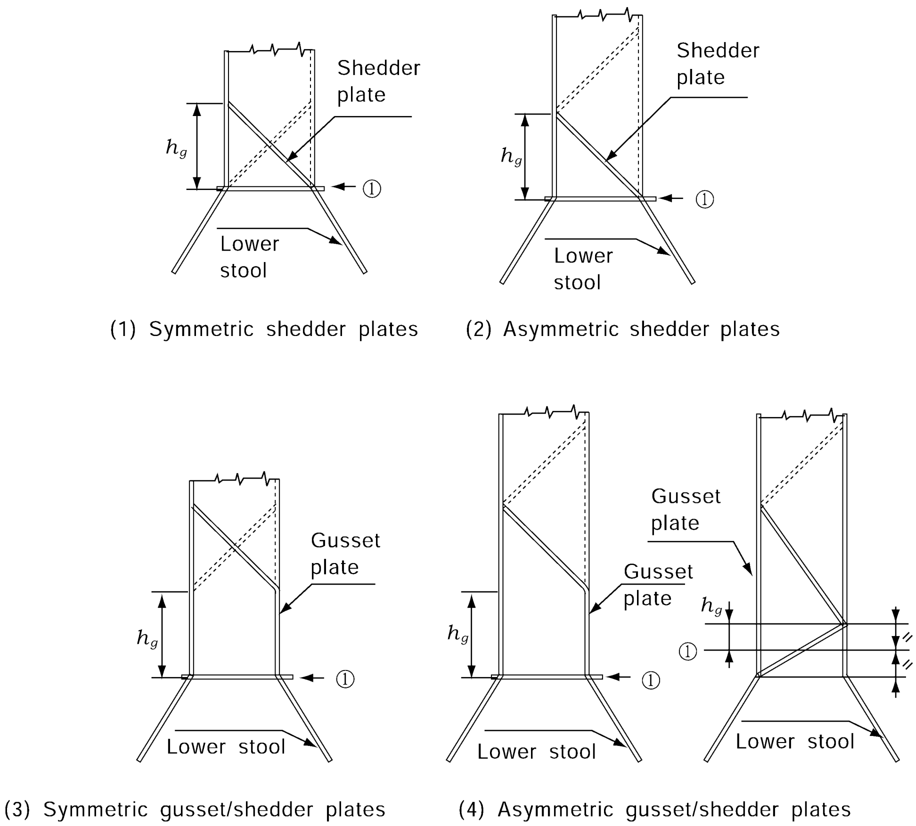


Fig. 7.3.19 Shedder plate and gusset plate

(3) If the corrugation webs are welded to a sloping stool top plate, which have an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in above (2). No credit can be given to shedder plates only. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30 % for 0° and 100 % for 45°.

4. Section modulus of corrugations at cross-sections other than the lower end

The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, b_{ef}, not larger than as given in **Par 6.**

5. Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a given by:

$$\sigma_a = \sigma_y \quad (\text{N/mm}^2)$$

$$\tau_a = 0.5\sigma_y \quad (\text{N/mm}^2)$$

σ_y = the minimum upper yield stress of the material (N/mm^2).

6. Effective compression flange width and shear buckling checks

(1) Effective width of the compression flange of corrugations
The effective width b_{ef} of the corrugation flange is given by :

$$b_{ef} = C_e \alpha \quad (\text{m})$$

$$\beta > 1.25 \ : \ C_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2}$$

$$\beta \leq 1.25 \ : \ C_e = 1.0$$

$$\beta = \frac{a}{t_f}\sqrt{\frac{\sigma_y}{E}} \times 10^3$$

where,

t_f = net flange thickness (mm).

α = width of the corrugation flange (m) (See **Fig 7.3.16**)

σ_y = the minimum upper yield stress of the material (N/mm^2).

E = modulus of elasticity of the material (N/mm^2) to be assumed equal to 2.06×10^5 for steel.

(2) Shear
The buckling check is to be performed for the web plates at the corrugation ends. The shear stress τ is not to exceed the critical value τ_c , as given by the following formulae.

$$\tau_c = \tau_E \qquad : \quad \tau_E \leq 0.5\tau_y$$

$$\tau_c = \tau_y\left(1 - \frac{\tau_y}{4\tau_E}\right) \qquad : \quad \tau_E > 0.5\tau_y$$

where,

τ_y = shear stress of material, in N/mm^2, t_y is to be determined as $\sigma_y/\sqrt{3}$

τ_E = ideal elastic buckling stress is determined as following :

$$\tau_E = 0.9 k_t E\left(\frac{t}{1000c}\right)^2 \quad (\text{N/mm}^2)$$

$k_t = 6.34$

t = net thickness of corrugation web (mm).

c = width of corrugation web (m). (See, **Fig 7.3.16**)

σ_y and E = as given in above (1).

7. Local net plate thickness

(1) The bulkhead local net plate thickness t_{net} is given by :

$$t_{net} = 14.9 S_w \sqrt{\frac{1.05P}{\sigma_y}} \quad (\text{mm})$$

where,

S_w = plate width, to be taken equal to the width of the corrugation flange or web, whichever is the greater (m) (See **Fig 7.3.16**).

P = resultant pressure as defined in **1202. Par 5,** at the bottom of each strake of plating, in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of sheddres, if shedders or gusset/shedder plates are fitted (kN/m^2).

σ_y = minimum upper yield stress of the material (kN/m^2).

(2) For built-up corrugation bulkheads, when the thicknesses of the flange and web are different,

(A) The net thickness of the narrower plating is to be not less than t_n, given by :

$$t_n = 14.9 S_n \sqrt{\frac{1.05P}{\sigma_y}} \quad (\text{mm})$$

where,

S_n = the width of the narrow plating (m).

P and σ_y = as given in (1).

(B) The net thickness of the wider plating is not to be taken less than the maximum of the following values :

$$t_{w1} = 14.9 S_w \sqrt{\frac{1.05P}{\sigma_y}} \quad (\text{mm})$$

$$t_{w2} = \sqrt{\frac{440\,S_w^2 \times 1.05\,P}{\sigma_y} - t_{np}^2} \quad (\text{mm})$$

where,

t_{np} = not to be more than the smaller value of the actual net thickness of the narrower plating and t_{w1}.

S_w = the breath of the wider plating (m).

P and σ_y = as given in (1).

1205. Local details

1. As applicable, the design of local details is to be designed such that transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures, is sufficient.

2. In particular, the thickness and stiffening of effective gusset and shedder plates is to comply with the Society requirement, on the basis of the load model in **1204. Par 2.**

1206. Corrosion addition

The corrosion addition t_s is to be taken equal to 3.5 mm.

Section 13 Requirements for the Fitting of a Forecastle for Bulk Carriers, Ore Carriers and Combination Carriers

1301. Application and definitions

These requirements apply to all bulk carriers, ore carriers and combination carriers which are contracted for construction on or after 1 January 2004. Such ships are to be fitted with an enclosed forecastle on the freeboard deck. The required dimensions of the forecastle are defined in **1302.**
The structural arrangements and scantlings of the forecastle are to be determined at the discretion of the Society.

1302. Dimensions

1. The forecastle is to be located on the freeboard deck with its an bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in **Fig 7.3.21.**

However, if this requirements hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of the ship length abaft the forward perpendicular where the ship length and forward perpendicular are defined in the International Convention of Load Line 1966 and its Protocol 1988.

2. The forecastle height H_F above the main deck is to be not less than:

-the standard height of a superstructure as specified in the International Convention on Load Line 1966 and its Protocol of 1988,
-$H_C + 0.5\,\mathrm{m}$, where is the height of the forward transverse hatch coaming of cargo hold No.1,
whichever is the greater.

3. All points of the aft edge of the forecastle deck are to be located at a distance l_F:
$l_F \leq 5\sqrt{H_F - H_C}$ from the hatch coaming plate in order to apply the reduced loading to the No.1 forward transverse hatch coaming and No.1 hatch cover in applying **Sec. 9. 904. 1.** and **905. 2.**

4. A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centre line is not less than $H_B/\tan 20°$ forward of the aft edge of the forecastle deck, where h_B is the height of the breakwater above the forecastle (see **Fig 7.3.21**).

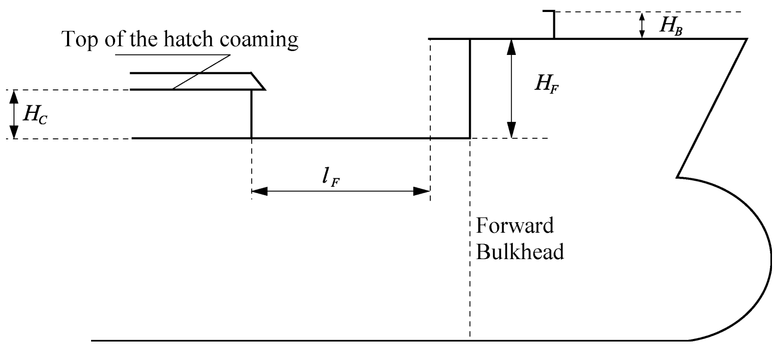


Fig 7.3.21

Section 14 Water Level Detection & Alarms and Drainage & Pumping Systems for Bulk Carriers and Single Hold Cargo Ships

1401. General

Arrangements, testing and etc. for water level detectors, alarms and drainage, pumping systems required by **1403.** and **1404.** are to be followed in accordance with the requirements specified by the Society.

1402. Application

The requirements of this section apply to the ships of 500 tons gross tonnage and above and engaged on international voyage as follows;

1. A ship which is constructed before 1 July 2006 and constructed generally with single deck, top-side tanks and hopper side tanks in cargo spacs, and is intended primarily to carry dry cargo in bulk, and includes such types as ore carriers and combination carriers and a ship which is constructed on or after 1 July 2006 and is intended primarily to carry dry cargo in bulk, and includes such types as ore carriers and combination carriers(hereinafter referred to as 「Bulk carrier」) are to be installed relevant systems in accordance with the requirements in **1403. 1** and **1404.**

2. Cargo ships other than bulk carriers having a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to the deck(hereinafter referred to as「Single hold cargo ship」) and come fall under following (1) or (2) are to be installed relevant systems in accordance with the requirements of **1403. 3.**

(1) Ships having a length(L) of less than 80 m if constructed on or after 1 July 1998
(2) Ships having a length(L) of less than 100 m if constructed before 1 July 1998

However, the water level detectors required by **1403. 3** need not be fitted in ships fitted with water level detectors complying with the requirements in **1403. 1**, or in ships having suitable width watertight side compartments each side of the cargo hold length extending vertically at least from inner bottom to freeboard deck.

Ships constructed before 1 January 2007 are to be in accordance with the requirements in **Pt 1, Ch.2, 1602.**

1403. Water level detectors, alarms and etc.

1. Water level detectors, audible and visual alarms are to be fitted in each cargo hold, ballast tanks forward of the collision bulkhead, dry space and void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold for bulk carriers.

2. Such alarms specified in **Par. 1** need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the ship‘s maximum displacement volume.

3. Single hold cargo ships having a length(L) of less than 80 m(ships having a length(L) of less than 100 m if constructed before 1 July 1998) are to be fitted with water level detectors, audible and visual alarms in cargo hold. And ships having cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to the deck are to be fitted with water level detectors, audible and visual alarms in each cargo hold.

4. The audible and visual alarms specified in **Par. 1** and **3** shall be located on the navigation bridge.

1404. Draining and pumping system

1. Means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces in any part of which extends forward of the foremost cargo hold are to be provided.

2. Means for draining and pumping specified in **Par. 1** brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks.

Section 15 Supplementary Provisions for Carriage of Liquid in Holds

1501. General

1. Bulk carriers whose holds are loaded with cargo oil (hereinafter referred to as "B/O Carriers") are to be in accordance with the requirements in this Section and also those for oil tankers.

2. Other important items required for B/O carriers than those specified in this Section are to be at the discretion of the Society.

3. Where holds are loaded with cargo oil or ballast water, the scantlings of plates, stiffeners and girders composing bilge hopper tanks, topside tanks, transverse bulkheads and their stools as well as side structures are not to be less than those obtained from the relevant formulae, where the value of h specified in **Pt 3, Ch 15, 105.** is applied. The scantlings of structural members of double bottom under holds loaded with ballast are to be at the discretion of the Society.

4. When ships are designed to transport alternatively oil having a flash point below 60°C (closed cup test) or dry cargoes, openings which may be used for cargo operations are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless alternative approved means are provided to ensure equivalent integrity.

1502. Holds half-loaded with cargo oils

Where holds are half-loaded with cargo oils, special care is to be taken to avoid synchronization of the natural period of oscillation of liquid in the holds with the natural periods of rolling and pitching of the ship. Where synchronization is not avoidable, plating, stiffeners and girders of transverse bulkheads and topside tanks are to be specially strengthened.

Section 16 Electrical Equipment of Coal Carriers

1601. General

The requirements in this Section apply to the electrical equipment installed in the cargo holds and the compartments adjacent thereto of coal carriers.

1602. Dangerous spaces

The following spaces and zones are dangerous spaces, therefore no electrical equipment except those of explosion protected type is to be installed
(1) Enclosed cargo holds
(2) Ventilation ducts for cargo holds

1603. Electrical equipment

1. Electrical equipment in cargo hold

In principle no electrical equipment is to be installed in the cargo holds. Where it is inevitable to install electrical equipment in the holds, the equipment is to comply with the following requirements:

(1) Switches and socket-outlets are not to be installed except those connected to intrinsically safe circuits.
(2) In case where other electrical equipment than those specified in (1) above is inevitably installed, the equipment and its associated cables are to be installed so as to be kept from mechanical damage. In addition, the feeder circuits for the equipment are to be provided with multipole linked isolating switches situated outside the holds, so deviced as to have the equipment usually locked with the switch in "off" position.
(3) The cables passing through the cargo holds are to be led in gastight heavy gauge steel pipes, and the both ends of the pipes are to be sealed using cable glands and the like in way of the boundaries of the cargo holds.

2. Electrical equipment in the compartments adjacent to cargo holds

The electrical equipment which is installed in the compartments adjacent to the cargo holds and having an opening such as non-gastight door, hatch and like in their bulkheads and decks is to be of explosion protected type accepted by the Society.

3. Cargo lamps

Cargo lamps to be led and used in the cargo holds are to be the types accepted by the Society.

Section 17 Renewal Criteria for Side Shell Frames and Brackets in Single Side Skin Bulk Carriers and Single Side Skin OBO Carriers

1701. Application and definitions

1. These requirements apply to the side shell frames and brackets of cargo holds bounded by the single side shell of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk, which were not built in accordance with **Ch 3, Sec. 7.**

2. In addition, these requirements also apply to the side shell frames and brackets of cargo holds bounded by the single side shell of Oil/Bulk/Ore(OBO) carriers, as defined in **Pt 1, Annex 1-1** of the Guidance relating to the Rules but of single side skin construction.

3. In the case a vessel as defined above does not satisfy above definition in one or more holds, the requirements in this section do not apply to these individual holds.

4. For the purpose of this section, "ships" means both "bulk carriers" and "OBO carriers" as defined above, unless otherwise specified.

5. Bulk carriers subject to these requirements are to be assessed for compliance with the requirements of this rules, the details of these requirements to be followed **Pt 1, Ch 3, 201.** (4) (A).

6. OBO carriers subject to these requirements are to be assessed for compliance with the requirements of this rules, the details of these requirements to be followed **Pt 1, Ch 3, 201.** (4) (B).

7. These requirements define steel renewal criteria or other measures to be taken for the webs and flanges of side shell frames and brackets as per **1702.**

8. Reinforcing measures of side frames are also defined as per **1702. 3.**

9. Finite element or other numerical analysis or direct calculation procedures cannot be used as an alternative to compliance with the requirement of this rule, except in cases off unusual side structure arrangements or framing to which the requirements of this rule cannot be directly applied.

10. Ice strengthened ships

(1) Where ships are reinforced to comply with an ice class notation the intermediate frames are not to be included when considering compliance with this rule
(2) The renewal thicknesses for the additional structure required to meet the ice strengthening notation are to be based on **Pt 3, Ch 20.**
(3) If the ice class notation is requested to be withdrawn, the additional ice strengthening structure, with the exception of tripping brackets (see **1702. 1.** (2) (A) (b) and **1702. 3.**), is not considered to contribute to compliance with this requirement.

1702. Renewal or other measures

1. Criteria for renewal or other measures

(1) Symbols

t_M = thickness as measured, in mm

t_{REN} = thickness at which renewal is required. See **1702. 1.** (2).

$t_{REN,d/t}$ = thickness criteria based on d/t ratio. See **1702. 1.** (2) (A)

$t_{REN,S}$ = thickness criteria based on strength. See **1702. 1.** (2) (B)

t_{COAT} = $0.75 t_{S12}$

t_{S12} = thickness in mm as required by **Ch 3, 106. 3., 4.** for frame webs and by **Ch 3, 702.** for upper and lower brackets webs

t_{AB} = thickness as built, in mm

t_C = See **Table 7.3.12** below

Table 7.3.12 t_C **Values, in** mm

Ship's length L, in m	Hold other than No.1		Hold No.1	
	Span and upper brackets	Lower brackets	Span and upper brackets	Lower brackets
≤100	2.0	2.5	2.0	3.0
150	2.0	3.0	3.0	3.5
≥200	2.0	3.0	3.0	4.0
Note: For intermediate ship lengths, t_C is obtained by linear interpolation between the above values.				

(2) Criteria for webs (Shear and other checks)
The webs of side shell frames and brackets are to be renewed when the measured thickness (t_M) is equal to or less than the thickness (t_{REN}) as defined below:

t_{REN} is the greatest of:

(a) $t_{COAT} - t_C$

(b) $0.75\, t_{AB}$

(c) $t_{REN,d/t}$ (applicable to Zone A and B only)

(d) $t_{REN,S}$ (where required by **1702. 1.** (2) (B))

(A) Thickness criteria based on d/t ratio
Subject to (b) and (c) below, $t_{REN,d/t}$ is given by the following equation:

$$t_{REN,d/t} = (\text{web depth in mm})\ /R$$

where:

R = for frames

$65\, k^{0.5}$ for symmetrically flanged frames

$55\, k^{0.5}$ for asymmetrically flanged frames

for lower brackets (see (a) below):

$87\, k^{0.5}$ for symmetrically flanged frames

$73\, k^{0.5}$ for asymmetrically flanged frames

k = According to **Pt 3, Ch 1, Sec. 4.**

In no instance is $t_{REN,d/t}$ for lower integral brackets to be taken as less than $t_{REN,d/t}$ for the frames they support.

(a) Lower brackets
Lower brackets are to be flanged or face plate is to be fitted.
In calculating the web depth of the lower brackets, the following will apply:

The web depth of lower bracket may be measured from the intersection of the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see **Fig 7.3.24**).
Where stiffeners are fitted on the lower bracket plate, the web depth may be taken as the distance between the side shell and the stiffener, between the stiffeners or between the outermost stiffener and the face plate of the brackets, whichever is the greatest.

(b) Tripping bracket alternative

When t_M is less than $t_{REN,d/t}$ at section b) of the side frames, tripping brackets in accordance with **1702. 3**. may be fitted as an alternative to the requirements for the web depth to thickness ratio of side frames, in which case $t_{REN,d/t}$ may be disregarded in the determination of t_{REN} in accordance with **1702. 1.** (2).

(c) Immediately abaft collision bulkhead
For the side frames, including the lower bracket, located immediately abaft the collision bulkheads, whose scantlings are increased in order that their moment of inertia is such to avoid undesirable flexibility of the side shell, when their web as built thickness t_{AB} is greater than $1.65t_{REN,S}$, the thickness $t_{REN,d/t}$ may be taken as the value $t'_{REN,d/t}$ obtained from the following equation:

$$t'_{REN,d/t} = \sqrt[3]{t^2_{REN,d/t} \quad t_{REN,S}}$$

where, $t_{REN,S}$ is obtained from **1703. 3.**

(B) Thickness criteria based on shear strength check
Where t_M in the lower part of side frames, as defined in **Fig 7.3.22**, is equal to or less than t_{COAT}, $t_{REN,S}$ is to be determined in accordance with **1703. 3.**

(C) Thickness of renewed webs of frames and lower brackets
Where steel renewal is required, the renewed webs are to be of a thickness not less than t_{AB}, $1.2t_{COAT}$ or $1.2t_{REN}$, whichever is the greatest.

(D) Criteria for other measures
When $t_{REN} < t_M < t_{COAT}$, measures are to be taken, consisting of all the following:
(a) sand blasting, or equivalent, and coating (see **1702. 2.**),
(b) fitting tripping brackets (see **1702. 3.**), when the above condition occurs for any of the side frame zones A, B, C and D, shown in **Fig 7.3.22**, and
(c) maintaining the coating in "as-new" condition (i.e. without breakdown or rusting) at Special and Intermediate Surveys.

The above measures may be waived if the structural members show no thickness diminution with respect to the as built thicknesses and coating is in "as-new" condition (i.e. without breakdown or rusting).
When the measured frame webs thickness t_M is such that $t_{REN} < t_M < t_{COAT}$ and the coating is in GOOD condition, sand blasting and coating as required in (a) above may be waived even if not found in "as-new"condition, as defined above, provided that tripping brackets are fittted and the coating damaged in way of the tripping bracket welding is repaired.

(3) Criteria for frames and brackets (Bending check)
Where the length or depth of the lower bracket does not meet the requirements in **Ch 3, Sec. 7.**, a bending strength check in accordance with **1703. 4.** is to be carried out and renewals or reinforcements of frames and/or brackets effected as required therein.

2. Thickness measurements, steel renewal, sand blasting and coating

(1) For the purpose of steel renewal, sand blasting and coating, four zones A, B, C and D are defined, as shown in **Fig 7.3.22.**
(2) Representative thickness measurements are to be taken for each zone and are to be assessed against the criteria in **1702. 1.**
(3) In case of integral brackets, when the criteria in **1702. 1.** are not satisfied for zone A or B, steel renewal, sand blasting and coating, as applicable, are to be done for both zones A and B.

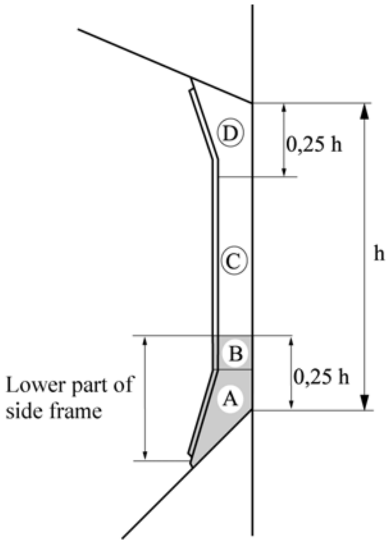
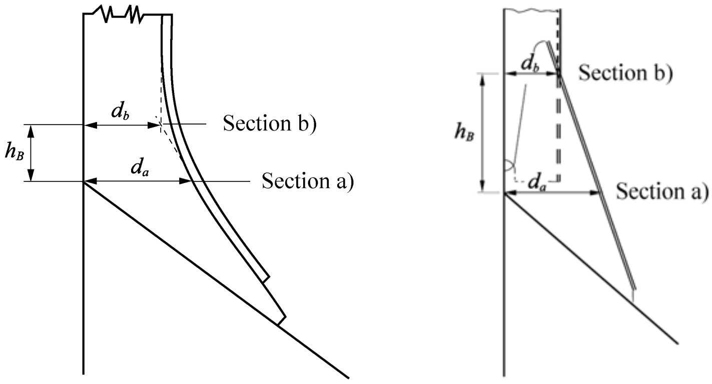


Fig 7.3.22 Lower part and zones of side frames



d_a = lower bracket web depth for determining $t_{REN,S}$

d_b = frame web depth

h_B = lower bracket length

Fig 7.3.23 Sections a) and b)

(4) In case of separate brackets, when the criteria in **1702. 1.** are not satisfied for zone A or B, steel renewal, sand blasting and coating is to be done for each one of these zones, as applicable.

(5) When steel renewal is required for zone C according to **1702. 1.**, it is to be done for both zones B and C. When sand blasting and coating is required for zone C according to **1702. 1.**, it is to be done for zones B, C and D.

(6) When steel renewal is required for zone D according to **1702. 1.**, it needs only to be done for this zone. When sand blasting and coating is required for zone D according to **1702. 1.**, it is to be done for both zones C and D.

(7) Special consideration may be given by the Society to zones previously renewed or recoated, if found in "as-new" condition (i.e., without breakdown or rusting).

(8) When adopted, on the basis of the renewal thickness criteria in **1702. 1.**, in general coating is to be applied in compliance with the requirements of **Ch 3, 107.,** as applicable.

(9) Where, according to the requirements in **1702. 1.**, a limited number of side frames and brackets are shown to require coating over part of their length, the following criteria apply.

(A) The part to be coated includes:

- the web and the face plate of the side frames and brackets,

- the hold surface of side shell, hopper tank and topside tank plating, as applicable, over a width not less than 100 mm from the web of the side frame.

(B) Epoxy coating or equivalent is to be applied.

(10) In all cases, all the surfaces to be coated are to be sand blasted prior to coating application.

(11) When flanges of frames or brackets are to be renewed according to this rule, the outstanding breadth to thickness ratio is to comply with the requirements in **Ch 3, 701. 8.**

3. Reinforcing measures

(1) Reinforcing measures are constituted by tripping brackets, located at the lower part and at mid-span of side frames (see **Fig 7.3.25**). Tripping brackets may be located at every two frames, but lower and midspan brackets are to be fitted in line between alternate pairs of frames.

(2) The thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

(3) Double continuous welding is to be adopted for the connections of tripping brackets to the side shell frames and shell plating.

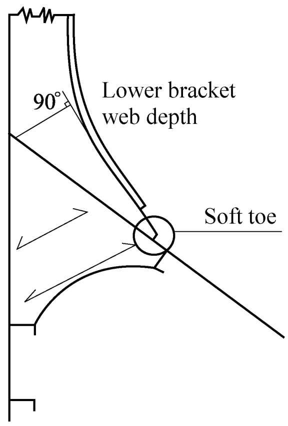


Fig 7.3.24 Definition of the lower bracket web depth for determining $t_{REN,d/t}$

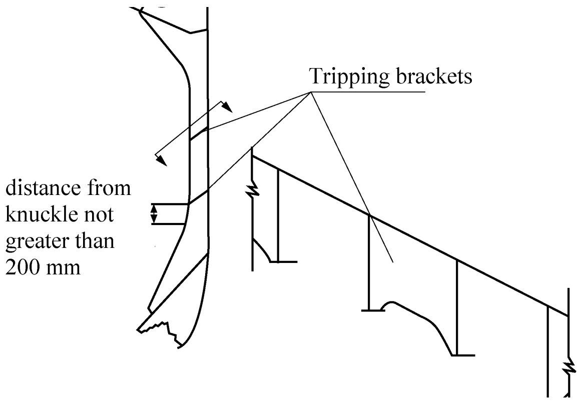


Fig 7.3.25 Tripping brackets

4. Weld throat thickness

In case of steel renewal the welded connections are to comply with **Ch 3, 702. 4.**

5. Pitting and grooving

(1) If pitting intensity is higher than 15% in area (see **Fig 7.3.26**), thickness measurement is to be taken to check pitting corrosion.

(2) The minimum acceptable remaining thickness in pits or grooves is equal to:

- 75% of the as built thickness, for pitting or grooving in the frame and brackets webs and flanges
- 70% of the as built thickness, for pitting or grooving in the side shell, hopper tank and top-side tank plating attached to the side frame, over a width up to 30 mm from each side of it.

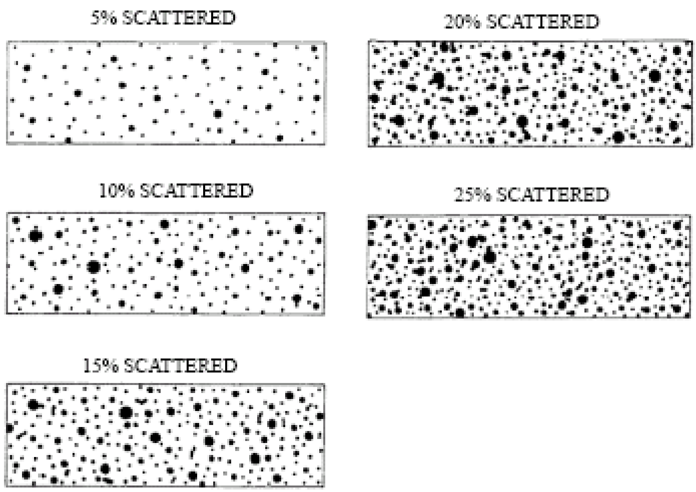


Fig 7.3.26 Pitting intensity diagrams (from 5% to 25% intensity)

6. Renewal of all frames in one or more cargo holds

When all frames in one or more holds are required to be renewed according to this rule, the compliance with the requirements in **Ch 3, Sec. 7.** may be accepted in lieu of the compliance with the requirements in this rule, provided that:

- It is applied at least to all the frames of the hold(s)
- The coating requirements for side frames of "new ships" are complied with
- The section modulus of side frames is calculated according to this Society's rules.

1703 Strength check criteria

In general, loads are to be calculated and strength checks are to be carried out for the aft, middle and forward frames of each hold. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the above frames.
When scantlings of side frames vary within a hold, the required scantlings are also to be calculated for the mid frame of each group of frames having the same scantlings. The scantlings required for frames in intermediate positions are to be obtained by linear interpolation between the results obtained for the calculated frames.

1. Load model

(1) Forces

The forces $P_{fr,a}$ and $P_{fr,b}$, in kN, to be considered for the strength checks at sections a) and b) of side frames (specified in **Fig 7.3.23**; in the case of separate lower brackets, section b) is at the top of the lower bracket), are given by:

$$P_{fr,a} = P_S + \max(P_1, P_2)$$

$$P_{fr,b} = P_{fr,a}\frac{h-2h_B}{h}$$

where,

P_S = still water force, in kN

- when the upper end of the side frame span h (see **Fig 7.3.22**) is below the load water line

$$P_S = Sh\left(\frac{p_{S,U}+p_{S,L}}{2}\right)$$

- when the upper end of the side frame span h (see **Fig 7.3.22**) is at or above the load water line

$$P_S = Sh'\left(\frac{p_{S,L}}{2}\right)$$

P_1 = wave force, in kN, in head sea

$$= Sh\left(\frac{p_{1,U}+p_{1,L}}{2}\right)$$

P_2 = wave force, in kN, in beam sea

$$= Sh\left(\frac{p_{2,U}+p_{2,L}}{2}\right)$$

h, h_B = side frame span and lower bracket length, in m, defined in **Fig 7.3.22** and **7.3.23**, respectively

h' = distance, in m, between the lower end of side frame span h (see **Fig 7.3.22**) and the load water line

S = frame spacing, in m

$p_{S,U}$, $p_{S,L}$ = still water pressure, in kN/m^2, at the upper and lower end of the side frame span h (see **Fig 7.3.22**), respectively

$p_{1,U}$, $p_{1,L}$ = wave pressure, in kN/m^2, as defined in **1703. 1.** (2) (A) below for the upper and lower end of the side frame span h, respectively

$p_{2,U}$, $p_{2,L}$ = wave pressure, in kN/m^2, as defined in **1703. 1.** (2) (B) below for the upper and lower end of the side frame span h, respectively

(2) Wave Pressure

(A) Wave pressure p_1

The wave pressure p_1, in kN/m^2, at and below the waterline is given by:

$$p_1 = 1.50\left[p_{11} + 135\frac{B}{2(B+75)} - 1.2(T-z)\right]$$

$$p_{11} = 3k_s C + k_f$$

The wave pressure p_1, in kN/m^2, above the water line is given by:

$$p_1 = p_{1wl} - 7.50(z-T)$$

(B) Wave pressure p_2

The wave pressure p_2, in kN/m^2, at and below the waterline is given by

$$p_2 = 13.0\left[0.5B\frac{50C_r}{2(B+75)} + C_b\frac{0.5B+k_f}{14}(0.7+2\frac{z}{T})\right]$$

The wave pressure p_2, in kN/m^2, above the water line is given by:

$$p_2 = p_{2wl} - 5.0(z-T) \quad (\mathrm{kN/m^2})$$

where,

p_{1wl}= p_1 wave sea pressure at the waterline

p_{2wl}= p_2 wave sea pressure at the waterline

L = Rule length, in m, as defined in **Pt 3, Ch 1**

B = greatest moulded breadth, in m

C_b = block coefficient, as defined in **Pt 3, Ch 1**, but not to be taken less than 0.6

T = maximum design draught, in m

C = coefficient

$$= 10.75 - \left(\frac{300-L}{100}\right)^{1.5} \qquad \text{for } 90 \le L \le 300\ \mathrm{m}$$

= 10.75 for $L > 300$ m

$C_r = \left(1.25 - 0.025 \frac{2k_r}{\sqrt{GM}}\right) k$

k = 1.2 for ships without bilge keel

= 1.0 for ships with bilge keel

k_r = roll radius of gyration.

If the actual value of k_r is not available

= 0.39B for ships with even distribution of mass in transverse section (e.g. alternate heavy cargo loading or homogeneous light cargo loading)

= 0.25B for ships with uneven distribution of mass in transverse section (e.g. homogeneous heavy cargo distribution

GM = 0.12B if the actual value of GM is not available

z = vertical distance, in m, from the baseline to the load point

k_s = $C_b + \frac{0.83}{\sqrt{C_b}}$ at aft end of L

= C_b between 0.2L and 0.6L from aft end of L

= $C_b + \frac{1.33}{\sqrt{C_b}}$ at forward end of L

Between the above specified points, k_s is to be interpolated linearly.

k_f = $0.8C$

2. Allowable stresses

The allowable normal and shear stresses σ_a and τ_a, in N/mm^2, in the side shell frames and brackets are given by:

$$\sigma_a = 0.9\sigma_y$$
$$\tau_a = 0.4\sigma_y$$

where σ_y is the minimum upper yield stress, in N/mm^2, of the material.

3. Shear strength check

(A) Where t_M in the lower part of side frames, as defined in **Fig 7.3.22**, is equal to or less than t_{COAT}, shear strength check is to be carried out in accordance with the following.

(B) The thickness $t_{REN,S}$, in mm, is the greater of the thicknesses $t_{REN,Sa}$ and $t_{REN,Sb}$ obtained from the shear strength check at sections a) and b) (see **Fig 7.3.23** and **1703. 1.**) given by the following, but need not be taken in excess of $0.75t_{S12}$.

- at section a) : $t_{REN,Sa} = \frac{1000\,k_s P_{fr,a}}{d_a \sin\phi\, \tau_a}$ (mm)
- at section b) : $t_{REN,Sa} = \frac{1000\,k_s P_{fr,b}}{d_b \sin\phi\, \tau_a}$ (mm)

where:

k_s : shear force distribution factor, to be taken equal to 0,6

$P_{fr,a}$, $P_{fr,b}$: pressures forces defined in **1703. 1.**

d_a, d_b : bracket and frame web depth, in mm, at sections a) and b), respectively (see **Fig**

7.3.23); in case of separate (non integral) brackets, d_b is to be taken as the minimum web depth deducing possible scallops

ϕ : angle between frame web and shell plate

τ_a : allowable shear stress, in $\mathrm{N/mm^2}$, defined in **1703. 2.**

4. Bending strength check

(1) Where the lower bracket length or depth does not meet the requirements in **Pt 7, Ch 3, Sec. 7**, the actual section modulus, in $\mathrm{cm^3}$, of the brackets and side frames at sections a) and b) is to be not less than:

- at section a) : $Z_a = \dfrac{1000 P_{fr,a} h}{m_a \sigma_a} \quad (\mathrm{cm^3})$
- at section b) : $Z_b = \dfrac{1000 P_{fr,a} h}{m_b \sigma_a} \quad (\mathrm{cm^3})$

where:

$P_{fr,a}$ = pressures force defined in **1703. 1**.

h = side frame span, in m, defined in **Fig 7.3.22**

σ_a = allowable normal stress, in $\mathrm{N/mm^2}$, defined in **1703. 2.**

m_a , m_b = bending moment coefficients defined in **Table 7.3.13**

(2) The actual section modulus of the brackets and side frames is to be calculated about an axis parallel to the attached plate, based on the measured thicknesses. For precalculations, alternative thickness values may be used, provided they are not less than:

- t_{REN} for the web thickness
- the minimum thicknesses allowed by the Society renewal criteria for flange and attached plating.

(3) The attached plate breadth is equal to the frame spacing, measured along the shell at midspan of h.

(4) If the actual section moduli at sections a) and b) are less than the values Z_a and Z_b, the frames and brackets are to be renewed or reinforced in order to obtain actual section moduli not less than $1.2\,Z_a$ and $1.2\,Z_b$, respectively.

(5) In such a case, renewal or reinforcements of the flange are to be extended over the lower part of side frames, as defined in **Fig 7.3.22**.

Table 7.3.13 Bending moment coefficients m_a and m_b

	m_a	m_b		
		$h_B = 0.08h$	$h_B = 0.1h$	$h_B = 0.125h$
Empty holds of ships approved to operate in non homogeneous loading conditions	10	17	19	22
Other cases	12	20	22	26

Note
1. Non homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, exceeds 1.20 corrected for different cargo densities.
2. For intermediate values of the bracket length h_B, the coefficient m_b is obtained by linear interpolation between the table values.

Section 18 Cargo Hatch Cover Securing Arrangements

1801. Application and implementation

1. These requirements apply to all bulk carriers which were not built in accordance with **Pt 7 Ch 3 Sec 9** and are for steel hatch cover securing devices and stoppers for cargo hold hatchways No.1 and No.2 which are wholly or partially within 0.25*L* of the fore perpendicular, except pontoon type hatch cover.

2. All bulk carriers not built in accordance with **Pt 7, Ch 3, Sec. 9** are to comply with the requirements in accordance with **Pt 1, Ch 3, 201.** (6)

3. All bulk carriers not built in accordance with **Pt 7, Ch 3, Sec. 9** and in order to postpone these requirements are to be followed **Pt 1, Ch 3, 201.** (6).

1802. Securing devices

1. The strength of securing devices is to comply with the following requirements:

2. Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

3. The net sectional area of each securing device is not to be less than:

$$A = 1.4\, a/f \quad (\text{cm}^2)$$

a = spacing between securing devices not to be taken less than 2 meters

$f = (\sigma_y/235)^e$

σ_y = specified minimum upper yield stress in N/mm^2 of the steel used for fabrication, not to be taken greater than 70% of the ultimate tensile strength.

$e = 0.75$ for $\sigma_y > 235$

$= 1.0$ for $\sigma_y \leq 235$

4. Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

5. Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weather tightness is to be maintained by the securing devices.

6. For packing line pressures exceeding 5 N/mm, the cross section area is to be increased in direct proportion. The packing line pressure is to be specified.

7. The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, I, of edge elements is not to be less than:

$$I = 6\, p\, a^4 \quad (\text{cm}^4)$$

where,

p : packing line pressure in N/mm, minimum 5 N/mm

a : spacing in m of securing devices.

8. Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

9. Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

10. Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

1803. Stoppers

1. No. 1 and 2 hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

2. No. 2 hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

3. No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted.

4. The equivalent stress in stoppers and their supporting structures, and calculated in the throat of the stopper welds is not to exceed the allowable value of $0.8\sigma_y$.

1804. Materials and welding

Where stoppers or securing devices are fitted to comply with the these requirements, they are to be manufactured of materials, including welding electrodes, meeting the relevant requirements. ⚓

CHAPTER 4 CONTAINER SHIPS

Section 1 General

101. Application

1. The construction and equipment of ships intended to be registered and classed as "Container Ship" are to be in accordance with the requirements in this Chapter, where, "Container Ship" means a ship designed exclusively for the carriage of containers in holds and on deck.

2. Except where specially required in this Chapter, the general requirements for the construction and equipment of steel ships are to be applied.

3. The requirements in this Chapter apply to ships which are single deckers having double bottoms in cargo holds and having decks and bottoms framed longitudinally.

4. The container ships with different type from that specified in **Par 3** to which the requirements in this Chapter are not applicable, are to be at the discretion of the Society.

Section 2 Longitudinal Strength

201. Bending strength

The section modulus, minimum section modulus and minimum moment of inertia of the transverse sections of the hull throughout $0.4L$ amidships are to be in accordance with the requirements in **Pt 3, Ch 3, 201.** However, the midship moment of inertia for the ship to which the requirements in this Chapter are not applicable with the abrupt changes in shape of the transverse section is to be increased at the discretion of the Society.

202. Torsional strength

Where the width of hatchway at midship exceeds $0.7B$, special considerations are to be paid to the additional stress and the deformation of hatchway openings due to torsion. Where, however, the ship has two or more rows of hatchways, the distance between the outermost lines of hatchway openings is to be taken as the width of hatchway.

Section 3 Double Bottoms

301. General

1. The construction of double bottoms in holds which are exclusively loaded with containers is to be in accordance with the requirements of this Section.

2. Side girders or solid floors are to be arranged in the double bottoms under corner fittings. Otherwise, double bottoms are to be effectively strengthened so as to support container loads.

3. Where cargo hold is exclusively used for the stowage of containers, the requirements for ceiling and the increment of inner bottom plating under hatchways specified in **Pt 3, Ch 7, 501.** may not be applied.

302. Longitudinals

The section modulus of bottom or inner bottom longitudinals is not to be less than that obtained from the formula given in **Table 7.4.1,** respectively.

Table 7.4.1 Section modulus of longitudinals

Item	Section modulus (cm^3)
Bottom longitudinals	$Z=\frac{CKSl^2}{24-15.0f_BK}(d+0.026L')$
Inner bottom longitudinals	$Z_i \geq 0.75Z_b$

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.
l = spacing of solid floors (m).
S = spacing of longitudinals (m).
C = coefficient given in the following table.

Case	C
In case where no strut specified in **303.** is provided midway between floors	100
In case where a strut specified in **303.** is provided midway between floors	62.5

NOTE:
Where, however, the width of vertical stiffeners provided on floors and that of struts are large enough, the coefficient may be properly reduced.

303. Vertical struts

1. Vertical struts are to be of rolled sections other than flat bars or bulb plates and to be overlapped with the webs of bottom and inner bottom longitudinals.

2. The sectional area of the vertical struts is not to be less than that obtained from the following formula :

$$A=1.8\,CKSbh \quad (cm^2)$$

where:

S = spacing of longitudinals (m).

b = breadth of the area supported by the strut (m).

h = as obtained from the following formula (m).

$$h=\frac{d+0.026L'}{2}$$

L' = as specified in **Table 7.4.1.**

C = coefficient obtained from the following formula. In no case is the value of coefficient to be less than 1.43.

$$C=\frac{1}{1-0.5\frac{l_s}{k\sqrt{K}}}$$

l_s = length of struts (m).

k = minimum radius of gyration of struts obtained from the following formula (cm).

$$k = \sqrt{\frac{I}{A}}$$

I = the least moment of inertia of the struts (cm^4).

A = sectional area of struts (cm^2).

304. Thickness of inner bottom plating

1. The thickness of inner bottom plating is not to be less than that obtained from the following formulae, whichever is the greater :

$$t_1 = \frac{CKB^2d}{d_0} + 1.5 \quad (\mathrm{mm})$$

$$t_2 = C'S\sqrt{hK} + 1.5 \quad (\mathrm{mm})$$

where :

d_0 = height of centre girder (mm).

S = spacing of inner bottom longitudinals for longitudinal framing or frame spacing for transverse framing (m).

h = as given by the following formula.

$h = 1.13(d - 0.001d_0)$

C = coefficient obtained from **Table 3.7.7**. of **Pt 3.**

C' = coefficient obtained from **Table 3.7.8.** of **Pt 3.**

2. The inner bottom plating with which the lower ends of corner fittings of containers are in contact is to be strengthened by means of doubling or by other appropriate means.

Section 4 Double Side Construction

401. General

1. Side construction in holds is to be double hull construction as far as practicable and is to be thoroughly stiffened by providing side transverse girders and side stringers within double hull.

2. Double side construction is to be in accordance with the requirements in **Pt 3, Ch 14** in addition to the requirements of this Section.

3. Double side shell structures which are used as deep tanks are to be in accordance with the requirements in **Pt 3, Ch 15,** in addition to the requirements of this Section.

4. Side stringers are to be provided in a proper spacing considering the depth of holds. And, side transverse girders are to be provided at the location of solid floors in double bottoms.

5. The scantlings in case where the width of double side shell structures changes in bilge parts, are to be at the discretion of the Society.

6. The scantlings in case where the height from the load line to the strength deck is specially large, are to be at the discretion of the Society.

7. Where structures effectively supporting deck structures and side shell structures are provided in the midway of holds, the requirements in this section may be appropriately modified.

8. At the location where the longitudinal bulkheads and the inner bottom plating are combined, considerations are to be paid with regard to their structural arrangement so as not to cause stress concentration.

9. At the fore and aft ends of double side construction, sufficient considerations are to be paid to the continuity of construction and strength.

402. Side transverse and side stringers

The thickness of side transverse and side stringers is not to be less than that obtained from the following formula. However, where deemed necessary by the Society, the thickness of these members is to be determined in consideration of bending and shear strength.

$$t = 8.5 \frac{S_2}{\sqrt{K}} + 1.5 \quad (\text{mm})$$

where:

S_2 = S_1 or d_1, whichever is the smaller.

S_1 = spacing of the stiffeners provided in the direction of the depth of transverse on the web of transverse for side transverse or spacing of the stiffeners provided in the direction of the depth of stringer on the web of stringer for side stringer (m), respectively.

d_1 = depth of side transverse or side stringers (m). Where, however, the depth of webs is divided by providing stiffeners in the direction of the length of side transverse on the webs or of side stringer on the webs, d_1 may be taken as the divided depth, respectively.

403. Longitudinal bulkheads

The thickness of longitudinal bulkheads and the section modulus of longitudinal stiffeners in case where the double side structure is used as deep tanks, are not to be less than those obtained from the following formulae, respectively.

(1) The thickness of longitudinal bulkheads is not to be less than that obtained from the following formula. However, the thickness of longitudinal bulkheads which are not in contact with sea water in service conditions may be reduced from the following requirements by 0.5 mm.

$$t = 3.6\, C_1 S \sqrt{h} + 2.0 \quad (\text{mm})$$

where:

S = spacing of longitudinal stiffeners (m).

h = vertical distance measured from the lower edge of plate to the midpoint of the distance between the top of tanks and the top of overflow pipes (m). However, with respect to the longitudinal bulkheads composing a large tank, appropriate additional water pressure specified in **Pt 3, Ch 15, 204.** is to be taken into account.

C_1 = coefficient obtained from **Table 7.4.2.**

Table 7.4.2 Coefficients C_1, C_2 and C_3

Framing	C_1
Transverse system	$27.7\sqrt{\dfrac{K}{767-\alpha^2K^2}}$
Longitudinal system	$3.72\sqrt{\dfrac{K}{27.7-\alpha K}}$ but C_1 is not to be less than 1.0

α = as obtained from the following formulae, whichever is the greater: However the value of α_1 or α_2 is not to be less than α_3

$\alpha_1 = 15.0 f_D\left(\dfrac{y-y_B}{Y'}\right)$ $\quad y \geq y_B$

$\alpha_2 = 15.0 f_B\left(\dfrac{y_B-y}{y_B}\right)$ $\quad y < y_B$

$\alpha_3 = \beta\left(\dfrac{B-2b}{B}\right)$

y = distance (m) from the top of keel to the lower edge of plating when the platings under consideration are under y_B and to the upper edge of plating when the platings under consideration are above y_B, respectively.

y_B = vertical distance from the top of keel to the horizontal neutral axis of transverse section (m).

Y' = the greater of the value specified in **Pt 3, Ch 3, 203.,** (5), (a) or (b).

β = coefficient determined according to values of L as specified below :

$\beta = 6/a$ when L is 230 m and under

$\beta = 10.5/a$ when L is 400 m and above

For intermediate values of L, β is to be obtained by linear interpolation.

a = $\sqrt{K}$ when high tensile steels are used for not less than 80 % of side shell plating at the transverse section amidship and 1.0 for other parts.

b = width of double side shell (m).

(2) The section modulus of longitudinal stiffeners on longitudinal bulkheads is not to be less than that obtained from the following formula.

$$Z = 125\, C_1 C_2 C_3 S h l^2 \quad (\text{cm}^3)$$

where:

C_1 : coefficients determined according to the values as specified below :

1.0 where L is 230 m and under,

1.07 where L is 400 m and above.

For intermediate values of L, C_1 is to be obtained by linear interpolation.

C_2 : $K/18$, the value C_2 for h_1, however, is to be as obtained from the following formula.

$$C_2 = \frac{K}{24-\alpha K} \quad (\geq K/18)$$

α : coefficient determined according to **Table 7.4.2.**

C_3 : coefficient given in **Table 7.4.3.**

S : spacing of longitudinal stiffeners (m).

h : the following h_1 or h_2

h_1 : vertical distance measured from the midpoint of the distance between the top of tanks and the top of overflow pipes to the mid-point of distance between the adjacent stiffeners (m).

h_2 : the value obtained from the following formula

$$h_2 = 0.85(h_1 + \Delta h) \quad (\mathrm{m})$$

Δh : the vaule obtained from the following formula

$$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10) \quad (\mathrm{m})$$

l_t : tank length (m) (≥ 10)

b_t : tank breadth (m) (≥ 10)

l : span of girders (m).

Table 7.4.3 Coefficient C_3

One end of stiffener / The other end of stiffener	Connection with hard bracket	Connection with soft bracket	Supported by rule girder or lug connection
Connection with hard bracket	0.70	1.15	0.85
Connection with soft bracket	1.15	0.85	1.30
Supported by rule girder or lug connection	0.85	1.30	1.00
Snip	1.30	1.15	1.50

1. Connection with hard bracket is a connection by bracket to the double bottoms or to the adjacent members, such as longitudinals or stiffeners in line, of the same or larger sections, or a connection by bracket to the equivalent members mentioned above. (See **Fig 3.14.2** (a))
2. Connection with soft brackets is a connection by bracket to the transverse members such as beams or equivalent thereto. (See **Fig 3.14.2** (b))

404. Brackets

Brackets are to be provided on the upper and lower corners inside the double side structure, at every frame in case where transversely stiffened and at an appropriate spacing between side transverse girders in case where longitudinally stiffened.

Section 5 Transverse Bulkheads

501. Construction

1. Transverse bulkheads are to be constructed so as to be sufficiently supported at the location of deck. In case where the width of bulkhead is specially large, the upper parts of transverse bulkheads are to be appropriately strengthened by providing box-shaped structures or by other means.

2. The scantlings of bulkheads and stiffeners are to comply with the requirements in **Pt 3, Ch 14, Sec 3.**

502. Partial bulkheads

Where non-watertight partial bulkheads are provided in cargo holds, the construction and scantlings are to be made to have sufficient strength and rigidity, considering the size of cargo hold, the depth of bulkheads, etc.

Section 6 Deck Construction

601. Construction

1. The thickness of deck plating is to comply with the requirement in **Pt 3, Ch 5, Sec 3.**

2. The scantlings of decks inside the line of deck openings are to be appropriately strengthened in consideration of bending in the plane of deck.

602. Cross ties

1. Where the length of hatchway is large in comparison with the width of hatchway, cross ties are to be provided in the hatchway opening with suitable spacing.

2. Where structures effectively supporting the loads from the side and deck of ship are not provided at the location of cross ties in the holds, special considerations are to be paid to the scantlings of cross ties.

603. Continuity of thickness of deck plating

Consideration is to be paid to the continuity in the thickness of deck plating. Especially, the abrupt change between the thickness inside and outside the line of deck openings is to be avoided.

Section 7 Freight Container Securing Arrangements

701. Cell guide

1. The cell guides supporting containers are to be constructed so as to effectively transmit the loads to double bottom structure, side construction and transverse bulkheads.

2. The strength of cell guide is to be sufficient for the loads from the bottom and side of ship and the loads due to container loads.

702. Freight container securing systems

1. For freight container securing systems plans showing materials, arrangement and scantling, etc. may be submitted for approval of the Society. Where container securing fittings are applied for part container only, this requirements may be suitably applied.

2. Securing devices specified in **Par 1** are to be approved in accordance with the special requirements given by the Society prior to installation on board the ship.

Section 8 Welding

801. Application

1. Fillet welding is to be applied to longitudinals with a web plate thickness over 40 mm and up to 80 mm, which are used for the strength deck or for side shell plating and longitudinal bulkheads that extend upwards from a position 0.25 D below the strength deck.

2. Where longitudinals with a web plate thickness over 80 mm are used, the kind and size of the weldings are to be at the discretion of the Society.

802. Fillet Welding

1. Fillet welding is to be continuous.

2. The size of fillet is to be not less than 8 mm. ⚓

CHAPTER 5
SHIPS CARRYING LIQUEFIED GASES IN BULK

(Separate Publication)

CHAPTER 6
SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

(Separate Publication)

CHAPTER 7 CAR FERRIES AND ROLL-ON/ROLL-OFF SHIPS

Section 1 General

101. Application

1. This Chapter applies to seagoing roll-on/roll-off cargo ships specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded and unloaded by wheeled vehicles.

2. The hull structures and equipments of ships that are intended for restricted service and carriage of vehicles through the bow door, inner door, side door or ramp formed the hull structures (hereinafter refered to as vehicle doors) is to in accordance with the discretion of the Society.

3. The scantlings and arrangements are to be as required by **Pt 3** except as otherwise specified in this Chapter.

102. Construction and arrangement

1. The requirements provide for a basic structural configuration of a multideck hull which includes a double bottom, and in some cases wing tanks up to the lowest deck. Special consideration is to be given to roll on-roll off cargo ships and ferries intended to be operated only in certain areas or conditions which have been agreed by the Society.

2. Where bulkheads are omitted in accordance with **Pt 3, Ch 9,** a system of partial bulkheads, web frames and deck transverses should be fitted to provide equivalent transverse strength.

3. Longitudinal framing is to be adopted at the strength deck and at the bottom, but special consideration will be given to proposals for transverse framing in these regions.

103. Submission of plans and documentations

In addition to plans and documentations required by **Pt 3, Ch 1, Sec 3,** the following details are to be submitted:

(1) The intended service areas required for ships designed to operate within specified geographical limits.
(2) Bow or stern ramps
(3) Bow, stern and side doors
(4) Movable decks, if fitted, including stowing arrangements for portable components.

Section 2 Longitudinal Strength

201. General

Longitudinal strength calculations are to be made in accordance with the requirements given in **Pt 3, Ch 3.**

Section 3 Deck Structure

301. Application

The arrangements and scantlings of vehicle decks for the carriage of cars, trucks, etc., are be in accordance with the discretion of the Society.

302. Securing arrangements

Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

Section 4 Electrical Equipment of Automobile Carriers

401. General

The requirements in this Section apply to the electrical equipment installed in the cargo holds and the compartments adjacent thereto of automobile carriers.

402. Electrical equipment

1. Electrical equipment in cargo hold

(1) In principle no portable electrical appliance are to be located in the cargo holds. Where it is inevitable to locate the appliances in the holds, they are subject to the approval of the Society.

(2) All electrical circuits terminating in the cargo holds are to be provided with multipole linked isolating switches situated outside the cargo holds, and accessible only to authorized personnel. Provision is to be made for isolation and for locking in the "off" position of the means of control of such circuits. However, this requirement does not apply in respect of safety devices such as fire, smoke or gas detector.

(3) In addition to the requirements in this section, the requirements in **Pt 8, Ch 5, 302.** of the Rules are to be complied with.

2. Electrical equipment in the compartment adjacent to cargo holds

For the electrical equipment in the compartments adjacent to the cargo holds and having an opening such as nongastight door, hatch, scuttle and the like in their bulkheads and decks, the requirements in **Par 1** are generally to be applied. ⚓

CHAPTER 8 OFFSHORE SUPPLY SHIPS

Section 1 General

101. Application

1. The construction and equipment of ships intended to be registered and classed as "Offshore Supply Ship" are to be in accordance with the requirements in this Chapter, where "Offshore Supply Ship" means a ship designed and constructed for the carriage of specialized stores and cargoes to mobile offshore units and other offshore installations, and also to "Offshore Tug and Supply Ship" which in addition to the above perform the duties of a tug.

2. The scantlings and arrangements are to be as required by **Pt 3,** except as otherwise specified in this Chapter.

3. Attention is drawn to the need for masters to be able to assess the stability of their ships quickly and accurately in all service conditions.

102. Submission of plans and documentations

In addition to plans and documentations required by **Pt 3, Ch 1, Sec 3,** the followings are to be submitted.

(1) Separate or independent cargo tanks
(2) Cargo tank foundations and securing arrangements
(3) Towing arrangements, including supports and foundations of towing winches
(4) Supports and foundations for anchor handling and laying arrangements for anchors carried as cargo.
(5) Arrangements for the stowage of deck cargoes (cargo containment) and details of any associated racks or other similar structures and their supports and foundations.
(6) Movable decks including the stowing arrangements for portable components
(7) Freeing arrangements

Section 2 Longitudinal Strength

201. General

Longitudinal strength calculations for an offshore supply ship or an offshore tug/supply ship are to comply with the relevant requirements of **Pt 3, Ch 3.**

Section 3 Shell Plating

301. Shell plating

1. The thickness of side shell is to be that required by **Pt 3, Ch 4,** but is in no case to be less than 9 mm.

2. Efficient fenders are to be fitted, with adequate support behind them, in exposed areas.

3. Shell in way of stern rollers immediately adjacent to high duty bollards and in other high load areas is to be suitably reinforced.

Section 4 Deck Plating

401. Weather decks

1. Where cargo is to be carried on weather decks, the scantlings are to be suitable for the specified loadings, but in no case is a head less than 3.5 m to be used. Additional local increases in scantlings may be required where specialized cargoes are likely to induce concentrated loads.

2. The thickness of deck plating is to be not less than that obtained from the following formula.

$$t = 0.025L + 6 \quad \text{(mm)}$$

402. Cargo containment

1. Means are to be provided to enable deck cargoes to be adequately secured and protected. In general, suitable inner bulwarks, rails, bins or storage racks of substantial construction are to be provided and properly secured to adequately strengthened parts of the hull structure .

2. Properly designed locking equipment or efficient means of lashing containers are to be fitted where appropriate.

3. Small hatches (including escape hatches), valve controls, ventilators, air pipes, etc., are to be situated clear of the cargo containment areas.

Section 5 Framing

501. Transverse framing

The section moduli of the main and tween deck frames are to be 25 percent greater than those required by **Pt 3, Ch 8, Sec 4.** Frames are not to be scalloped.

Section 6 Superstructures and Deckhouses

601. Scantlings

The scantlings of deckhouses situated on the forecastle deck and above are to comply with the requirements of **Table 7.8.1.**

Table 7.8.1 Thickness of plating and section modulus of bulkhead stiffeners etc.

Position	Thickness of plating t (mm)	Modulus of stiffeners Z (cm^3)	Depth of stiffeners d (mm)
Fronts	The greater of t = 0.012S or 8.0	$Z = 0.034\,S\,l^2$	$d \geq 100$
Sides	The greater of t = 0.01S or 6.5	$Z = 0.027\,S\,l^2$	$d \geq 75$
Aft ends	The greater of t = 0.008S or 6.5	$Z = 0.021\,S\,l^2$	$d \geq 65$
S = stiffener spacing (mm) l = effective length of stiffeners (m)			
NOTE : The ends of stiffeners are to be connected on all tiers.			

Section 7 Watertight Bulkhead Doors

701. Watertight doors

Watertight doors are to be efficiently constructed and fitted in accordance with **Pt 3, Ch 14, Sec 4.**

Section 8 Engine Exhaust Outlets

801. Location

Engine exhaust outlets are to be located as high as is practicable above the deck and are to be fitted with spark arresters. ⚓

CHAPTER 9 TUGS

Section 1 General

101. Application

1. The construction and equipment of ships intended to be registered as "Tug" are to be in accordance with the requirements in this Chapter. The construction and equipment of ships intended to be registered as "Offshore Tug/Supply Ships" are to be in accordance with the requirements of **Ch 8.**

2. The scantlings and arrangements are to be as required by **Pt 3** except as otherwise specified. The draught d used for the determination of scantlings is to be not less than $0.85D$.

Section 2 Longitudinal Strength

201. General

Longitudinal strength calculations are to be made in accordance with the requirements given in **Pt 3, Ch 3.**

Section 3 Single Bottoms

301. Floors

Single bottom floors are to be in accordance with the requirements of **Pt 3, Ch 6.**

Section 4 Panting and Strengthening of Bottom Forward

401. Panting region reinforcement

The arrangements to resist panting required by **Pt 3, Ch 9,** do not apply to tugs less than 46 m in length. In tugs 46 m or more in length, addition stiffening is also to be fitted in the tween decks throughout the panting region.

402. Strengthening of bottom forward

The requirements for strengthening of bottom forward detailed in **Pt 3, Ch 7, Sec 8,** do not apply to tugs.

Section 5 Machinery Casings

501. Escape hatches

Any emergency exit from the machinery room to the deck is to be capable of being used at extreme angles of heel, and should be positioned as high as possible above the waterline and on or near the ship's centerline. Covers to escape hatches are to have hinges arranged athwartships. Coaming heights are to be at least 600 mm above the upper surface of the deck.

502. Exposed casings

Exposed machinery casings are to be not less in height than 900 mm above the upper surface of the deck. Stiffeners to exposed casings are to be connected to the deck or carried through.

Section 6 Towing Arrangements

601. Towing hooks

1. Towing hooks or equivalent should normally be 5 to 10 percent of the ship's length abaft amidships, but in no circumstances should they be sited forward of the longitudinal center of gravity of the tug in any anticipated condition of loading. In addition, the towing hook should be located as low as practicable in order to minimize heeling moments arising in normal working conditions.

2. Towing hooks are to have reliable release slip arrangement which facilitate towline release regardless of the angle of heel. It is recommended that release units should also be operable from the bridge. The arrangements should be tested to the surveyor s satisfaction. The breaking strength of the hook or its equivalent should generally be 50 percent in excess of that of the towline.

Section 7 Fenders

701. Ship's side fenders

An efficient fender is to be fitted to the ship's side at deck level extending all fore and aft. ⚓

CHAPTER 10 DOUBLE HULL TANKER

Section 1 General

101. Application

1. The requirements in this Chapter apply to double hull oil tankers which were contracted for construction after 1 April 2006, excluding the vessels which should be applied **Pt.12** (IACS Common Structural Rules for Oil Tankers).

2. The constructions and equipments of ships of 90 m and above in length which are framed for tankers with machinery aft having one or more longitudinal bulkheads and single decks with double bottom or with double hull structures, intended to be registered and classed as "tanker" and intended to carry crude oil, petroleum products having a vapour pressure (absolute pressure) less than 0.28 MPa at 37.8 ℃ or other similar liquid cargoes in bulk are to be in accordance with the requirements in this Chapter.

3. In tankers intended to carry liquid cargoes other than crude oil and petroleum products, having the vapour pressure (absolute pressure) less than 0.28 MPa at 37.8 ℃ and having no hazard as poisonous, corrosive, etc. and moreover less inflammablity than that of crude oil and petroleum products, the structural arrangements and scantlings are to be to the satisfaction of the Society, having regarded to the properties of the cargoes to be carried.

4. In case where the construction differs from that specified in **Par 1** and the requirements in this Chapter are considered to be not applicable, matters are to be determined as deemed appropriate by the Society.

5. As regards matters not specifically provided for in this Chapter, the general requirements for the construction and equipment of steel ships given in the relevant **Pts** are to be applied.

6. In addition to the requirements specified in **Par 5,** the relevant requirements in **Ch 1, Secs l0** to **11** and **Pt 8, Ch 2, 104** are to be applied to ships specified in **Par 2.**

102. Location and separation of spaces

1. In cargo oil spaces, the standard arrangement of bulkheads is to be such that the interval between longitudinal bulkheads or transverse bulkheads does not exceed $1.2\sqrt{L}$ (m).

2. Cofferdams are to be provided in accordance with the following (1) to (3) :

(1) Cofferdams of air-tight construction and not to be less than 600 mm in width access are to be provided at fore and aft terminations of cargo oil spaces and the space between cargo space and accommodation space. Where, however, for oil tankers intended to carry cargo oil having a flash point above 60 ℃ this requirements may be suitably modified.
(2) Cofferdams specified in (1) may be used as pump rooms.
(3) Fuel oil or ballast water tanks may be concurrently used as the cofferdams to be provided between cargo oil tanks and fuel oil or ballast tanks, subject to the approval by the Society.

3. Passageways leading to cargo areas are to be provided in accordance with the following (1) to (4):

(1) Access to cofferdams, ballast tanks, cargo oil tanks and any other spaces in the cargo area are to be direct from the open deck and such as to ensure their complete inspection. Access to double bottom spaces may be through a cargo pump room, pump room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.
(2) For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a selfcontained air breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the spaces. The minimum clear opening is not to be less than 600 mm × 600 mm.
(3) For Access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening should be not less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom shell plating unless grating or other footholds are provided.

(4) For tankers with a deadweight tonnage of less than 5000 tons, smaller dimension of minimum clear opening specified in (2) and (3) may be approved by the Society in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

4. Air-tight bulkheads

All areas, where cargo oil pumps and cargo oil piping are provided, are to be segregated by an air-tight bulkhead from areas where stoves, boilers, propelling machinery, electric installations other than those of explosion-proof type in accordance with the requirements in **Pt 6, Ch 1, Sec 9** where source of ignition is normally present. Where, however, for oil tankers carrying cargo oil having a flash point above 60℃, the requirements may be suitably modified.

5. Ventilations

Ventilation inlets and outlets are to be arranged so as to minimize the possibilities of vapours of cargoes being admitted to an enclosed space containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. Especially, opening of ventilation for machinery spaces are to be situated as far afterwards apart from the cargo spaces as practicable.

6. Ullage openings, sighting ports and tank cleaning opening are not to be arranged in enclosed spaces.

7. Openings in superstructure and deckhouse

The arrangement of openings on the boundaries of superstructures and deckhouse are to be such as to minimize the possibility of accumulation of vapours of cargoes. Due consideration in this regard is to be given for the openings in superstructures and deckhouse when the ship is equipped with cargo piping to load or unload at the stern. The scuttles to the poop front or other similar walls are to be of fixed type.

8. Pipe duct in double bottom

Pipe ducts in the double bottom shall comply with the following requirements :

(1) They should not communicate with the engine room.
(2) Provision shall be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.
(3) In the duct, provision shall be made for adequate mechanical ventilation.
(4) For ships to which the convention applies, refer to **SOLAS 1974(as amended) Regulation II-2/4.5.2.4.**

103. Minimum thickness

1. The thickness of structural members in cargo oil tanks and deep tanks such as bulkhead plating, floors, transverse girders including struts and their end brackets is not to be less than the value determined from **Table 7.10.1** according to the Length of Ship.

2. The thickness of structural members other than **Par 1** in cargo oil tanks and deep tanks is not to be less than 7 mm.

Table 7.10.1 Minimum thickness

L (m)												
	and over		105	120	135	150	165	180	195	225	275	325	375
	and under	105	120	135	150	165	180	195	225	275	325	375	
Thickness(mm)		8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5

104. Direct strength calculation

Where approved by the Society, the scantlings of structural members may be determined basing upon direct strength calculation defined in **Pt 3, Ch 1, 206.** Notwithstanding the results of direct strength calculation, where, however, this is not to be applied to the minimum thickness specified in **103.** and the special requirements for corrosion specified in **605.** to **607.**

105. Symbols

The definition of symbols used in this Chapter otherwise specified, are to be in accordance with following :

L' = length of ship (m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.

l = span of stiffeners, longitudinals, frames, transverses or girders (m).

S = spacing of stiffeners, longitudinals, frames, transverses or girders (m).

C_1 = coefficients determined according to values of L as specified below :

C_1 = 1.0 where L is 230 m and under,
1.07 where L is 400 m and above.

For intermediate values of L, C_1 are to be obtained by linear interpolation.

C_1' = coefficients determined according to values of L as specified below :

C_1' = 1.0 where L is 230 m and under,
1.2 where L is 400 m and above.

For intermediate values of L, C_1' are to be obtained by linear interpolation .

f_D and f_B = section modulus ratios are as following formulae, f_B, however, is not to be less than 0.85 or 0.0015L + 0.5, whichever is the lesser.

$$f_D = \frac{Z_{DMreq}}{Z_{Dact}} \qquad f_B = \frac{Z_{BMreq}}{Z_{Bact}}$$

Z_{DMreq} and Z_{BMreq} = section modulus at the deck and bottom of transverse sections of the hull determined to the requirements in **Ch 3, 201.** respectively, when mild steel material symbol A, B, D and E specified in **Pt 2, Ch 1, 301. Par 1** is used (cm^3).

Z_{Dact} and Z_{Bact} = actual section modulus at the deck and bottom of transverse sections of the hull respectively. (cm^3)

α = either α_1 or α_2 according to value of y. However, value of α is not to be less than α_3.

$$\alpha_1 = 15.0 f_D \left(\frac{y - y_B}{Y'} \right) \qquad \text{for} \quad y \geq y_B$$

$$\alpha_2 = 15.0 f_B \left(\frac{y_B - y}{y_B} \right) \qquad \text{for} \quad y < y_B$$

$$\alpha_3 = \beta \left(\frac{B - 2b}{B} \right)$$

y = distance from the top of keel to the lower edge of plating when the platings under consideration are under y_B, to the upper edge of plating when the platings under consideration are above y_B and to the longitudinals stiffener under consideration for longitudinal stiffener, respectively (m).

y_B = distance from the top of keel to the horizontal neutral axis of transverse section amidship (m).

Y' = the greater of the value specified in **Pt 3, Ch 3, 203.,** (5), (a) or (b).

β = coefficient determined according to the values of L as specified below: For intermediate values of L, the value of b is to be determined by linear interpolation:

β = 6.0 when L is 230 m and under,
10.5 when L is 400 m and above.

a = $\sqrt{K}$ when high tensile steels are used for not less than 80 % of side shell platings at the transverse section amidship and 1.0 for other parts.

b = horizontal distance from the side shell plating to the longitudinal bulkhead plating under consideration (m).

Section 2 Bulkhead Plating

201. Bulkhead plating in cargo oil tanks and deep tanks

1. The thickness of bulkhead plating is not to be less than the greatest of the values obtained from the following formula when h is substituted with h_1, h_2 and h_3.

$$t_1 = C_1 C_2 S \sqrt{h} + 2.5 \quad (\mathrm{mm})$$

Table 7.10.2 Water head h_1, h_2, and h_3

<table>
<tr><th></th><th>Cargo oil tanks</th><th>Deep tanks</th></tr>
<tr><td>h_1</td><td>Vertical distance from the lower edge of the bulkhead plating under consideration to the top of hatchway. For side shell plating, a water head corresponding to the minimum draught amidship d_{min} (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of keel is to be d_{min}, value at point d_{min} above the top of keel, 0, and value at an intermediate point is to be obtained by linear interpolation.</td><td>Vertical distance from the lower edge of the bulkhead plating under consideration to the mid-point between the point on tank top and the upper end of the overflow pipe. For side shell plating, a water head corresponding to the minimum draught amidship d_{min} (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of keel is to be d_{min}, value at point d_{min} above the top of keel, 0, and value at an intermediate point is to be obtained by linear interpolation</td></tr>
<tr><td>h_2</td><td colspan="2">As obtained from the following formula

$h_2 = 0.85(h_1 + \Delta h)$

where:
Δh = additional water head given by the following formula;
For L-type, U-type etc. of tanks,
Δh is to be determined as deemed appropriate by the Society

$\Delta h = \frac{16}{L}(l_t - 10) + 0.25(b_t - 10)$
l_t = tank length (m), 10, when less than 10 m.
b_t = tank breadth (m), 10, when less than 10 m</td></tr>
<tr><td>h_3</td><td>$h_3 = 0.3\sqrt{L}$ (m)</td><td>Value (m) obtained by multiplying 0.7 by vertical distance from the lower edge of the bulkhead plating under consideration to the point 2.0 m above the top of overflow pipe..</td></tr>
</table>

Table 7.10.3 Coefficient C_2

	longitudinal bulkhead of longitudinal framing	longitudinal bulkhead of transverse framing
For h_1	$C_2 = 13.4\sqrt{\dfrac{K}{27.7-\alpha K}}$	$C_2 = 100\sqrt{\dfrac{K}{767-\alpha^2 K^2}}$
	minimum : $3.6\sqrt{K}$	
For h_2 or h_3 and for transverse bulkhead	$C_2 = 3.6\sqrt{K}$	

where:

h = water head of h_1, h_2 or h_3 is obtained from **Table 7.10.2.**

C_2 = coefficients is obtained from **Table 7.10.3.**

C_1 and S = as specified in **105.**

2. In determining the thickness of longitudinal bulkhead plating, coefficient C_2 for h_1 may be gradually reduced for the parts forward and aftward the midship part, and it may be taken as $3.6\sqrt{K}$ in calculations at $0.1L$ from fore end and aft end.

202. Swash bulkhead

1. Stiffeners and girders of swash bulkhead are to be of sufficient strength considering the size of tanks and opening ratios.

2. The thickness of swash bulkhead plating is not to be less than that obtained from the following formula :

$$t = 0.3S\sqrt{K(L+150)} + 2.5 \quad (\mathrm{mm})$$

where:

S = as specified in **105.**

3. In determining the thickness of swash bulkhead plating, sufficient consideration is to be given for buckling.

203. Trunks

The thickness of trunk top and side plating are to be determined applying the requirements in **201.** in addition to the requirements in **Pt 3, Ch 5.**

Section 3 Longitudinals and Stiffeners

301. Longitudinals

1. The section modulus of bottom longitudinals is not to be less than the value obtained from the formula in **Table 7.10.4.**

2. The section modulus of side longitudinals including bilge longitudinals is not to be less than the value obtained from the formula in **Table 7.10.4.** The section modulus, however, need not exceed that of bottom longitudinals specified in **Table 7.10.4,** but is not to be less than that obtained from the following formula :

$Z = 2.9K\sqrt{L}Sl^2$ (cm^3)

where:

S and l = as specified in **105.**

Table 7.10.4 Section modulus of bottom and side longitudinal

longitudinals	section modulus (cm^3)
Bottom longitudinals	$Z = 100C_1C_2Shl^2$
Side longitudinals including bilge longitudinals	

h = distance from the longitudinals under consideration to the h' (m).
C_2 and h' = as given in following table

	h'	C_2
Bottom longitudinals	$h' = d + 0.026L'$	$C_2 = \frac{K}{24 - 15.0f_BK}$
Side longitudinals including bilge longitudinals	$h' = d + 0.038L'$	$C_2 = \frac{K}{24 - \alpha K}$

C_1, S, l, L', α and f_B = as specified in **105.**

3. For the parts forward and aftward of midship part, the scantlings of longitudinals may be gradually reduced and at $0.1L$ from fore end and aft end they may be reduced by 15 % of the value obtained from the requirements in **Pars 1** and **2.** In no case, however, are the scantlings of longitudinals to be less than those required in **Pars 1** and **2** for the part between a point $0.15L$ from the fore end and the collision bulkhead.

4. For side longitudinals, sufficient consideration is to be given for fatigue strength.

5. In addition to the requirements in **Pars 1** to **4,** the beams or longitudinals on deck or side shell consisting of deep tanks should comply with the requirements in **302.**

302. Bulkhead stiffeners in cargo oil tanks and deep tanks

1. Section modulus of stiffeners is not to be less than that obtained from the following formula :

$Z = 125C_1C_2C_3Shl^2$ (cm^3)

Where:

h = water head h_1, h_2 or h_3 as specified in **Table 7.10.2.** Where, however, "the lower edge of the bulkhead plating under consideration" is to be construed as "the mid-point of the stiffener under consideration" for vertical stiffeners and as "the stiffener under consideration" for horizontal stiffeners. And "side shell plating" is to be construed as "stiffener attached to side shell plating".

C_2 = value obtained from following formula. The value C_2 for h_1, however, is to be as obtained from the formula in **Table 7.10.5.**

$$C_2 = \frac{K}{18}$$

C_3 = as determined from **Table 7.10.6** according to the fixity condition of stiffener ends;
C_1, S and l = as specified in **105.**

Table 7.10.5 Coefficient C_2

Bulkhead and framing systems	C_2
Longitudinal bulkhead of longitudinal framing system	$C_2 = \frac{K}{24 - \alpha K}$ minimum $C_2 = \frac{K}{18}$
Longitudinal bulkhead of transverse framing system, transverse bulkhead	$C_2 = \frac{K}{18}$
α = as specified in **105.**	

Table 7.10.6 Coefficient C_3

One end of stiffener / The other end of stiffener	Connection be hard bracket	Connection be soft bracket	Supported by rule girder or lug connection	Snip
Connection be hard bracket	0.70	1.15	0.85	1.30
Connection be soft bracket	1.15	0.85	1.30	1.15
Supported by rule girder or lug connection	0.85	1.30	1.00	1.50
Snip	1.30	1.15	1.50	1.50

1. Connection by hard bracket is a connection by bracket to the double bottoms or to the adjacent members, such as longitudinals or stiffeners in line, of the same or larger sections, or a connection by bracket to the equivalent members mentioned above. (See **Fig 3.14.2** (a))
2. Connection by soft brackets is a connection by bracket to the transverse members such as beams or equivalent thereto. (See **Fig 3.14.2** (b))

4. For the parts forward and aftward of midship part in determining the section modulus of stiffeners attached to longitudinal bulkhead of longitudinal framing systems, coefficient C_2 for h_1 may be gradually reduced, and at the end parts C_2 may be as $K/18$.

303. Buckling strength

1. Buckling strength of longitudinal frames, beams and stiffeners is to be in accordance with the requirements (1) to (3) below. In case where the Society specially considers necessary according to the materials, scantling, geometries and the point of arrangement of these structural members, detailed assessment may be required.

(1) Longitudinals beams, side longitudinals attached to sheer strakes and longitudinal stiffeners attached to the longitudinal bulkhead within $0.1D$ from the strength deck are to have a slenderness ratio not exceeding 60 at the midship part as far as practicable.

(2) As for flat bars used for longitudinal beams, frames and stiffeners, the ratio of depth to thickness is not to exceed 15.

(3) The full width of face plate of longitudinal beams, frames and stiffeners is not to be less than that obtained from the following formula:

$$b = 2.2\sqrt{d_0 l} \quad (\mathrm{mm})$$

where :

d_0 = depth of web of longitudinal beam, frame or stiffener (mm).

l = as specified in **105.**

2. In case where assembled members, special shape steels or flanged plates are used for frames, beams or stiffeners in cargo oil tanks and deep tanks whose scantlings are specified only in terms of section modulus, the thickness of web is intended to be greater than the required level due to reasons other than strength, it may be suitably modified.

$$t = 0.015 k_0 d_0 + 2.5 \quad (\text{mm})$$

where:

d_0 = depth of web (mm).

k_0 = coefficient according to the location of stiffeners as given **Table 7.10.7.**

Table 7.10.7 Coefficient k_0

Locations	k_0
Bottom longitudinals located not more than $0.25D$ above top of keel	$k_0 = \sqrt{0.25\left(3f_B + \frac{1}{K}\right)}$
Deck longitudinals located not less than $0.25D$ below deck	$k_0 = \sqrt{0.25\left(3f_D + \frac{1}{K}\right)}$
Other structural members	$k_0 = \sqrt{0.25\left(3 + \frac{1}{K}\right)}$

Section 4 Girders

401. General

1. The double bottom and double side hull structures and arrangements and scantlings of girders in cargo oil spaces are to be determined based upon direct strength calculations.

2. Notwithstanding the requirement in **Par 1,** when approved by the Society, the scantlings of these girders may be determined in accordance with the requirements in **403.** to **407.** provided that the arrangements of girders in the double bottom, double side hull and cargo oil tank at cargo oil spaces are determined referring to the structural types shown in following (1) to (5) as the standard:

(1) The height of double bottom at cargo oil spaces is not to be less than $B/20$ (m).
(2) The width of double side hull is not to be less than $D/9$ (m).
(3) In double bottoms at cargo oil spaces, girders are to be provided at a spacing not exceeding $0.9\sqrt{l_t}$ (m) and floors are to be provided at a spacing not exceeding $0.55\sqrt{B}$ (m) or $0.75\sqrt{D}$ (m), whichever is smaller. l_t is the length of a cargo hold (m).
(4) In double side hull, stringer are to be provided at a spacing not exceeding $1.1\sqrt{l_t}$ (m).
(5) Transverse in double side hull and girders in cargo oil tanks and deep tanks are to be provided at positions on floors in double bottoms.

402. Direct strength calculation of girders

The structural models, loads, allowable stress levels, etc. for determining the arrangement of girders and scantling based upon direct strength calculation are to as deemed appropriate by the Society.

403. Scantlings of girders and floors in double bottom

The scantling of girders and floors in double bottom are to be as deemed appropriate by the

Society.

404. Scantlings of stringers and transverse in double side hull

The scantling of stringers and transverse in double side hull are to be as deemed appropriate by the Society.

405. Girders and transverse in cargo oil tanks and deep tanks

1. The section modulus of girders is not to be less than that obtained from the following formula :

$$Z = 7.13\, C_1' k^2 K S h l^2 \quad (\text{cm}^3)$$

Where:

h = waterhead h_1, h_2 or h_3 as specified in **Table 7.10.2.** whichever is the greatest. Where, however, "from the lower edge of the bulkhead plating under consideration" is to be construed as "from the mid-point of S" for horizontal girders, and as "from the mid-point of l " for vertical girders in applying the value of h.

k = correction factor for brackets, and to as obtained from the following formula:

$$k = 1 - \frac{0.65(b_1 + b_2)}{l}$$

b_1 and b_2 = arm length of brackets at respective ends to be girders and transverses (m).

C_1', S and l = as specified in **105.**

2. The moment of inertia of girders is not to be less than that obtained from the following formula. However, in no case is the depth of girders to be less than 2.5 times the depth of slots.

$$I = 30\, h l^4 \quad (\text{cm}^4)$$

Where:

h and l = as specified in **Par 1.**

3. The thickness of girders is not to be less than the greatest of the following t_1, t_2 or t_3 :

$$t_1 = 41.7 \frac{C_1' C_2 K S h l}{d_1} + 2.5 \quad (\text{mm})$$

$$t_2 = 0.174 \sqrt[3]{\frac{C_1' C_2 S h l S_1^2}{d_1}} + 2.5 \quad (\text{mm})$$

$$t_3 = 0.01 S_1 + 2.5 \quad (\text{mm})$$

Where:

h = as specified in **Par 1.**

S_1 = spacing of stiffeners of girders or the depth of girders, whichever is the smaller (mm).

d_1 = depth of the girder under consideration (mm) subtracting the depth of openings.

C_2 = coefficient as obtained from the following formula. In no case is it to be less than 0.5 :

Vertical girder : $C_2 = \left| 1 - \frac{2x}{l} \right|$

Horizontal girder : $C_2 = \left| 1 + \frac{0.2\,l}{h} - \left(2 + \frac{l}{h}\right)\frac{x}{l} + \frac{l}{h}\left(\frac{x}{l}\right)^2 \right|$

Where:

x = distance from the end of l to the sectional area under consideration(m), and from the lower end for vertical girders.

C_1', S and l = as specified in **105.**

4. Where, the stiffeners are provided within the effective width, they may be included in the effective steel plates for calculating actual moment of inertia of girders and section modulus.

5. The thickness of webs at the root of struts for girders and transverse in case where struts are provided, is not to be less than that obtained from following formula. Where slots are provided in bs at the root of struts, they are to be covered effectively with collar plates.

$$t = 16 S_1 \sqrt{\frac{C_1' S b_s h_s}{A}} \quad (\text{mm})$$

Where:

b_s = width supported by struts (m).

h_s = distance from mid-point of b_s to the point of $d + 0.038L'$ above top of keel (m).

S_1 = spacing of stiffeners provided depthwise on the web plates of transverses at the portion where cross ties are connected (m).

C_1' and S = as specified in **105.**

A = as specified in **Pt 7, Ch 1, 403.** (1).

6. The thickness of face plates forming a girder is to be greater than the thickness of web, and the total width is not to be less than that obtained from the following formula :

$$b = 2.7\sqrt{d_0\, l'}$$

where:

d_0 = depth of girder (mm)

l' = distance between supporting points of girders (m). Where, however, if effective tripping brackets are provided, they may be regarded as supporting points.

406. Girders of ships without double side hull

1. In addition to the requirements in **405.**, depth of side transverse d_0 and section modulus of transverse Z are not to be less than those obtained from the following formula :

$$d_0 = 150\, l \quad (\text{mm})$$
$$Z = 8.7 k^2 K S h l^2 \quad (\text{cm}^3)$$

Where:

h = distance from mid-point of l to the point $d + 0.038L'$ above top of keel (m)

k, l and S = as specified in **405.1.**

2. The scantlings of deck transverses are to as given in (1) and (2) below :

(1) Section modulus of deck transverse of a ship without trunks is not to be less than that obtained from the following formula :

$$Z = 3k^2 KS\sqrt{L}\,l^2 \quad (\mathrm{cm}^3)$$

Where:

k, l and S = as specified in **405.1.**

(2) For ships with trunks, the construction of providing continuous deck transverses across the trunk is to be considered as the standard. In this case, the depth of deck transverses that can be regarded as those supported by trunks may be $0.03B$.

3. For transverses provided on the centreline bulkhead, the section modulus Z and depth d_0 of deck transverses are to be less than those obtained from the following formula :

$$d_0 = 120\,l \quad (\mathrm{mm})$$
$$Z = 7.0k^2 KS\,h\,l^2 \quad (\mathrm{cm}^3)$$

Where:

k, l, S and h = as specified in **Par 1.**

407. Stiffeners attached to girders in cargo oil tanks and deep tanks

The thickness of flat bar stiffeners and tripping brackets provided on girders and transverses is not to be less than that obtained from the following formula. However, it needs not exceed the thickness of webs of the girder to which they are provided.

$$t = 0.5\sqrt{L} + 2.5 \quad (\mathrm{mm})$$

408. Cross ties

1. Cross ties in ships having two or more rows of longitudinal bulkheads, where they are effectively connected with longitudinal bulkhead transverses in cargo oil tanks are to be in accordance with this requirements.

2. The sectional area of cross ties interconnecting longitudinal bulkhead transverses in cargo oil tanks is not to be less than that obtained from the following formula :

$$A = C_1' C_2 KS b_s h \quad (\mathrm{cm}^2)$$

Where:

b_s = as specified in **405. 5.**

h = h_s where cross ties are provided in wing cargo oil tanks, vertical distance from mid-point of b_s to top of hatchways of adjacent cargo oil tanks where struts are provided in centre cargo oil tanks (m).

C_2 = coefficient obtained from the following formula, in no case, however, is to be less than 1.1

$$C_2 = \frac{0.77}{1 - 0.5\dfrac{l}{k}}$$

l = length of cross ties between the inner surface of longitudinal bulkhead transverses (m).

k = as given below : $k=\sqrt{\frac{I}{A}}$

I = moment of inertia of cross ties (cm^4).

A = sectional area of cross ties (cm^2)

C_1' and S = as specified in **105.**

Section 5 Structural Details

501. General

1. The principal structural members are to be arranged so that continuity of strength can be secured throughout the cargo area. In forward and afterward parts of the cargo area, the structures are to be effectively strengthened so that continuity of strength is not impaired sharply.

2. For the principal structural members, sufficient consideration is to be given for fixity at ends, supporting and stiffening systems against out-of-plane deflections and the construction is to minimize local stress concentration.

502. Frames and stiffeners

Longitudinal beams, frames and stiffeners are to be of continuous structures, or to be connected securely so that their sectional area at ends can be properly maintained providing sufficient resistance against bending moments.

503. Girders and cross ties

1. Girders provided within the same are to be arranged to avoid sharp changes in strength and rigidity, and brackets in suitable size are to be provided at the ends of girders, and bracket toes are to be sufficiently rounded.

2. In case where the depth of longitudinal girders is large, stiffeners are to be arranged in parallel with face plates.

3. Brackets are to be provided at the ends of cross ties to connect to transverses or girders.

4. Transverses and vertical webs are to be provided with tripping at the junctions with cross ties.

5. Where breadth of face plates forming cross ties exceeds 150 mm on one side of the web, stiffeners are to be provided at proper interval to support the face plates as well.

6. Tripping brackets are to be provided on the web plate transverses at the inner edge of end brackets and at the connecting part of cross ties, etc. and also at the proper interval in order to support transverses effectively. In case where the width of face plates of each girder exceeds 180 mm on one side, the tripping brackets shown above are to support face plates as well.

7. Webs for the upper and lower end brackets of side transverses and longitudinal bulkhead transverses and areas in the vicinity of their inner ends and those in the vicinity of the roots of cross ties are to be stiffened specially with closer spacing.

Section 6 Special Requirements for Corrosion

601. Thickness of shell plating

1. The thickness of shell plating forming casing cargo oil tanks planned to carry ballast water in ships without double side hull is not to be less than a thickness added with 0.5 mm to that obtained from the formula given in **Pt 3, Ch 4.**

2. The thickness of shell plating when applying the requirements of this Chapter may be reduced with 0.5 mm from the thickness obtained from the formula given in **201.**

602. Thickness of deck plating

1. The thickness of freeboard deck plating when applying the requirements of this Chapter may be reduced with 0.5 mm from the thickness obtained from the formula given in **201.**

2. The thickness of the freeboard deck plating in spaces carrying cargo oil when applying the requirements in **Pt 3, Ch 5,** is not to be less than a thickness added with 0.5 mm to that obtained from the formula given in **Pt 3, Ch 5.**

603. Thickness of tank top plating

The thickness of tank top plating in cargo oil tanks and deep tanks is not to be less than the thickness corresponding to that obtained from the formula given in **201.** added by 1.0 mm. Such an addition, however, is not required for the thickness of inner bottom plating.

604. Section moduli of longitudinal beams, frames and stiffeners

1. The section modulus of longitudinal beams provided on deck plating forming casing cargo oil tanks is not to be less than 1.1 times that calculated according to the requirements of **Pt 3, Ch 10.**

2. The section modulus of frames and stiffeners provided on shell plating and bulkheads forming cargo oil tanks planned to carry also ballast water, except the tank to carry ballast water only in heavy weather conditions, is not to be less than 1.1 times that calculated in accordance with the requirements **301.** and **302.**

605. Thickness of plate members in ballast tanks adjacent to cargo oil tanks

1. The thickness of bulkhead plating at the boundaries between ballast tanks and cargo oil tanks is not to be less than the thickness specified in **103.** added by 1.0 mm.

2. In case where the adjacent cargo oil tanks are equipped with heating systems, the thickness of bulkhead plating at the boundaries between ballast tanks and cargo oil tanks is not to be less than the thickness determined from **Par 1** added by 1.0 mm.

606. Thickness of deck plating in cargo oil tanks

The thickness of deck plating in cargo oil tanks is not to be less than the thickness specified in **103.** added by 1.0 mm.

607. Thickness of inner bottom plating in cargo oil tanks

1. The thickness of inner bottom plating of cargo oil tanks is to be sufficient considering the effects of pitting corrosion.

2. The thickness of inner bottom plating in the vicinity of suction bell mouths in cargo oil tanks, and the thickness of suction well, when provide, are not to be less than the thickness obtained by the requirements in **201.** for the appropriate area of application added by 2.0 mm.

Section 7 Special Requirements for Forward Wing Tanks

701. Application

For tankers of not less than 200 m, in length, the structural members in wing tanks which become empty in full loaded condition for spaces from a point $0.15L$ from the fore end to the collision bulkhead are to comply with the requirements in this Section as well as the requirements in each previous Articles concerned.

702. Side longitudinal

1. The section modulus of side longitudinals is not to be less than that obtained from the following formula :

$$Z = 9 C_1 K S h l^2 \quad (\text{cm}^3)$$

Where :

h = distance (m) from the longitudinals under consideration to the point $0.7d + 0.05L$ above top of keel. Where, however, in no case is h to be less than obtained from the following formula (m);

$$h_{\min} = 0.2\sqrt{L} + 0.03L$$

C_1, S and l = as specified in **105.**

2. In case where side longitudinals are connected to transverses by brackets, the section modulus may be determined by multiplying the value obtained from the following formula by the value obtained from the formula specified in **Par 1 :**

$$(1 - C)^2$$

Where:

C = as obtained from the following formulae:

where brackets are provided at both ends $C = \dfrac{b_1 + b_2 - 0.3}{l}$

where a bracket is provided at one end $C = \dfrac{b - 0.15}{l}$

b_1, b_2 and b = length of bracket arms along longitudinals (m). Where, however, in case where the value of C is negative, C = 0 (See **Fig 7.10.1**)

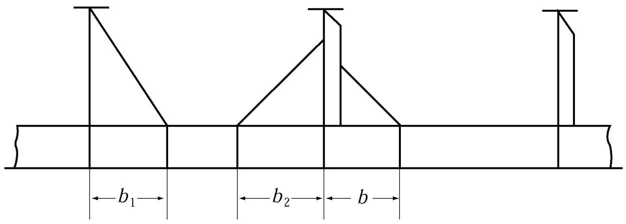


Fig 7.10.1 Measurement of b, b_1 and b_2

703. Reinforcement of bottom forward

The requirements of bottom forward are to comply with the requirements in **Pt 3, Ch 4, 404.** and **Pt 3, Ch 7, Sec 8.**

Section 8 Special Requirements for Tankers with Mid-deck

801. Application

1. The structural members of tankers having mid-deck penetrating longitudinally through the cargo areas are to comply with the requirements in **Sec 1** to **Sec 7.**

2. The scantling of structural members in cargo oil tanks below mid-deck are be as deemed appropriate by the Society.

Section 9 Special Requirements for Hatchways and Permanent Gangway

901. Ships having unusually large freeboard

Relaxation from the requirements specified hereunder will be considered to ships having an unusally large freeboard.

902. Hatchways to cargo oil tanks

1. The thickness of coaming plates is not to be less than 10 mm. Where the length and coaming height of a hatchway exceed 1.25 m and 760 mm respectively, vertical stiffeners are to be provided to the side or end coamings and the upper edge of coamings is to be suitably stiffened.

2. Hatchway covers are to be steel or other approved materials. The construction of steel hatchway covers is to comply with the following requirements. The construction of hatchway covers of materials other than steel is to be in accordance with the discretion of the Society.

(1) The thickness of cover plates is not to be less than 12 mm.

(2) Where the area of a hatchway exceeds 1 m^2 but dose not exceed 2.5 m^2, cover plates are to be stiffened by flat bars of 100 mm in depth spaced not more than 610 mm apart. Where, however, the cover plates are 15 mm or more in thickness, the stiffeners may be dispensed with.

(3) Where the area of a hatchway exceeds 2.5 m^2, cover plates are to be stiffened by flat bars of 125 mm in depth spaced not more than 610 mm apart.

(4) Covers are to be secured oiltight by fastenings spaced not more than 457 mm apart in circular hatchways or 380 mm apart and not more than 230 mm far from the corners in rectangular hatchways.

3. The cover is to be provided with an opening at least 150 m in diameter which is to be so constructed as to be capable of being closed oiltight by means of a screw plug or a cover of peep hole.

4. Hatchway coamings are to be provided with gas cocks or other suitable exhausting devices.

903. Hatchway to spaces other than for cargo oil tanks

In exposed positions on the freeboard and forecastle decks or on the tops of expansion trunks, hatchways serving spaces other than cargo oil tanks are to be provided with steel watertight covers having scantlings complying with the requirements in **Pt 4, Ch 2, Sec 2.**

904. Permanent gangway and passageway

1. A fore and aft permanent gangway complying with the requirements of **Pt 4, Ch 5, 503.** is to be provided at the level of the superstructure deck between the midship bridge or deckhouse and poop or aft deckhouse, or equivalent means of access is to be provided to carry out the purpose of gangway, such as passage below deck. Elsewhere and in ships without midship bridge or deckhouse, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

2. Safe and satisfactory access from the gangway level is to be available between crew accommodations and machinery space or between separated crew accommodations.

3. Where superstructures are connected by trunks, open rails are to be provided for the whole length of the exposed parts of the freeboard deck.

Section 10 Welding

1001. Application

The welding in tankers is to be accordance with the requirements given in **1002.** in addition to **Pt 3, Ch 1, Sec 5.**

1002. Fillet welding

1. The application of fillet welding to structural members within the cargo area is to as given in **Table 7.10.9.**

2. The leg length of fillet welds in areas given in (1) and (2) below is to be at least 0.7 times the plate thickness as specified in the requirements in this Chapter.

(1) Fillet welding at the connected parts between the outermost girders in the double bottom and floors.

(2) Fillet welding at the connected parts between the lowermost stringers in the double side hull and transverses.

Table 7.10.9 Application of Fillet Welding

Column	Item		Application	kind of weld
1	Girders and Transverses	Web plates	Shell, deck, longitudinal bulkhead or inner bottom plating	F1
2			Web plates	F1
3			Face plates	F2
4		Slots in web plates	Web plates of longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads	F2
5		Tripping brackets and stiffeners provided on web plates	Web plates	F3
6			Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads	F1
7	Longitudinal frames, beams and horizontal stiffeners on longitudinal bulkheads		Shell, deck or longitudinal bulkhead plating	F3
8	Cross ties		Members forming cross ties (web plates to face plates)	F3
9			Face plates of transverses or girders	F1

Note:
Where the radius at the toe of end brackets is small, it is recommended that F1 be used for appropriate length at the toe of bracket.

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KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 7

Ships of Special Service

GA-07A-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 7 "SHIPS OF SPECIAL SERVICE"

1. Unless expressly specified otherwise, the requirements in these Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date : 10 January 2011 (based on the application date for classification survey)

Chapter 10 Double hull Tanker

Section 2 Bulkhead Plating

- 201. 3 has been newly added.

Effective Date : 1 July 2011

CHAPTER 7 CAR FERRIES AND ROLL-ON/ROLL-OFF SHIPS

Section 3 Deck Structure

- 301. has been amended.

CONTENTS

CHAPTER 1 OIL TANKERS

Section 1 General

101. Application

1. The prescription in this Guidance principally apply to oil tankers having two longitudinal bulkheads and constructed on the longitudinal framing system, intended for carriage of oils of flash point not exceeding 60°C. Unless otherwise specially noted, the prescriptions in other parts apply for matters common to both cargo ships and tankers.

2. Proposal of novel construction type

In the event that a novel construction type is proposed, scantlings are to be determined by carrying out comparative calculations with the standard structural model conforming to the requirements of the Rules. Submission of data covering the results of model experiments or real ship experiments may be requested by the Society as necessary.

3. Ships carrying liquid cargoes other than crude oil and petroleum products

In application of **101. 4** of the Rules, ships intended to carry liquid cargoes having a vapour pressure (absolute pressure) less than 0.28 MPa at 37.8 ℃ other than crude oil and petroleum products, are to be in accordance with the followings.

(1) The scantlings of structural members of the cargo oil tank part of tankers carrying liquid cargoes of a specific gravity ρ exceeding 1.0 are to be of the values obtained by the following two procedures, whichever is greater:

(A) To calculate for all of the structural members in accordance with the relevant requirements of the Rules

(B) To calculate for respective structural members in accordance with the following prescription:

(a) The scantlings of members attached to shell plating, cross ties and members attached to longitudinal bulkhead which are connected with members attached to shell plating through cross ties are to be determined by the formulae in the Rules, in which h is to be replaced by h_0 shown in **Fig 7.1.1.**

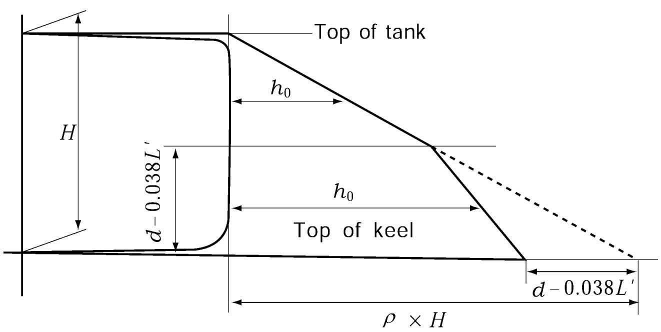


Fig 7.1.1. Measurement of h_0

(b) The scantlings of bulkhead plating, members attached to bulkheads and cross ties are to be determined on the assumption that the tank concerned is filled with liquid cargo of specific gravity ρ up to the top of tank.

(c) The section modulus of deck transverses in centre tanks are to be multiplied by ρ.

(d) The values of ρ are to be selected for respective cases except those contained in **Table 7.1.1.**

Table 7.1.1 Value of ρ

Cargo	ρ
Molasses	1.4
Asphalt	1.1
Concentrated sulphuric acid	1.85

(2) For tankers carrying dangerous chemicals in bulk, the requirements in **Ships Carrying Dangerous Chemicals in Bulk** of the Rules are also to be applied.

102. Arrangement of bulkheads in cargo tanks

1. The length of tanks in cargo oil spaces is less than the greater 10 m or the following value.

(1) Where the longitudinal bulkhead is not installed---------------------------------- $0.1L_f$
(2) Where the longitudinal bulkhead is only installed at centreline ------------- $0.15L_f$
(3) Where two or more longitudinal bulkheads are installed
(A) Wing tank -- $0.2L_f$
(B) Centre tank

(a) for $\frac{b_i}{B_f} \geq \frac{1}{5}$ -- $0.2L_f$

(b) for $\frac{b_i}{B_f} < \frac{1}{5}$

(i) Where the longitudinal bulkhead, which is not on the centreline : $\left(0.5\frac{b_i}{B_f}+0.1\right)L_f$

(ii) Where the longitudinal bulkhead, which is on the centreline : $\left(0.25\frac{b_i}{B_f}+0.15\right)L_f$

b_i = the minimum breadth at location on the load line of the wing tank.(m)

2. In the centre tanks and inner tanks, transverse swash bulkheads are to be provided at an interval not exceeding 15 m or $0.1L$, whichever is greater.

3. In wing tanks, rings and/or girders are to be so constructed as to avoid discontinuity of strength at the positions of longitudinal bulkheads in the centre tanks and inner tanks.

103. Cofferdams

1. Cofferdams and bulkheads bounding cargo oil tanks

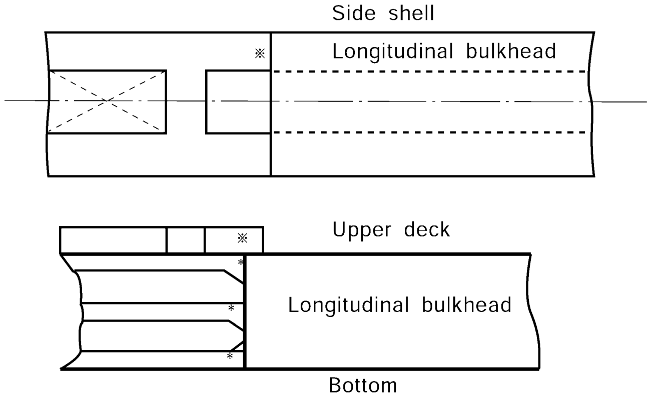
(1) Compartment destined to carriage of fuel oil or water ballast may be utilized as cofferdams needed for isolation from cargo tanks, if such compartments are of all welded construction except deck stringer angles. (See **1003. 2** and **3** of the Rules)
It is recommended that tanks containing such liquid cargoes as will be heavily damaged by contamination of fuel oil-gasoline, molasses, etc. be isolated by cofferdams from fuel oil tanks.
(2) If the fore peak compartment (or tank) is continuous to cargo tanks, the collision bulkhead is not to have any opening except special cases. (See **1003. 2** and **3** of the Rules)
(3) Divisions between compartments defined as cofferdams and other compartments (except cargo oil tanks and fuel oil tanks) are not to have any openings with the exception of bolted watertight manholes provided in chain locker bulkheads, etc. (no watertight door is permitted).

2. Superstructures and deckhouses

The deckhouse protecting the entrance to pump rooms is to be as follows:

(1) The strength of front wall is to be equivalent to that of wall of the bridge.
(2) The strength of side and after walls are to be equivalent to that of front wall of the poop.
(3) The height of doorway coaming is not to be less than 600 mm above the freeboard deck.

3. At the after end of cargo tank region, attention is to be given to keep continuity between the ends of longitudinal bulkheads and the longitudinal members of poop deck, etc. (See **Fig 7.1.2**)



※ : The wall of deckhouse is to be of steel, and be provided on the longitudinal bulkhead.
* : The brackets are to be of big size.

Fig 7.1.2 Continuity of after end of longitudinal bulkhead

4. Tankers having double bottoms under cargo tanks

Access to the double bottoms is not to be provided in cargo tanks. It is to be made from cofferdams at the forward and after ends or through oiltight trunks led from the exposed main deck to the double bottom.

104. Airtight bulkheads

1. Cofferdams which are not utilized as main or auxiliary pump rooms and compartments utilized as cofferdams under the freeboard deck are to meet the requirements for the strength of deep tanks. The bulkhead between the main pump room and engine room is to have structural scantlings of watertight bulkheads in ships of not less than 100 m in length and of airtight bulkheads in ships of less than 100 m in length.

2. The scantlings of airtight bulkheads for which no hydrostatic tests are required are to comply with the following standards. Airtightness tests may be replaced by hose tests.

(1) Thickness : It is not to be less than 6 mm, which may, however, be reduced to 4.5 mm in ships of less than 100 m in length.

(2) Section modulus of stiffeners and girders : It is to be 50 % of the rule requirements for watertight bulkheads. Where connected to shell and decks, however, these stiffening members are to be of such an effectiveness as is equivalent to frames and beams.

109. Direct strength calculation

When determining the scantlings of structural members of cargo hold for a tanker by direct strength calculations, the procedure is to comply with the **Pt 3, Annex 3-2 Guidance for the Direct Strength Assessment** of the Guidance.

Section 2 Hatchways, Gangways and Freeing Arrangement

202. Hatchways to cargo oil tanks

1. In case where hatchway covers of glass-fibre reinforced plastics are provided for cargo oil tanks, they are to comply with the following requirements:

(1) The basic materials is to be of fire-resistant nature.
(2) Model tests are to be carried out according to the standard fire test method specified in SOLAS 1974 (including amendments 1981/ 1983) through exposing the inside face to fire. This standard fire test is to be carried out for a time duration of not less than 20 minutes at a highest temperature of 790℃ to confirm that there is no passage of flame until the end of the first 20 minutes of the test.
(3) Steaming tests are to be carried out to confirm that no deformations causing leakage occur.
(4) Each model of different dimensions is to be subject to hydraulic test with a pressure not less than 0.028 MPa to confirm its strength.
(5) The cover is to be designed to be set either at full-open position or full-close position only. A notice indicating this manner of handling is to be fitted to the upper surface of cover.

2. Materials of tank cleaning hatch covers are to comply with the following requirement.

(1) Covers may be of brass, bronze or steel, but are not to be of aluminium.
(2) Synthetic materials such as glass-fibre reinforced plastics materials may be used only when all the requirements under **Par 1** above can be met.

3. The tightening devices of covers of tank-cleaning hatches are to be capable of keeping an ample tightness under pressure corresponding to water head of 2.45 m above the tank top. If the devices are constructed in any of the types mentioned below or in their equivalent type, the height of hatch coamings required by the provisions of **Pt 4, Ch 2, 102.** (1) of the Rules may be reduced in accordance with the provisions of **Pt 4, Ch 2, 102. 2** and **301.** (4) of the Rules.

(1) In such a type of construction that a liner is placed on the tank top and the cover is tightened by means of bolts, the pitch between these bolts is not to exceed 150 mm, and the number of bolts is not to be less than 10. Any constructions using butterfly-nuts, etc., which can be opened by simple manipulations, is not permitted. The liners are to be of a same material as the upper deck.
(2) The hatch of a type having hinged cover with arm is to have a coaming. The construction is to be such that the hatch cannot be opened simply by hand. (See **Fig 7.1.3**)

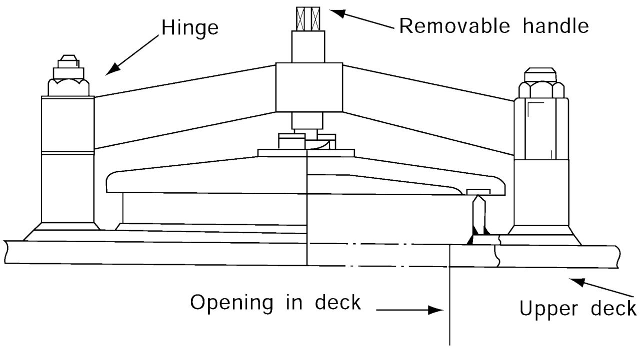


Fig 7.1.3 Cover of tank cleaning hatch

205. Freeing arrangement

Open guardrails for a length not less than half of the length of the exposed parts of the freeboard deck may be replaced by freeing ports, in the lower parts of bulwark, of a total area not less than 33 % of the total area of bulwarks.

Section 3 Longitudinal Frames and Beams in Cargo Oil Spaces

302. Scantlings

1. Slenderness ratio

In 0.4 L amidships, the slenderness ratios of longitudinal beams and longitudinal frames attached to sheer strakes are not to exceed 60 for the large ships and 80 for the small ships. In the calculation of slenderness of ratio, the dimensions of attached plate to be included into calculation are to be (actual spacing of beams or frames) × (actual plate thickness).

2. Side longitudinal

In calculating the side longitudinals as bulkhead stiffeners of deep tanks, h in the formula in Rules is to be that in **510.** of the Rules, if the length or breadth of side tanks exceeds 10 m.

303. Attachment

1. At the intersection of transverse bulkheads, longitudinal frames and beams marked with ○ in **Table 7.1.2** are to be connected by means of through-brackets or they are to penetrate.

Table 7.1.2 Where through-brackets are needed

L (m)	$90 \le L \le 120$	$120 \le L$
Longitudinal beams and side longitudinals attached to sheer strakes	○	○
Side longitudinals and longitudinals on longitudinal bulkhead (except those specified above)	—	○[1)]
Bottom longitudinals and longitudinals on bilge strake	○	○

Note:
(1) The manner of penetration of longitudinals may be as shown in **Fig 7.1.4**, except side longitudinals within 0.2D from top and bottom and longitudinals on longitudinal bulkhead within 0.1D from top and bottom

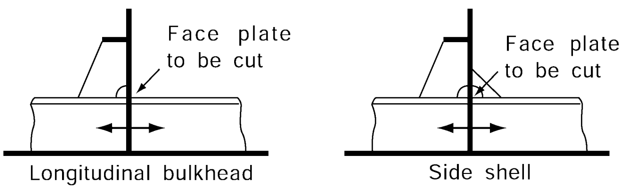


Fig 7.1.4

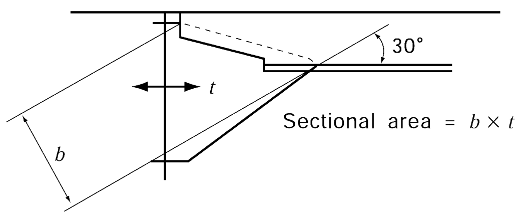


Fig 7.1.5

2. The calculation of sectional area of end bracket is to be as shown in **Fig 7.1.5** so that the area may not be less than the sectional area of the longitudinal beam, frame or stiffener concerned.

3. The connection of end brackets and longitudinal frames or beams is to be as follows.

(1) In ships of 120 m and above in length, the end brackets and longitudinal beams or frames are to overlap each other for an ample length as shown in **Fig 7.1.6.**

(2) In cases other than those under (1) above, the arrangements may be as shown in **Fig 7.1.7.** The bracket is to be brought as close to the plane of web of longitudinal as possible. Where the longitudinals are of flanged plate, the bracket is to be placed on the line of end of curva-

ture and, further, ribs are to be fitted at a point about 10 mm inward of the toe of bracket.

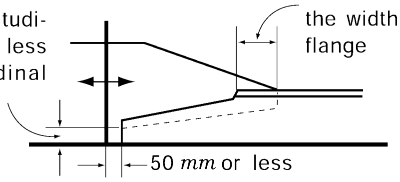


Fig 7.1.6

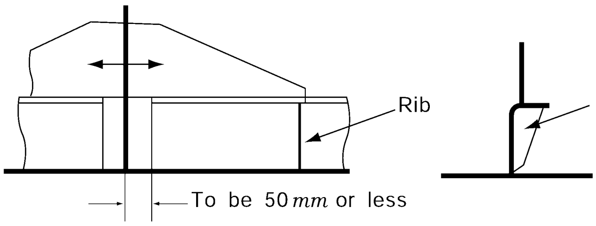


Fig 7.1.7

4. The connection of transverse bulkheads and brackets are to be rounded or levelled, as shown in **Fig 7.1.8.**

(1) The penetrating parts of end brackets are to be rounded or bevelled, as shown in **Fig 7.1.8.**

(2) The connection of end brackets and bulkhead plating is to be reinforced to avoid hard spots, as shown in **Fig 7.1.9.**

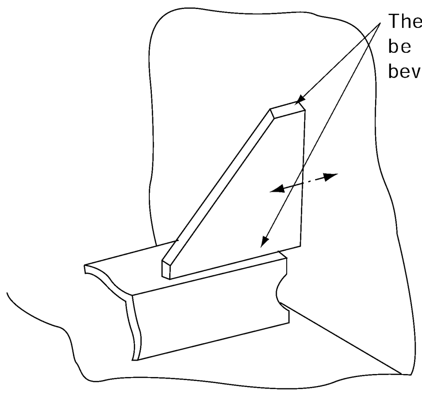


Fig 7.1.8

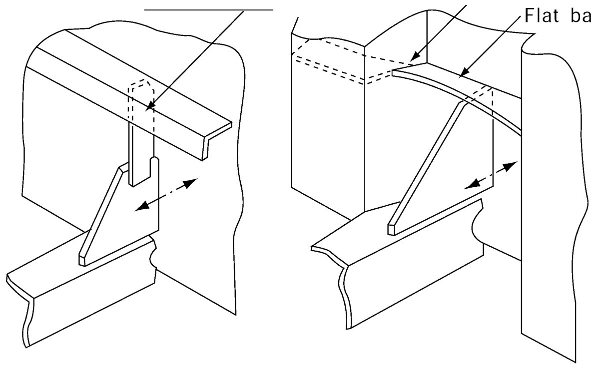
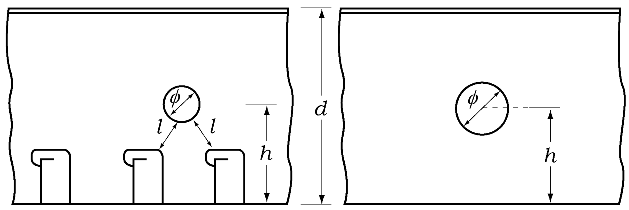


Fig 7.1.9

Section 4 Girders, Transverses and Cross Ties in Cargo Oil Spaces

401. General

1. The dimension and locations of lightening holes, if any, are to be as shown in **Fig 7.1.10.**



$\phi \leq \frac{d}{4}$ $\qquad \phi \leq \frac{d}{3}$

$h \leq \frac{d}{2}$ $\qquad h \leq \frac{d}{2}$

$l \geq \phi$

Fig 7.1.10 Locations and dimensions of lightening holes

2. Slots are to be reinforced with collars where flanges of longitudinals are facing each other or where slots are provided at small intervals as is often the case with bilge part.

3. Where the depth of a girder is smaller than the required depth, its section modulus is to be obtained through multiplying the required section modulus by the ratio of required depth to the actual depth.

4. In pump rooms or void spaces, the web thickness may be 1 mm smaller than the required thickness for webs in cargo oil tanks.

5. The scantlings of members in segregated ballast tanks in the midship part are to be same as those of members in cargo oil tanks (**401. 5** of the Rules)

6. Connection of web plates is to be of butt-welding. If lap-welding is adopted, stiffeners are to be provided across the connection lines.

7. In end bracket parts, at connections with cross ties, etc. of transverses where sharing stress and/or compressive stress are expected to be high, additional stiffeners are to be fitted. These parts are not to have lightening holes. If considered necessary, slots for penetration of longitudinals in these parts are to be reinforced with collars.

8. No scallop is to be permitted in the web plate at the connections of face plates or webs. Inevitable scallops for work are to be filled up by welding. For face plates adjacent to the scallop, abrupt change of dimensions is to be avoided carefully. (See **Fig 7.1.11**)

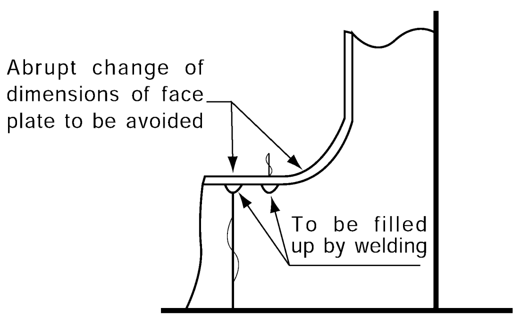


Fig 7.1.11

9. Where angle bars are used instead of flat bars as stiffeners of transverses, etc., their section modulus with effective plates is to be approximately equivalent to the required ones.

10. Where longitudinal frames or stiffeners penetrate bottom transverses, side transverses and vertical webs on longitudinal bulkhead, proper reinforcement is to be made in the extents stipulated in **Table 7.1.3** by fitting brackets on the opposite side of stiffeners on webs of transverse, for connecting longitudinals to transverse, by fitting collars at slots, or by other suitable means. In ships not exceeding 230 m in length, however, the extent of application of such reinforcement may be properly reduced. This reinforcement is to apply to the slots under conditions similar to those in the above-mentioned girders or transverses(for example, slots in transverse swash bulkheads, etc.)

Table 7.1.3 Extents of reinforcement

Member	Extent of reinforcement
Bottom transverse	All connections
Side transverse	All connections below the upper end of curvature of upper cross tie, or the load waterline, whichever is the higher. In ships of 300 m and above in length, it is recommended that similar reinforcement be applied in wider extent upward beyond the limit stipulated above.
Vertical webs on longitudinal bulkhead	All connections below the upper end of curvature of upper cross tie.

402. Transverses and girders provided in centre or inner tanks in ships having two or more rows longitudinal bulkheads

1. Where transverse swash bulkheads complying with rule requirements are provided in tanks, L_0 may be the distance between the transverse bulkhead and the swash bulkhead.

2. As for the treatment of Note 1 to **Table 7.1.3** of the Rules, the value of C_4 is to be equal to 1.2 times the value of C_4 in **Table 7.1.3** of the Rules.

3. As for the treatment of Note 2 to **Table 7.1.3** of the Rules, the value of C_4 in **Table 7.1.3** of the Rules, may be multiplied by $0.25D/d_1$, if the depth of the centreline bottom longitudinal girder d_1 exceeds 25 % of the ship's depth D.

4. The centreline bottom longitudinal girder is to have docking brackets at the middle of span between bottom transverses and between the bottom transverse and transverse bulkhead. If these brackets are of large dimensions, their free edges are to be reinforced against buckling.

5. Where the depth d_2 of centreline vertical web on transverse bulkhead is greater than the spacing S of transverses, the web thickness of bottom girders is to be obtained form the formula in Rules, where d_1 is to be used in place of d_1' and the coefficient η is to be derived form **Table 7.1.4.** (See **Fig 7.1.12**)

Table 7.1.4 Coefficient η

Number of transverse	η
2	0.55
3	0.67
4	0.75
5	0.80

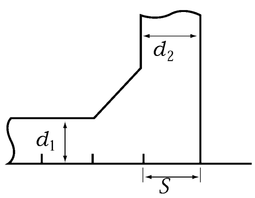


Fig 7.1.12

403. Transverses and girders in wing tanks in ships having two or more rows of longitudinal bulkheads

1. Side transverse

The span l_0 of side transverses is to be measured as shown in **Fig 7.1.13.** The lower end is to be determined in a similar manner.

2. Vertical webs on longitudinal bulkheads

(1) Even when large brackets are provided on the opposite side of longitudinal bulkhead, the span l_0 and radius of transverses are to be measured on the wing tank side in a same manner as (1) above. The size of bracket b may be $(b' + b'')/2$, except when b is to be taken as equal to b' if b'' is smaller than b'.(See **Fig 7.1.14**)

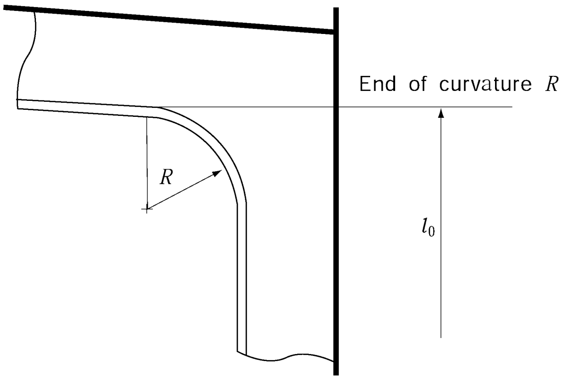


Fig 7.1.13 Measurement of l_0

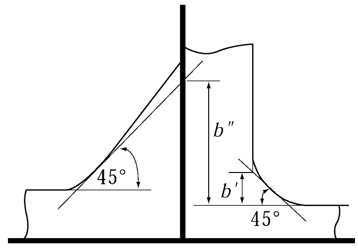


Fig 7.1.14 Measurement of b' and b''

(2) In calculating the web thickness in regard to the shearing force, the brackets on the opposite side of longitudinal bulkhead may be taken into account.
(3) Collars are to be fitted to close slots in the vicinity of the toe of bracket of bottom transverse, which is connected to longitudinal bulkhead, in the centre tank or inner tank.
(4) Girders on corrugated bulkheads are to be balanced girders. Where balanced girders are not adoptable, the neutral axis is to be brought as close to bulkhead plating as possible.

3. Moment of inertia of bottom and deck transverses

The standard values of moment of inertia of bottom and deck transverses are to be obtained from the following formulae :

Bottom transverses : $I = 160 C_0 C_2 Q l_0^2 \dfrac{B_S}{D}$ (cm^4)

Deck transverses : $I = 58 C_0 C_2 Q l_0^2 \dfrac{B_S}{D}$ (cm^4)

where:

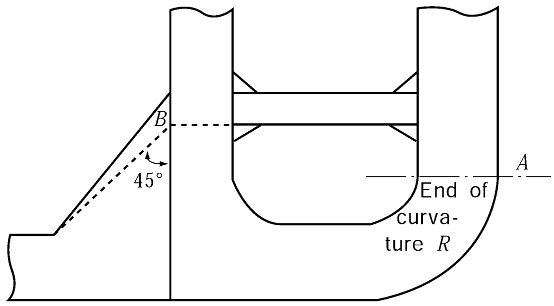
C_0 and C_2 = as specified in **Table 7.1.3** of the Rules

Q and l_0 = as specified in **403. 1** of the Rules

B_S = breadth of wing tank

4. Transverses at bilge part and lower end of longitudinal bulkhead

If the lowest cross tie is located as shown in **Fig 7.1.15** the section modulus of transverse at the bilge part and the lower end of longitudinal bulkhead may be reduced to 90 % of the values obtained from the formula. Further, the web thickness of side transverse at "A" may be 0.5 mm thinner than that obtained from the formula, but is not to be less than the thickness according to **405.** of the Rules.



The lower face of cross tie should be located at least lower than the point "B"

Fig 7.1.15

5. Where side stringers are provided

(1) If a swash bulkhead is provided in the centre tank, l_1 is to be measured as shown in **Fig 7.1.16.**

(2) In addition to the prescriptions in **403. 5** (1) of the Rules, the side stringers and cross ties are to meet the following condition.

$l_1 > l_2 > l_3$ ------------- (See **Fig 7.1.17**)

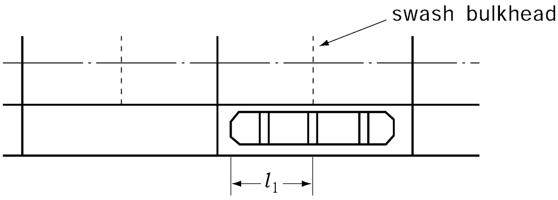


Fig 7.1.16 Measurement of l_1

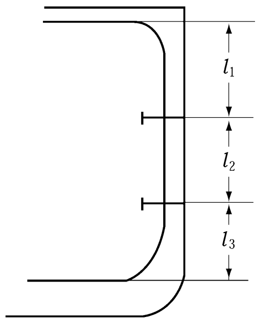


Fig 7.1.17

(3) Where four transverse rings and one horizontal ring are connected by one cross tie, the coefficients C_3 and C_4 for calculation of the scantlings of horizontal ring are to be obtained from **Table 7.1.5. 404. 2** is to apply to the cross tie.

(4) If stringers are arranged asymmetrically or two cross ties are provided, the scantlings of these members are to be decided on the basis of equivalent effectiveness.

Table 7.1.5. C_3 **and** C_4 **of coefficient**

<table>
<tr><th colspan="2">Coefficient</th><th>C_3</th><th>C_4</th></tr>
<tr><td rowspan="4">$K=\frac{d_0}{d_1}\left(\frac{l_1}{l_0}\right)^2$</td><td>$K \leq 0.2$
$0.2 < K \leq 0.3$
$0.3 < K \leq 0.4$</td><td>62
54
50</td><td>5.32
4.51
4.22</td></tr>
<tr><td>$0.4 < K \leq 0.5$
$0.5 < K \leq 0.6$
$0.6 < K \leq 0.7$</td><td>48
45
43</td><td>3.92
3.62
3.40</td></tr>
<tr><td>$0.7 < K \leq 0.8$
$0.8 < K \leq 0.9$
$0.9 < K \leq 1.0$</td><td>41
40
38</td><td>3.18
3.03
2.88</td></tr>
<tr><td>$1.0 < K \leq 1.2$
$1.2 < K \leq 1.4$
$1.4 < K \leq 1.6$</td><td>36
33
32</td><td>2.66
2.44
2.30</td></tr>
</table>

6. Side stringers in bow part(longitudinal bulkhead in centreline only)

(1) Where strong stringers support transverse rings(without cross tie) (See **Fig 7.1.8**)

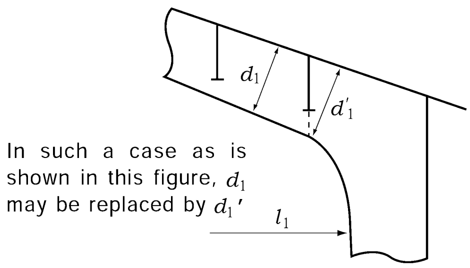


Fig 7.1.18

Transverse ring:

Average depth of girder : $d = C_0 l_0$ (m)

Section modulus of girder :

average over span : $Z = C_2 K^2 Q l_0$ (cm^3)

bilge part : $Z = C_2' Q l_0$ (cm^3)

Longitudinal girder :

Web thickness : $t = C_3 \frac{Q}{d_1} + 2.5$ (mm)

Section modulus of girder : $Z = C_4 K Q l_1$ (cm^3)

C_0, C_2, C_2', C_3 and C_4 are to be obtained from **Table 7.1.6.** These formulae apply to the type of construction comprising three or four transverse rings supported by one or two strong stringers, where K does not exceed 0.5. Symbols are to be as per **403.** of the Rules.

Table 7.1.6 Coefficient C_0, C_2, C_2', C_3 and C_4

No. of longitudinal girders	No. of transverses	Coefficient	$K=\frac{d_0}{d_1}\times\left(\frac{l_1}{l_0}\right)^2$	
			0	0.5
1	3 or 4	C_0 C_2 C_2'	0.080 1.46 2.89	0.125 3.88 5.10
	3	C_3 C_4	54 10.20	36 5.60
	4	C_3 C_4	72 10.60	45 6.40
2	3 or 4	C_0 C_2 C_2'	0.065 0.68 1.36	0.115 3.40 4.76
	3	C_3 C_4	41 7.20	23 3.80
	4	C_3 C_4	50 7.7	32 4.3

Note:
Where only two transverse rings are provided, C_3 and C_4 are to be replaced by $1.2C_3$ and $1.2C_4$, respectively, for the lower longitudinal girder and $0.8C_4$, respectively, for the upper longitudinal girder.

(2) Where the side transverse is connected by cross ties to the vertical webs on the centreline bulkhead (without longitudinal girders), the principal scantlings are to be determined according to **403. 1** (1) to (4), **2** (1) and **3** (3) of the Rules, in which the coefficient in formulae may be those in **Table 7.1.7.** The prescriptions in **404.** of the Rule are to apply to cross ties.

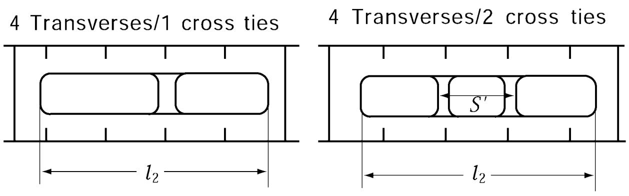
Table 7.1.7 Coefficient C_0, C_2 and C_2'

Coefficient \ No. of cross tie	1	2
C_0	0.10	0.09
C_2	2.52	1.94
C_2'	3.83	2.89

404. Cross ties

1. In the construction of 4 transverses ring/1 cross ties or 4 transverses ring/ 2 cross ties type as per **403. 5** (3), the value of S in the formula is to be obtained from the following formulae.(See **Fig 7.1.19**)

2. In such a construction as shown in **Fig 7.1.20,** brackets asterisked are to be fitted.



$S = \frac{l_2}{2}$ (m) $S = \frac{l_2 + S'}{4}$ (m)

l_2 = span of longitudinal girder/stringer (m).
S' = spacing of cross ties (m).

Fig 7.1.19 Value of S

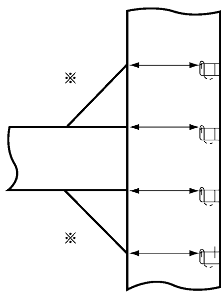
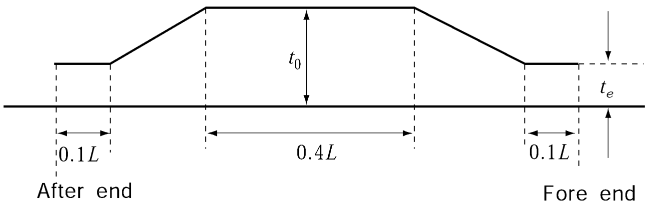


Fig 7.1.20

Section 5 Bulkheads in Cargo Oil Spaces

502. Thickness of bulkhead plating

The thickness of the uppermost and the lowest strake of longitudinal bulkheads stipulated in **502. 2** may be tapered down as shown in **Fig 7.1.21,** provided that their thickness is not less than obtained according to **502. 1** and **3** of the Rules.



t_0 = actual thickness in midship part ⌧
t_e = thickness as per Rules, **Table 7.1.1**

Fig 7.1.21 Tapering of thickness of uppermost and lowest strakes of longitudinal bulkhead.

504. Strong vertical webs

1. Centreline vertical webs on transverse bulkhead

d_l and d_u in the prescriptions in **504.** of the Rules are to include the depth of brackets, if there are brackets on the opposite side of the bulkhead.

2. End connection of webs attached to bulkheads

The connection of a member having a large moment of inertia, such as longitudinal girder on bulkhead, and a member having a small moment of inertia, such as longitudinal frames, is to be arranged as shown in **Fig 7.1.22.**

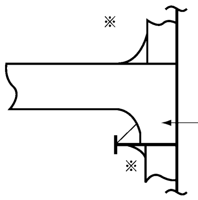


Fig. 7.1.22

506. Horizontal girders supporting vertical webs

Connection of webs and longitudinal frames, etc. is to be as specified in **504. 2.**

511. Swash bulkheads

1. The breadth and thickness of the uppermost and lowest strakes of the centreline swash bulkhead may be 90 % of those required by the Rules for the uppermost and lowest strakes, respectively, of the longitudinal oiltight bulkhead.

2. The "opening ratio" means the ratio of the sum of areas of openings, except slots and scallops, to the area of the bulkhead.

3. The section modulus of stiffeners is to be obtained from the following formula;

$$Z = CSh_s l^2 \quad (\text{cm}^3)$$

where:

S = spacing of stiffeners (m)

l = span of stiffener between supports (m)

C = coefficients stipulated below

both ends effectively bracketed -- 7.1

one end effectively bracketed and the other end supported by girder ---- 8.4

both ends effectively bracketed -- 10.0

h_s = value obtained from the following formula. In no case is it to be less than 2.0

$$h_s = \left(0.176 - \frac{0.025}{100}L\right)(1-a)l_t$$

where :

L = length of ship (m)

a = opening ratio of bulkhead plating

l_t = length of tank (m)

4. Where a vertical web at the middle of two longitudinal bulkheads serves as a strong web supporting horizontal girders, the scantlings of the vertical web are to be obtained from the following formulae:

(1) Depth of web

$$d = 3\left(\frac{l_1}{B_0}\right)^2 d_0 \quad (\text{m})$$

where:

l_1, B_0 and d_0 = as specified in **504.** of the Rules

(2) Sectional area of web at the upper end of lower bracket

$$A = 1.74 \frac{(D - h_1)}{D} S(h - 0.32d)(l - S)C \quad (\text{cm}^2)$$

where:

S, h, l and C = as specified in **501.** of the Rules.

h_1 = vertical distance from the top of keel to the inner toe of lower bracket of the web (m)

But, the sectional area of web is to include the bulkhead plating of the part within the distance form the web to the nearest opening or the distance equal twice the deck longitudinal spaces on each side of the web, whichever is the smaller.

(3) Thickness of web at the upper end of lower bracket

$$t = 12Kb + 2.5 \quad (\text{mm})$$

where:

b = spacing of vertical stiffeners fitted to web (mm)

K = as specified in following formula

$$K = \sqrt{\frac{A}{A_0}}$$

A = sectional area as specified in (2) (cm^2)

A_0 = sectional area of the vertical web (cm^2)

(4) Section modulus of vertical web

$$Z = 4k^2 B_0 h_s l_1^2 \quad (\text{cm}^3)$$

where:

k, B_0 and l_1 = as specified in **504.** (1) of the Rules.

h_s = as specified in **Par 3.** above.

5. The scantlings of waves supporting vertical webs or horizontal girders are not to be less than obtained from the formula in **506.** of the Rules. In applying the formula for W_i, h is to be replaced by h_s prescribed in **Par 3.**

6. The scantlings of webs supporting stiffeners are to be obtained according to **507.** of the Rules in which h is to be replaced by h_s prescribed in **Par 3** and X is to be taken as zero.

7. Where a swash bulkhead consists of bottom transverses, deck transverses, side transverse, vertical webs on longitudinal bulkhead and struts, the scantlings of these webs and struts are to be obtained by applying **402., 403.** and **405.** of the Rules correspondingly. In this case, the section modulus of strut about vertical axis is not to be less than obtained from the following formula.

$$Z = 7.13 d_0 h_s l^2 \quad (\text{cm}^3)$$

where:

d_0 = depth of strut (m)

l = span (m) between supports, to be equal to the breadth of side tank in case of side tanks, or to the distance between longitudinal bulkheads or between centreline vertical web and longitudinal bulkhead. If tripping brackets for the webs and transverses are provided at the ends of the face plates, l may be the distance between the face plates of transverse.

h_s = as specified in **Par 3** above.

Section 6 Relative Deformation of Wing Tanks

601. Relative deformation of wing tanks

1. Special considerations for the case of exceeding limit values

It is required to submit data enough to prove that the proposed construction has an equivalent effectiveness.

2. Mean thickness in formulae

The mean thickness of plating in the formulae in **601.** of the Rules is to be obtained from the following formula.

$$t = \frac{\Sigma l_i t_i}{\Sigma l_i}$$

where :

l_i and t_i are to be taken as follows;

(1) Transverse bulkheads and perforated swash bulkheads : The thickness and breadth of each strake of the bulkhead are to be taken at the middle of the breadth of the tank as shown in **Fig 7.1.23.**

(2) Transverse rings and swash bulkheads of transverse ring type: The thickness and vertical extent of the deck transverse, transverse on longitudinal bulkhead between face bar of deck transverse and upper face bar of the uppermost strut and so on, and parts from the uppermost strut to the bottom transverse are to be taken at the middle of the breadth of the tank (at the bulkhead side if no plating is present at the middle of the breadth of the tank) as shown in **Fig 7.1.24.**

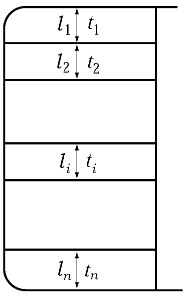


Fig 7.1.23

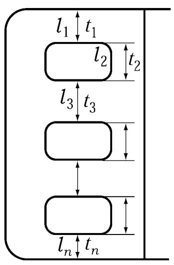


Fig 7.1.24

Section 10 Piping Systems and Venting Systems for Oil Tankers

1001. General

1. In case where double bottom used as other than cargo oil tank is provided below cargo oil tank, the requirements specified in **Sec 10** of the Rules and additionally the requirements specified in the following are to be complied with ;

(1) The air pipes and sounding pipes provided in double bottom may pass through cargo oil tanks. In this case, all pipe joints in the cargo oil tanks are to be of welded joints with a sufficient thickness according to the requirements of **Table 7.1.8.** Further, consideration is to be given to the piping arrangement for expansion and contraction of the pipes.

Table 7.1.8 The sounding pipes and air pipes passing through cargo oil tanks

Nominal diameter(mm)	Thickness of pipe	Reference[(1)]
$A < 100$	8.7	Sch. 160
$100 \le A < 200$	11.1	Sch. 120
$200 \le A < 250$	12.7	Sch. 80
$250 \le A$	15.1	Sch. 80

Note:
(1) Standard specified in *KSD* 3562 and *KSD* 3570

(2) Valve operating rods are not to pass through any part subjected to liquid head at all time, such as the inner bottom plate of the cargo tank.

(3) Pipes conveying liquid and bilge suction pipes for tank or void space at the forward position of the ship are to comply with the following requirements:

(A) Pipes for tank or void space adjacent to the forward end of cargo oil tank may be led to the aft pump room. Fuel oil transfer pipes may be led to the pump provided in the engine room.

(B) Pipes for forepeak tank or void space not adjacent to cargo oil tank may be led to the pump provided in the engine room or the pump to provided in the aft pump room. Where this tank used ballast tank, ballast pipe may be led to the pipes for ballast tank adjacent to the cargo oil tank

(C) Where ballast pipes are arranged without passing through cargo oil tanks, piping for fore peak ballast tanks not located adjacent to cargo oil tanks may be led to the pipe lines for ballast tanks located adjacent to cargo oil.(As for bilge pipes, the requirements of **1003. 1.** (3) of the Rules are to apply) To the contrary, however, ballast pipes for ballast tanks located adjacent to cargo oil tanks are not to be led to the pumps which are installed in the engine room for the use of the ballast tanks not located adjacent to cargo oil tanks.

2. In application of the **1001. 3,** "Requirements concerning use of crude oil or slops as fuel for tanker boilers" are to comply with **Annex 7-1.**

1002. Cargo oil pumps and cargo oil piping systems, pipings in cargo oil tank, etc.

1. In case of maintaining the gastight using by the oil lubricated device specified in **1002. 1** (1) (B) of the Rules, apply to **Ch. 6, 303. 6.**

2. In the provision **1002. 3** of the Rules, the changable device which the Society requires means the following device.

(1) Cargo oil tanks also used as ballast tanks
In case where a tank is used both as a cargo oil tank and a ballast tank alternatively, the cargo oil pipes, ballast pipes and vent pipes are to be arranged changeable so as to serve respective cases by giving reference to the example shown in **Fig 7.1.25.** Further, for other piping systems, the requirements for the piping systems in cargo oil tanks are to be complied with.

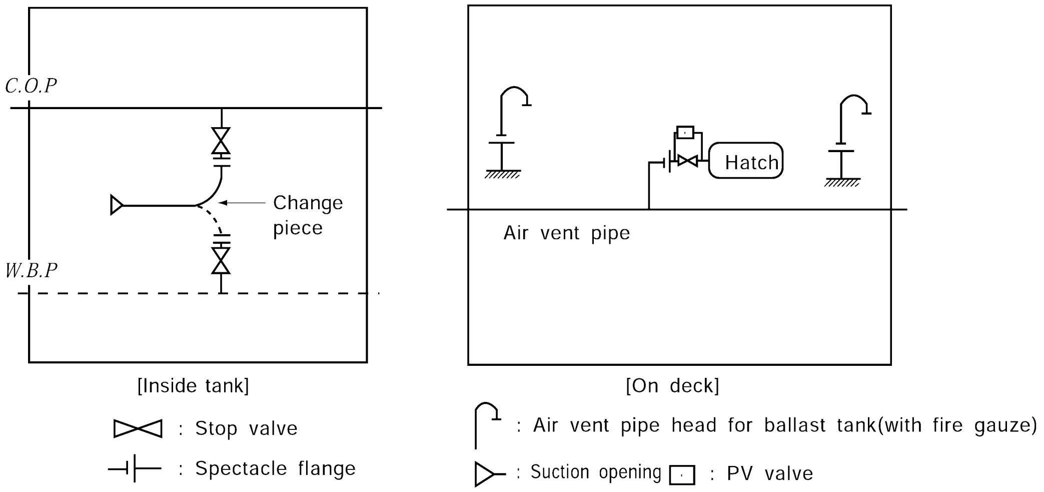


Fig 7.1.25 Example of piping arrangement for a tank used as cargo oil tank and ballast tank in alternative use

(2) Cargo oil tanks also used as fuel oil tanks
In case where a tank is used both as a cargo oil tank and a fuel oil tank alternatively the cargo oil pipes, fuel oil pipes and vent pipes are to be arranged changeable so as to serve respective cases by giving reference to the example shown in **Fig 7.1.26.** Further, for other piping systems, the requirements for the piping systems in cargo oil tanks are to be complied with.

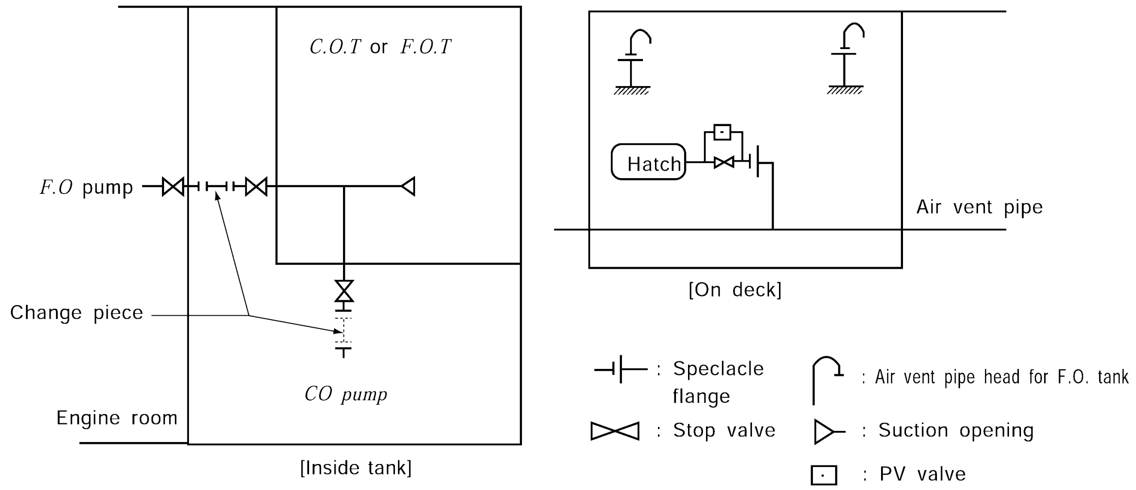


Fig 7.1.26 Example of piping arrangement for a tank used as cargo oil tank and fuel oil tank in alternative use

3. In application to **1002. 4** of the Rules, Piping systems to be connected to cargo oil piping are to be dealt with under the following requirements;

(1) Pumps and pipes in any piping system connected to cargo oil pipes are to be dealt with as those in the cargo oil piping system. However, for piping systems specified in **1002. 2** (4), **9** (6), **1003. 1** (2), **2** (2), Guidance **Pt 8. Appendix 8-5. 7** (7) and item (2) below, this requirement may be dispensed with. The piping systems connected to cargo oil piping mean those connected to cargo oil pipes having openings thereto. Hence, for example, hydraulic oil pipes for the control of cargo oil piping system are not regarded as the piping system connected to the cargo oil piping.

(2) In case where the cargo oil piping system is connected to;

(A) Tank vent pipes : The requirements in Guidance **Pt 8. Appendix 8-5 7** (7) & (8) are to be complied with. Ventilating fans except inert gas blowers, are to be installed within the dangerous spaces.

(B) Pressure gauge pipes for cargo oil piping system (including pumps) :

The pressure gauge to which cargo oil is directly led is to be installed in the pump room or on the weather deck. However, when a stop valve is provided at the joint between the pressure gauge piping system and the cargo oil piping system, and a bulkhead valve is provided at the penetration between the engine room and the pump room, the pressure gauge may be installed in the engine room.

(C) Pipes for measuring oil content :

The sampling pipe for measuring oil content may be led to the spaces other than the dangerous spaces, when the pipe is of nominal diameter of 25 A or less, and two or more stop valves are provided between cargo oil piping and the penetration of the casing of the non-dangerous spaces.

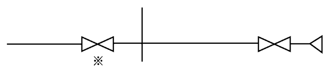
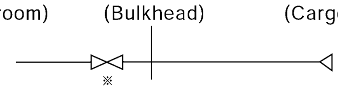
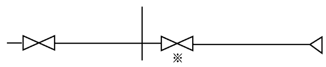
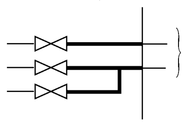
4. In application to **1002. 4.** (5) and (6) of the Rules, where at the request of the owner, cargo piping and the valve control piping are located above the double bottom, the vessel will be assigned with the notation **PCP**(Protected Cargo Piping). This applies also to cargo piping and valve control piping installed in pipe tunnel or duct keel.

5. Bulkhead valves of cargo oil piping systems

In application of **1002. 5** of the Rules, bulkhead valves in cargo oil tanks is to be comply with the following requirements.

(1) The arrangement and type of bulkhead valves are to be as given in **Table 7.1.9.**

Table 7.1.9 Arrangement and type of bulkhead valves

Arrangement A	(Pump room) (Bulkhead) (Cargo oil tank)  ※	In case where stop valve is provided at the end of opening in the cargo oil tank: No specific requirements are imposed on type and material of bulkhead valve.
Arrangement B	(Pump room) (Bulkhead) (Cargo oil tank)  ※	In case where no stop valve is provided at the end of opening in the cargo oil tank: The bulkhead valve is to be of steel castings and be operable from a control position on deck.
Arrangement C	(Pump room) (Bulkhead) (Cargo oil tank)  ※	In case where bulkhead valve is provided in the cargo oil tank: The valve on the tank side is to be operable from a control position on deck.
Arrangement D	(Pump room) (Bulkhead) (Cargo oil tank)  Piping arrangement on the cargo oil tank side is same as shown in A or B.	In cases where bulkhead valve is not provided close to the bulkhead: If those indicated with bold lines in the figure are of cast steel pipes having thickness of 13.5 mm or more or of heavy gauge steel pipes of 16 mm or more, the requirements for bulkhead valves as shown in Arrangement. A or B may be accepted.
Note: ※ This valve is to be installed as close to the bulkhead as practicable		

6. In application of **1002. 7** of the Rules, piping in cargo oil tanks is to be comply with the following requirements.

(1) Pipes for measuring instruments and remote control equipment.

Steel pipes for measuring instruments and remote control equipment provided in cargo oil tanks are to have minimum thickness of Sch. 80., except when they have openings in cargo oil tanks.

(2) Scupper pipes and sanitary pipes

Scuppers draining weather decks may pass through cargo oil tanks. In this case, all of their pipe joints within cargo oil tanks are to be of welded type and wall thickness of the pipes is to be not less than 16 mm. As for the pipes of small diameter, however, consideration may be given reasonably. Scuppers or sanitary pipes from the spaces where ignition source exists such as accommodation space and others, are not to pass through cargo oil tanks. When the pipes of diameter is less than 100A, pipes of Sch. 160 specified in KSD 3570.

(3) Overboard discharge pipes (bilge or ballast pipes)

Overboard discharge pipes passing through cargo oil tanks are to be dealt with under the following requirements;

(A) Overboard discharge pipes are not to pass through the cargo oil tanks other than those having relatively small capacity (e.g., slop tanks, etc.).
(B) Such pipes thickness in cargo oil tanks are to be 16 mm and all pipe joints in cargo oil tanks are to be of welded joints. In case where cast steel pipes are used, the pipe thickness may be 15 mm or more.
(C) Bent pipes are to be provided adequately to absorb the expansion and contraction of the pipe line.
(D) Internal surface of the pipe is to be coated with paints of good corrosion resistance, except where cast steel pipes specified in (b) above or steel pipes of adequate thickness considering corrosion allowance are used.
(E) The pipes are to be supported firmly enough to withstand vibration of ship, and to be so arranged as to enable maintenance and inspection to be carried out satisfactorily after ships are in service. As to the construction and workmanships of the penetration part of shell platings and bulkheads, special care is to be given.
(F) No valves are to be provided in cargo oil tanks.

7. The sounding device of cargo oil tanks is to be of the construction capable of measuring the ullage without opening the tank hatch cover and installed separately from the opening provided in accordance with the requirements of **1002. 8** of the Rules.

(1) Means for ullage measurement of cargo oil tanks are to be such as can make the measurement without opening the tanks.
(2) When sounding pipe is provided, the open end is to be led to the weather deck and to be provided with the pipe heads having a sluice valve or cock fitted with an automatic closing device.
(3) In case where level indicating device is provided, the device is to be of the one approved in accordance with the requirements of the 「**Guidance for the Approval of Manufacturing Process and Type approval. etc**」.
(4) Level indicating device fitting to cargo oil tank of tanker, which is fitted with fixed inert gas system, are to be fixed and closed type.

1003. Piping systems for cargo oil pump rooms, cofferdams and tanks adjacent to cargo oil tanks

1. The open ends of sounding pipes specified in **1003. 1** (4) of the Rules may be provided in pump room. However, that when the open end is lower than the bulkhead deck, the requirements in **Pt 5, Ch 6, 203. 2** (2) of the Rules are to be complied with.

2. In application of the **1003. 2** (2) of the Rules, ballast piping system for ballast tanks adjacent to cargo oil tanks is to be dealt with under the following requirements:

(1) Ballast tanks defined as being safe are to be ballasted and deballasted by pumps which are located in gas safe area. However, they may be deballasted by pumps which are located in dangerous area, provided that a check valve fitted on the line for only deballast.
(2) In case where ballast tanks adjacent to cargo oil tanks are intended to be deballasted by cargo oil pumps in an emergency, a spool piece(or blank flange) and a screw-down non-return valve are to be provided on each ballast pipe at the joint with the cargo oil pipe. Further, a warning notice is to be posted stating that spool pieces are to be removed except for emergencies.

3. In the apply to the **1003. 2** (3) of the Rules, Air vent pipes of ballast tanks adjacent to cargo oil tanks is to be dealt with under the following requirements;

(1) The wording "flame screen" specified in **1003. 2** (3) of the Rules means the screen meeting the following requirements:
(A) To be made of corrosion resisting material.
(B) To comprise two fitted screens of at least 20 × 20 mesh spaced 25.4 ± 12.7 mm apart or single fitted screen of at least 30 × 30 mesh, or to have a performance equivalent thereto
(2) The total sectional area of air vent pipes in case where high level alarm or hatchway specified in **202.** of the Rules is provided in ballast tanks adjacent to cargo oil tanks may be larger than the sectional area under the requirements of **Pt 5, Ch 6, 201. 4** (1) of the Rules or 1,000 cm^2 whichever is the smaller.

4. In application of **1003. 2** (4) of the Rules, the open ends of sounding pipes for ballast tanks adjacent to cargo oil tanks is to be comply with **1003. 1.**

5. In application of **1003. 4** of the Rules, the open ends of sounding pipes for fuel oil tanks adjacent to cargo oil tanks is to be comply with **1003. 1.**

1005. Venting systems of cofferdams adjacent to cargo oil tanks

The wording "flame screen" specified in **1005.** of the Rules means the one specified in **1003. 4** (1).

1006. Positions of openings of machinery spaces, deck house, etc. and electrical equipment, etc.

Where cargo pipe is provided to stern regard as dangerous spaces within 3 m from opening.

1007. Tankers carrying only oils having flash point exceeding 60°C

Ventilation system specified in **1007. 6** of the Rules may be deduct 6 times from ventilation frequency and may not non-sparking construction.

Section 11 Electrical Equipment of Oil Tankers

1101. General

1. The term "semi-enclosed spaces" specified in **1101. 2** of the Rules means the spaces separated by decks and bulkheads where the condition of ventilation is significantly different from that of exposed part of ship.

2. In the case of small ships where part of the forecastle deck corresponds to the dangerous space under the requirements of **1101. 2** (1) (B) (k) & (C) (e) of the Rules and when electrical equipment other than explosion-protected ones are installed under an inevitable reason, the following requirements are to be complied with:

(1) A steel gas barrier is to be provided on the forecastle deck.
(2) The height of the steel gas barrier is to be 2.4 m or more above the upper deck with the full width of the forecastle deck where the steel gas barrier is installed.
(3) The steel gas barrier is not to be provided with any opening.
(4) Electrical equipment is to be at least of the totally enclosed water-proof type.

3. The requirement of **Pt 1101. 3** (2) (D) apply to the following circuit.

(1) Condenser circuit for filter
(2) Earthing circuit for composing intrinsic safety circuit
(3) Neutral circuit of 3000 *V* and above high voltage 3 phase distribute cabling in main machinery, special safety area. etc.

4. Examples of dangerous spaces for **1101. 2** of the Rules are classified as follows.

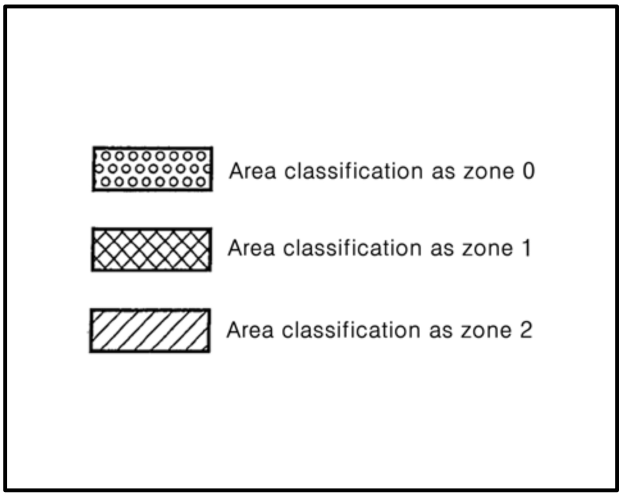


Fig 7.1.27 Classification symbols of dangerous spaces

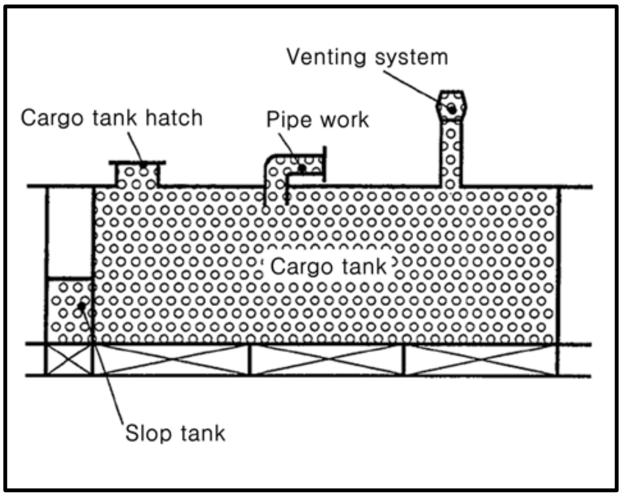


Fig 7.1.28 Example of (1) (A) zone 0

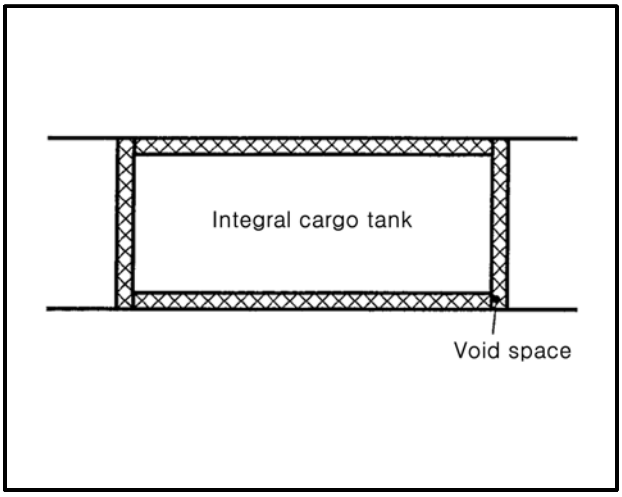


Fig 7.1.29 Example of (1) (B) zone 1 (a)

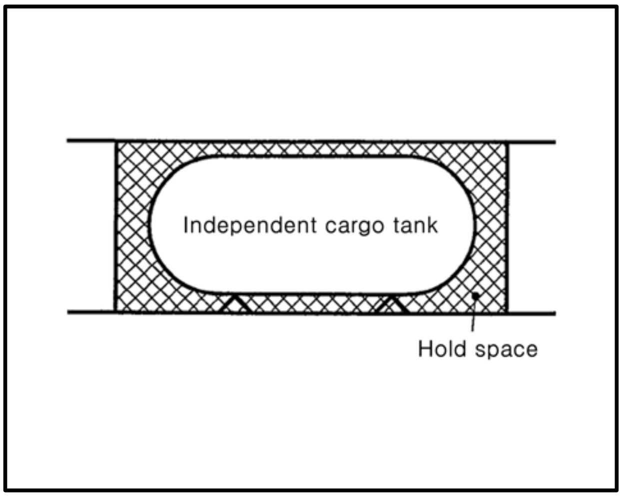


Fig 7.1.30 Example of (1) (B) zone 1 (b)

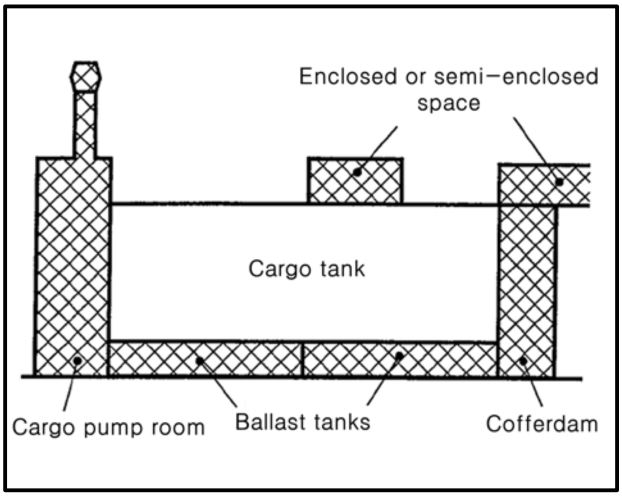


Fig 7.1.31 Example of (1) (B) zone 1 (c) ~ (f)

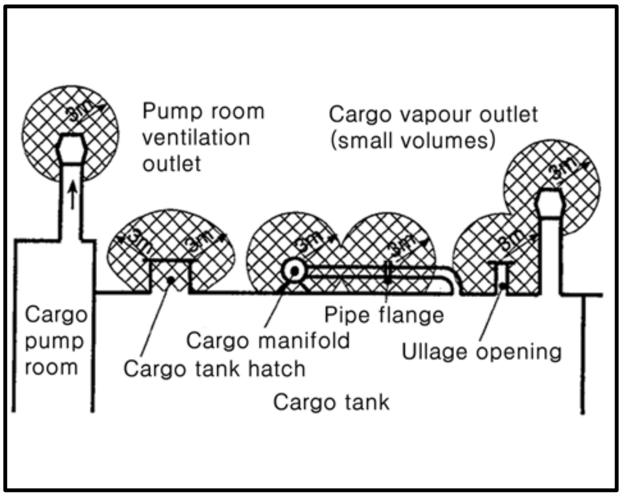


Fig 7.1.32 Example of (1) (B) zone 1 (g)

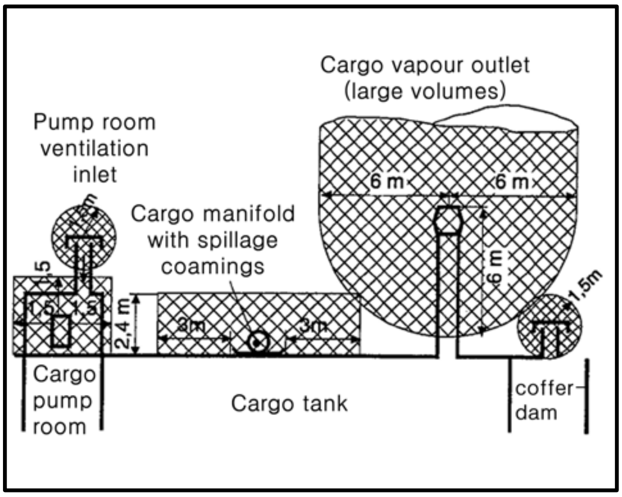


Fig 7.1.33 Example of (1) (B) zone 1 (h) ~ (j)

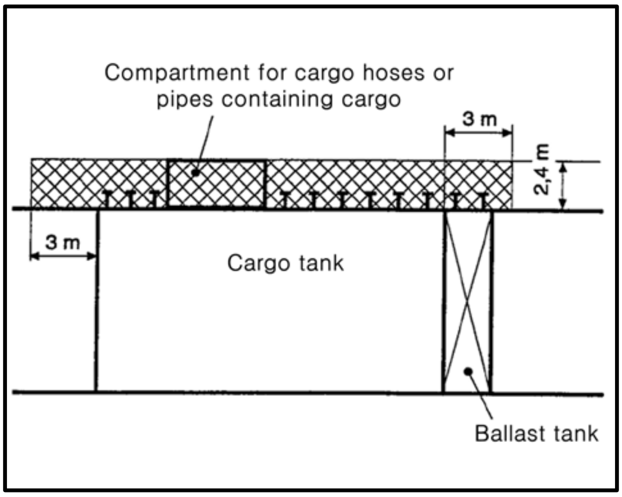


Fig 7.1.34 Example of (1) (B) zone 1 (k) ~ (m)

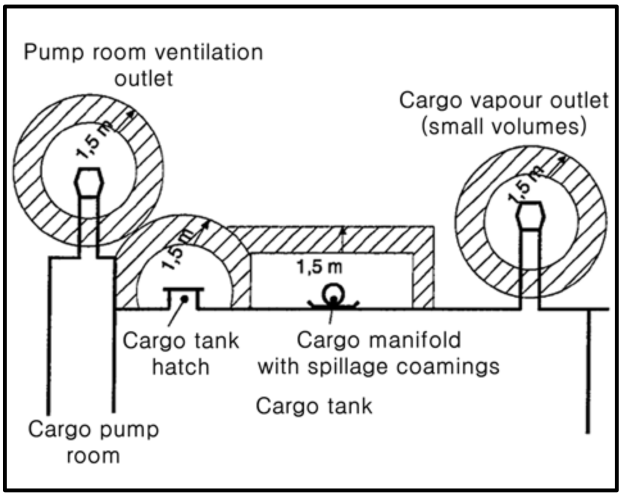


Fig 7.1.35 Example of (1) (C) zone 2 (a)

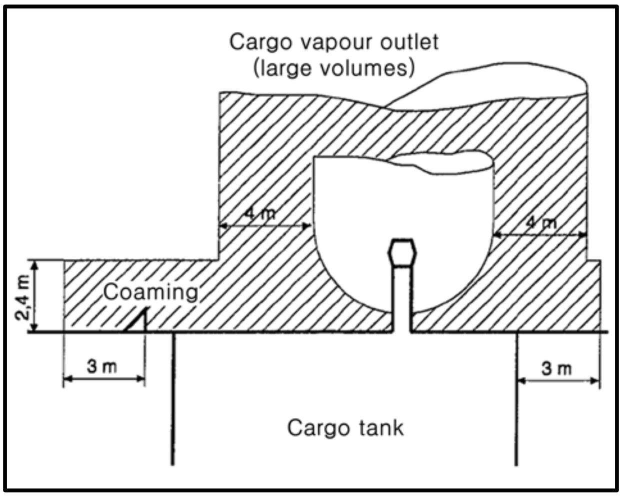


Fig 7.1.36 Example of (1) (C) zone 2 (b),(d),(e)

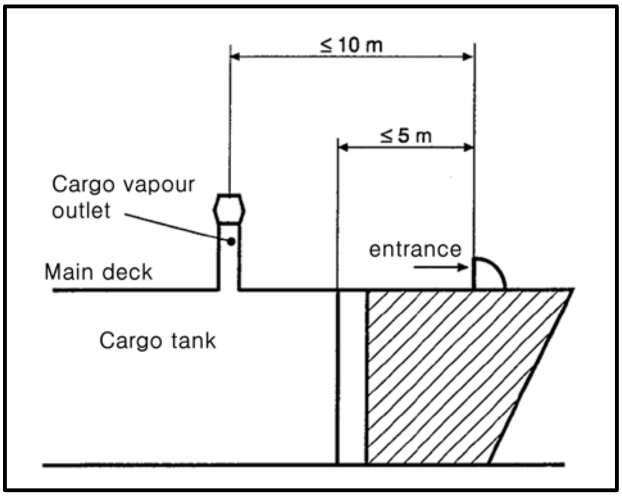


Fig 7.1.37 Example of (1) (C) zone 2 (f)

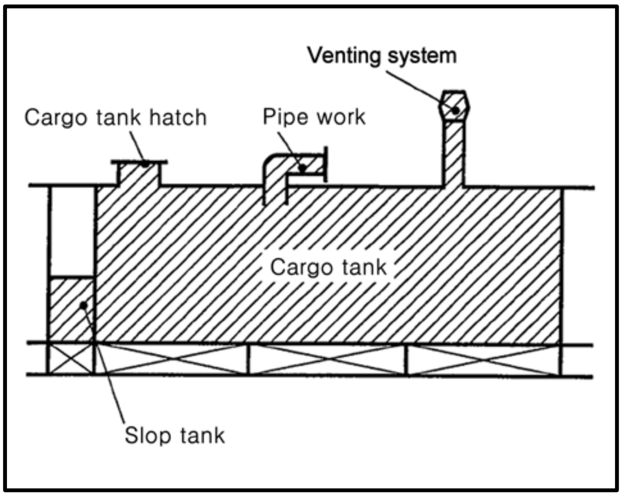


Fig 7.1.38 Example of (2) (B) zone 2 (a) ~ (d)

1103. Electrical equipment in dangerous spaces

1. Explosion-protected electrical equipment in dangerous spaces is to be suitable for use in the explosion gas atmosphere classified into gases and vapours group IIB and temperature class T3 as specified in (KS C) IEC 60079, or equivalent thereto.

2. In addition to the requirements of **1103. 3** of the Rules following requirements are to be satisfied.

(1) In application of (2) and (3), cargo tank includes tanks adjacent to cargo tanks.

(2) The height of the anode is to be measured from the bottom of the tank to the center of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts. However, where aluminum anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface.

1104. Earthing and bonding of cargo tanks, process plant and piping systems for the control of static electricity

1. In application to **1104. 1, 2** of the Rules, where bonding straps are not provided, resistance tests are to be carried out and confirmed that each resistance for the related places is not greater than 1 MΩ. ⚓

CHAPTER 2 ORE CARRIERS

Section 1 General

101. Application

1. The provisions in **Ch 2.** of the Rules assume, as a standard, loading of ore of an apparent specific gravity (quotient of cargo weight divided by hold volume) of 2.0 and an internal friction angle of 35°.

2. The arrangements and scantlings of transverses and cross ties in wing tanks of ships over 230 m in length are to be determined based on direct calculations upon applying the requirements in **102.**. The arrangements and scantlings of structural members other than stated above are to be determined applying the related requirements specified in **Ch 1** and **Ch 2** with a reference of the followings.

(1) When determining H_2 specified in **Ch 1, 403. 1.** of the Rules and h_1 specified in **Ch 1, 403. 3.** of the Rules, L is to be 230 m.

102. Direct strength calculation

When determining the scantlings of structural members of cargo hold for a ore carrier by direct strength calculations, the procedure is to comply with the **Pt 3, Annex 3-2 Guidance for Direct Strength Assessment** of the Guidance and with the following conditions **1**, **2** and **3.**

1. Structural members to be calculated

The direct calculations can be applied for determined the scantlings of the following members forming transverse rings:

Bottom transverse, deck transverse, side transverse, vertical webs on longitudinal bulkhead, cross tie, floors, inner bottoms, bottom shell plating and cross decks.

2. Loads, boundary conditions, and supporting conditions and modelling of structure

Assumed loads, structural models, boundary conditions and supporting condition for the calculation are to be as follows:

(1) Loads
The loads are to be as shown in the column of load in **Table 7.2.1**. Among these, the hydraulic test condition (b), the oil loading condition and the ballasted condition (a) apply to ore/oil carriers only.

(2) The procedure of structural modelling is to be as follows:

(A) Range of analysis
The range of structure to be analyzed is, one side of the adjacent cargo hold(or tank) in the parallel part of the hull, including whole length or half length of each cargo hold(or tank) and transverse bulkhead between these cargo holds(or tanks).
However, this range is to be determined considering the loading patterns of cargo and ballast and longitudinal and transverse symmetries of the bulkheads and girders attached thereto.

(B) Structural modelling
The following standards (a) to (c) apply to divisions in meshing for structural modelling.

(a) In meshing, proper sizes of meshes are to be selected by predicting the stress distribution in the model, and meshes with abnormally large aspect ratios are to be avoided.

(b) Girders and similar members having stress gradients along their depth are to be so meshed as to enable their discrimination.

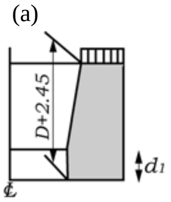
(c) The length of the short side of each mesh is to be restricted to longitudinal spacing or thereabouts.

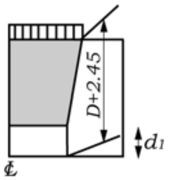
(C) Boundary condition and supporting condition of structural modelling
Boundary condition and supporting condition of structural modelling are to be such that the behavior of that can be effectively reproduced in accordance with the range of structural modelling.

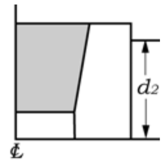
3. Permissible stress

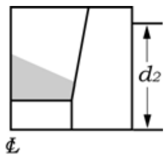
The standard values of permissible stress obtained by the direct calculation using the initial scantlings of members including corrosion margins are shown in **Table 7.2.2.**

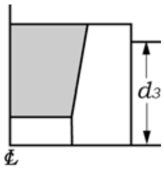
Table 7.2.1

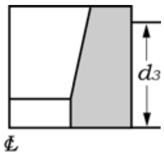
<table>
<tr><td colspan="2"></td><td>Hydraulic test</td><td>Ore loading</td><td>Oil loading</td><td>Ballasted</td></tr>
<tr><td rowspan="2">Load</td><td>In still water</td>
<td>(a)


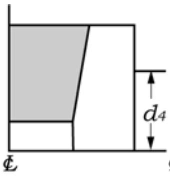
(b)


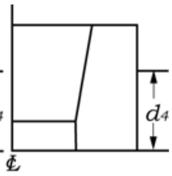
d_1 = 1/3 × Designed maximum load draught</td>
<td>(a) In case the density of ore is light


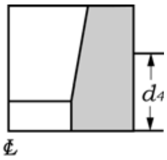
(b) In case the density of ore is heavy


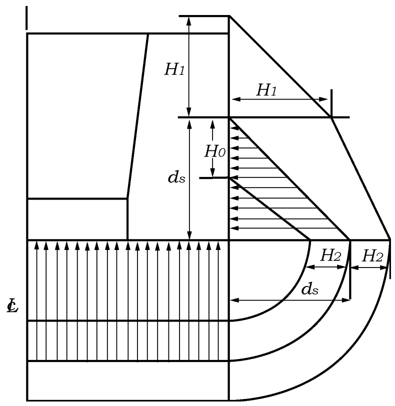
d_2 = Designed maximum load draught</td>
<td>(a)


(b)


d_3 = Designed maximum load draught</td>
<td>(a)


(c)


(b)


d_4 = Ballasted draught</td></tr>
<tr><td>In waves</td><td></td>
<td colspan="3">

d_s ; Draught in still water
H_w ; $0.61\,L^{1/2}$ ...... $L \leqq 150$ m
$1.41\,L^{1/3}$ ...... 150 m < $L \leqq 250$ m
$2.23\,L^{1/4}$ ...... 250 m < $L \leqq 300$ m
$9.28\,m$ ...... 300 m < L
$H_0 = \frac{H_w}{2}$
$H_1 = h_1 \times H_0$
$H_2 = h_2 \times H_0$
$h_1 = 1.8$
$h_2 = 0.5$
H_0, H_1 and H_2 are to be added to or subtracted from d_s as shown in the above figure.</td></tr>
<tr><td colspan="2">Range of strength calculation</td><td>All transverses</td><td colspan="3">In the range where load (a) to (c) are present</td></tr>
<tr><td colspan="6">Notes:
1. The density, loading height and angle of repose under ore loading, oil loading and ballasted conditions are to be selected on reference to the Loading Manual. The angle of repose is to be taken 30° unless otherwise specified.
2. The ballasted draught is to be the mean of draught at A.P. and F.P.
3. When the density of cargoes is not specified in loading manual etc, it is to be taken as 3.0(t/m^3) and the apparent density of cargoes(W/V).
W : Maximum mass of cargoes for the hold (t)
V : Volume of the hold excluding its hatchway (m^3)</td></tr>
</table>

Table 7.2.2 Allowable stress for modelling by using shell elements

	Structural members considered		σ_l	$\sigma_t \sigma_t$	σ_a	σ_e
Longitudinal strength members	Bottom shell plating, Inner bottom plating		$145/K-35f'$ max $125/K$	$145/K$	-	$145/K$
	Girder		-	-	-	$175/K$
Transverse strength members	Bottom transverse, Deck transverse, Side transverse, Longitudinal BHD transverse, Cross tie	Face plate (parallel)	-	-	$175/K$	-
		Face plate (corner)	-	-	$195/K$	-
		Web plate (parallel)		-	-	$175/K$
		Web plate (corner)		-	-	$195/K$
	Floor, Cross deck		-	-	-	$175/K$

Notes:

1. Unit : $\mathrm{N/mm^2}$
2. σ_e : $\sqrt{(\sigma_l^2 - \sigma_l \bullet \sigma_t + \sigma_t^2 + 3\tau^2)}$ (for longitudinal strength member)

   $\sqrt{(\sigma_x^2 - \sigma_x \bullet \sigma_y + \sigma_y^2 + 3\tau^2)}$ (for transverse strength member)

   σ_l : Normal stress in lengthwise direction
   σ_t : Normal stress in breadthwise direction
   τ : Shearing stress on the lengthwise face in the breadthwise-direction for longitudinal strength member
   Shearing stress on the X face in the Y-direction of element coordinate system for transverse strength member
   σ_x : Normal stress in X-direction of element coordinate system
   σ_y : Normal stress in Y-direction of element coordinate system
   σ_a : Normal stress of face plate
3. Openings in floors and girders, if any, are to be taken into consideration in evaluating the stresses.
4. The pont of detecting stress is to be the centre of the element.
5. f' : 0 at the position of the horizontal neutral axis of the cross sectional area of hull, f_B on bottom shell plating. For intermediate values, f' is to be determined by linear interpolation in accordance with vertical distance from the baseline.

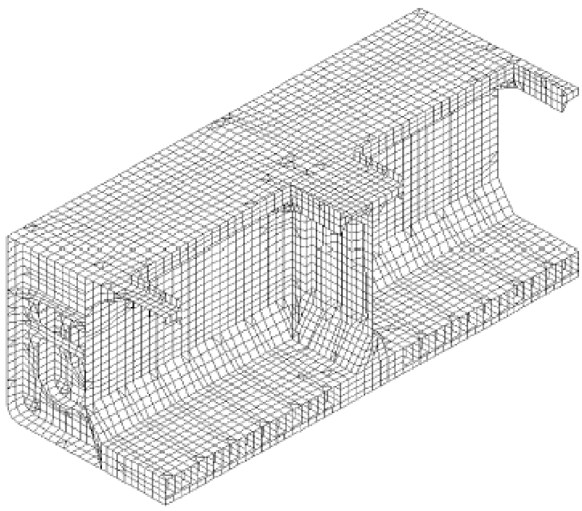


Fig 7.2.1 Example of divisions in meshing structural modelling as a standard

Section 2 Construction and Dimension

202. Double bottoms

1. The transverses between floors in the double bottom under ore holds are to have a section modulus obtained by the following formula:

$$Z = 14.3 S h l^2 \quad (\text{cm}^3)$$

where :

S = distance between the transverse and the floor (m)

h = height from top of inner bottom to the upper deck at the centre line (m)

l = span of transverse (m)

2. The thickness of webs is to be such that the shearing stress due to cargo weight may be lower than 100 N/mm^2 for the members excluding the corrosion margin of 2.5 mm.

203. Construction and scantlings of wing tanks or void spaces

1. Unless otherwise specified, the requirements for tankers specified in the Rules may apply to the construction and scantlings. In tanks and spaces other than water ballast tanks, the thickness of transverses and swash bulkheads may be reduced by 1 mm, except where the provisions of **Ch 10, 103.** of the Rules, are to be applied.

2. The provision in **Fig 7.10.5** of the Guidance is to be referred to for the measurement of span l of transverse in wing tanks and void spaces. The provision **Ch 10, 503.** of the Rules is to be applied to structural details of transverse and cross ties.

3. Longitudinal bulkheads

(1) Where the longitudinal bulkhead is inclined, the scantlings for the pressure of ore are to be determined as prescribed below, depending on the angle of inclination β(degrees) of the bulkhead to the horizontal. (See **Fig 7.2.2**)

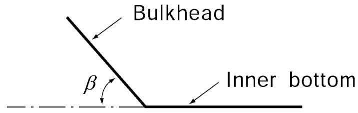


Fig 7.2.2

(A) The thickness of bulkhead plating t is not to be less than that obtained from the following formula:

$$t = CS\sqrt{h} + 2.5 \quad (\text{mm})$$

where :

S = spacing of stiffeners (mm)

h = vertical distance from the lower edge of the strake to the upper deck at the ship's centre line (m)

C = coefficient depending on β (degrees):

β	C
$\beta \leq 40°$	6.51
$40° < \beta < 80°$	$9.80 - 0.0823\beta$
$\beta \geq 80°$	3.22

(B) The section module of longitudinal stiffeners are not to be less than the product of the value determined by application of prescriptions in **204. 1** (2) of the Rules and the following coefficient depending on the inclination of bulkhead β (degrees):

β	C'
$\beta \leq 40°$	3.9
$40° < \beta < 80°$	$6.7 - 0.07\beta$
$\beta \geq 80°$	1.1

(C) It is recommended to increase properly the scantlings of vertical webs on longitudinal bulkhead and cross ties.

204. Transverse bulkheads in ore holds

Where the transverse bulkhead is inclined, the scantlings of the members for pressure of ore are to be determined as prescribed below, depending on the angle of inclination β (degrees) of the bulkhead to the horizontal.

(1) The thickness of bulkhead plating may be 10 % less than obtained according to **203. 3** (1) (A).

(2) In applying the prescriptions in **204. 1** (2) of the Rules for the bulkhead stiffeners, the section modulus are to be multiplied by the following coefficients, if β is less than 80.

$\beta \leq 40°$ ----------------- 3.55

$40° < \beta < 80°$--------------- $6.10 - 0.0638\beta$

(3) The construction in the lower stools of transverse bulkheads is to be as follows:

(A) Stiffening webs are to be provided at a space not exceeding approximately 3.6 m. It is recommended that these stiffening webs be of diaphragm construction.

(B) The depth of stiffening webs is not to be less than 1/5 of l defined under (D) or 2.5 times the depth of slots for penetration of stiffeners, in case of horizontal stiffeners, whichever is greater.

(C) The thickness of stiffening webs is not to be less than the sum of 1/100 of the depth of web plus 4 mm or 8 mm, whichever is greater.

(D) In the case of horizontal stiffening, the section modulus of webs are to be obtained from the following formula.

$$Z = Ck^2 Shl^2 \quad (\text{cm}^3)$$

where :

S = breadth supported by the web, i.e., spacing of webs (m)

h = vertical distance from mid-length of l to the upper deck at the ship's centre line (m)

l = extreme length of web (m)

k = as specified in **Table 7.1.3, Ch 1.** of the Rules

C = coefficient depending on β (degrees)

β	C
$\beta \leq 40°$	18.98
$40° < \beta < 80°$	$31.1 - 0.303\beta$
$\beta \geq 80°$	6.86

(4) Where transverse bulkhead has lower stool, proper consideration should be given to the over-all strength of the bulkheads as a whole.

205. Relative deformation of wing tanks

1. Where the longitudinal bulkheads are inclined, a and b are to be so taken that the hatched areas may be same as shown in **Fig 7.2.3.**

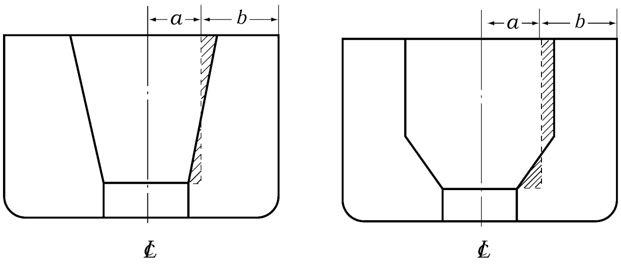


Fig 7.2.3

2. Special considerations for the case of exceeding limit values and how to measure mean thickness of transverse bulkhead plating are to comply with **Ch 1, 601. 2.**

206. Ore/oil carriers

1. General

The construction, arrangement and equipment of ore/oil carriers are to be in accordance with the following, in addition to the provisions in **206. 2** of the Rules.

(1) The piping arrangement is to comply with **Par 3.**
(2) The length of combined ore holds/cargo oil tanks is to comply with **Pt 3, Ch 15, 103. 1.**
(3) Any openings which may be used for cargo operations are not to be fitted to bulkheads and decks separating the cargo oil tanks (including combined ore holds/cargo oil tanks) designed and equipped for the carriage of oil having a flash point below 60°C from other spaces not designed and equipped for the carriage of oil having a flash point below 60°C.
(4) When used as ore carrier, all compartments except slop tanks are to be gas-freed.
(5) As for the equipment, required time, etc. for cleaning and gas-freeing of cargo oil tanks, design documents are to be submitted to the Society for reference.
(6) At the time of approval of plans of ore/oil carriers, manuals containing precautions needed in the process of works for converting from oil tanker into ore carrier and vice versa are to be submitted to the owner and their copies submitted to the Society.

2. Construction of pump rooms

(1) The bottom of pump room of ore/oil carrier is to be constructed with particular care for the continuity of structural members. As example of standard construction of a pump room bottom of single bottom system is shown in **Fig 7.2.4.**

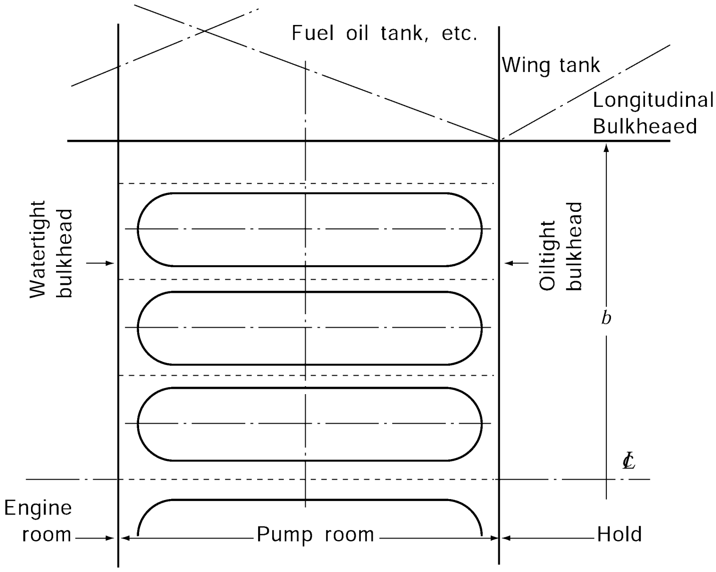


Fig 7.2.4 Example of construction of pump room bottom

(A) The longitudinal bulkheads in the hold space are to be extended aft as far as practicable. Deep horizontal girders are to be provided on the longitudinal bulkheads at the level of the inner bottom in the hold space. The webs of these girders are to be of approximately same thickness as the inner bottom.

(B) Centre girder
Height : same as double bottom in the hold space
Thickness : same as centre girder in the hold space

(C) Side girders
Number : if $b \leq 15$ m------ 2 lines each side,
if $b > 15$ m------ 3 lines each side,
Thickness : same as centre girder
Height : greater than double bottom height in engine room
It is recommended that the side girders be as high as possible.

(D) Sectional area of face plates of girders
The total sectional area of face plates of girders (including total sectional areas of horizontal girders on longitudinal bulkheads, if any) is not to be less than 35 % of the sectional area of inner bottom in the hold space.

(E) Bottom longitudinals
The section modulus of bottom longitudinals Z is to be 10 % times of that obtained from the formula in **Ch 1, 302** of the Rules. However, it is not to be less than that obtained from the following formula:

$$Z = 290\, d\, S \quad (\mathrm{cm}^3)$$

where :
d = draft (m)
S = space of longitudinal (m)

(F) Omission of side girders
One of side girders as per (C) above may be omitted, provided that the thickness of bottom shell plating under the pump room is increased by 2 mm in excess of the required thickness (including tapering).

(G) If high tensile steel is used for deck plating over the pump room, the sectional area of deck in this part is to be suitably increased in excess of the required area.

3. Piping systems

(1) Application

This requirements apply to piping systems and venting systems of ships designed to carry oil or alternatively solid cargoes in bulk.

(2) Terminology

(A) Combination carrier is a ore/oil carrier specified in **Ch 2, 206. 1** of the Rule and a B/O carrier specified in **Ch 3, 801. 1** of the Rules.

(B) Slop tank is a tank which is provided mainly for the carriage of tank washings and cargo oil and which is designed to be capable of loading oil whose flash point does not exceed 60℃ when the ship is in the dry cargo mode.

(C) Solid cargo/oil hold is a compartment which is used as a solid cargo stowing hold when the ship is in the dry cargo mode and which is used as a cargo oil tank when the ship is not in the dry cargo mode.

(D) Ballast/solid cargo hold is a compartment which is used as an exclusive tank for ballast adjacent to a cargo oil tank when the ship is not in the dry cargo mode and which is used as a solid cargo stowing hold when the ship is in the dry cargo mode.

(E) Exclusive solid cargo hold is a compartment which is used as a void space adjacent to a cargo oil tank when the ship is not in the dry cargo mode and which is used as a solid cargo stowing hold when the ship is in the dry cargo mode.

(F) Oil/ballast tank is a tank which is used as a cargo oil tank when the ship is not in the dry cargo mode and which is used as a ballast tank or void space when the ship is in the dry cargo mode.

(G) Exclusive ballast tank is a compartment which is adjacent to a cargo oil tank when the ship is not in the dry cargo mode and which is used as an exclusive tank for ballast even when the ship is in or not in the dry cargo mode.

(H) Cargo hold is a general term for solid cargo/oil hold, ballast/solid cargo hold and exclusive solid cargo hold.

(I) Cargo oil tank is a general term for solid cargo/oil hold, oil/ballast tank and slop tank.

(3) Bilge Piping Systems

(A) Bilge piping systems for the cargo holds are not to be led to the engine room. The cargo oil pump may be used for the purpose of bilge suction on condition that the cargo oil piping systems in the cargo oil pump room used for the bilge suction comply with the requirements in **Pt 5, Ch 6, 404** and **405.** of the Rules.

(B) Bilge suction pipes for the cargo holds

(a) Where two or more cargo oil piping systems (e.g. main and stripping lines) are provided or cargo oil piping systems are provided independently for the oil/ballast tanks and cargo holds and where these cargo oil piping systems are so arranged that liquid in all or selected oil/ballast tanks and cargo holds can be discharged (for the oil/ballast tanks, include the filling of ballasting water) simultaneously when the ship is in the dry cargo mode, these cargo oil pipes may be used as the bilge suction pipes for cargo holds. The diameter of these cargo oil pipes used as bilge suction pipes is not to be less than that specified for the bilge suction pipes.

(b) Where bilge suction pipes are provided for the exclusive use, an exclusive pump for bilge suction is to be provided in the cargo oil pump room or the bilge suctions are to be connected to the cargo oil pump in the cargo oil pump room. Where cargo oil pumps are used as a bilge pump, a stop valve and a screw-down non-return valve are to be provided at the connection between the bilge pipe and cargo oil pump.

(C) Bilge suctions in cargo holds

(a) In general, one bilge suction is to be arranged on each side of the after end of the cargo hold. Where the length of cargo hold in ships having only one cargo hold exceeds 66 m, an additional bilge suction is to be arranged in a suitable position in the forward half-length of the hold.

(b) Bilge wells are to be arranged at suitable positions so as to protect the cover plates from the direct strike of solid cargoes, and to be provided with rose boxes or other suitable means so that the suction may not be choked by ore dust, etc.

(c) Bilge wells in solid cargo/oil holds and ballast/solid cargo holds, except where these bilge wells are also used as cargo oil suction wells, are to be provided with cover plates to blank off these wells or to be provided with blind flanges to blank off the open ends of the bilge suction pipes when the ship is not in the dry cargo mode.

(D) Bilge suction pipes
For exclusive bilge suction pipes, branch bilge suction pipes are to comply with the requirements in **Pt 5, Ch 6, Sec 4** in addition to the requirements in (C). In calculating the inside diameter of the branch bilge suction pipes for draining cargo hold bilge of ore/oil carriers, the mean width of cargo hold may be used in lieu of B. Bilge suction pipes which are also used as a cargo oil pipe or which are connected to eductors are to be as specified in **Table 7.2.3** in addition to comply with the requirements in (b) and (c).

Table 7.2.3 Bilge suction arrangement in cargo hold (common service piping or using eductor)

Type of cargo hold	Bilge suction main	Bilge suction branch	Bilge well	Provisions of valve, blind flange, etc.(3)
Solid cargo/oil hold	common service with cargo oil main	Exclusive	Exclusive	Screw-down non-return valve for branch line; blind flange for open end(1)
		Partial common service(2)	Exclusive(2)	Screw-down non-return valve and blind flange for bilge suction branch line
		common service with cargo oil suction branch line	Common service with cargo oil suction well	Screw-down non-return valve for branch line
	use of eductor	—	Exclusive	Screw-down non-return valve for branch line; blind flange for open end
Ballast/solid cargo hold	common service with cargo oil main	Exclusive	Exclusive	Screw-down non-return valve for branch line; blind flange for open end
	use of eductor	—	—	Screw-down non-return valve for Suction side; blind flange for open end
Segregated solid cargo hold	common service with cargo oil main	Exclusive	Exclusive	Screw-down non-return valve for suction side; blind flange for open end
	use of eductor	—	Exclusive	Screw-down non-return valve for branch line

(Remark)
(1) Wells are to be closed with blind plates or open ends are to be closed with blind flange
(2) As specified in the example of **Fig 7.2.5.**
(3) Valves, in each case, are to be capable of being operated at control position above the bulkhead deck

(4) Cargo Oil Piping Systems
(A) Cargo oil piping systems, except for cargo oil pipes connected to the slop tanks specified in (5), are to be completely gas-freed when the ship is in the dry cargo mode.
(B) Cargo oil suctions in solid cargo/oil hold, except where these suctions are also used as bilge suctions, are to be provided with blank flanges to blank off the open end of the cargo oil suction pipes or to be provided with cover plates to blank off the cargo oil suction wells when the ship is in the dry cargo mode.
(C) Means are to be provided for isolating the piping connecting to the cargo oil pump room with the slop tanks where slop may be carried on dry cargo mode. The means of isolation are to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable it may be located within the pump room directly after the

piping penetrates the bulkhead.(See **Fig 7.2.6**)

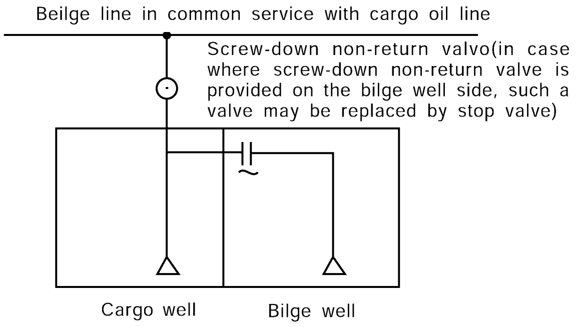


Fig 7.2.5 Examples of bilge suction arrangement in solid cargo/oil hold

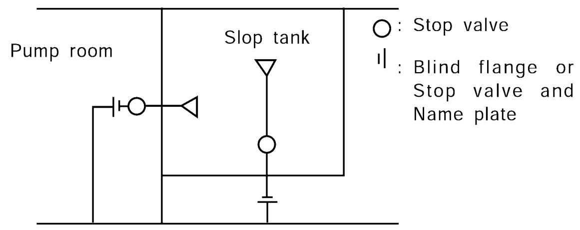


Fig 7.2.6 Examples of piping system of slop tank

(D) A separate pumping and piping arrangement is to be provided for discharging the contents of the slop tanks directly over the open deck when the ship is in the dry cargo mode.

(E) Cargo oil lines below deck are to be installed inside the cargo wing tanks or to be placed in special ducts which are to be capable of being adequately cleaned and ventilated.

(5) Ventilating systems

(A) Combination carriers which are not provided with slop tanks are to comply with the requirements in **Ch 1, 1004.** of the Rules for the ventilating systems for cargo oil tanks of oil tankers.

(B) Vent pipes for slop tanks are to be led to a suitable position in the open air so as to preclude any danger in case where oil having a flash point not exceeding 60°C is carried therein when the ship is in the dry cargo mode. Where vent pipes for slop tanks are connected to the vent pipes for the cargo oil tanks, a change-over device is to be provided to prevent the vapour in the slop tanks from entering into other compartments when the ship is in the dry cargo mode. This change-over device is in general to consist of a valve followed by a blank flange.

(C) All cargo spaces and any enclosed spaces adjacent to cargo spaces are to be capable of mechanically ventilated. The mechanical ventilation may be provided by portable fans. ⚓

CHAPTER 3 BULK CARRIERS

Section 1 General

101. Application

1. The provisions of **Ch 3** of the Rules are to apply correspondingly to ships having structural configuration similar to bulk carriers such as chip carrier, log/timber carrier.

2. All bulk carriers of 150 m in length and above, intending to carry solid bulk cargoes having a density of 1.78 t/m^3, or above, with single deck, topside tanks and hopper tanks, which have the foremost hold stipulated in the following (1) or (2) and have not been constructed in compliance with **Pt 7, Ch 3, Sec 11** and **Sec 12** of the Rules are to be complied with **Annex 7-5.**

(1) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998.
(2) the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999.

103. Direct strength calculation

When determining the scantlings of structural members of cargo hold for a bulk carrier by direct strength calculations, the procedure is to comply with the **Pt 3, Annex 3-2 Guidance for Direct Strength Assessment** of the Guidance.

Section 3 Double Bottoms

301. General

1. Value of k in the case of large slope angle of bilge hoppers or double-hull construction

Where the angle of slope of bilge hoppers to the horizontal exceeds 60° the value of k is to be obtained from the formula in **301. 4** of the Rules, assuming β = 60°. In ships with double-hull construction, the value of k may be 70 % of the value obtained from the same formula.

2. Measurement of hold length l_h

Where the angle of slope of lower stool of transverse bulkhead is smaller than 60° the hold length l_h in the formula in **301. 4** of the Rules, is to be the distance(m) between the intersections of the inner bottom and straight lines having a slope of 60° and passing through the top of the lower stool of the transverse bulkhead.

302. Centre girders and side girders

1. In ships having unusually large freeboards, the height of centre girders may be reduced to the values obtained from the formula in **Table 7.3.2** of the Rules in which D is to be replaced by D', the depth to the assumed freeboard deck. In no case, however, is this height to be less than B/20.

2. Thickness of partial intermediate side girders

The thickness of partial intermediate side girders prescribed in **Table 7.3.2** of the Rules is not to be less than that obtained from the following (1) or (2), whichever is greater.

(1) Minimum thickness as specified in **Par 106.** of the Rules

(2) $t = \frac{C_1'' d_2}{1000} + 2.5 \quad (\mathrm{mm})$

where:

d_2 = as specified in **Table 7.3.2** of the Rules.
C_1'' = as specified in **Table 7.3.1**
S_1 = as specified in **Table 7.3.2** of the Rules.

3. The "specially short holds" in **Table 7.3.2** and **304. 1** of the Rules are holds having a length equal to or less than 30 % of the length of adjacent holds.

4. When calculating the thickness of side girder just under the hopper plate of bilge hopper tank, S in the formula in **Table 7.3.2** of the Rules is to be measured, as a standard, as shown in **Fig 7.3.1.** Further, when calculating the effective sectional area of the above-mentioned side girder, the sectional area obtained from the following formula of the hopper plate in the extent shown in **Fig 7.3.1** may be included into the effective sectional area of the same side girder.

$$A = 10\Sigma h_i t_i\left(1 - \frac{\theta}{90}\right) \quad (\mathrm{cm}^2)$$

where:

h_i = height in the hopper plate (m)

t_i = thickness of subtracted by the thickness 2.5 mm from the hopper plate (mm)

θ = angle between the side girder and the hopper plate (degrees)

Table 7.3.1 Coefficient C_1''

S_1/d_2	C_1''
upto 0.3	3.0
0.4	3.5
0.5	4.3
0.6	5.1
0.7	5.8
0.8	6.5
0.9	7.0
1.0	7.4
1.2	8.0
1.4	8.4
1.6 upward	8.6

Note:
For intermediate value of S_1/d_2, C_1'' is obtained by linear interpolation.

303. Floor plates

1. Thickness of partial intermediate floors

(1) The thickness of partial intermediate floors prescribed in **Table 7.3.3** of the Rules is not to be less than that obtained from the following (1) or (2), whichever is greater:
(A) Minimum thickness as specified in **106.** of the Rules
(B) The thickness of neighbouring floors obtained from the formulae in **Table 7.3.3** of the Rules with the value of S reduced to 60 % of the actual one.

304. Inner bottom plating

For the definition of "specially short holds," **302. 3** is to be referred to **304. 1** of the Rules.

Section 4 Hopper Tanks

401. General

Floor plates are to be provided at the forward and after ends of hopper tanks, and the tank top plating in the engine room is to be keep the continuity of hopper tanks at ends extended into the hopper tanks by about 2 frame spaces.

402. Thickness of hopper plates

1. Where the hopper plate has transverse stiffeners, the thickness of hopper plate is not to be less than that obtained from the following formula:

$$t = 9.6S + 1.5 \quad (\text{mm})$$

where:

S = spacing of stiffeners (m)

The thickness of hopper plates to be included into the calculation of section modulus of hull girder is, but, to be the actual thickness multiplied by a factor of 0.5 when the ratio of the actual thickness to the thickness derived from the above formula is 1.0, or by a factor of 1.0 when the same ratio is 2.0 and above, or by a factor obtained by linear interpolation for an intermediate value of the ratio.

2. The construction at the intersection of inner bottom plating and hopper plate is to be as follows:

(1) The construction at the above-mentioned intersections is to be either of the following two types.

(A) The scallop in the hopper transverse at the above-mentioned intersection is to be filled up or closed by a collar plate. (See **Fig 7.3.2**)

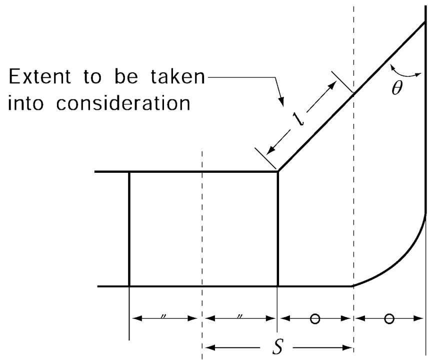


Fig 7.3.1 Measurement of S

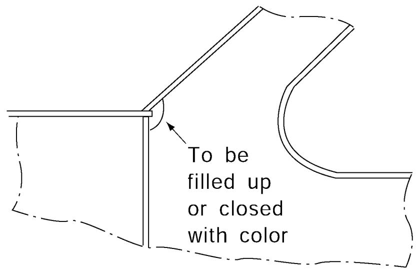


Fig. 7.3.2

(B) Gusset plates are to be fitted onto the hopper transverse in the extension of inner bottom plating. (See **Fig 7.3.3**)

(2) Where the spacing of floor plates in 2 m or more, a bracket is to be provided at the mid-length between floor plates. This bracket is to reach the inner bottom longitudinal and the hopper plate longitudinal next to the side girder located at the intersection. (See **Fig 7.3.4**)

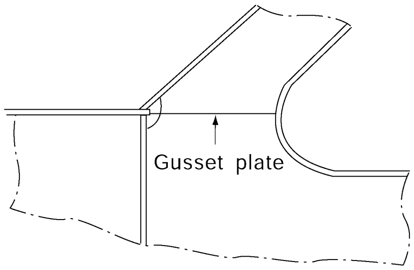


Fig. 7.3.3

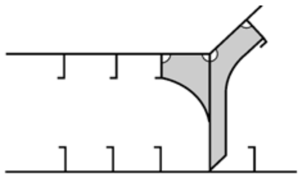


Fig. 7.3.4

Section 5 Topside Tanks

502. Thickness of sloping plates

Where the sloping plate of topside tank has transverse stiffeners, the thickness of sloping plate is not to be less than that obtained from the following formula:

$$t = 12S + 1.5 \quad (\mathrm{mm})$$

where:

S = spacing of transverse stiffeners (m).

The thickness of sloping plates to be included into the calculation of section modulus of hull girder is, however, to be the actual thickness multiplied by a factor of 0.5 when the ratio of the actual thickness to the thickness derived from the above formula is 1.0, or by a factor 1.0 when the same ratio is 2.0 and above, or by a factor obtained by linear interpolation for an intermediate value of the ratio.

507. Large topside tanks

Where the longitudinal diaphragm has transverse stiffeners, the thickness of diaphragm is not to be less than that obtained from the following formula:

$$t = 12.8S + 1.5 \quad (\mathrm{mm})$$

where:

S = spacing of transverse stiffeners (m)

The thickness of diaphragms to be included into the calculation of section modulus of hull girder is, however, to be the actual thickness multiplied by a factor of 0.5 when the ratio of actual thickness to the thickness derived from the above formula is 1.0, or by a factor 1.0 when the same ratio is 2.0 and above, or by a factor obtained by linear interpolation for an intermediate value of the ratio.

Section 6 Transverse Bulkhead and Stools

601. Transverse bulkhead

For transverse bulkhead without lowest stool, the thickness of the lowest strake of bulkhead plating is to be 1 mm greater than those specified in formulae.

Section 7 Hold Frame

702. Top and bottom end connections of frames

Figs. 7.3.5 and **7.3.6** show examples of connection of the upper and lower ends of hold frame to the topside tank and the bilge hopper tank respectively.

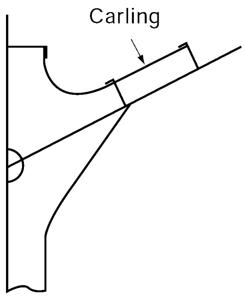


Fig 7.3.5

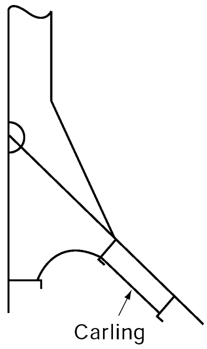


Fig 7.3.6

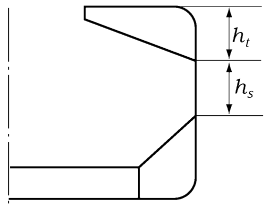


Fig. 7.3.7

Section 8 Decks and Shell Platings

801. Deck plating outside the line of openings

The effective sectional area of deck outside the line of openings at the ends of topside tank is to be determined by tapering from the value obtained from the following formula:

$$A = \left(1 + \frac{A_t}{2A_d}\right) A_d$$

where:

A_t = effective sectional area of sloping plate of topside tank in the midship part

A_d = effective sectional area, required by the Rules, of the strength deck in the midship part

802. Deck plating inside the line of openings

Where the deck inside the line of openings is constructed on the longitudinal framing system, the thickness of deck plating is not to be less than that obtained from the following formula:

$$t = 1.69 \sqrt[3]{\frac{F}{l} S^2} + 1.5 \quad (\mathrm{mm})$$

where:

S = spacing of longitudinal beams (m)

l = length of deck inside the line of openings (m)

$$F = F_1 + F_2 \quad (\mathrm{kN})$$

$$F_1 = 0.49 h_t^2 (\alpha + 1)^2 (l_1 + l_2) \quad (\mathrm{kN})$$

$F_2 = 0.26 LBC_b$ (kN)

$\alpha = \dfrac{h_s}{h_t}$

h_t and h_s = vertical distance from the intersection of sloping plate of topside tank and side shell plating to the upper end of D(m) and vertical distance from the intersection of sloping plate of topside tank and side shell plating to the intersection of hopper plate of bilge hopper tank and side shell plating (m) (See **Fig 7.3.7**)

l_1 and l_2 = lengths (m) of holds forward of and abaft the deck inside the line of openings concerned. But, the lengths of holds are defined as the distances between bulkheads.

Section 9 Hatch Covers and Hatch Coamings of Cargo Holds

905. Closing arrangements

1. Securing devices

(1) When calculating the moment of inertia ($I = 6pa^4$) as specified in **905. 1** (7) of the Rules, the spacing between securing devices, a(m) is maximum of the distance between two consecutive devices, measured along hatch cover periphery(m), and not to be taken as less than 2.5 a_c.

Where,

a_c = max ($a_{1.1}$, $a_{1.2}$) (m) (Refer to **Fig 7.3.8**)

(2) When calculating the actual gross moment of inertia of the edge element, the effective breadth of the attached plating of the hatch cover is to be taken equal to the lesser of the following values.

(A) $0.165a$

(B) Half the distance between the edge element and the adjacent primary member

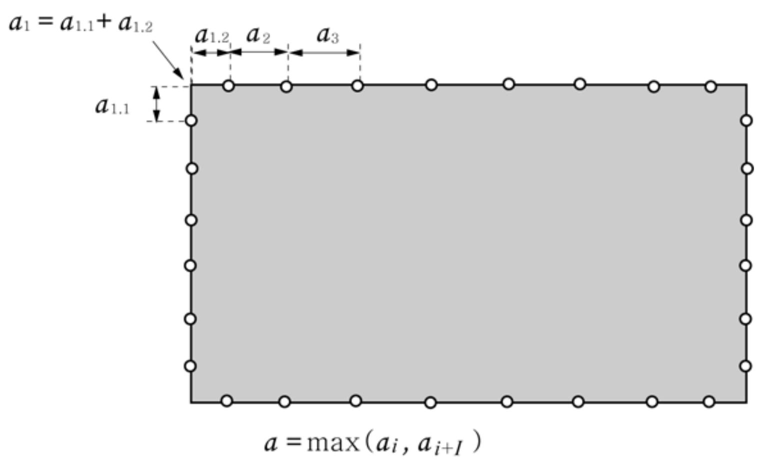


Fig 7.3.8 Spacing of securing devices

Section 14 Water Level Detection & Alarm and Drainage & Pumping Systems for Bulk Carriers and Single Hold Cargo Ships

1401. General

Arrangement and testing etc. for water level detectors, alarms and drainage and pumping systems required by the **1403.** and **1404.** of the Rule are to be in accordance with the requirements of the **Annex 7-6.**

1402. Application

In application to **1402. 2.** of the Rules, "suitable width" means that the distance between the side shell and the inner bulkhead in any part of the watertight compartments is not less than 760 mm measured perpendicular to the side shell.

Section 15 Supplementary Provisions for Carriage of Liquid in Holds

1501. General

1. When cargo holds are utilized as ballast tanks, they are to be kept empty or full throughout the duration of voyage in order to avoid impact due to dynamical load of ballast water.

2. When cargo holds are utilized for ballasting, or under special loading conditions due to loading at two ports, etc., the scantlings of structural members of double bottoms are, in addition to compliance with the provision in **Sec 3.** of the Rules not to be less than that obtained from the formulae concerned which are modified as indicated below.

(1) Designed maximum load draught d is to replace with the draught in the considered loading condition d_b.

(2) The value of coefficient a in the formulae is to be equal to 0.45 + 0.026L'/d or the value obtained from either of the following two formulae depending on whether the hold is loaded or empty, whichever is greater.

For loaded hold : $a = h\gamma/d_b - (1 - 0.026L'/d_b)$

For hold which may be empty during navigation : $a = 1 + 0.026L'/d_b$

where:

γ = as specified in **301. 3** of the Rules

L' = as specified in **Table 7.3.2** of the Rules

(3) The value of coefficient n in the formulae prescribed in **Table 7.3.2** of the Rules is to be obtained from the following formula. But, the value of B/l_h in this formula is to be taken as 1.8 if it is not less than 1.8 and 0.5 if it is less than 0.5

$$n = \frac{1}{3}\left\{\alpha\left(2 - \frac{B}{l_h}\right) + 5 - \frac{B}{l_h}\right\}$$

where:

l_h = as specified in **301. 4** of the Rules

α = ratio of the load difference between the cargo load per unit area on the double bottom of the adjacent hold and the bottom water pressure including added variable wave pressure as prescribed in **Table 7.3.2** of the Rules to the similar load difference of the hold under consideration. The largest value of this ratio within the expected range of bottom water pressure is to be taken. α is to lie in the range from -1.0 to 1.0.

Table 7.3.2 Value of h

	h (m)
Pitching	$h = h_1 + 0.1\, l + 0.77\dfrac{h_1}{h_2}\left(1 - \dfrac{h_1}{h_2}\right)$
Rolling	$h = 0.4B\left\{\dfrac{3\times\dfrac{h_1}{h_2}+0.6}{\sqrt{\left\{1-\left(\dfrac{x}{l_s}\right)^2\right\}^2+\left\{17\left(\dfrac{h_1}{h_2}-0.45\right)^2+0.12\right\}\left(\dfrac{x}{l_s}\right)^2}} - 9.69\left(0.7-\dfrac{h_1}{h_2}\right)\left(0.3-\dfrac{h_1}{h_2}\right)\right\}$
h_1 = height of cargo oil level measured from the top of inner bottom (m) h_2 = height of upper deck, at centreline, above the top of inner bottom(m) l = length of hold (distance between transverse bulkheads) l_s = vertical distance from the intersection of side shell with hopper plate of bilge hopper tank to the intersection of side shell with the sloping plate of topside tank (m) x = vertical distance from the intersection of side shell with hopper plate of bilge hopper tank to the member under consideration (m)	

1502. Holds half-loaded with cargo oils

Where synchronism between pitching and/or rolling and the natural oscillations of cargo oil half-loaded in a hold is unavoidable, the scantlings of plating, stiffeners and girders, near the synchronizing oil level, of the transverse bulkheads in case of pitching or of the sloping plates of topside tanks in case of rolling are not to be less than that obtained from the respective formulae in which h is to be determined by the **Table 7.3.2.**

Section 16 Electrical Equipment in Coal Carriers

1602. Electrical equipment

1. The wording "explosion-protected type as deemed appropriate by the Society" in 1602. 1. (2) of the Rules means those generally meeting the requirements in **Pt 6, Ch 1, Sec 9** of the Rules having the flash point G4, the explosion-protective construction of the explosion grade d1 over (Group Ⅱ A, Temperature Class T4 as specified in (KS C) IEC 60079) or equivalent the explosion-proof construction, intrinsic safety pressurized protected construction which are serviceable safely in coal dust.
2. Cables led to electrical equipment installed within cargo holds are to be generally mineral insulated copper sheathed cables, lead sheathed armour cables or non-metal sheathed armour cables.
3. To the explosion-protected type approved by the Society in electrical equipment in compartments adjoining cargo holds specified in **1602. 1.** (1) of the Rules the requirements in **1602. 1** above apply correspondingly.

Section 17 Renewal Criteria for Side Shell Frames and Brackets in Single Side Skin Bulk Carriers and Single Side Skin OBO Carriers

1701. Application and definitions

Where the finite element or other numerical analysis or direct calculation procedure are allowed according to the Rules, i.e. in case of unusual side structure arrangements or framing, the analysis criteria and the strength check criteria are to be determined at the discretion of the Society.

1702. Renewal or other measures

1. Lower end bracket flanges

The requirements in **1702. 1** (2) (A) of the Rules specify that lower end bracket are required to be fitted and are to be provided with flanges. Bracket flanges are to be fitted on lower end brackets also in the following cases:

(1) When end brackets were not fitted with flanges at design stage and are required to be fitted according to the Rules. In this case, care is to be paid to ensure adequate back-up structure in the hopper and that the bracket is aligned with the back-up structure.

(2) When non-integral lower end brackets were not fitted with flanges at the design stage. In this case, flanges are to be fitted so as to meet the bending strength requirements in **1703. 4** of the Rules. The full width of the bracket flange is to extend up beyond the point at which the frame flange reaches full width.

2. t_M less than $t_{REN,d/t}$ at section b) of the frame

For the comparison with $t_{REN,d/t}$ at section b), the measured value, t_M , is to be based on zone B according to **Table 7.3.23** of the Rules.

3. Tripping brackets

(1) Where there are two existing tripping brackets supporting frames but their location is not in complete compliance with the Rules, i.e. one located less than h/3 above zone A and one less than 2h/3 from intersection of the hopper plate with the side shell, this may be accepted as equivalent to the requirements in **1702.** of the Rules, provided that the tripping bracket thickness is not less than the frame web thickness.

(2) Tripping brackets not connected to flanges are accepted for the purposes of the Rules, provided that have soft toe and the distance between the bracket toe and the frame flange is not greater than about 50 mm. (See **Fig 7.3.9**)

4. Bending check

The bending check needs not be carried out in the case the bracket geometry is modified so as to comply with **Pt 7, Ch 3, Sec 7.**

5. Blast cleaning and coating

When renewal is to be carried out according to the Rules, surface preparation and coating are required for the renewed structures for cargo holds of new buildings.

6. Zone B made of different plate thickness

When zone B is made up of different plate thickness, the lesser thickness is to be used for the application of the requirements in the Rules.

7. Repair of damaged frames already complying with the Rules.

In case of renewal of a damaged frame already complying with the Rules, the following requirements apply:

(1) The conditions accepted in compliance with the Rules are to be restored as a minimum.

(2) For localized damages, the extension of the renewal is to be carried out according to the standard practice of the Society, as the frame already complies with the Rules.

(3) Replacements of rolled profile are preferably to be made of the same rolled section. Built-up profiles are allowed in exceptional cases only. A repair made of an inserted built-up profile in a rolled profile could be acceptable provided some precautions are taken. The flange of the built-up profile is to overlap the repair area with sniped shape to smoothly allow the stresses to pass from the rolled profile to the built-up profile and vice versa.

8. Repair of damaged frames before Ch 3, Sec 17 of the Rules implementation

In case of renewal of a damaged frame before implementation date of the Rules for the considered ship, as built scantlings may be applied. For practical reason, it is up to the Owner whether to renew according to the relevant Rules or not.

9. Tripping brackets for higher strength steel side frames and side shell

Where side frames and side shell are made of higher strength steel (HSS), normal strength steel (NSS) tripping brackets may be accepted, provided the electrodes used for welding are those required for the particular HSS grade, and the thickness of the tripping brackets is equal to the frame web thickness, regardless of the frame web material.

1703. Application of roll radius of gyration(k_r) and bending moment coefficient(m_a)

The following loading conditions are to be considered for the application of the **Ch 3, Sec 17** of the Rules.

(1) Homogeneous heavy cargo (density greater than 1.78 t/m^3), considering k_r=0.25B
(2) Homogeneous light cargo (density less than 1.78 t/m^3), considering k_r=0.39B
(3) Non homogeneous heavy cargo, if allowed, considering k_r=0.39B
(4) Multi port loading/unloading conditions need not be considered.

Therefore, the following combination of roll radius of gyration(k_r) and bending moment coefficient (m_a) table apply for the purpose of the relevant Rules.

(1) Empty holds of ships allowed to operate in non homogeneous loading conditions, k_r=0.38B and m_a=10, m_b=17, 19 or 22
(2) Loaded holds of ships allowed to carry only light cargo(density less than 1.78 t/m^3) k_r=0.38B and m_a=12, m_b=20, 22 or 26
(3) Other cases k_r=0.25B and m_a=12, m_b=20,22 or 26. This represents the loaded hold of a ship in homogeneous heavy cargo loading condition, which is more severe than a loaded hold in non homogeneous cargo condition, where k_r=0.39B. ⚓

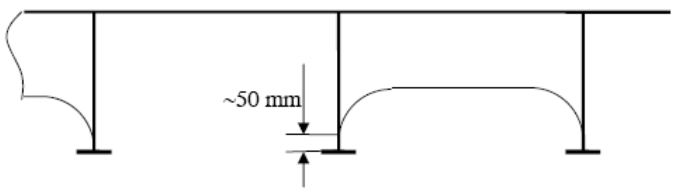


Fig 7.3.9 Tripping bracket

CHAPTER 4 CONTAINER CARRIERS

Section 2 Longitudinal Strength

201. Bending strength

1. The moment of inertia I_0 of the transverse section of hull at the midship of L is to be greater than the following value.

$$I_0 = 3.2 Z_{min} L \quad (\mathrm{cm}^4)$$

where :

Z_{min} = as specified in the requirements in **Pt 3, Ch 3, Table 3.3.1** of the Rules

2. The scantlings of longitudinal members are not to be less than the scantlings of longitudinal members at the midship of L as determined in accordance with the preceding **1.** and in **Pt 3, Ch 3, 201. 2** of the Rules, except for the scantlings of members which differ with the change of the sectional form of the hull.

202. Torsional strength

The torsional strength of hull at each sectional position from the collision bulkhead to the watertight bulkhead at the fore end of the machinery space is to be such that the following relationship is satisfied.

$$\sqrt{(0.75\sigma_V)^2 + \sigma_H^2 + \sigma_W^2} + |\sigma_S| \leq 175/K$$

where:

σ_S = the longitudinal bending stress by the longitudinal bending moment in still water as obtained from the following formula

$$\sigma_S = M_S / Z_V \times 1000 \quad (\mathrm{N/mm^2})$$

σ_V = the longitudinal bending stress by the longitudinal bending moment in wave as obtained from the following formula

$$\sigma_V = M_W / Z_V \times 1000 \quad (\mathrm{N/mm^2})$$

σ_H = the horizontal bending stress by the horizontal bending moment in wave as obtained from the following formula

$$\sigma_H = M_H / Z_H \times 1000 \quad (\mathrm{N/mm^2})$$

M_S, M_W = as specified in **Pt 3, Ch 3, Table 3.3.1** of the Rules

M_H= the horizontal bending moment as obtained from the following formula:

$$M_H = 0.45 C_1 L^2 d (C_b + 0.05) C_H \quad (\mathrm{kN\text{-}m})$$

C_H = coefficient as given in **Table 7.4.1** whose value depends on the ratio of the distance X(m) from the aft end of L to the position of the section under consideration, where intermediate values are to be determined by interpolation.

Table 7.4.1 Coefficient C_H

X/L	0.0	0.4	0.7	1.0
C_H	0.0	1.0	1.0	0.0

Z_V = section modulus of strength deck with respect to longitudinal bending of hull at the position of the section under consideration (cm^3).

Z_H = section modulus of hatch side with respect to horizontal bending of hull at the position of the section under consideration (cm^3).

C_1 = as specified in **Pt 3, Ch 3, Table 3.3.1** of the Rules

σ_W = warping stress due to bending torsion of hull, which is are to be in accordance with the discretion of the Society. But, the value of bending torsion of hull is calculated according to the following formula

$$M_T = \frac{M_0}{2}\left(1 - \cos\frac{2\pi}{L}X\right) \quad (\text{kN-m})$$

$$M_0 = 7.0 K_2 C_W^2 B^3\left(1.75 + 1.5\frac{e}{D_S}\right) \quad (\text{kN-m})$$

C_W= water plane area coefficient.

e = the distance from the top of keel to the shear centre (m). For which is in the below of top of keel, e is taken as positive.

K_2 = as given by the following formula:

$$L < 300\,m \; : \; K_2 = \sqrt{1 - \left(\frac{300 - L}{300}\right)^2}$$

$$L \geq 300\,m \; : \; K_2 = 1.0$$

X = distance from the aft end to considering section (m)

Section 3 Double Bottom Construction

302. Longitudinals

Where the widths of vertical stiffeners on floor plates and vertical struts are specially large, the co-efficient C prescribed in **Table 7.4.1** of the Rules may be modified as prescribed in **Pt 3, Ch 7, 403. 2.**

Section 4 Double Side Construction

401. General

1. Where the breadth of double side construction varies in the bilge part, t_1 in **Table 7.4.2** of the Rules is to be determined as follows:

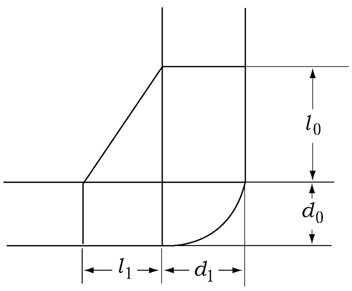
(1) β_T and β_L are to be obtained from the following formulae:

$$\beta_T = 1 + \frac{0.42\left(\frac{B}{D_S}\right)^2 - 0.5}{0.59\frac{D_S - \frac{d_0}{2} - l_{OR}}{B - d_1 - 2l_{1R}}\left(\frac{d_0}{d_1}\right)^2 + 1.0}, \qquad \beta_L = 1 + \frac{0.18\left(\frac{B}{D_S}\right)^2 - 0.5}{0.59\frac{D_S - \frac{d_0}{2} - l_{OR}}{B - d_1 - 2l_{1R}}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

l_{OR} and l_{1R} are to be obtained as follows:

(a) Bilge hopper type (See **Fig 7.4.2**)

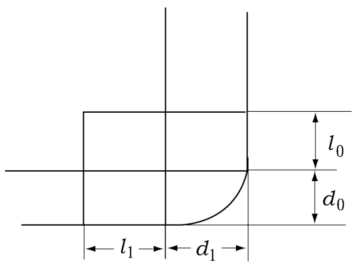
(b) Stepped type (See **Fig 7.4.3**)



$$l_{OR} = \frac{l_0 l_1}{d_1 + l_1}$$

$$l_{1R} = \frac{l_0 l_1}{d_0 + l_0}$$

Fig 7.4.2



$$l_{OR} = l_O$$

$$l_{1R} = l_1$$

Fig 7.4.3

(2) The lower end of h is to be a point at a height of l_{OR} above the inner bottom.

(3) $(d - l_{OR} + 0.038L')$ is to be substituted for $(d + 0.038L')$.

2. Where the height from the designed maximum load line to the strength deck is usually large, t_1 as per **Table 7.4.2** is to be calculated as follows

(1) β_T and β_L are to be obtained from the following formulae:

$$\beta_T = 1 + \frac{0.42\frac{B^2}{D_S D'} - 0.5}{0.59\frac{D_S - \frac{d_0}{2}}{B - d_1}\left(\frac{d_0}{d_1}\right)^2 + 1.0}, \qquad \beta_L = 1 + \frac{0.18\frac{B^2}{D_S D'} - 0.5}{0.59\frac{D_S - \frac{d_0}{2}}{B - d_1}\left(\frac{d_0}{d_1}\right)^2 + 1.0}$$

where :

D' = depth of the ship (m), where the imaginary freeboard deck is provided according to **Pt 3, Ch 1, 203. 2.** (1). D' may be the height from the top of keel to this assumed deck (m).

(2) The value obtained from the following formula is to be substituted for $(d+0.038L')$

$$(d+0.038L')\sqrt{\frac{D'}{D_S}}$$

where :

D' = as specified in (1).

3. If there is a combination of a cross-tie having an ample sectional area and non-watertight partial bulkhead or any similar construction is provided midway in the hold, the l_h in provisions in **Table 7.4.2** may be measured from the bulkhead to such a construction.

4. In case where the breadth of angles or flat bars supporting stiffeners in double hull of side construction is unusually large, scantlings of stiffeners may be determined in accordance with the provision of **Pt 3, Ch 7, 403. 2.**

402. Side transverse and side stringer

The thickness of side transverse girders for shear force and shear buckling strength is not to be less than that obtained from the **Table 7.4.2** in addition to the requirement of Rules, whichever is greatest.

Table 7.4.2 The thickness of side transverse and side stringer

division	thickness (mm)
Side transverse and Side stringer	$t_1 = 0.083\dfrac{CSl_h}{d_1 - a}(d + 0.038L') + 1.5$, $\quad t_2 = 8.6\sqrt[3]{\dfrac{d_1^2(t_1 - 1.5)}{k}} + 1.5$

C : as specified in the following Table.

Side transverse

$$C = (C_1 + \beta_T C_2)C_3$$

$$\beta_T = 1 + \frac{0.42\left(\dfrac{B}{D_S}\right)^2 - 0.5}{0.59\dfrac{\left(D_S - \dfrac{d_0}{2}\right)}{(B - d_1)}\left(\dfrac{d_0}{d_1}\right)^2 + 1.0}$$

C_1, C_2 = as obtained from the following table, in accordance with the value of h/l_h. For intermediate values of h/l_h, the values of C_1 and C_2 are to be determined by linear interpolation.

h/l_h	C_1	C_2
0.5 and under	0.18	0.05
0.75	0.21	0.08
1.00	0.24	0.09
1.25	0.25	0.10
1.50	0.26	0.11
1.75 and above	0.27	0.12

C_3 = as obtained from the following formula, but not to be less than 0.2.

$$C_3 = 1 - 1.8\frac{y}{h}$$

Side stringer

$$C = (C_1 + \beta_L C_2)C_3$$

$$\beta_L = 1 + \frac{0.42\left(\dfrac{B}{D_S}\right)^2 - 0.5}{0.59\dfrac{\left(D_S - \dfrac{d_0}{2}\right)}{(B - d_1)}\left(\dfrac{d_0}{d_1}\right)^2 + 1.0}$$

C_1, C_2 = as obtained from the following table, in accordance with the value of h/l_h. For intermediate values of h/l_h, the values of C_1 and C_2 are to be determined by linear interpolation.

h/l_h	C_1	C_2
0.5 and under	0.20	0.07
0.75	0.24	0.05
1.00	0.26	0.03
1.25		0.01
1.50 and above		0.00

C_3 = as obtained from the following formula

$$C_3 = \left|1 - \frac{2x}{l_h}\right|$$

h = vertical distance from the top of inner bottom to the strength deck at side(m)
l_h = length of hold(m)
d_0 = height of centre girder(m)
L' = length of ship(m). Where, however, L exceeds 230 m, L' is to be taken as 230 m.
d_1 = depth of side transverse or side stringer(m). where, the depth of webs is divided by providing stiffeners in the direction of the length of girder on the webs, d_1 in the formulae for t_2 may be taken as the divided depth.
S = width of the area supported by the side transverse girders(m)
a = depth of the openings at the location under consideration(m)
S_2 = S_1 or d_1, whichever is smaller
y = distance from the lower end of h to the location under consideration(m)
x = distance from the end of l_h to the location under consideration(m)
k = coefficient obtained from table in accordance with the ratio of the spacing S_1 (m) of the stiffeners provided in the direction of the depth of girder on the web of side transverse girder and d_1. For intermediate values of S_1/d_1, the value of k is to be determined by linear interpolation.

S_1/d_1	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and above
k	60	40	26.8	20	16.4	14.4	13.0	12.3	11.1	10.2

Section 6 Deck Construction

601. Construction

The requirements of decks inside the line of deck openings in connection with bending in the plane of deck are not to be less than that obtained from the **Table 7.4.3.** In the calculations of section modulus and moment of inertia, the deck inside the line of deck openings is to be regarded as a web and the hatch end coaming as a flange.

Table 7.4.3 Decks inside the line of deck opening

Item	Framing	Scantling
Thickness of deck	Boxshaped construction	$t = 0.00417 C_1 \left(\frac{l_V^2 l_C}{\omega_C} \right) + 4.0$ (mm) But, it is to be included the thickness of bottom plating.
	Others	$t = 0.00417 C_1 \left(\frac{l_V^2 l_C}{\omega_C} \right) + 1.5$ (mm)
Section modulus	$Z = 1.43 C_2 l_V^2 l_C^2$ (cm^3)	
Moment of inertial	$I = 0.38 \frac{l_C^4}{S l_V^3} I_V$ (cm^4)	

l_V = distance from the top of inner bottom plating to the bulkhead deck at the centre line of ship (m)
l_C = width of hatchway(m). where two or more rows of hatchway are provided, the width of the widest hatchway is to be taken.
ω_C = width of deck inside the line of deck openings(m)
C_1, C_2 = as obtained form Table in accordance with the value of α. For intermediate values of α, the value of C_1, C_2 are to be determined by linear interpolation.

α	C_1	C_2
0.5 and under	1.00	0.50
1.5 and above	0.37	0.10

α = as obtained form the following formula

$$\alpha = 0.5 l_C \sqrt[4]{\frac{3}{4 S l_V^3} \times \frac{I_V}{I_C}}$$

S = spacing of vertical webs provided on transverse bulkhead (m)
I_V = moment of inertia vertical webs provided on transverse bulkhead (cm^4)
I_C = moment of inertia of decks inside the line of deck openings (cm^4)

Section 7 Freight Container Securing Arrangement

702. Freight container securing systems

1. In case of intending to be approved by the Society for freight container securing arrangement as specified in **702.** of the Rules, it is to be satisfied with the requirement of **Annex 7-2 Guidance for the Container Securing Arrangements.**

2. For approval of manufacturing process and type approval of securing arrangement are to comply with the requirements in **Ch 3, Sec 25.** of 「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」

3. Inspection procedure of Freight container securing arrangement

(1) Inspection procedure of type approved freight container securing arrangement in accordance with the requirements of **Ch 3, Sec 25** of 「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」 is as follows.

(2) The nature and extent of production testing will be considered but the arrangements are to be at least equivalent to one of the following schemes:

(A) (a) For rod lashings, fittings and securing devices
One sample from every fifty pieces, or from each batch if less than fifty piece, is to be proof loaded to 1.5 times the safe working load for which the item is intended.

(b) For chain or wire rope lashings
One sample from every fifty pieces, or from each batch if less than fifty piece, is to be to breaking.

(B) Alternatively, every piece of fittings, securing devices and lashings is to be proof loaded to the safe working load of the item and in addition, one sample from every batch of chain or wire rope lashings is to be tested to breaking.

(3) For fixed securing devices such as items **11.** to **14.** in **Table 3.25.2** of 「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」 consideration will be given to a reduced frequency of mechanical production testing provided the following (A) and (B). Where manufacturer for the fixed securing devices has the certificates of this Class' quality assurance system, inspection procedure is to comply with **Ch 5, 305.** of 「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」

(A) Prototype test results indicate a breaking strength at least 50 % greater than that required by the **Table 3.25.1** of 「**Guidance for Approval of Manufacturing Process and Type Approval, etc.**」

(B) A suitable non-destructive inspection procedure is agreed.

(4) For production tests carried out in accordance with (1)(A) permanent deformation(other than that due to initial embedding of component parts) will not be accepted within the range of loading up to :

(A) where SWL is less than 25 tones : 1.5 × SWL (ton)

(B) where SWL is 25 tones or greater : SWL ×12.5 (ton)
Consideration may be given to acceptance of permanent deformation in the load range between that given in (2) and the proof load provided that satisfactory manual operation can be achieved after completion of tests.

(5) In the event of premature failure or serious plastic deformation occurring in a test sample a further sample should be selected for testing. In the event that this sample is found to be unsatisfactory, the associated batch will be rejected.

(6) For production tests carried out in accordance with (2)(B) permanent deformation will not be accepted. ⚓

CHAPTER 5 SHIPS CARRYING LIQUEFIED GASES IN BULK

(Separate Publication)

CHAPTER 6 SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

(Separate Publication)

CHAPTER 7 CAR FERRIES AND ROLL-ON/ROLL-OFF SHIPS

Section 1 General

101. Application

The ship specified in **101. 2** of the Rules are to comply with the requirement **Annex 7-3 Guidance for Cargo Ferries and Passenger Ferries.**

Section 3 Deck Structure

301. Application

1. Thickness of vehicle deck

The thickness of vehicle deck is to be less than that obtained from the following (1) and (2). However, the thickness of plating of weather decks is to be 1 mm thicker than obtained from those formulae.

(1) Where the distance between centres of wheel prints in a panel is not less than $2S+a$ (See **Fig 7.7.1**)

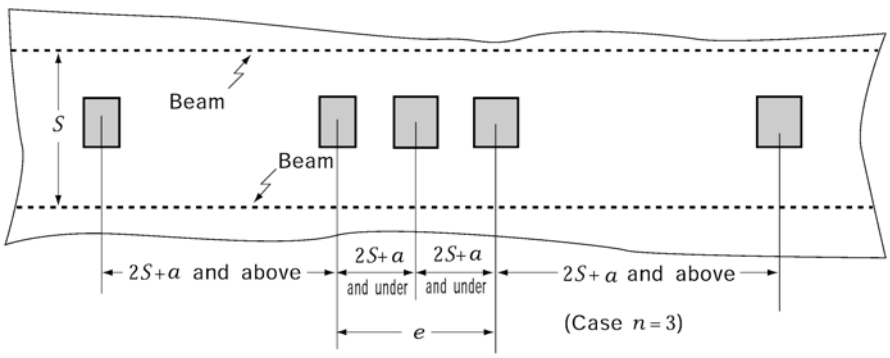


Fig 7.7.1 Measurement of e

$$t = C\sqrt{K}\sqrt{\frac{(2S-b')}{(2S+a)} \times \frac{P}{9.81}} + 0.5 \quad (\mathrm{mm})$$

C = coefficient determined as specified in **Table 7.7.1.**

S = beam spacing (m)

P = maximum design wheel load (kN). if $b > S$, a value equal to the maximum designed wheel load multiplied by the value of S/b

b' = b or S, whichever is the smaller (m)

a and b = length of wheel print measured in parallel and perpendicular to beam (See **Fig 7.7.2**). For vehicles with ordinary pneumatic tires, however, values of a and b in **Table 7.7.2** may be used.

Table 7.7.1 Coefficient C

Frames \ Vehicles		Vehicles used for cargo handling	Other vehicles
Midship part of strength deck	Longitudinal framing	4.6	$\frac{3.64}{\sqrt{1-0.64f_D}}$
	Transverse framing	4.9	$\frac{5.15}{\sqrt{1-0.41{f_D}^2}}$
Elsewhere		4.6	5.2
f_D = as specified in **Pt 3, Ch 1, 124** of the Rules. But, it is to be less than 0.79.			

Table 7.7.2 Wheel print length a and b

wheel \ direction	Wheel print length parallel to axle In **Fig 7.7.2,** a in Case (I), b in Case (II)	Wheel print length right angle to axle In **Fig 7.7.2,** a in Case (I), b in Case (II)
Single tire	Tire width	$\frac{1}{20}\sqrt{P}$
Double tire	2×tire width. Interval between tires, if any, may be added	$\frac{9}{250}\sqrt{P}$
P = as specified in **Par 301. 1 (1)**		

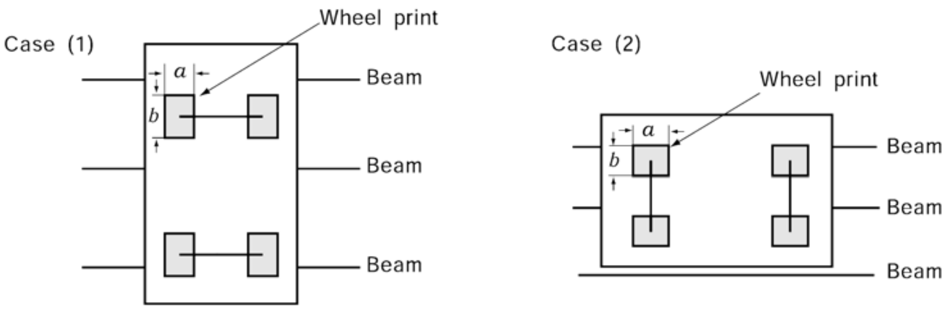


Fig 7.7.2 Measurement of a and b

(2) Where the distance between centres of wheel prints in a panel is less than $2S + a$ (See **Fig 7.7.1**)

$$t = C\sqrt{K}\sqrt{\frac{2S-b')}{(2S+a+e)}\times\frac{nP}{9.81}}+0.5 \quad (\mathrm{mm})$$

e = sum of distances between centres of wheel prints in case where wheels are placed side by side at a spacing less than $2S+a\,(\mathrm{m})$ (See **Fig 7.7.1**)

n = number of wheel loads in the range of e

C, S, a, b' and P = as specified in (1)

2. Section modulus of vehicle deck beams

The section modulus of beams of decks loaded with wheeled vehicles is not to be less than that obtained from the following formula:

$$Z = KC_1C_2M \quad (\mathrm{cm}^3)$$

C_1 = coefficient determined as follows.

for $b/S \leq 0.8$: $C_1 = 1.0$
for $b/S > 0.8$: $C_1 = 1.25 - 0.31b/S$

C_2 = coefficient determined from **Table 7.7.3**

Table 7.7.3 Coefficient C_2

members \ vehicles	Vehicles exclusively used for cargo handling	Other vehicles
Longitudinal beams of strength decks in midship region	$\dfrac{3.6}{1-0.34f_D}$	$\dfrac{4.6}{1-0.64f_D}$
Elsewhere	3.6	4.6
f_D = as specified in **Pt 3, Ch 1, 124** of the Rules. But, it is to be less than 0.79		

b, P and S = as specified in **Par 1.** (1)
M = M_1 or M_2 obtained from the following formulae, whichever is greater.

$$M_1 = \frac{1}{9.81}\left(\sum_{i=1}^{N_I} 4P_{Ii}\alpha_{Ii}\left\{1-\left(\frac{\alpha_{Ii}}{l_I}\right)^2\right\} + \sum_{j=1}^{N_{II}} P_{IIj}\alpha_{IIj}\left(1-\frac{\alpha_{IIj}}{l_{II}}\right)\left(7-5\frac{\alpha_{IIj}}{l_{II}}\right) - \sum_{k=1}^{N_{III}} P_{IIIk}(l_{III}-\alpha_{IIIk})\left\{1-\left(\frac{l_{III}-\alpha_{IIIk}}{l_{III}}\right)^2\right\}\right)$$

$$M_2 = \frac{1}{9.81}\left(-\sum_{i=1}^{N_I} P_{Ii}\alpha_{Ii}\left\{1-\left(\frac{\alpha_{Ii}}{l_I}\right)^2\right\} + \sum_{j=1}^{N_{II}} P_{IIj}\alpha_{IIj}\left(1-\frac{\alpha_{IIj}}{l_{II}}\right)\left(2+5\frac{\alpha_{IIj}}{l_{II}}\right) + \sum_{k=1}^{N_{III}} 4P_{IIIk}(l_{III}-\alpha_{IIIk})\left\{1-\left(\frac{l_{III}-\alpha_{IIIk}}{l_{III}}\right)^2\right\}\right)$$

I_I, I_{II}, I_{III} = span of beam between support points(m)
P_{Ii}, P_{IIj}, P_{IIIk} = maximum design wheel load between support points (kN)
α_{Ii}, α_{IIj}, α_{IIIk} = distance from each support point to the point of action of wheel load (See **Fig 7.7.3**)
N_I, N_{II}, N_{III} = number of wheel loads between each span

3. Scantlings of vehicle deck beams

Scantlings of beams of car decks may be determined by direct strength calculations using the following standards.

(1) The model of structures and the method of calculation are to be those approved by the Society.

(2) Loads are to be assumed as follows;

(a) 1.5×maximum design wheel load for loaded condition with vehicles on car decks.

(b) 1.2×maximum design wheel load for vehicles used for cargo handling only(forklifts or similar vehicles used for handling cargo in ports only).

(3) The allowable stressed for calculation of section moduli are to be as shown in **Table 7.7.4.**

(4) Considering corrosion, etc, the section moduli obtained on the basis of conditions (1) to (3) above are to be multiplied by 1.2 to determine the actual section moduli.

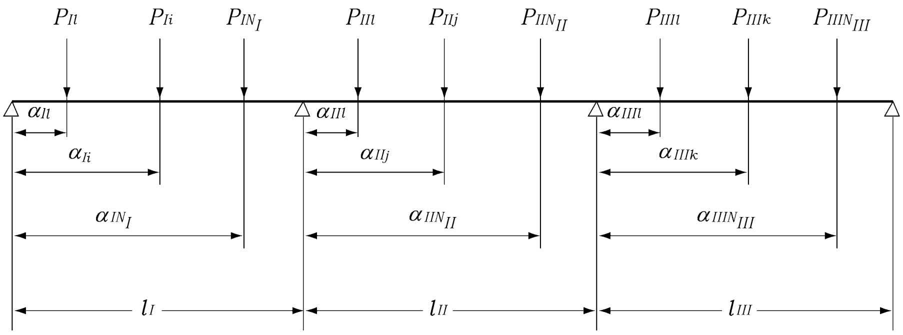


Fig 7.7.3 Measurement of P_{Ii}, α_{Ii}, l_I

Table 7.7.4 Permissible stress (N/mm^2)

Members	Vehicles used for cargo handling only	Other vehicle
Longitudinal beams of strength decks in midship region	$\frac{235-80f_D}{K}$	$\frac{235-150f_D}{K}$
Elsewhere	$\frac{235}{K}$	$\frac{235}{K}$
f_D = as specified in **Pt 3, Ch 1, 124.** of the Rules. But, it is to be less than 0.79		

4. Movable vehicle deck girder

(1) General

Deck girders of movable vehicle decks and similar constructions are to be in accordance with the requirements in this Section in addition to **Pt 3, Ch 11, 103.**

(2) Strength requirement

The scantlings of movable vehicle deck girders are to be determined with the following requirements in (A) through (C).

(A) The effective width of compressive plate flange for each girder is to be determined by the following (a) and (b) corresponding to the stiffening direction of panel.

(a) Effective width for girders parallel to the stiffening direction
The value specified in **Pt 3, Ch 3, 602.**

(b) Effective width for girders crossing at right angles with the stiffening direction

$$b_{eft} = \sum_n \left(\frac{C_{et} \cdot a}{2}\right) \quad \text{(mm)}$$

In case buckling stiffeners for deck plate are fitted properly, these may be taken into account for the determination of effective width. However, it is not to exceed the value specified in **Pt 3, Ch 3, 602.**

C_{et} : Coefficient as given by the following formula. Where, however, C_{et} exceeds 1.0, C_{et} is to be taken as 1.0.

$$C_{et} = \left(\frac{3}{\beta} - \frac{1.75}{\beta^2}\right)\frac{b}{a} + \left(\frac{0.075}{\beta} + \frac{0.75}{\beta^2}\right)\left(1 - \frac{b}{a}\right)$$

n : 1 for girders located on the periphery of vehicle deck, and 2 for the others
a : Spacing of girders crossing at right angles with the stiffening direction (mm)
b : Spacing of stiffeners (mm)
β : Coefficient as given by the following formula

$$\beta = \frac{b}{t}\sqrt{\frac{\sigma_F}{E}}$$

t : Thickness of vehicle deck plating (mm)
σ_F : Minimum upper yield stress or proof stress of the vehicle deck material (N/mm^2)
E : Modulus of elasticity of the material to be assumed equal to 2.06 $\times 10^5$ (N/mm^2) for steel.

(B) Design load and allowable stresses are to be in accordance with the requirements of following (a), (b).
(a) Design load P (kN/mm^2)
- For loaded condition with vehicles on vehicle decks

$$P = 1.5(p + w_{deck})$$

p : Design load on vehicle deck (kN/mm^2)
w_{deck} : Tare of vehicle deck per unit area (kN/mm^2)

- For vehicles used for cargo handling only (fork lifts or similar vehicles used for handling cargo in ports only)

$$P = 1.2(p + w_{deck})$$

(b) Allowable stresses (N/mm^2)
As specified in **Table 3.11.1**. Where, σ_F(N/mm^2) is minimum upper yield stress or proof stress of the material.

Table 3.11.1 Allowable stress

Normal stress	$0.8\sigma_F$
Shear stress	$0.46\sigma_F$

(C) In case the scantlings of girders are determined based upon direct calculations, the method of assessments is to be a grillage model analysis or that can take account of the elastic buckling effects of compression panels of vehicle deck. Otherwise, it may be acceptable that elastic FEM analysis by using shell elements model is carried out and, in addition, buckling strength of compression panels is checked complying with the requirements of **Pt 3, Annex 3-2, III.2.**

(3) Structural details

(A) Fillet weld of the connection of girder webs to the vehicle deck is to be in accordance with **Table 3.11.2.**

(B) The thickness of web plates is not to be less than that obtained by the following formula, except where buckling strength of web plate is examined precisely.

$$\frac{d}{C}+1.0$$

d : Depth of girders (mm)

C : Coefficients are given by the followings.

65 for symmetrically flanged girders

55 for asymmetrically flanged girders

Table 3.11.2 Fillet weld of girder to movable vehicle deck

<table>
<tr><th></th><th>Panel on which vehicular traffic is frequent (1)</th><th>Panels other than the specified in the left column</th></tr>
<tr><td>1) Girders on the deck panel periphery</td><td rowspan="5">F2
(Both sides)</td><td rowspan="4">F2
(Both sides)</td></tr>
<tr><td>2) Within $0.3l$ midspan of girders other than mentioned in (1)(2)</td></tr>
<tr><td>3) Within $0.1l$ end part of girders other than mentioned (1)(2)</td></tr>
<tr><td>4) Intersection for $0.2l'$ of girders other than mentioned in (1)(3)</td></tr>
<tr><td>5) Other than those mentioned above</td><td>F2
(One side, at least)</td></tr>
</table>

(1) Deck panels which are subject to the dynamic load in the vicinity of ramp way and are on the route between a ramp way and another ramp way to reach another deck

(2) l : The total length of each girder

(3) l' : The span of each girder, and $0.1l'$ on either side of the inter section of girders is to be welded

(4) $F2$: As specified in **Pt 3, Ch 1, Table 3.1.6**

5. Supporting structures of movable vehicle deck

(1) The requirements in this section apply to structures supporting movable vehicle decks.

(2) Considering the shape, designed load, etc., of deck panels, supporting structures of movable vehicle decks are to be arranged appropriately.

(3) The connection of supporting members to hull structural members is to be suitably constructed so as to avoid stress concentration. If necessary, suitable reinforcement is to be provided by means of stiffeners, brackets, etc.

(4) In case deck panels are suspended by wire ropes, the ropes are to comply with the require-

ments of **Pt 4** of the Rules or the requirements of the standards as deemed appropriate by the Society, and subjected to suitable corrosion prevention treatment.
The safety factor of the wire ropes is not to be less than the following value, but may not exceed 4.

$$\frac{10^4}{8.85W+1910}$$

Where,
W : Safe working load (ton)

(5) Scantlings of supporting structural members are to be determined to withstand the design loads defined in **4** (B) (a) using the following allowable stresses.

shear stress : $\tau = 0.34\sigma_F$
bending stress : $\sigma = 0.50\sigma_F$
equivalent stress : $\sigma_e = \sqrt{\sigma^2 + 3\tau^2} = 0.64\sigma_F$

Where,
σ_F : Minimum upper yield stress or proof stress of the material (N/mm^2) ⚓

CHAPTER 10 DOUBLE HULL TANKER

Section 1 General

101. Application

1. Application

(1) For ships having the structural features similar to double hull tankers; e.g. ships carrying dangerous chemicals in bulk, the requirements in **Pt 7, Ch 10** of the Rules are to be applied.
(2) Unless otherwise specially noted, the prescriptions in other Parts apply for matters common to both cargo ships and tankers.

2. Proposal of novel construction type

In the event that a novel construction type is proposed, scantlings are to be determined by carrying out comparative calculations with the standard structural model conforming to the requirements of the Rules. Submission of data covering the results of model experiments or real ship experiments may be requested by the Society as necessary.

3. Ships carrying liquid cargoes other than petroleum

(1) The scantlings of structural members of the cargo oil tank part of tankers carrying liquid cargoes of a specific gravity ρ exceeding 1.0 are to be of the values obtained by the following two procedures, whichever is greater:
   (a) To calculate for all of the structural members in accordance with the relevant requirements of the Rules
   (b) To calculate for respective structural members in accordance with the following prescription:
      (i) The scantlings of the bulkhead plates, stiffeners attached bulkhead plating and girders attached bulkhead plating are to be calculated h in the formulae specified in **Sec 2** to **4** of the Rules by multiplying gravity ρ.
      (ii) The scantlings of girders and floors in double bottom and girders and transverses in double side hull are to be calculated h' in the formulae specified in **403.** and **404.** of the Rules by multiplying gravity ρ.
      (iii) The values of ρ are to be selected for respective cases except those contained in **Table 7.10.1.**
(2) For tankers carrying dangerous chemicals in bulk, the requirements in **Ch 6** of the Rules are also to be applied.

Table 7.10.1 Value of ρ

Cargo	ρ
Molasses	1.4
Asphalt	1.1
Concentrated sulphuric acid	1.85

102. Location and separation of spaces

1. The size and arrangement of cargo oil tanks segregated ballast tanks are to comply with the requirements of **MARPOL 1973/78.**

2. Cofferdams and bulkheads bounding cargo oil tanks

(1) In case where a cargo oil tank is adjacent to the fore peak (fore peak tank), the collision bulkhead is to be free from openings.
(2) Divisions between compartments defined as cofferdams and other compartments (except cargo oil tanks and fuel oil tanks) are not to have any openings with the exception of bolted watertight manholes provided in chain locker bulkheads, etc. (no watertight door is permitted).

3. Airtight bulkheads

(1) Cofferdams which are not utilized as main or auxiliary pump rooms and compartments utilized as cofferdams under the freeboard deck are to meet the requirements for the strength of deep tanks. The bulkhead between the main pump room and engine room is to have structural scantlings of watertight bulkheads in ships of not less than 100 m in length and of airtight bulkheads in ships of less than 100 m in length.

(2) The scantlings of airtight bulkheads for which no hydrostatic tests are required are to comply with the following standards. Airtightness tests may be replaced by hose tests.

(A) The plate thickness is not to be less than 6 mm, which may, however, be reduced to 4.5 mm in ships of less than 100 m in length.

(B) The section modulus of stiffeners and girders is to be 50 % of the Rule requirements for watertight bulkheads. Where connected to shell and decks, however, these stiffening members are to be of such an effectiveness as is equivalent to frames and beams.

4. Superstructures and deckhouses

The deckhouse protecting the entrance to pump rooms is to be in accordance with the following requirements:

(1) The strength of front wall is to be equivalent to that of wall of the bridge.

(2) The strength of side walls and after wall are to be equivalent to that of front wall of the poop.

5. Pipe duct in double bottom

"Adequate mechanical ventilation" defined in **102. 8** (3) of the Rules is to be in accordance with the requirements in **Pt 7, Ch 6, 1203.** of the Rules.

Section 2 Bulkhead Plating

201. Bulkhead plating in cargo oil tanks and deep tanks

1. "Bulkhead plating" referred to in this Chapter of the Rules means those plate members used in the boundaries of cargo oil tanks and deep tanks where longitudinal bulkheads, transverse bulkheads, decks plates, side shell and inner bottom plates are included.

2. Distribution of Δh and measurement of b_t for L-Type and U-Type tank of **Table 7.10.2** of the Rules are to be in accordance with **Fig 7.10.1.**

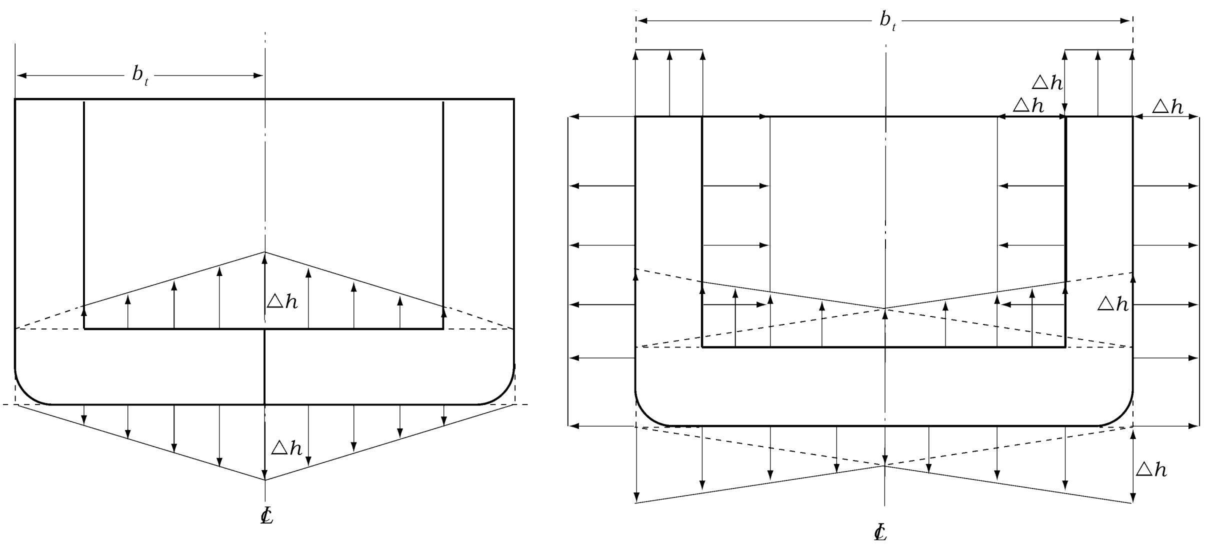


Fig 7.10.1 b_t **and** $\triangle h$ **of L-type and U-type tanks**

3. In the provision of h_3 specified in **Table 7.10.2** of the Rules, for side shell plating, a water head corresponding to the minimum draught amidship d_{min} (m) under all operating conditions of the ship may be deducted therefrom. The deductible water head at the top of keel is to be d_{min}, value at point d_{min} above the top of keel, 0, and value at an intermediate point is to be obtained by linear interpolation.

202. Swash Bulkheads

1. Arrangements of swash bulkheads

In case where the length or breadth of a cargo oil tank exceeds, 15 m or $0.1L$ (m), whichever is greater, swash bulkheads are to be provided in cargo oil tanks. Where, however, this requirement may be dispensed with if special consideration is given to sloshing.

(1) The breadth and thickness of the uppermost and lowest strakes of the centreline swash bulkhead may be 90 % of those required by the Rules for the uppermost and lowest strakes, respectively, of the longitudinal oiltight bulkhead.

(2) The "opening ratio" means the ratio of the sum of areas of openings, except slots and scallops, to the area of the bulkhead.

(3) The section modulus of stiffeners is to be obtained from the following formula.

$$Z = CSh_2 l^2 \quad (\text{cm}^3)$$

where:

C = coefficients given below;

both ends effectively bracketed : C = 7.1

one end effectively bracketed and the other end supported by girder : C = 8.4

both ends supported by girders : C = 10.0

h_s = value obtained from the following formula. In no case is it to be less than 2.0.

$$h_s = (0.176 - 0.00025L)(1-\alpha)l_T$$

α = opening ratio of bulkhead plating.

l_T = length of tank (m).

S and l = spacing of stiffeners and span of stiffener between supports (m).

(4) In applying the requirements of **405. 1** to **3** of the Rules, the scantlings of girders supporting stiffeners are to be obtained in such a way that values of h specified in the requirements under consideration referred to are not less than that obtained by substituting h with h_s specified in (3).

Section 3 Longitudinals and Stiffeners

301. Longitudinals

For the assessment fatigue strength of ship structure according to **301. 4** of the Rules is to comply with **Pt 3, Annex 3-3** of the Guidance.

Section 4 Girders

401. General

1. Notwithstanding the requirement in **401. 2** the scantlings of girders may be determined for tankers with L less than 200 m. in accordance with the requirements in **403.** through **407.** In this case, the arrangement of primary members in the double bottom, double side hull and cargo oil tank at cargo tank area are to be determined referring to the structural types shown in following (1) through (3) as the standard. However, in tankers without partial loading conditions such as half-loading or alternate loading, the spacing of girders and floors in double bottom and stringers and transverses in double side hull may be increased.

(1) Tankers with double bottom structures having longitudinal bulkhead only on the centreline, (hereinafter referred to as "Type A tankers") (See **Fig 3.3.7** of the Rules)

(2) Tankers with double hull structures having no longitudinal bulkhead on the centreline (hereinafter referred to as "Type C tankers") (See **Fig 3.3.7** of the Rules)

(3) Tankers with double hull structures having longitudinal bulkhead only on the centreline (hereinafter referred to as "Type D tankers") (See **Fig 3.3.7** of the Rules)

2. In tankers without partial loading conditions such as half-loading or alternate loading, if the spacing of girders and floors in double bottom and stringers and transverses in double side hull according to type A, C, D tankers of **Par 1** are smaller than the values shown in (1) and (2) , the spacing may be increased to the values given in (1) and (2) :

(1) Girders in double bottom and stringers in double side hull ..... 4.1 (m)

(2) Floors in double bottom and transverses in double side hull ..... 2.8 (m)

402. Direct strength calculations for girders

When determining the scantlings of girders for double hull tankers by direct strength calculations, the procedure is to comply with the **Pt 3, Annex 3-2** of the Guidance.

403. Scantlings of girders and floors in double bottom

1. The thickness of centre girders and side girders in double bottom is not to be less than the greatest of either of the value t_1 specified in the following (1) , t_2 or t_3 specified in the following (2). Where, however, the thickness of centre girders of tankers having the longitudinal bulkhead on the centreline may be determined using only t_3.

(1) The thickness obtained from the following formula according to the each location in the cargo oil tank

$$t_1 = C_1 K \frac{S h_B x}{d_0 - d_1} + 1.5 \quad (\text{mm})$$

where :

S = distance between the centres of two adjacent spaces from side girder under consideration to the adjacent girders or the inner end of tank side brackets (m).

h_B = the values obtained from the following formulae, whichever is the greater :

$$h_{B1} = 0.6d + 0.026L \quad (\text{m})$$
$$h_{B2} = h' - (d - 0.026L) \quad (\text{m})$$

h' = vertical distance from the top of the inner bottom plating to the top of hatches (m).

d_0 = depth of side girder under consideration (m).

d_1 = depth of opening at the point under consideration (m). Where, however, if vertical webs attached the transverse bulkhead are provided in the cargo oil tank, openings in girders provided within the range between the transverse bulkhead and the inner end of bracket of the lower vertical webs under consideration may be omitted except when the Society considers it to be necessary. (See **Fig 7.10.2**)

x = longitudinal distance between the centre of l_T of each cargo oil tank and the point under consideration (m). Where vertical webs attached the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of the bracket attached the lower vertical webs. And where x is under $0.25l_T$, x is to be taken as $0.25l_T$.(see **Fig 7.10.2**)

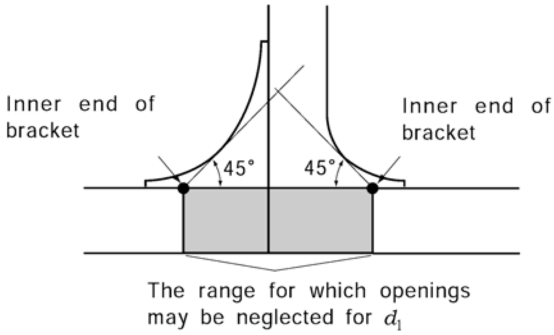


Fig 7.10.2 Based point of d_1, x, y and z

C_1 = coefficient obtained from **Table 7.10.2** and **Table 7.10.3** depending on b/l_T. For intermediate values of C_1 is to be obtained by linear interpolation.

b = distance between the side shell plating and the longitudinal bulkhead on the centreline of the hull at the top of the inner bottom plating at the midship part (m).

l_T= length of the cargo oil tank under consideration (m).

Table 7.10.2 Coefficient of type A and D tanker

b/l_T		0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and under
C_1	Type A	0.045	0.054	0.061	0.068	0.073	0.076	0.079	0.081	0.082
	Type D	0.037	0.044	0.051	0.059	0.065	0.070	0.074	0.076	0.079

Table 7.10.3 Coefficient C_1 of type B tanker

b/l_T	1.0 and under	1.2	1.4	1.6 and over
C_1	0.073	0.079	0.082	0.083

(2) The thickness obtained from the following formula according to the each location in cargo oil tank :

$$t_2 = 8.6\sqrt[3]{\frac{H^2 a^2}{C_3 K}(t_1 - 1.5)} + 1.5 \quad (\text{mm}), \qquad t_3 = \frac{C_4 a}{\sqrt{K}} + 1.5 \quad (\text{mm})$$

where :

a = depth of girders at the point under consideration(m)
Where, however, if horizontal stiffeners are provided at the half way of the depth of girders, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance form the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration (m)

t_1 = thickness of girders calculated under the requirements of (1) according to the type of tankers(mm)

C_3 = coefficient obtained from **Table 7.10.4** according to the ratio of spacing S_1 (m) of stiffeners provided in the direction of the depth of girders and a. For intermediate values of S_1/a, C_3 is to be determined by linear interpolation.

S_1 = spacing of stiffeners provided depthwise on the girder(m)

H = value obtained from the following formulae:

(a) Where the girder is provided with an unreinforced opening.

$$H = 1 + 0.5\phi/a$$

where :
ϕ = major diameter of the openings(m)
α = the greater of a or S_1 (m)

(b) In cases other than(a) : H = 1.0

C_4 = coefficient obtained from **Table 7.10.4** depending on S_1/a. For intermediate values of S_1/a, C_4 is to be obtained by linear interpolation.

Table 7.10.4 Coefficient C_3 and C_4

S_1/a		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_3		64	38	25	19	15	12	10	9	8	7	7
C_4	center girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

2. The thickness of floors in double bottom is not to be less than the greatest of either of the value t_1 specified in the following (1), t_2 or t_3 specified in the following (2).

(1) The thickness t_1 obtained from **Table 7.10.5** according to the type of oil tank

Table 7.10.5 Thickness of floor t_1

Type of tankers	Type A tankers	Type C and D tankers
t_1	$t_1 = C_2 K \frac{S b h_B}{d_0 - d_1}\left(1 - \frac{4y}{3b'}\right) + 1.5 \quad (\mathrm{mm})$	$t_1 = C_2 K \frac{S b h_B}{d_0 - d_1} \times \frac{2y}{b'} + 1.5 \quad (\mathrm{mm})$

S = spacing of floors (m)

h_B = the values obtained from the following formula, whichever is the greater. Where, however, for tankers without abnormal loading conditions such as half-loading or alternate loading, specified in **Par 1. (1)** may be used

$h_{B1} = d + 0.026L \quad (\mathrm{m})$

$h_{B2} = h' - (0.6d - 0.026L) \quad (\mathrm{m})$

d_0 = height of floors at the point under consideration (m).

d_1 = depth of opening at the point under consideration (m). Where, however, if transverses attached the longitudinal bulkhead or side transverses attached the side shell plating are provided in the cargo oil tank, openings in floors provided within the range between the longitudinal bulkhead or side shell plating and the inner end of the brackets of the lower transverses under consideration may be omitted except when the Society considers it to be necessary. (See **Fig 7.10.2**)

b' = $b\,(m)$ of **Par 1. (1)** measuring at the floors under consideration.

y is to comply with type of tankers

(A) Type A of tankers : Athwartship distance at the floors under consideration from centreline of the hull to the point under consideration (m). However, if transverses attached the longitudinal bulkhead are provided in the cargo oil tank, for space between the longitudinal bulkhead and the inner end of the bracket of lower transverses under consideration, y may be calculated as the distance up to the inner end of the bracket under consideration. If y exceeds $0.3b'$, y is to be taken as $0.3b'$.

(B) Type C of tankers : Athwartship distance at the floors under consideration from the centreline of the hull to the point under consideration (m). However, if brackets attached the lower transverses of double side hull are provided, y may be calculated as the distance up to the inner end of the bracket under consideration. If y is under $0.25\,b'$, y is to be taken as $0.25\,b'$.

(C) Type D of tankers : Athwartship distance at the floors under consideration from centre of b' to the point under consideration (m). However, if brackets attached the lower transverses of double side hull or the lower transverses of the longitudinal bulkhead on the centreline of the hull in the cargo oil tank are provided, y may be calculated respectively as the distance up to the inner end of the bracket attached the lower transverses of double side hull or up to the inner end of the bracket attached the lower transverses of longitudinal bulkhead on the centreline of the hull. If y is under $0.25b'$, y is to be taken as $0.25b'$.

C_2 = coefficient obtained from **Table 7.10.6** and **Table 7.10.8** depending on b/l_T. For intermediate values of C_2 is to be obtained by linear interpolation.

b, l_T and h' are to be in accordance with the requirements of **Par 1. (1).**

(2) The thickness t_2 or t_3 obtained from the following formula

$$t_2 = 8.6\sqrt[3]{\frac{H^2 a^2}{C_3 K}(t_1 - 1.5)} + 1.5 \quad (\mathrm{mm}), \qquad t_3 = \frac{8.5 S_2}{\sqrt{K}} + 1.5 \quad (\mathrm{mm})$$

where :

a = depth of floors at the point under consideration(m)

Where, however, if horizontal stiffeners are provided at the half way of the depth of floors, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance form the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration(m)

t_1 = thickness of floors calculated under the requirements of (1) according to the type of tankers(mm)

C_3 = coefficient obtained from **Table 7.10.9** according to the ratio of spacing S_1 (m) of stiffeners provided in the direction of the depth of floors and a. For intermediate values of S_1/a, C_3 is to be determined by linear interpolation.

S_1 = spacing of stiffeners provided depthwise on the floor(m)

H = value obtained from the following formulae **Par 1.** (1)

S_2 = S_1 or a, whichever is the smaller(m)

3. When calculating the thickness of side girder just under the hopper plate of bilge hopper tank, S in the formulae in **Par 1.** (1) and **Fig 7.10.3.** is to be measured, as a standard, as shown in **Fig 7.10.3.** For the hopper plate within the range of l in the figure, the sectional area obtained form the following formula may be included into the effective sectional area of the same side girder under consideration. However, if l exceeds the breadth of the hopper plate b_H, l is to be taken as b_H.

$$A_e = 10 \Sigma h_i t_i \left(1 - \frac{\theta}{90}\right) \quad (\text{cm}^2)$$

h_i = breadth of hopper plate within l (mm)

t_i = thickness of hopper plate - 2.5 (mm)

θ = angle between side longitudinal girder plate and hopper plate(degree)

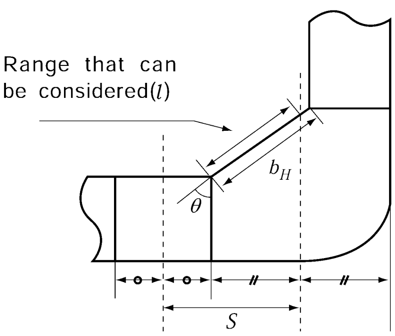


Fig 7.10.3 Measured method of S

Table 7.10.6 Coefficient C_2 of the Type A tankers

b/l_T	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_2	0.047	0.048	0.047	0.046	0.045	0.043	0.041	0.039	0.037

Table 7.10.7 Coefficient C_2 of the Type C tankers

b/l_T	1.0 and under	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6 and over
C_2	0.036	0.033	0.031	0.028	0.026	0.024	0.022	0.021	0.019

Table 7.10.8 Coefficient C_2 of the Type D tankers

b/l_T	0.6 and under	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_2	0.042	0.041	0.041	0.040	0.039	0.038	0.036	0.035

Table 7.10.9 Coefficient C_3

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_3	64	38	25	19	15	12	10	9	8	7

404. Scantlings of stringers and transverses in double side hull

1. The thickness of stringers in double side hull is not to be less than the greatest of either of the value t_1 specified in the following (1), t_2 or t_3 specified in the following (2) :

(1) The thickness obtained by the following (1) or (2) according to the type of tankers :

$$t_1 = C_5 K \frac{S h_s x}{d_0 - d_1} + 1.5 \quad (\mathrm{mm})$$

where :

S = breadth of part supported by stringers (m).

h_s = the values obtained from the following formulae, whichever is the greater :

$$h_{s1} = (0.6d - d_3) + 0.038L \quad (\mathrm{m})$$
$$h_{s2} = h' \quad (\mathrm{m})$$

h' = vertical distance from the upper end of bilge hopper, if provided, or top of inner bottom plating to top of hatches (m).

d_3 = height of double bottom at ship's sides (m). Where, however, vertical distance up to the upper end of bilge hopper, if provided.

d_0 = depth of stringers (m).

d_1 = depth of opening at the point under consideration (m). Where, however, if horizontal girders attached the transverse bulkhead are provided in the cargo oil tank, openings in stringers provided within the range between the transverse bulkhead and the inner end of bracket at the end of horizontal girders under consideration may be omitted except when the Society considers it to be necessary. (See **Fig 7.10.2**)

x = longitudinal distance between the centre of l_T of each cargo oil tank and the point under consideration (m). However, if horizontal girders attached the transverse bulkhead are provided in the cargo oil tank, x may be calculated as the distance up to the inner end of bracket attached the end of horizontal girders under consideration. If x is under $0.25l_T$, x is to be taken as $0.25l_T$. (See **Fig 7.10.2**)

C_5 = coefficient obtained from **Table 7.10.10** depending on D'/l_T. For intermediate values of D'/l_T, it is to be obtained by linear interpolation.

D' = value obtained from the following formula :

$$D' = D - d_3 \quad (\mathrm{m})$$

l_T = length of the cargo oil tank under consideration (m).

Table 7.10.10 Coefficient C_5

D'/l_T		0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_5	Type C	0.013	0.019	0.025	0.030	0.034	0.037	0.039	0.042	0.045
	Type D	0.020	0.024	0.028	0.032	0.035	0.038	0.040	0.042	0.045

(2) The thickness t_2 or t_3 obtained from the following formulae according to the location in the cargo oil tank.

$$t_2 = 8.6\sqrt[3]{\frac{H^2a^2}{C_6K}(t_1-1.5)}+1.5 \quad (\mathrm{mm}), \qquad t_3 = \frac{8.5S_2}{\sqrt{K}}+1.5 \quad (\mathrm{mm})$$

where :

a = depth of stringers at the point under consideration (m). Where, however, if horizontal stiffeners are provided at the half way of the depth of stringers in the direction of the length of stringers, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side hull or the distance between the horizontal stiffeners under consideration (m).

t_1 = thickness of stringers calculated under the requirements of (1) (mm).

C_6 = coefficient obtained from **Table 7.10.11** according to the ratio of spacing S_1 of stiffeners provided in the direction of the depth of stringers and a. For intermediate values of S_1/a, C_6' is to be obtained by linear interpolation.

S_1 = spacing of stiffeners provided depthwise on the stringer(m)

H = as specified in **403. 1.** (2)

S_2 = S_1 or a, whichever is the smaller

Table 7.10.11 Coefficient C_6

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_6	64	38	25	19	15	12	10	9	8	7

2. The thickness of transverses in double side hull is not to be less than the greatest of either of the value t_1 specified in the following (1), t_2 or t_3 specified in the following (2).

(1) The thickness obtained by the following (a) or (b) according to the type of tankers.

$$t_1 = C_7K\frac{SD'h_s}{d_0-d_1}\left(1-1.75\frac{z}{D'}\right)+1.5 \quad (\mathrm{mm})$$

where :

S = breadth of part supported by transverses (m).

h_s = the value obtained from the following formulae, whichever is the greater. Where, however, for tankers without abnormal loading conditions such as half-loading or alternate loading, specified in **Par 1.** (1) may be used.

$$h_{s1} = (d - d_3) + 0.038L \quad (\mathrm{m})$$
$$h_{s2} = h' \quad (\mathrm{m})$$

d_0 = depth of transverses (m).

d_1 = depth of opening at the point under consideration (m). Where, however, if brackets attached the lower transverses of double side hull are provided, the openings in transverses provided within the range between the top of the inner bottom plating and the inner end of the bracket under consideration may be omitted except when the Society considers it to be necessary.(See **Fig 7.10.2**)

z = distance in the direction of ship's depth between the top of the inner bottom plating or the top of the bilge hopper, if provided, and the point under consideration (m). However, if brackets attached the lower transverses of double side hull are provided, for space between the top of the inner bottom plating and the inner end of the bracket under consideration, z may be calculated as the distance at the inner end of the bracket under consideration. If z exceeds $0.4D'$, z is to be taken as $0.4D'$.(See **Fig 7.10.2**)

C_7 = coefficient obtained from **Table 7.10.12** depending on D'/l_T. For intermediate values of D'/l_T, C_7 is to be obtained by linear interpolation.

D', h', l_T and d_3 are to be in accordance with the requirements of **Par 1** (1).

Table 7.10.12 Coefficient C_7 of the Type C and D tankers

D'/l_T		0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_7	Type C	0.052	0.051	0.049	0.046	0.043	0.041	0.038	0.036	0.034
	Type D	0.034	0.034	0.034	0.034	0.033	0.033	0.032	0.031	0.030

(2) The thickness t_2 or t_3 obtained from the following formulae.

$$t_2 = 8.6\sqrt[3]{\frac{H^2a^2}{C_6K}(t_1 - 1.5)} + 1.5 \quad (\mathrm{mm}), \qquad t_3 = \frac{8.5S_2}{\sqrt{K}} + 1.5 \quad (\mathrm{mm})$$

where :

a = depth of transverses at the point under consideration (m). Where, vertical stiffeners are provided at the half way of the depth of transverses in the direction of the length of transverses, distance from the vertical stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration (m).

t_1 = thickness of transverse calculated under the requirements of (1) (mm).

C_6 and S_2 = as specified in **1.** (2)

H = as specified in **403. 1.** (2)

3. When calculating the thickness of stringers and transverses in double side hull, S in the formulae in **1,** (1) is to be measured, as a standard, as shown in **Fig 7.10.4.** For the hopper plate within the range of l in the **Fig 7.10.4,** the sectional area obtained from the following formula may be included into the effective sectional area of the stringer under consideration. However, if l exceeds the breadth of the hopper plate b_H, l is to be taken as b_H.

$$A_e = 10\Sigma h_i t_i \left(1 - \frac{\theta}{90}\right) \quad (\text{cm}^2)$$

where :

h_i = breadth of hopper plate within l (mm)

t_i = thickness of hopper plate - 2.5 (mm)

θ = angle between side longitudinal girder plate and hopper plate (degree)

405. Girders and transverses in cargo oil tanks and deep tanks

1. Measurement of span l

Measurement of span of girder l is to be as specified in **Fig 7.10.5.**

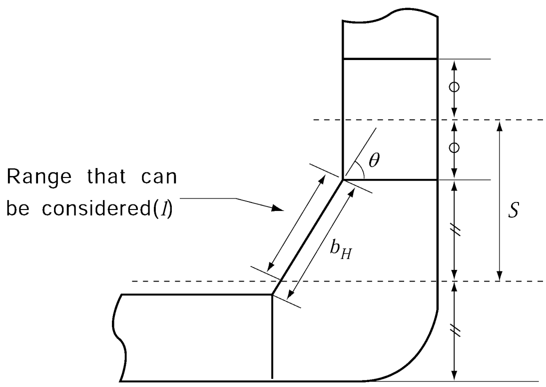


Fig 7.10.4 Measurement of S

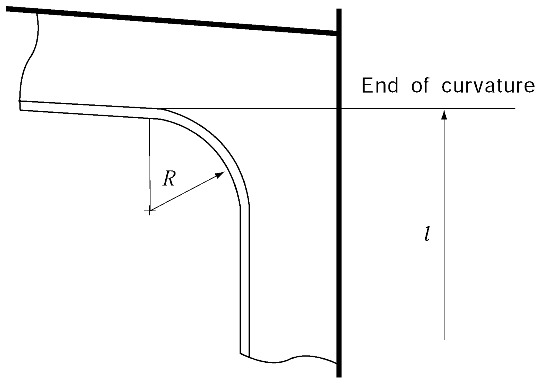


Fig 7.10.5 Measurement of l

2. Transverses on longitudinal bulkhead

(1) Even when large brackets are provided on the opposite side of a longitudinal bulkhead, span l and radius R of transverses are to be measured on the wing tank side in the same manner as in **Par 1.** But, the size of bracket b may be $0.5(b' + b'')$, except when b is to be taken as b' if b'' is smaller than b'. (See **Fig 7.10.6**)

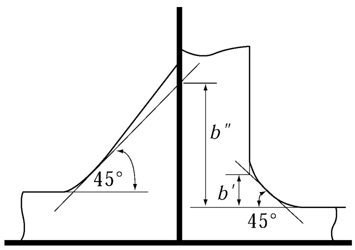


Fig 7.10.6 Measurement of b', b''

(2) In calculating the thickness of web plates in regard to shearing force, the brackets on the opposite side of longitudinal bulkheads may be taken into account.

(3) Girders on corrugated bulkheads are to be of balanced girders. Where balanced girders are not adaptable, the neutral axis is to be brought as close to the bulkhead plating as possible.

Section 5 Structural Details

501. General

Areas represented by mark "○" in **Table 7.10.13** are required to penetrate longitudinal beams and longitudinals.

Table 7.10.13 Required areas of longitudinal beam and longitudinals

Length of Ship (m)	$90 \leq L < 120$	$L \geq 120$
Longitudinal beams and side longitudinals attached to sheer strake	○	○
Side longitudinals and longitudinals on longitudinal bulkhead (except those specified above)	—	○
Bottom longitudinals, inner bottom longitudinals and longitudinals on bilge strake	○	○

503. Girders and cross ties

1. General

(1) The dimensions and locations of lightening holes, where provided, are to be as shown in **Fig 7.10.7.**

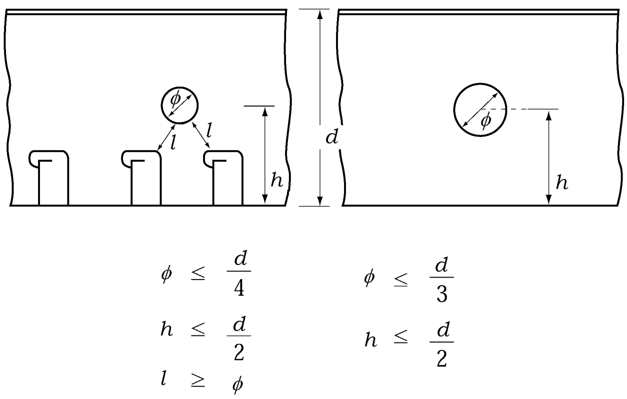


Fig 7.10.7 Locations and dimensions of lightening holes

(2) Slots are to be reinforced with collars where flanges of longitudinals are facing each other or where slots are provided at small intervals as is often the case with bilge part.
(3) In case where the depth of girders is smaller than the required depth, the section modulus of girders is to be obtained by multiplying the Rule-required section modulus by a ratio of the required depth of girder to actual depth.
(4) In pump rooms or void spaces, the thickness of webs may be reduced by 1 mm from the required thickness of webs in cargo oil tanks.
(5) The scantlings of members in segregated ballast tanks in the midship part are to be same as those of members in cargo oil tanks.
(6) In end bracket parts, at connections with cross ties, etc. of transverses where shearing stress and/or compressive stress are expected to be high, additional stiffeners are to be fitted. These

parts are not to have lightening holes. If considered necessary, slots for penetration of longitudinals in these parts are to be reinforced with collars.

(7) The radius of the rounded corner of girder is to be as large as practicable.

(8) Where angle bars are used instead of flat bars as stiffeners of transverses, etc., their section modulus with effective plates is to be approximately equivalent to the required ones.

(9) No scallops are to be permitted in web plates at the connection of face plates on transverses and those of girder plates. Scallops cut out for work convenience are to be filled up by welding. Abrupt change of dimensions is to be avoided carefully. (See **Fig 7.10.8**)

(10)Where longitudinal frames or stiffeners penetrate bottom transverses, side transverses and vertical webs on longitudinal bulkhead, proper reinforcement is to be made in the extents stipulated in **Table 7.10.14,** by fitting brackets on the opposite side of stiffeners on webs of transverse, for connecting longitudinals to transverse, by fitting collars at slots, or by other suitable means. In ships not exceeding 230 m in length, however, the extents of application of such reinforcement may be properly reduced.

Table 7.10.14 Reinforcing range

Member	Reinforcing range
Bottom transverse	All connections
Side transverses	All connections below the upper end of curvature of upper cross tie, or the designed maximum load line, whichever is higher. In ships of 300 m and above in length, it is recommended that similar reinforcement be applied in wider extent upward beyond the limit stipulated above.
Transverses on longitudinal bulkhead	All connections below the upper end R of longitudinal bulkhead curvature of upper cross tie.

(11)Connection of web plates is to be of butt-welding or other type of connection as deemed appropriate by the Society.

2. The intersections of inner bottom plating and bilge hopper

The construction at the intersections of the inner bottom plating and hopper plates is to be as follows:

(1) Where the constructions at the intersection of the inner bottom plating and hopper plates forms a built up construction as specified in **Fig 7.10.9.** It is to comply with following:

(A) Scallops at the above-mentioned intersections in bilge hopper transverses are to be filled up by welding or closed with collar plates. (See **Fig 7.10.9**)

(B) Bilge hopper transverses on the extended line of the inner bottom plating are to be fitted with gusset plates. (See **Fig 7.10.9**)

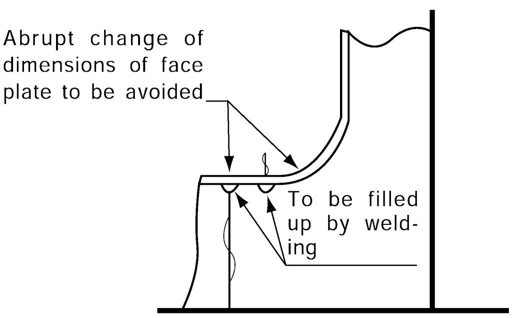


Fig. 7.10.8

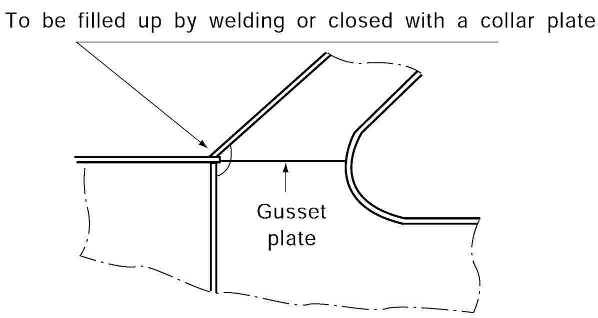


Fig. 7.10.9

(C) Where the spacing of floor plates is 2 m or more, a bracket is to be provided at the mid-length between floor plates. This bracket is to reach the inner bottom longitudinal and the hopper plate longitudinal next to the side girder located at the intersection. (See **Fig 7.10.10**)

(2) Where the constructions at the intersection of the inner bottom plating and hopper plates forms a knuckle construction as specified in **Fig 7.10.11.** The construction at the above mentioned intersection is to be comply with following (A) and/or (B), and (C) in addition to prescribed (1)(C) :

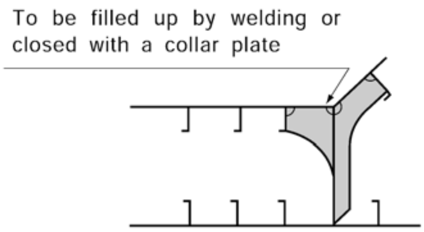


Fig. 7.10.10

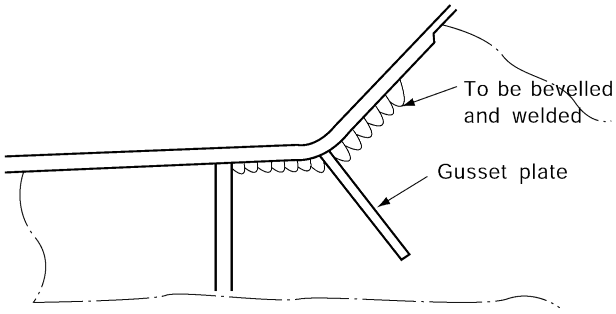


Fig. 7.10.11

(A) Knuckled part is to be bevelled and welded as far as possible.

(B) In areas where brackets are provided, gusset plates are to be attached transverses of bilge hoppers on the extended line of the inner bottom plating. In case where the radius of curvature at the knuckle is large, the number of gusset plates is to be suitably increased.

(C) Stiffeners as shown in **Fig 7.10.10** are to be fitted within 300 mm afore and abaft the bracket.

3. The construction at the intersections of longitudinal bulkheads in double side hull structures and hopper plates is to comply with the requirements prescribed in **Par 2.**

4. Details of end structure of strong brackets

For detailed end structures of end brackets of girders cross tie and transverse is to be standard **Fig 7.10.12.**

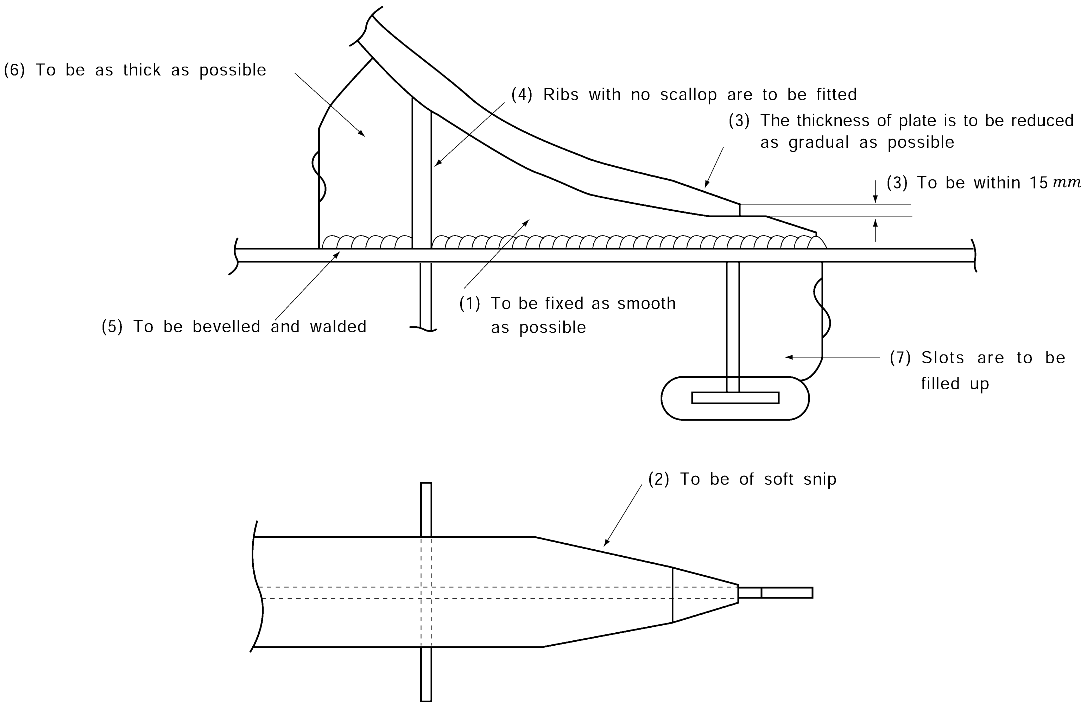


Fig. 7.10.12 Structural details of bracket toe

5. Connection of struts

In the such a construction as shown in **Fig 7.10.13,** brackets, as asterisked, are to be fitted.

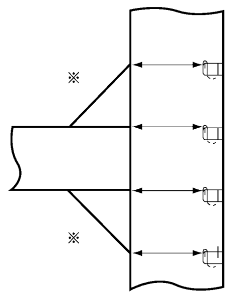


Fig 7.10.13

Section 6 Special Requirements for Corrosion

607. Thickness of inner bottom plating in cargo oil tanks

1. Thickness of inner bottom plating specified in **Par 1.** of the Rules is to comply with following requirement. In the ships engaged in the carriage of crude oil mainly, the thickness t of inner bottom plating is not to be less than obtained from the following formula, except where inner bottom is inclined appropriately;

$$t = 0.026L + 9.0 \quad (\mathrm{mm})$$

2. Thickness increasing range according to **Par 2** of the Rule is to comply with **Fig 7.10.14.** The thickness of range is not to be less than that specified in **607. 2** of the Rule or **Par 1.** adding 2.0 mm, whichever is the greater.

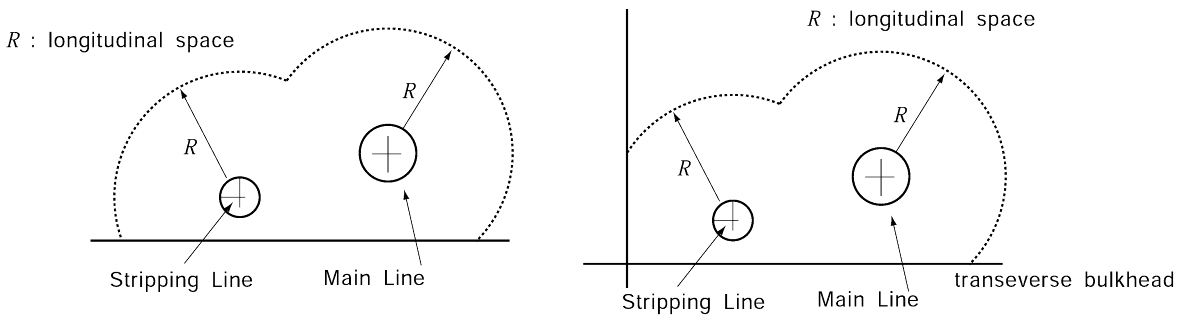


Fig. 7.10.14 Range of strengtened for corrosion of inner bottom

Section 8 Special Requirements for Tankers with Mid-deck

801. Application

1. The structural members of tankers having mid-deck penetrating longitudinally through the cargo areas are to comply with the requirements in **201, 301** and **403.** Values of h_1, h_2 and h_3 are to as specified in **Table 7.10.15.**

Table 7.10.15 Load h_1, h_2 and h_3

Load \ Provision	**201.** of the Rules	**302.** of the Rules	**403.** of the Rules
h_1	Vertical distance form the lower edge of bulkhead plating to the mid-deck(m)	Vertical distance from mid-length of l for vertical stiffeners, and from mid-point between the upper and lower stiffeners for horizontal stiffeners to the mid-deck(m)	Vertical distance from mid-length of S for horizontal girders, and from mid-length of l for vertical girders to the mid-deck (m)
h_2	$0.85(h_1+\Delta h)$ (m), Δh is to be as specified in **Table 7.10.2** of the Rules.	$0.85(h_1+\Delta h)$ (m), Δh is to be as specified in **Table 7.10.2** of the Rules.	$0.85(h_1+\Delta h)$ (m), Δh is to be as specified in **Table 7.10.2** of the Rules.
h_3	0.7 times the vertical distance from the lower edge of bulkhead plating to the top of hatchway multiplied(m)	0.7 times the vertical distance from mid-length of l for vertical stiffeners, and from mid-span of the upper and lower stiffeners for horizontal stiffeners to the top of hatchway(m)	0.7 times the vertical distance from mid-length of S for horizontal girders, and from mid-length of l for vertical girders to the top of hatchway(m)

2. In case where the thickness of a mid-deck plating is counted as the top plating of the lower cargo oil tank, it is not to be less than the thickness obtained form the formula given in **Par 1** using the loads specified in **201.** of the Rules adding 1.0 mm thereto.

Section 9 Special Requirements for Hatchways and Freeing Arrangements

902. Hatchways to cargo oil tanks

1. In case where hatchway covers of glass-fibre reinforced plastics are provided for cargo oil tanks, they are to comply with the **Ch 1, 202. 1.**
2. For the tank cleaning hatch covers, It is to comply with **Ch 1, 202. 2** and **3.**

Section 10 Welding

1002. Fillet welding

In areas where bending, shearing or axial force is particularly significant, the leg length of fillet welds is to be suitably increased or to be bevelled and welded. ⚓

Annex 7-1 Additional Requirements for Oil Tankers Using Crude Oil as a Fuel for Boilers

1. Application

(1) This Annex is apply to the tankers using crude oil or slops as a fuel for main or auxiliary boilers.
(2) Requirements which are not specified in this Annex, may be applied to the related requirements of the Rules for the Classification of Steel Ships.

2. Approval drawings and documents

The approval drawings and documents are to be submitted by the following:

(A) Arrangement
(B) Arrangement of crude oil and slop tank
(C) Piping diagram
(D) Plans and documents specified in **Pt 5, Ch 1, 208** of the Rules
(E) Power and control diagram
(F) Gas instruments and alarm arrangement
(G) Other plans and documents deemed necessary by the Society

3. The crude oil or slops used as a fuel for main or auxiliary boilers.

(1) Crude oil or slops are to be only used as a fuel on the voyage.
(2) Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.
(3) When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

4. Boiler

(1) The whole surface of the boilers shall be gas-tight separated from the engine room. The boilers themselves are to be tested for gas-tightness before being used.
(2) Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 20% of the vessel's beam amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room. In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank.
(3) Boilers shall be fitted with a suitable hood placed in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing, on the other side, air inlet to burner register.
  (A) The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it.
  (B) It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flame wire gauze, easily dismountable for cleaning.
  (C) At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room.
    (a) The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.
    (b) The exhaust fan prime movers shall be placed outside the duct and a gas-tight bulkhead penetration shall be arranged for the shaft.
(4) When using fuel oil for delivery to and return from boilers fuel oil burning units in accordance with **Pt 5, Ch 6, 902** of the Rules shall be fitted in the boiler room. Fuel oil delivery to, and returns from, burners shall be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.
(5) One pilot burner in addition to the normal burning control is required.

(6) The boiler compartments are to be fitted with a mechanical ventilation plant and shall be designed in such a way as to avoid the formation of gas pockets. Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants shall be separated from those for service of other compartments and shall be in accordance with Classification Societies' requirements.
(7) Means are to be provided for the boiler to be automatically purged before firing.

5. Observation tanks

(1) When crude oil is heated by stream or hot water the outlet of the heating coils should be led to a separate observation tank.
(2) The observation tank is to be fitted with a air pipes and the opening end is to be flame screen led to the safe position.

6. Installation of associated components

(1) Pumps, strainers, separators and heaters etc. The whole system of pumps, strainers, separators and heaters, if any, shall be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from engine and boiler room by gas-tight bulkheads.
(2) Electric, internal combustion and steam (when the steam temperature is higher than 220°C) prime movers of pumps, of separators (if any), etc., shall be fitted in the engine room or in another non-dangerous room. Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted by **Pt 7, Ch 1, 1002. 1** (1) (B).

7. Pumps

(1) Pumps shall be fitted with a pressure relief by pass from delivery to suction side
(2) It shall be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.

8. Electrical equipments

Electrical equipments installed in gas dangerous areas is to be applied in **Pt 7, Ch 1, 1103.** of the Rules.

9. Piping systems

(1) The minimum thickness of the piping for crude oil or slops and draining pipes for the tray defined in a (2) are to comply with the **Pt 5, Ch 6, 102. 6** of the Rules.
(2) The piping connections are to be reduced to a minimum. For the piping connections are to be fitted inevitably, it is to comply with the **Pt 5, Ch 6, 104.** of the Rules.
(3) Within the engine room and boiler room these pipes are to be fitted within a metal duct. This duct is to be specified in the following requirement.
  (A) It is to be gas tight and tightly connected to the fore bulkhead separating the pump room and to the tray specified in **4.** (2).
  (B) It is to be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure.
  (C) This duct is to be fitted at a distance from the ship's side of at least 20 % of the vessel's beam amidships.
  (D) It is to be fitted with inspection openings with gas tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.
  (E) A vent pipe is to be fitted at the highest part of the duct and is to be led to the opening a safe position.
  (F) In way of the bulkhead to which the duct is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves should be interlocked with the hood exhaust fans defined in **4.** (5)(C) to ensure that whenever crude oil is circulating the fans are running.
(4) In the piping to supply with oil to boiler manifold, the remote closing means is to be provided.

10. System for monitoring the concentration of hydrocarbon gases

If the concentration of hydrocarbon gases exceeds 30% of the lower flammable limit. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided. Gas detector is to be fitted at the following position at least.

(A) Duct defined in **9.** (3)
(B) Duct defined in **4.** (3)
(C) Near the boiler
(D) All zones where ventilation may be reduced.

11. Fire protection, inert gas generators and steam supply system

(1) Independent of the fire extinguishing plant as required by **Pt 8, Ch 2** and **Ch 3** of the Rules or Korean Ship Safety Act, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in **4.** (2). The emission of extinguishing medium should automatically stop the exhaust fan of the boiler hood specified in **4.** (5)(C).

(2) The duct specified in **9.** (3) is to be permanently connected to an approved inert gas system or steam supply in order to make possible:
(A) In case of fire or leakage
(B) Purging of the duct before carrying out work on the piping in case of leakage.

12. Warning Notice

The following warning notice must be fitted in an easily visible position near the boiler front.

「 **Warning**
When an explosive mixture is signally by the gas detector plant, the watchkeepers are to do as following.
- shut off the remote controlled valves on the crude oil delivery
- return pipes in the pump room,
- inject inert gas into the duct
- turn the boilers to normal running on fuel oil.」 ⚓

Annex 7-2 Guidance for the Container Securing Arrangements

1. Application

(1) This Annex is to be applied to securing system of 20 ft and 40 ft container among standard containers in accordance with the requirements of **ISO 668**. The securing system of other special type or use of containers are to be in accordance with the requirements as deemed appropriate by the Society.
(2) Where the securing system is designed and arranged by other than the requirements of this Annex, it is to be in accordance with the requirements as deemed appropriate by the Society.

2. Type of Securing systems

(1) Containers are to be secured by one, or a combination, of the following systems. Containers secured by the other method are to be in accordance with the requirements as deemed appropriate by the Society.
  (A) Container locking devices
  (B) Rod, wire and chain lashing
  (C) Buttresses, shores or equivalent structural restraint.
  (D) Cell guides
(2) Dunnage is not to be used in associated with approved container securing systems except where forming part of an approved line load stowage specified in **Par 5.** (5)

3. Material and design

(1) Steel used for the construction of the cell guides and for fixed fittings attached to the ship's structure is to comply with the requirements of **Pt 2, Ch 1,** of the Rules or with an equivalent specification acceptable to the Society. Due account is to be taken of the grade and tensile strength of the hull material in way of the attachment and the chemical composition of the steel is to be such as to ensure acceptable qualities of weldability. Where deemed necessary by the Society, tests are to be carried out to establish specific welding procedures.
(2) Where cell guides or other securing arrangements are intended to operate in enclosed spaces at low ambient temperatures, special consideration is to be given to the specification of the steel.
(3) Steel used for loose fittings attached to the containers, and for the lashings and securing devices, is to be of a specification acceptable to the Society.

4. Submission of plans and documents

The following plans and documents are to be submitted for the approval of the Society.

(1) General arrangement plan showing the disposition and design weights of the containers
(2) Arrangement and detail plans of container securing arrangements
(3) Calculations on the strength of container securing arrangement including the following ship parameters
  (A) Moulded draught d_c, vertical centre of gravity (VCG), longitudinal centre of flotation (LCF) and transverse metacentric height(GM)
  (B) Design wind speed
(4) Other plans and documents deemed necessary by the Society.

5. Arrangements for stowage on exposed decks without cell guides

(1) General
  (A) Containers stowed on deck or on hatch covers are generally to be aligned in the longitudinal direction. In case of stowing the transverse direction it is to be in accordance with the requirements as deemed appropriate by the Society.
  (B) Containers are to be stowed so that they do not extend beyond the ship's side.
  (C) Where containers are stowed on hatch covers, the covers are to be effectively restrained against sliding by approved type stoppers or equivalent. Details of the locations of stoppers relative to the supporting structure are to be submitted at as early a stage as possible.
  (D) Stool, pillar and similar structure supporting containers and securing devices are to be of adequate strength for the imposed loads and of sufficient stiffness to minimize any deflection which could lead to reduction in the effectiveness of the securing device.
  (E) In the region forward of $0.25L_{pp}$ abaft the fore perpendicular additional securing devices may be required **8.** (1)(E).

(2) Containers in one tier
The containers are to be secured by one of the following (A) to (B);
(A) Containers are to be secured at their lower corners by approved locking devices.
(B) Alternatively, containers may be secured by lashings fitted diagonally or vertically at both ends of each containers, in association with corner fittings at each container corner.
(3) Containers in two tiers
The containers are to be secured by one of the following (A) to (C);
(A) Containers are to be secured at their lower corners at each tier by approved locking devices.
(B) Where the calculations indicate that separation forces will not occur at any point in the stack, double stacking cones may be fitted at all internal corners of the stack and bridge fittings used to connect the tops of the rows in the transverse direction. Locking devices are to be fitted at all external corners.
(C) Alternatively, containers may be secured by lashings in association with stacking cones or, where the calculations indicate that separation forces may occur, with locking device.
(4) Containers in more than three tiers
(A) Where a three tier of containers is fitted, the containers are to be secured by one of the following (a) to (b);
(a) Containers are to be secured at their lower corners at each tier by approved locking devices.
(b) Alternately containers may be secured by lashings. One or two tiers of lashings may be fitted in association with stacking cones or, where the calculations indicate that separation forces may occur, with locking devices.
(B) Where a fourth tier of containers is fitted, it is generally to be secured to the third tier by locking devices at each corner.
(C) Proposals to stow more than five tiers is to be in accordance with the discretion of the Society.
(5) Line load stowage
(A) Where the containers are supported on bearers placed to distribute the stackweight as uniform line loads, the following requirements are to be complied with;
(a) The stack is, in general, to comprise a maximum of two tiers of loaded containers.
(b) The load from the upper tier is to be transferred through the container corners. Line loading is not to be used between tiers.
(c) The load on each vertical corner post of the bottom tier, calculated in accordance with **Par 9**, is not to exceed one half of the rated load of the container.
(d) Where the calculations indicate that lifting forces may occur, locking devices are to be fitted at the container corners.
(e) The clearance below the bottom container corner casting is to be such that the stacking cone or equivalent cannot be dislodged under shear loading.
(B) Where an approved line load stowage system (A) is installed the securing arrangement notation are to comply with **Pt 1, Ch 1, 201.** of the Rules.
(6) Systems incorporating structural restraint
(A) Containers may be secured by the use of a fixed structure providing permanent buttresses in association with portable frameworks.
(B) The framework or other devices securing the containers are to be aligned with the container corner fittings and any clearance gap is to be kept to the minimum to reduce shifting.

6. Arrangements for under-deck stowage without cell guides

(1) Containers are generally to be stowed in holds longitudinally and the stowing of transverse are to be in accordance with the requirements as deemed appropriate by the Society.
(2) Containers may be secured by locking devices only or by a combination of locking devices, buttresses, shore or lashings. Containers are, in general, to be restrained at every corner at the base of the stack and at all intermediate levels.
(3) Where stacks consist of one or two tiers only, consideration will be given to the omission of corner locking devices. Containers must, however, be secured by a minimum of two corner locking devices.
(4) Where the calculations indicate that separation forces could occur at any particular level, twistlocks or equivalent means of securing are to be fitted at that level. Elsewhere, consideration will be given to the use of double stacking cones.
(5) Where the calculations indicate that separation forces will not occur between containers at any

level, consideration will be given to the use of double stacking cones in lieu of locking devices throughout.

(6) Buttresses are generally to be of the tension and compression type and are to be provided with means of adjustment to ensure tightness when fitted in place.

(7) Shores of compression only type may be permanently attached to the ship structure or they may be hinged or portable. When in place they are to abut on the container corner fittings with minimal clearance. Means are to be provided to prevent slackening of the device.

(8) Adjacent stacks of containers are to be linked in line with buttresses or shores in order to transmit lateral loads. The fittings used for these linkages are to be of adequate strength to transmit the loads imposed.

(9) The ships structure supporting shores and buttresses is to be reinforced as necessary.

7. Arrangements for stowage using cell guides

(1) General

(A) The cell guides are not to form an integral part of the ship's structure. The guide system is generally to be so designed as to keep it free of the main hull stresses.

(B) Cell guides are to be designed to resist loads caused by loading and unloading of the containers, to prevent shifting of the containers and to transmit the loads caused by motions of the ship into the main hull structure.

(2) Arrangement and construction

(A) Cell guides are to have sufficient vertical extent and continuity to provide efficient support to containers. Guide bars are to be effectively attached to the supporting structure to prevent tripping or distortion resulting from container loading.

(B) The intersection between cell guide and cross ties is to provide adequate torsional stability.

(C) Intermediate brackets are to be fitted to vertical cell guides at suitable intervals.(See **Fig 1**)

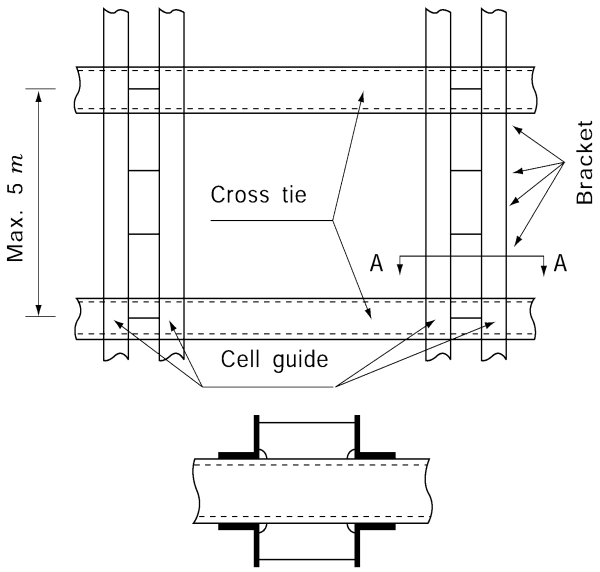


Fig 1 Typical arrangement of cell guides

(D) The cell guides are to give a total clearance between the container and guide bars not exceeding 25 mm in the transverse direction and 40 mm in the longitudinal direction. The deviation of the cell guide bar from its intended line is not generally to exceed 4 mm in the transverse direction and 5 mm in the longitudinal direction.

(3) Cell guide systems in holds

(A) Athwartship cross ties are to be fitted between cell guides at a spacing determined from the loading on the guides but, generally, not more than 5 m part, wherever possible, cross ties are to be arranged in line with the corners of the containers as stowed and are to be supported against fore and aft movement at a minimum of two points across the breadth of the hold. Where, however, the maximum fore and aft deflection in the cross tie can be shown

not to exceed 20 mm, then one support point may be accepted.
(B) Longitudinal tie bars may be required to be fitted where shown necessary by the force calculations for the structure. Where fitted they are to be specified in (A) above.
(C) Where, at the sides or ends of holds, the guide rails are fitted to transverse or longitudinal bulkheads, the bulkhead is to be locally reinforced to resist the additional loads.

(4) Cell guide systems on exposed decks
(A) Analysis methods for the strength of the cell guide structure are to take due account of the interactive effects between guide structure and supporting deck structure and also of the deformation of the hull girder.
(B) At its lower end the guide structure is to be efficiently connected to the deck structure. Cross ties are to be arranged between guides in a transverse direction at a spacing determined by the loading on the guides but in general not more than 3 m apart. Cross bracing members of adequate strength and sufficient number are to be fitted in the transverse and longitudinal directions to prevent excessive deflection of the guide structure.
(C) The height of guide bars above the deck is to be sufficient to ensure adequate restraint to the uppermost container tiers.
(D) Where the cell guide structure is attached to highly stressed hull or deck elements, such as sheer strake, special attention is to be given to the design of the connection and the grade and quality of steel utilized.

(5) Mixed stacks of 20 ft and 40 ft containers
(A) Where the cell guides are arranged for the carriage of 40 ft containers, provision should be made for the installation of temporary intermediate cell guides for 20 ft containers. The permanent structure is to be designed such that it is suitable for either loading pattern.
(B) Alternatively, permanent means for the support of 20 ft containers at the mid-length of a cell arranged for 40 ft containers should be considered. Such means may include the following:
(a) A pillar (inboard) and vertical rest bar (on the longitudinal bulkhead) against which the container stack may rest. The pillar is to be supported laterally by the deck structure over and is to be sufficiently stiff to control lateral deflection of the container stacks.
(b) Guide bars supported transversely by slim structure within the gap between containers and with longitudinal ties as necessary.

Details of proposals will be individually considered, taking into account the loads on the support structure and the resulting deflections.
(C) Where it is desired to stow 20 ft containers in the lower tiers without external support at the mid-bay location, arrangements meeting the following requirements will be considered:
(a) Maximum container weights for 20 ft containers stowed in cell guides with no 40 ft container overstowed, can be derived from **Tables 1** and **3** depending on the transverse acceleration and the number of tiers in the stack.
(b) Maximum container weights for 20 ft containers stowed in cell guides with at least one 40 ft container overstowed, can be derived from **Tables 2** and **4** depending on the transverse acceleration and the number of tiers in the stack.
(c) Where a mixed stack not covered by **Tables 1** to **4** is proposed, two-thirds of the transverse components of forces acting on 20 ft containers are to be assumed to be transmitted to the cell guides and one-third transmitted as a racking force through the unsupported end wall. The container weights are to be such that the racking force on the container end walls does not exceed 15 tonnes at the mid-hold end of the stack of 20 ft containers.
The allowable compressive forces in the container corner posts are not to be exceeded, taking due account of 40 ft containers above as per (5) (C) (e), if applicable. The container weights are to be defined to ensure separation is minimized.
(d) Means are to be provided to prevent transverse sliding of the bottom of the stacks of 20 ft containers at the mid-hold end. This is to be in the form of permanently attached chocks at the inner bottom or equivalent
(e) Stacking cones are to be fitted between each tier of the 20 ft containers to prevent transverse sliding. In addition, where a 40 ft container is required to be stowed above 20 ft containers, stacking cones are to be fitted at the ends of the 40 ft container between the 40 ft container and the 20 ft containers below.
(f) The 20 ft containers are to have steel walls and top (no open frame containers) and are to be of specially strengthened design, where necessary, to correspond to the vertical

compressive load at the cell guide end of the 40 ft containers above.

(g) Where fore and aft tension/pressure approved adapter cones are used to link two 20 ft containers to equate to a 40 ft container, the storage of 40 ft containers above is not required. Special consideration is to be given to the maximum stack weight which is stowed in association with this method of securing. In general, each stack of 20 ft containers is not to exceed 120 tonnes.

Proposals for stowage arrangements other than the above will be individually considered and are to be accompanied by supporting calculations.

Table 1 Maximum container weights of ISO 1496-1:1984 20 ft containers stowed in 40 ft cell guides with no overstow

Lowest tier Transverse acceleration (g)	Maximum container weights (tonnes)					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0.4	24.0	23.5	18.9	14.3	11.0	8.9
0.405	24.0	23.4	18.7	14.2	11.0	8.8
0.41	24.0	23.2	18.5	14.1	10.9	8.8
0.415	24.0	23.0	18.3	14.0	10.8	8.7
0.42	24.0	22.8	18.2	13.9	10.7	8.7
0.425	24.0	22.6	18.0	13.8	10.7	8.6
0.43	24.0	22.4	17.8	13.7	10.6	8.5
0.435	24.0	22.2	17.6	13.6	10.5	8.5
0.44	24.0	22.0	17.5	13.6	10.5	8.4
0.445	24.0	21.8	17.3	13.5	10.4	8.3
0.45	24.0	21.6	17.1	13.4	10.3	8.3
0.455	24.0	21.4	16.9	13.3	10.3	8.2
0.46	24.0	21.2	16.8	13.2	10.2	8.2
0.465	24.0	21.0	16.6	13.1	10.1	8.1
0.47	24.0	20.8	16.4	13.0	10.1	8.0
0.475	24.0	20.6	16.2	12.9	10.0	8.0
0.48	24.0	20.4	16.1	12.8	9.9	7.9
0.485	24.0	20.2	15.9	12.7	9.9	7.8
0.49	24.0	20.0	15.7	12.6	9.8	7.8
0.495	24.0	19.8	15.5	12.5	9.7	7.7
0.5	24.0	19.6	15.4	12.4	9.7	7.7
0.505	24.0	19.4	15.2	12.3	9.6	7.6
0.51	24.0	19.2	15.0	12.3	9.5	7.5
0.515	24.0	19.0	14.9	12.1	9.4	7.5
0.52	24.0	18.8	14.7	12.0	9.4	7.4
0.525	24.0	18.6	14.5	11.8	9.3	7.4
0.53	24.0	18.4	14.3	11.7	9.2	7.3
0.535	24.0	18.2	14.2	11.5	9.2	7.2
0.54	24.0	18.0	14.0	11.4	9.1	7.2
0.545	24.0	17.8	13.8	11.2	9.0	7.1
0.55	24.0	17.6	13.6	11.1	9.0	7.0

Table 2 Maximum container weights of ISO 1496-1:1984 20 ft containers stowed in 40 ft cell guides with overstow

Lowest tier Transverse acceleration (g)	Maximum container weights (tonnes), see Note					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0.4	24.0	24.0	24.0	19.4	16.5	13.7
0.405	24.0	24.0	23.6	19.3	16.4	13.7
0.41	24.0	24.0	23.3	19.1	16.3	13.6
0.415	24.0	24.0	22.9	19.0	16.2	13.5
0.42	24.0	24.0	22.5	18.8	16.1	13.5
0.425	24.0	24.0	22.1	18.7	15.9	13.4
0.43	24.0	24.0	21.8	18.5	15.8	13.3
0.435	24.0	24.0	21.5	18.4	15.7	13.2
0.44	24.0	24.0	21.2	18.2	15.6	13.2
0.445	24.0	24.0	21.0	18.0	15.5	13.1
0.45	24.0	24.0	20.8	17.9	15.4	13.0
0.455	24.0	24.0	20.6	17.7	15.2	13.0
0.46	24.0	24.0	20.5	17.6	15.1	12.9
0.465	24.0	24.0	20.3	17.4	15.0	12.8
0.47	24.0	24.0	20.2	17.3	14.9	12.8
0.475	24.0	24.0	20.1	17.1	14.8	12.7
0.48	24.0	23.9	19.9	17.0	14.7	12.6
0.485	24.0	23.8	19.8	16.8	14.5	12.6
0.49	24.0	23.6	19.6	16.7	14.4	12.5
0.495	24.0	23.4	19.4	16.5	14.3	12.4
0.5	24.0	23.2	19.3	16.4	14.2	12.4
0.505	24.0	23.1	19.1	16.2	14.1	12.3
0.51	24.0	22.9	18.9	16.1	13.9	12.2
0.515	24.0	22.7	18.8	15.9	13.8	12.1
0.52	24.0	22.5	18.6	15.7	13.6	12.0
0.525	24.0	22.4	18.5	15.6	13.5	11.8
0.53	24.0	22.3	18.3	15.4	13.3	11.7
0.535	24.0	22.2	18.2	15.3	13.2	11.6
0.54	24.0	22.1	18.1	15.1	13.0	11.4
0.545	24.0	22.0	18.0	15.0	12.9	11.3
0.55	24.0	21.8	17.9	14.8	12.8	11.2

NOTE
40 ft overstow containers not included in the number of tiers.

Table 3 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with no overstow

Lowest tier Transverse acceleration (g)	Maximum container weights (tonnes)					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0.4	24.0	23.5	18.9	15.6	13.4	11.6
0.405	24.0	23.4	18.7	15.5	13.2	11.5
0.41	24.0	23.2	18.5	15.3	13.1	11.4
0.415	24.0	23.0	18.3	15.2	12.9	11.3
0.42	24.0	22.8	18.2	15.0	12.8	11.1
0.425	24.0	22.6	18.0	14.9	12.7	11.0
0.43	24.0	22.4	17.8	14.7	12.5	10.9
0.435	24.0	22.2	17.6	14.6	12.4	10.8
0.44	24.0	22.0	17.5	14.4	12.3	10.6
0.445	24.0	21.8	17.3	14.3	12.1	10.5
0.45	24.0	21.6	17.1	14.1	12.0	10.4
0.455	24.0	21.4	16.9	14.0	11.8	10.2
0.46	24.0	21.2	16.8	13.8	11.7	10.1
0.465	24.0	21.0	16.6	13.7	11.6	10.0
0.47	24.0	20.8	16.4	13.5	11.4	9.9
0.475	24.0	20.6	16.2	13.4	11.3	9.7
0.48	24.0	20.4	16.1	13.2	11.2	9.6
0.485	24.0	20.2	15.9	13.1	11.0	9.5
0.49	24.0	20.0	15.7	12.9	10.9	9.4
0.495	24.0	19.8	15.5	12.7	10.8	9.2
0.5	24.0	19.6	15.4	12.6	10.6	9.1
0.505	24.0	19.4	15.2	12.4	10.5	9.0
0.51	24.0	19.2	15.0	12.3	10.3	8.8
0.515	24.0	19.0	14.9	12.1	10.2	8.7
0.52	24.0	18.8	14.7	12.0	10.1	8.6
0.525	24.0	18.6	14.5	11.8	9.9	8.5
0.53	24.0	18.4	14.3	11.7	9.8	8.3
0.535	24.0	18.2	14.2	11.5	9.7	8.2
0.54	24.0	18.0	14.0	11.4	9.5	8.1
0.545	24.0	17.8	13.8	11.2	9.4	8.0
0.55	24.0	17.6	13.6	11.1	9.2	7.8

Table 4 Maximum container weights of ISO 1496-1:1990 20 ft containers stowed in 40 ft cell guides with overstow

Lowest tier Transverse acceleration (g)	Maximum container weights (tonnes), see Note					
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers
0.4	24.0	24.0	24.0	19.6	17.1	15.2
0.405	24.0	24.0	23.6	19.4	17.0	15.1
0.41	24.0	24.0	23.3	19.2	16.8	14.9
0.415	24.0	24.0	22.9	19.1	16.7	14.8
0.42	24.0	24.0	22.5	18.9	16.5	14.7
0.425	24.0	24.0	22.1	18.8	16.4	14.5
0.43	24.0	24.0	21.8	18.6	16.2	14.4
0.435	24.0	24.0	21.5	18.4	16.1	14.3
0.44	24.0	24.0	21.2	18.3	15.9	14.1
0.445	24.0	24.0	21.0	18.1	15.8	14.0
0.45	24.0	24.0	20.8	18.0	15.7	13.9
0.455	24.0	24.0	20.6	17.8	15.5	13.7
0.46	24.0	24.0	20.5	17.7	15.4	13.6
0.465	24.0	24.0	20.3	17.5	15.2	13.5
0.47	24.0	24.0	20.2	17.3	15.1	13.3
0.475	24.0	24.0	20.1	17.2	14.9	13.2
0.48	24.0	23.9	19.9	17.0	14.8	13.1
0.485	24.0	23.8	19.8	16.9	14.6	12.9
0.49	24.0	23.6	19.6	16.7	14.5	12.8
0.495	24.0	23.4	19.4	16.5	14.3	12.7
0.5	24.0	23.2	19.3	16.4	14.2	12.5
0.505	24.0	23.1	19.1	16.2	14.1	12.4
0.51	24.0	22.9	18.9	16.1	13.9	12.2
0.515	24.0	22.7	18.8	15.9	13.8	12.1
0.52	24.0	22.5	18.6	15.7	13.6	12.0
0.525	24.0	22.4	18.5	15.6	13.5	11.8
0.53	24.0	22.3	18.3	15.4	13.3	11.7
0.535	24.0	22.2	18.2	15.3	13.2	11.6
0.54	24.0	22.1	18.1	15.1	13.0	11.4
0.545	24.0	22.0	18.0	15.0	12.9	11.3
0.55	24.0	21.8	17.9	14.8	12.8	11.2

NOTE
40 ft overstow containers not included in the number of tiers.

8. Determination and application of forces

(1) Determination of forces

(A) The forces action in the securing system are to be determined for each loading condition and associated set of motions of the ship.

(B) The following forces are to be taken into account:

(a) Static gravity forces
(b) Inertial forces generated by accelerations due to ship motions
(c) Wind forces
(d) Forces imposed by the securing arrangements
(e) Wave impact forces

(C) Where ship response data is not available, the value for roll, pitch and heave as given **Table 5** will be used for the calculation.

Table 5 Ship motions

Motion	Maximum single amplitude	Periods (sec)
Roll	$\phi = \sin^{-1}\theta^\circ$ but need not exceed 30° and is not to be taken less than 22° where $\theta = \sin\phi$ $= (0.45 + 0.1\frac{L}{B})(0.54 - \frac{L}{1270})$	$T_r = \frac{0.7B}{\sqrt{GM}}$
Pitch	$\psi = 12e^{-0.0033L}$, max 8°	$T_p = 0.5\sqrt{L_{pp}}$
Heave	$L_{pp}/80\,\mathrm{m}$	$T_h = 0.5\sqrt{L_{pp}}$
e = base of natural logarithm (2.7183) GM = transverse metacentric height when containers loaded.		

(D) Wind forces are generally to be based on a maximum wind speed of 40 m/s, acting on the outest container stack.

(E) The strength of the securing arrangements in the forward $0.25L_{pp}$ are to be suitable for forces increased by 20 % above the values calculated form these requirements, except where it can be shown that the containers are adequately protected by breakwaters or similar structure.

(F) The force acting on the container is the vectorial summation of the individual directional components of all forces acting at a given instant.

(2) Components of forces

(A) The individual components of forces due to gravity, wind and ship motion acting on a particular condition are to be determined in accordance with **Fig 2** and **Table 6**.

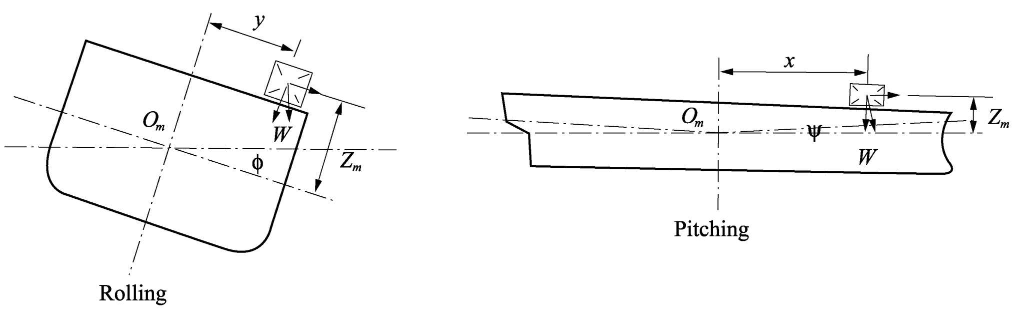


Fig 2 Diagrammatic representation of motion

Table 6 Components of forces

<table>
<tr><th colspan="2" rowspan="3">Source</th><th colspan="3">Component of forces (ton)</th></tr>
<tr><th rowspan="2">Vertical</th><th colspan="2">parallel</th></tr>
<tr><th>transverse</th><th>longitudinal</th></tr>
<tr><td rowspan="3">static</td><td>roll</td><td>$W\cos\phi$</td><td>$W\sin\phi$</td><td>-</td></tr>
<tr><td>pitch</td><td>$W\cos\psi$</td><td>-</td><td>$W\sin\psi$</td></tr>
<tr><td>combined</td><td>$W\cos(0.71\phi)\cos(0.71\psi)$</td><td>$W\sin(0.71\phi)$</td><td>$W\sin(0.71\psi)$</td></tr>
<tr><td rowspan="2">dynamic</td><td>roll</td><td>$0.07024\,W\frac{\phi}{T_r^2}y$</td><td>$0.07024\,W\frac{\phi}{T_r^2}Z_m$</td><td>-</td></tr>
<tr><td>pitch</td><td>$0.07024\,W\frac{\psi}{T_p^2}x$</td><td>-</td><td>$0.07024\,W\frac{\psi}{T_p^2}Z_m$</td></tr>
<tr><td rowspan="2">heave</td><td>roll</td><td>$0.05\,W\frac{L_{pp}}{T_h^2}\cos\phi$</td><td>$0.05\,W\frac{L_{pp}}{T_h^2}\sin\phi$</td><td>-</td></tr>
<tr><td>pitch</td><td>$0.05\,W\frac{L_{pp}}{T_h^2}\cos\psi$</td><td>-</td><td>$0.05\,W\frac{L_{pp}}{T_h^2}\sin\psi$</td></tr>
<tr><td colspan="2">wind</td><td>-</td><td>$8.25AV^2\cos\phi\times10^{-5}$</td><td>-</td></tr>
</table>

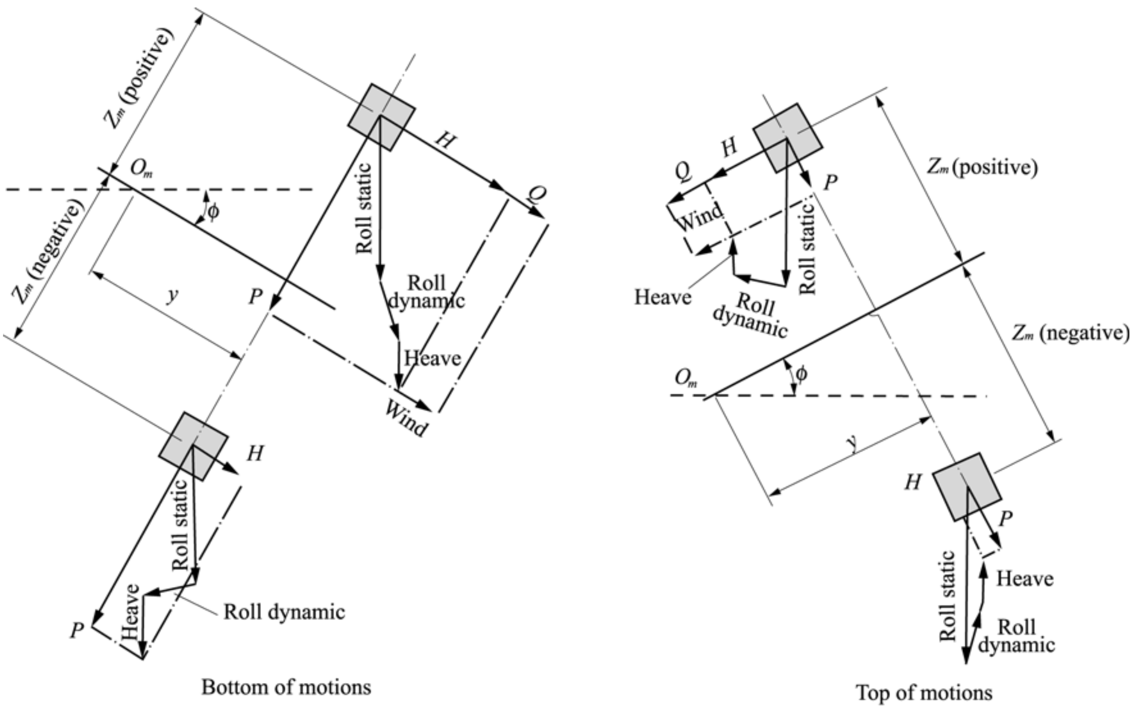


Fig 3 Components of forces on one container (rolling condition)

(B) The summation of the individual components of force for one container above and below the center of motion is shown for the rolling condition in **Fig 3**, and the resultants are obtained from the following expressions ;

(a) Bottom of motions
$$P_{\max} = W\left[\left(1+\frac{0.05L_{pp}}{T_h^2}\right)\cos\phi+\frac{0.07024\phi}{T_r^2}y\right]$$
$$H_{\max} = W\left[\left(1+\frac{0.05L_{pp}}{T_h^2}\right)\sin\phi+\frac{0.07024\phi}{T_r^2}Z_m\right]$$

(b) Top of motions

$$P_{\min} = W\left[\left(1 - \frac{0.05L_{pp}}{T_h^2}\right)\cos\phi - \frac{0.07024\phi}{T_r^2}y\right]$$

$$H_{\min} = W\left[\left(1 - \frac{0.05L_{pp}}{T_h^2}\right)\sin\phi + \frac{0.07024\phi}{T_r^2}Z_m\right]$$

(3) Application of design load

(A) The resultant forces derived for each container in the stack in accordance with (1) are assumed to be divided equally between the walls of the container as follows:

(a) The sliding force in one transverse end is to be 0.5 times of transverse sliding force acting on containers.

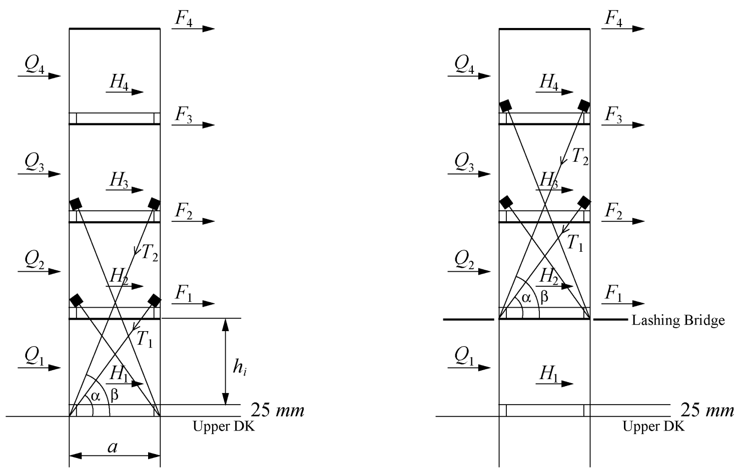
(b) The sliding force in one longitudinal side is to be 0.5 times of longitudinal sliding force acting on containers.

(c) The vertical force in each corner post is to be 0.25 times of sliding force acting on containers.

(d) The wind force in one transverse end is to be 0.5 times of wind force acting on containers.

(B) The sliding forces are taken to act at a mean height one third the height of the container above its base. That is, the force may be distributed as to 1/3 acting at the top of the container and 2/3 acting at the bottom.

(C) Wind force is divided equally between the top and bottom of the container.



Non-lashing bridge type   Lashing bridge type

$$F_4 = \frac{H_4}{3} + \frac{Q_4}{2}$$

$$F_3 = \frac{2H_4}{3} + \frac{H_3}{3} + \frac{Q_4 + Q_3}{2}$$

$$F_2 = \frac{2H_3}{3} + \frac{H_2}{3} + \frac{Q_3 + Q_2}{2}$$

$$F_1 = \frac{2H_2}{3} + \frac{H_1}{3} + \frac{Q_2 + Q_1}{2}$$

$$F_0 = \frac{2H_1}{3} + \frac{Q_1}{2}$$

Fig 4 Forces in four tier stack (rolling condition)

(4) Forces calculation

(A) Non-lashing bridge type

(a) Tension in the lashings

$$T_1 = \frac{1}{\cos\alpha}\left\{\frac{\sum_{i=2}^{n} F_i K_c K_{L2}}{K_{L2}(K_{L1}+K_c)+2K_c K_{L1}+K_c^2} + \frac{F_1 K_c (K_{L2}+K_c)}{K_{L1}K_C + (K_{L1}+K_c)(K_{L2}+K_c)}\right\}$$

$$T_2 = \frac{1}{\cos\beta}\left\{\frac{\sum_{i=2}^{n} F_i (2K_c K_{L1}+K_c^2)}{K_{L2}(K_{L1}+K_c)+2K_c K_{L1}+K_c^2} + \frac{F_1 K_{L1} K_c}{K_{L1}K_C + (K_{L1}+K_c)(K_{L2}+K_c)}\right\}$$

where

K_c = container spring constant from **Table 3**, in mm/ton

$K_{L1} = \dfrac{l_1}{A_1 E_1 \cos^2\alpha}$ (mm/ton) , $K_{L2} = \dfrac{l_2}{A_2 E_2 \cos^2\beta}$ (mm/ton)

l_1, l_2 = effective length of lashing assembly (mm)

A_1, A_2 = cross section area of lashing (mm^2) (When paired lashings are used, a cross-sectional area equal to 150 per cent of the cross-sectional area of one lashing is to be used unless an equalizing system is fitted. If an equalizing system is fitted, the sum of the cross-sectional area is to be used.)

E_1, E_2 = effective modulus of elasticity of lashing ($\mathrm{ton/mm^2}$)
(steel rod : 9.8 $\mathrm{ton/mm^2}$, steel wire : 9.0 $\mathrm{ton/mm^2}$, steel chain : 8.0 $\mathrm{ton/mm^2}$)

(b) Racking force, per end wall : $RF_i = \sum_1^i F_i$

Tier 4 : $RF_4 = F_4$

Tier 3 : $RF_3 = F_4 + F_3$

Tier 2 : $RF_2 = F_4 + F_3 + F_2 - T_2 \cos\beta$

Tier 1 : $RF_1 = F_4 + F_3 + F_2 + F_1 - T_2 \cos\beta - T_1 \cos\alpha$

(c) Shear force, per corner : $SF_i = 0.55 \sum_1^i (H_i + Q_i)$

Tier 4 : $SF_4 = 0.55(H_4 + Q_4)$

Tier 3 : $SF_3 = 0.55(H_4 + H_3 + Q_4 + Q_3)$

Tier 2 : $SF_2 = 0.55(H_4 + H_3 + H_2 + Q_4 + Q_3 + Q_2 - T_2 \cos\beta)$

Tier 1 : $SF_1 = 0.55(H_4 + H_3 + H_2 + H_1 + Q_4 + Q_3 + Q_2 + Q_1 - T_2 \cos\beta - T_1 \cos\alpha)$

(d) Maximum compressive force per bottom corner : $AF_i = P_i + R_i$

Tier 4 : $AF_4 = P_4 + \dfrac{F_4 h_4}{a}$

Tier 3 : $AF_3 = P_4 + P_3 + \dfrac{F_4(h_4 + h_3)}{a} + \dfrac{F_3 h_3}{a} + T_2 \cos(90^\circ - \beta)$

Tier 2 : $AF_2 = P_4 + P_3 + P_2 + \dfrac{F_4(h_4 + h_3 + h_2)}{a} + \dfrac{F_3(h_3 + h_2)}{a} + \dfrac{F_2 h_2}{a}$
$+ T_2 \cos(90^\circ - \beta) + T_1 \cos(90^\circ - \alpha) - \dfrac{T_2 \cos\beta\, h_2}{a}$

Tier 1 : $AF_1 = P_4 + P_3 + P_2 + P_1 + \dfrac{F_4(h_4 + h_3 + h_2 + h_1)}{a} + \dfrac{F_3(h_3 + h_2 + h_1)}{a} + \dfrac{F_2(h_2 + h_1)}{a}$
$+ \dfrac{F_1 h_1}{a} + T_2 \cos(90^\circ - \beta) + T_1 \cos(90^\circ - a) - \dfrac{T_2 \cos\beta (h_2 + h_1)}{a} - \dfrac{T_1 \cos\alpha\, h_1}{a}$

(e) Minimum compressive force per bottom corner : $BF_i = P_i - R_i$

Tier 4 : $BF_4 = P_4 - \dfrac{F_4 h_4}{a}$

Tier 3 : $BF_3 = P_4 + P_3 - \dfrac{F_4(h_4 + h_3)}{a} - \dfrac{F_3 h_3}{a}$

Tier 2 : $BF_2 = P_4 + P_3 + P_2 - \dfrac{F_4(h_4 + h_3 + h_2)}{a} - \dfrac{F_3(h_3 + h_2)}{a} - \dfrac{F_2 h_2}{a} + \dfrac{T_2 \cos\beta\, h_2}{a}$

Tier 1 : $BF_1 = P_4 + P_3 + P_2 + P_1 - \dfrac{F_4(h_4 + h_3 + h_2 + h_1)}{a} - \dfrac{F_3(h_3 + h_2 + h_1)}{a} - \dfrac{F_2(h_2 + h_1)}{a}$
$- \dfrac{F_1 h_1}{a} + \dfrac{T_2 \cos\beta (h_2 + h_1)}{a} + \dfrac{T_1 \cos\alpha\, h_1}{a}$

(B) Lashing bridge type

(a) Tension in the lashings

$$T_1 = \frac{1}{\cos\alpha}\left\{\frac{2K_c\sum_{i=2}^{n}F_i + K_cF_1}{(K_{L1}+2K_c)}\right\} - \frac{2K_c}{(K_{L1}+2K_c)}\left\{\frac{2K_{L1}K_c\sum_{i=1}^{n}F_i + F_1K_{L1}K_c + K_c(K_{L1}+2K_c)\sum_{i=3}^{n}F_i}{K_{L2}(K_{L1}+2K_c)+3K_{L1}K_c+2K_c^2}\right\}$$

$$T_2 = \frac{1}{\cos\beta}\left\{\frac{2K_{L1}K_c\sum_{i=2}^{n}F_i + F_1K_{L1}K_c + K_c(K_{L1}+2K_c)\sum_{i=3}^{n}F_i}{K_{L2}(K_{L1}+2K_c)+3K_{L1}K_c+2K_c^2}\right\}$$

where,

K_c = container spring constant from **Table 7** $(\mathrm{mm/ton})$

$K_{L1} = \dfrac{l_1}{A_1E_1\cos^2\alpha}$ $(\mathrm{mm/ton})$, $K_{L2} = \dfrac{l_2}{A_2E_2\cos^2\beta}$ $(\mathrm{mm/ton})$

l_1, l_2 = effective length of lashing assembly, (mm)

A_1, A_2 = cross section area of lashing $(\mathrm{mm^2})$ (When paired lashings are used, a cross-sectional area equal to 150 per cent of the cross-sectional area of one lashing is to be used unless an equalizing system is fitted. If an equalizing system is fitted, the sum of the cross-sectional area is to be used.)

E_1, E_2 = effective modulus of elasticity of lashing $(\mathrm{ton/mm^2})$
(steel rod:9.8 $\mathrm{ton/mm^2}$, steel wire:9.0 $\mathrm{ton/mm^2}$, steel chain:8.0 $\mathrm{ton/mm^2}$)

(b) Racking force, per end wall : $RF_i = \sum_{1}^{i} F_i$

Tier 4 : $RF_4 = F_4$

Tier 3 : $RF_3 = F_4 + F_3 - T_2\cos\beta$

Tier 2 : $RF_2 = F_4 + F_3 + F_2 - T_2\cos\beta - T_1\cos\alpha$

Tier 1 : $RF_1 = F_4 + F_3 + F_2 + F_1 - T_2\cos\beta - T_1\cos\alpha$

(c) Shear force, per corner : $SF_i = 0.55\sum_{1}^{i}(H_i + Q_i)$

Tier 4 : $SF_4 = 0.55(H_4 + Q_4)$

Tier 3 : $SF_3 = 0.55(H_4 + H_3 + Q_4 + Q_3 - T_2\cos\beta)$

Tier 2 : $SF_2 = 0.55(H_4 + H_3 + H_2 + Q_4 + Q_3 + Q_2 - T_2\cos\beta - T_1\cos\alpha)$

Tier 1 : $SF_1 = 0.55(H_4 + H_3 + H_2 + H_1 + Q_4 + Q_3 + Q_2 + Q_1 - T_2\cos\beta - T_1\cos\alpha)$

(d) Maximum compressive force per bottom corner : $AF_i = P_i + R_i$

Tier 4 : $AF_4 = P_4 + \dfrac{F_4h_4}{a} + T_2(90^\circ - \beta)$

Tier 3 : $AF_3 = P_4 + P_3 + \dfrac{F_4(h_4+h_3)}{a} + \dfrac{F_3h_3}{a} + T_2\cos(90^\circ - \beta) + T_1\cos(90^\circ - \alpha)$

Tier 2 : $AF_2 = P_4 + P_3 + P_2 + \dfrac{F_4(h_4+h_3+h_2)}{a} + \dfrac{F_3(h_3+h_2)}{a} + \dfrac{F_2h_2}{a} + T_2\cos(90^\circ - \beta)$
$+ T_1\cos(90^\circ - \alpha) - \dfrac{T_2\cos\beta(h_3+h_2)}{a} - \dfrac{T_1\cos\alpha\, h_2}{a}$

Tier 1 : $AF_1 = P_4 + P_3 + P_2 + P_1 + \dfrac{F_4(h_4+h_3+h_2+h_1)}{a} + \dfrac{F_3(h_3+h_2+h_1)}{a} + \dfrac{F_2(h_2+h_1)}{a}$
$+ \dfrac{F_1h_1}{a} + T_2\cos(90^\circ - \beta) + T_1\cos(90^\circ - \alpha) - \dfrac{T_2\cos\beta(h_3+h_2+h_1)}{a}$
$- \dfrac{T_1\cos\alpha(h_2+h_1)}{a}$

(e) Minimum compressive force per bottom corner: $BF_i = P_i - R_i$

Tier 4: $BF_4 = P_4 - \frac{F_4 h_4}{a}$

Tier 3: $BF_3 = P_4 + P_3 - \frac{F_4(h_4+h_3)}{a} - \frac{F_3 h_3}{a} + \frac{T_2 \cos\beta h_3}{a}$

Tier 2: $BF_2 = P_4 + P_3 + P_2 - \frac{F_4(h_4+h_3+h_2)}{a} - \frac{F_3(h_3+h_2)}{a} - \frac{F_2 h_2}{a}$

$+ \frac{T_2 \cos\beta (h_3+h_2)}{a} + \frac{T_1 \cos\alpha h_2}{a}$

Tier 1: $BF_1 = P_4 + P_3 + P_2 + P_1 - \frac{F_4(h_4+h_3+h_2+h_1)}{a} - \frac{F_3(h_3+h_2+h_1)}{a}$

$- \frac{F_2(h_2+h_1)}{a} - \frac{F_1 h_1}{a} + \frac{T_2 \cos\beta (h_3+h_3+h_1)}{a} + \frac{T_1 \cos\alpha (h_2+h_1)}{a}$

Table 7 Spring constant for containers

Height of container (m)	Spring constant (mm/ton)		
	Door End	Closed End	Side Wall
2.438	2.70	0.60	1.65
2.591	2.85	0.65	1.75
2.743	3.00	0.70	1.85
2.896	3.15	0.75	1.95

9. Allowable loads and allowable stresses

(1) Allowable forces on the securing system.
Where the container stack is to be secured by stack cone or locking device at the base of the stack and at levels by without lashing system, the load acting on stack cone or locking device specified in **Par 8.** is to be less than the allowable force approved of securing system.

(2) Allowable stress of cell guide
Cell guides systems on deck or in the container cargo hold are to be designed so that the following stress levels are not exceeded in the structure when loaded by forces from the containers calculated in accordance with **Par 8.**

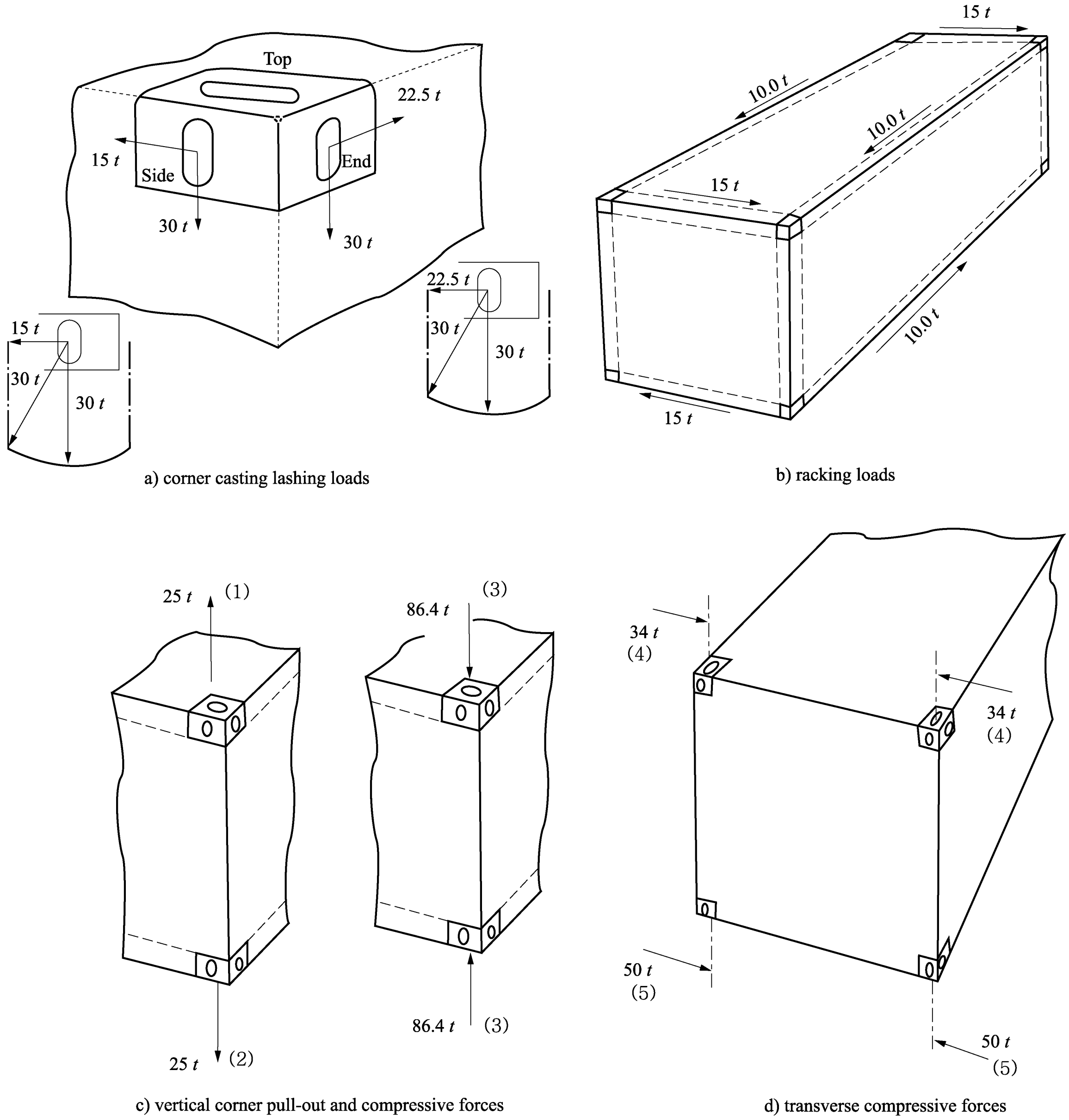
Vertical stress(Bending stress + axial stress) = $0.67\sigma_0$

Shear stress = $0.4\sigma_0$

σ_0 = the yield stress of the material in specified in **Pt 2, Ch 1, Table 2.1.8** of the Rule

(3) Allowable force of lashing
Where the stack is secured by lashing system, the tension acting on lashing system calculated in accordance with **Par 8.** is to be less than safety working load.

(4) Allowable forces on containers
(A) The securing arrangement are to be designed so that force acting on container calculated in accordance with **Par 8.** do not exceed the allowable forces as **Fig 5.**
(B) Where a buttress supports the stack at an intermediate level the total transverse force in the containers at the level is to be the sum of the allowable force of top and bottom.
(C) Where the allowable force of containers used higher strength steels are to be in accordance with the requirements as deemed appropriate by the Society. ⚓



※ These values are to be applied to all kinds of container. But value of ( ) means allowable load of containers suitable for ISO 1496-1:1984

(1) : 15 t
(2) : 20 t
(3) : 20 ft is 45 t, 40 ft is 67.5 t
(4) : 20 ft is 22.5 t
(5) : 20 ft is 35 t

Fig 5 Allowable forces (ISO 1496-1:1990)

Annex 7-3 Guidance for Cargo Ferries and Passenger Ferries

1. Application

(1) This Annex is applied to the cargo ferries and passenger ferries (hereinafter as referred to as "ferries") having a restricted to domestic service. And ferries constructed with material other than steel may be applied. However, ferries constructed in compliance with the related International Convention are regarded as complying with this Annex.
(2) This Annex is not applied to Pure Car Carries and General Cargo Ship which is designed and constructed for the carriage of vehicles in the cargo holds.
(3) For the requirements not mentioned in this Annex, they are to be comply with related requirements on Rules and Guidance.

2. Definition

(1) "Cargo ferry" means that a ship which is operating in regular route and carrying vehicles through the vehicle door (bow door, inner door, side door, ramp formed the hull structures).
(2) "Passenger ferry" means that the cargo ferry of carrying passengers not less than 13 persons in addition to vehicles.
(3) "Vehicle area" means the vehicle loading area providing the vehicle door.
(4) "Vehicle deck" means the deck providing passageway of vehicles or vehicle loading deck providing in vehicle area.
(5) "Open space" means the followings:
(A) The bulkhead is not provided at the end of fore and after, and openings are not provided on the shell plating of vehicle area. In this case, the area of openings on the upper deck of considering area is to be comply with the followings.

$$\frac{a}{A} \geq \frac{1}{2}$$

a = area of opening on the upper deck
A = area of vehicle deck

(B) When the openings are provided on the both side shell plating in vehicle area, the area of opening is comply with the following.

$$\frac{a}{A} + \frac{5}{3}\frac{S_a}{S_A} \geq \frac{1}{2}$$

a, A = as specified in (A)
S_a = area of opening on one side in vehicle area.
S_A = area of shell plating on one side in vehicle area.

(6) "Closed space" means closed space with weathertight other than above mentioned (5)

3. Submission of plans and documentations

For the ferries intended to register to this Society, the following plans and documentations are to be submitted to the Society in addition to plans and documentations described in **Pt 3, Ch 1, 301, 302, Pt 5, Ch 1, Sec 3, Pt 6, Ch 1, 102** and **Pt 8, Ch 1. 102** of the Rules prior to keel laid.
(A) Data which is able to be conformed the foreordinated route of ferry, (for examples; conviction certificate of Owner or provisional Approvals for operation issued by the Authority).
(B) Vehicle arrangement.
(C) Vehicle securing arrangement and details
(D) Vehicle door construction profile, details, opening equipment, closing equipment and description.

4. Arrangement of hull

(1) Forecastle
Forecastle is to be provided to the car ferries engaged in coastal service and it's over (For the

ship having a port of call in middle of operation, a port of call as regarded as departure port and arrival port.) However, when the operating time is not much than one hour, forecastle may not be provided.

(2) Fore peak bulkhead
For the ship which is able to take a both ahead and stern direction with proceeding direction, bulkheads having equivalent ability to fore peak bulkhead described in **Pt 3, Ch 14** are to be provided to both fore and after peak.

5. Vehicle deck

(1) Strength
Strength of vehicle deck is to be in accordance with **Pt. 7, Ch 7, Sec 3.**

(2) Exposed vehicle deck
(A) Bulwarks are to be provided to exposed vehicle deck. At the fore end part, height of bulwarks is to be appropriately increased.
(B) Freeing ports complying with **Pt 4, Ch 4, Sec 2.** of the Rules are to be provided in bulwark and overboard discharges complying with **Pt 5, Ch 6, Sec 3** of the Rules are to be provided on deck.

(3) Closed vehicle deck
Discharging equipments complying with **Pt 5, Ch 6, Sec 3** of the Rules are to be provided and they are not to be directly crossed through the engine room.

6. Vehicle area

(1) Construction
(A) Vehicle area for the car ferries engaged in coastal service and it's over is to be constructed with weather tightness. However, for the car ferries which are navigate to be less than one hour with their maximum speed in coastal area over fresh water area, they may not be constructed with weather tightness or for the car ferries having vehicle deck, which is located in upper deck upward to freeboard deck, is located in backward to fore peak bulkhead and having a vertical height between load line and considered vehicle area of 2 times higher than that of standard superstructure specified in the "Ship's Load Line" of Korean Ship Safety Act, it also may not be constructed with weather tightness.
(B) In closed vehicle area, for the fore castle having a length over than $0.25L_f$, inside door constructed with weather tightness formed as a part of bulkhead at the position of bulkhead is to be provided.

(2) Doors provided in closed vehicle area
(A) All doors passing to vehicle area may be automatically closed type which is made for steel and those may be opened from inside and outside.
(B) The height of doorsill for access door and coaming of opening which may be access through the under of freeboard deck from vehicle area is to be not less than 230 mm and access door and coaming of opening which may be access through machinery room is to be not less than 380 mm.
(C) Above (A) and (B) are not to be applied to the ferries engaging in smooth sea area.

(3) Passenger's room
(A) Passenger's room is not to be provided under the vehicle area.
(B) When the passenger's room is provided on the same deck, they are to be divided with bulkhead.

(4) Evacuation equipment
For the cargo ferries and passenger ferries, evacuation equipment is to comply with **Pt 8, Ch 4, Sec 2** of the Rules.

(5) Ventilation
(A) For the closed vehicle area, sufficient ventilation system is to be provided and it is to be exhausting type except when the prevention of inflow the gases from vehicle area is provided to machinery space, accommodation and service space, it is to be complied with the followings.
(a) It is to be independent from the other ventilation systems.
(b) It is able to ventilate the air of 10 times amount of closed vehicle area capacity (for the cargo ferries, 6 times when deemed appropriate by the Society).
(c) It is to be controlled in external space
(d) In addition to (a) to (c), it is also complied with **Pt 8, Ch 5, 302. 1.** (2) (C), **2.** and **4.**

(B) Sufficient ventilation by the suction type ventilation system(it is able to be sucked with fresh air of outside) is to be accomplished for the machinery, accommodation and service space located under the vehicle deck.

(6) Vehicle load method and load device

(A) Vehicles are to be loaded toward the direction of bow and stern.

(B) Vehicles are not to be loaded forward the fore peak bulkhead.

(C) For the ferries, when the lamp or inside door is not provided in location of fore peak bulkhead the warning mark "Vehicles may not be loaded forward the fore peak bulkhead" is to be provided.

(D) The space between loaded vehicles is not to be less than 600 mm.

(E) In the vehicle area, the protection is to be provided for the access prohibition within 1 m near the access door, stairway and fire extinguishing arrangements.

(F) On the vehicle deck of ferries engaging over coastal area, girders which are not less than 120 mm height between the row of vehicle are to be provided for the prevention of moving of transverse direction with the 2/3 length of deck. However, on the vehicle deck, when the non-slipped paint or other methods approved by this Society, it may be abbreviated. The non-slipped paint or other methods have a friction factor 0.7 and over and are to be assured that they have a sufficient strength of inner pressure and durability.

(G) On the vehicle deck, securing arrangements for the securing of vehicles are to be provided and they are to be ensure the load by the movements of ship which is described in the **Table 1.** For the ferries which is only engaged in smooth sea area and having not more than 30 min of navigating time, if they have a sufficient treatments for non-slip as keys with smooth sea condition, vehicles may not be secured.

Table 1 Ship motion

Classification \ Item	Rolling		Pitching		Safety factor
	degree	cycle	degree	cycle	
Ferries engaging over coastal area	20°	cycle of ship	5°	5 sec	4 over
Ferries that voyaged time is less one hour or smooth water area	10°				

(Note)
1. KG' is the value obtained from the following formula.

$$KG' = 0.5(KG + KB)$$

KG = the vertical position of the centric of the ship
KB = the vertical position of the buoyancy centric of the ship
2. The centric of pitching is to be longitudinal position of the centric of the ship.

(7) Cargo loading other than vehicles

In the vehicle area, unless it is approved by the Society, no cargoes other than vehicles may be loaded. For the cargoes loading other than vehicles, the documents for the closure and loading arrangements by the kinds of cargoes are to be submitted and approved by this Society.

(8) Indication in vehicle area

In the vehicle area, the passageway for the using of access door, stairway, life saving appliances or fire extinguishing appliances is to be provided. This passageway is to be discriminated boundary line with easily visible color.

7. Wagon door

(1) General

(A) Bow and stern door, inner door, side door and ramp of all ferries are to be provided in the upper freeboard deck.

(B) For the ferries engaged in coastal area and over, bow and stern door and side door is to be weather tightness. However, when the inner door or ramp with weather tightness is provided inside of bow door, closure of bow door may be properly considered.

(C) For the ferries having bow door, the structure and arrangement of lamp and inner door is to be in accordance with **Pt 3, Ch 14, 201** and **205** of the Rules.

(D) The strength of bow and stern door, inner door, side door and ramp are to be comply with **Pt 4, Ch 3.** and have a strength larger than that of near members. Near parts of side door is to be properly compensated.

(2) Strength of lamp

The strength of ramp is to be not less than that of deck where ramp is provided and it is to be complied with the followings. When the stern and inner door are used for ramp, the followings are to be satisfied.

(A) The thickness of deck to ramp t is not to be less than the value obtained from the following formula.

$$t = (C_1 + C_2 S)\sqrt{P} + 1.5 \quad (\mathrm{mm})$$

S = the spacing of midpoint of tripping brackets (m)

P = designed maximum vehicle load (ton)

C_1 and C_2 = coefficient as specified in **Table 2**

Table 2 Coefficient C_1 and C_2

Wheel No. \ value	C_1	C_2
Single Wheel	3.35	3.25
Double Wheel	2.06	3.67

(B) The section modulus Z of tripping brackets is not less than the value obtained from the following formula.

$$Z = 4.8\,Wl \quad (\mathrm{cm}^3)$$

W = designed maximum vehicle load (ton)

l = length of tripping bracket (m)

(C) The value is not less than the value calculated under the conditions such that the dimensions of longitudinal and transverse girder of ramp deck is to be regarded as simple supported continuous beam and load is 1.3 times of designed maximum vehicle load (ton), permissible stress 18 $\mathrm{kg/mm^2}$. Deflection is not more than 1/800 of span when the vehicle load is considered.

(D) The strength of ramp which is considered as one of shell for navigating is not less than that of side shell or upper structure.

(3) Remotely controlled opening/closing systems

(A) Where the remotely controlled opening/closing systems devices, the followings are to be complied with.

(a) Control panel is so to be placed that controller may easily observe excepting that the controller may observe opening/closing of the door at the position where the control panel is placed.

(b) The indicating system for opening/closing systems of door is to be provided at the navigation bridge.

(c) Locking device which is able to be stopped at each step is to be provided.

(B) Where the remote control panel is provided at the bow side of exposed deck, the door is to be closed when the lever is pulled to the direction of stern side. The hinged steel cover is to be provided for preventing damage due to the waves and so on.

(4) Closing devices

(A) For the car ferries, opening / closing systems and securing device (hereinafter as referred to closing devices) are to be provided for bow door's perfectly securing. These are able to prevent for easy opening of bow door due to vibration and ship's movement.
(B) In the above (A), closing device is provided with secondary means. If one device is damaged, closing of door is to be maintained by the other one.
(C) At least one of closing devices mentioned in (B) is able to be operated by manual and has a sufficient strength. For the inner door and ramps, wires for the purpose of opening and closing or hoisting is not be regarded as a closing device.
(D) Closing devices of bow door are to be easily confirmed the condition of closing at the bridge or control station. They does not cause any inconvenience for passing of passengers during navigation.
(E) Design load and permissible stress of securing devices are to be in accordance with **Pt 4, Ch 3.**

(5) Notice
Operation method and any attention for vehicle door are to be noticed near to the door or control panel.

8. Air pipe and sounding pipe

(1) Fuel tanks
(A) End of opening of air pipe in all fuel tanks is to be provided on safe area of exposed deck which has not a capability of overflow or gas emitting and it is to be opened in closed vehicle area.
(B) The upper parts of sounding pipe of fuel tanks are to be provided on safe area of exposed deck. However, if it is not available, it may be provided at the space from a distance with electrical equipments and other parts having high temperature. But in this case, cock or sluice valve which is a automatically closed type are to be provided.
(C) For the wire gauze to prevent the passage of flame provided on the end of openings or inside of air pipe, it is to be complied with **Pt 5, Ch 6, 201.** of the Rules.

9. Electric equipment

(1) The electric equipment in closed vehicle area are to be complied with **Pt 7, Ch 7, 402.** of the Rules.
(2) Emergency electric equipment
Requirements and application of emergency power of passenger ferries are in accordance with "Special Regulations for Car Ferries" in Korean Ship Safety Law.

10. Fire protection

(1) Application
(A) For the ferries engaging in lake, river or inside the harbour service area or having an operating time of no more than one hour, this requirement may not be applied.
(B) In spite of the above mentioned (A), All ferries are to be in accordance with the following (3) (F) and (G).
(2) Requirements for cargo ferries
(A) Deck and bulkhead of enclosed vehicle, machinery area and gallery are to be fitted with compartment for preservation of fire protection as specified in "Regulations for Ship's Fire Protection" in Korean Ship Safety Law.
(B) In spite of the above mentioned (A), for the ferries only engaging in smooth sea water area or having an operating time of no more than 2 hours with fully opened vehicle area, A_0 class may be used for deck or bulkhead being a boundary of vehicle, machinery area and gallery.
(C) In "Regulations for Ship's Fire Protection" in Korean Ship Safety Law, when deck and bulkheads are not specified of category, they are to be in accordance with the discretion of this Society.
(D) In case where "A" class divisions are penetrated into the passage of electric cables, pipes, trunks, ducts, etc., or for the provisions of girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.
(E) In case where "B" class divisions are penetrated into the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.
(F) Pipes penetrating "A" or "B" class divisions are to be of materials approved by the Society

due consideration given to the temperature that such divisions are required to withstand.

(G) In cases of boundaries of car spaces, machinery spaces and galleys, etc. where permeation of oil is possible, the surface of insulation is to be impervious to oil or oil vapours.

(H) Also, they are to be complied with **Pt 8, Ch 2, 201. 1** (1) and **Ch 3, 301. 3** (3) (C), (D) and **303. 2** of the Rules.

(I) Paints, varnishes and other finishes used on interior exposed surfaces are to be those which are considered by the Society that they will not offer undue fire risk and not produce excessive quantity of smoke or poisonous substances.

(3) Special requirements for passenger ferries

(A) Deck and bulkheads of being boundary to enclosed vehicle area are to be preservation of heat protection compartment specified in "Regulations for Ship's Fire Protection" in Korean Ship Safety Law in accordance with characteristic of the closed space.

(B) Deck and bulkheads of being boundary to machinery area and gallery, beside of the mentioned (A) are to be preservation of heat protection compartment specified in "Regulations for Ship's Fire Protection" in Korean Ship Safety Law.

(C) In spite of the above mentioned (A) and (B), for the ferries only engaging in smooth sea water area or having a operating time not much than 2 hours with fully opened vehicle area, A_0 class may be used for deck or bulkhead being a boundary of vehicle, machinery area and gallery.

(D) For deck and bulkhead not specified in "Regulations for Ship's Fire Protection" in Korean Ship Safety Law, they are to be in accordance with the discretion of this Society.

(E) Retardant materials are to be used for the furniture and equipments provided in accommodation and control area. However, where considered unnecessary by the Society, it may be dispensed with.

(F) Materials using for control area, accommodation area and ceiling, lining of bulkhead of stairway have to have a characteristic of putting off the spread of fire.

(G) Paints, varnishes and other finishes used on interior exposed surfaces are to be those which are considered by the Society that they will not offer undue fire risk and not produce excessive quantity of smoke or poisonous substances.

(H) In the compartments of category class A, opening/closing devices (openings of between each other of the cargo area excluding enclosed area of vehicle area, enclosed area, stowage area, baggage area of vehicle area are not included) are to be provided in openings.

(I) Above mentioned opening and closing devices have an equivalent fire resistance. However, if automatic sprinkler system is to be provided or opening and closing devices are to be provided in deck opening having category class A and being a boundary of space providing ceiling with category class B, opening and closing devices may be dispensed with.

(J) In the compartments of category class A, doors (including closing devices) are to be complied with the followings.

(a) Steel or any other similar materials are to be used.

(b) The fire resistance equivalent to that of bulkhead with doors is to be provided. However, arrangement and protection prevent the spread of fire may be dispensed with where water tightness doors are to be provided.

(c) When doors are closed, they are to be constructed for capable of preventing fumes and flames.

(d) From the both sides, they may be opened.

(K) Fire protection doors installed for access of vehicle area are to be provided with automatically closed type and they may be closed when ships inclined with 3.5 *degrees* to the opposite side.

(L) They are to be complied with **10** (2) (D) to (G) and **Pt 8, Ch 3, 301. 3** (3) (C), (D) and **303. 2** of the Rules. Passenger ferries with not less than 1,000 tons gross tonnage are to be also complied with **Pt 8, Ch 2, 202. 1** of the Guidance.

11. Intact stability for passenger ferry

(1) Standard

Intact stability of passenger ferries is to be, for all conditions (including the conditions that all passengers assembled on upper most deck and fully loaded conditions) always complied with the followings.

(A) When the ship has an angle of inclination in the following (2), it has a heeling moment lever more than described in the following (3)

(B) The transverse metacentric height GM is to be positive.

(2) Angle of inclination

(A) Angle of inclination α of (1) is to be satisfied in the following formula.

$$\tan\alpha = 0.8\tan\beta$$

β = the angle of flooding, 20° and angle of deck edge immersion, whichever is smaller

(B) For the ferries engaging in smooth sea area, GZ is to be obtained from the following formula for angle of inclination.

$$GZ = GM\tan\alpha$$

GM = transverse metacentric height

α = as specified in (A)

(3) Heeling moment lever

The heeling moment lever l_3 of (1) is comply with the following formula.

$$l_3 = \frac{2.74AZ + 0.214\Sigma\left(7 - \frac{n}{A_f}\right)A_m n}{100W} \quad (\mathrm{m})$$

n = all the number of passengers in each boarding area

A_f = area for each boarding area (m^2)

A_m = average breadth for using of passengers' movement in each boarding area (m)

A = projected area for the ship side to the above water line (m^2)

Z = distance from the center of A to the center of projected area for the ship side to the below water line (m)

W = displacement (ton)

(4) Passenger ferries engaging in coastal sea area

For the passenger ferries engaging in coastal sea area, the followings are to be complied with considering all the conditions in addition to (1). (See **Fig 1**)

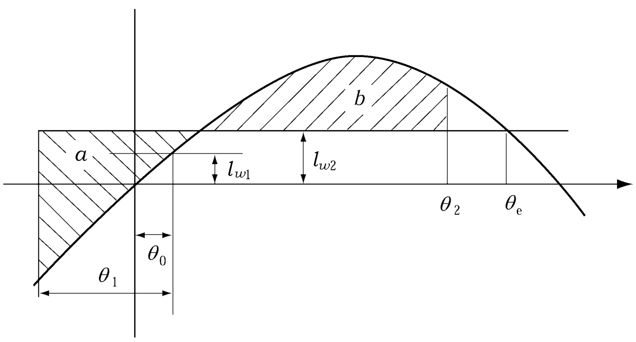


Fig 1 Stability curve

(A) Area "b" is not to be less than area "a".

(B) GZ is not less than $0.0215B$ (m) or 0.275 m, whichever is lesser.

l_{w1} = heeling moment lever caused by steady wind (m) given by the following formula.

$$l_{w1} = \frac{KAZ}{W} \quad (\mathrm{m})$$

K = coefficient specified in **Table 3** due to service area restrictions,

A, Z and W = as specified in (2)

l_{w2} = heeling moment lever caused by gust (m) given by the following formula.

$$l_{w2} = 1.5 l_{w1}$$

a = area encircled by stability curve, l_{w2} and θ_r (m − deg)

b = area encircled by stability curve, l_{w2} and θ_r (m − deg)

θ_r = angle of rolling stop motion (degree). In general, it may be given by the following formula.

$$\theta_r = \theta_0 - \theta_1$$

θ_0 = angle of heel under action of steady wind (degree)

θ_2 = downflooding angle θ_f and θ_c, whichever is smaller.

θ_1 = angle of roll to windward due to wave action (degree) given by the following formula.

$$\theta_1 = \sqrt{\frac{138 rS}{N}}$$

r = values obtained from the following formula.

$$r = 0.73 + 0.6\frac{OG}{d'}$$

OG = distance between the center of gravity and waterline (m), and is taken as positive when the center of gravity is above waterline.

d' = mean draught of the ship (m)

S = coefficient obtained from the following formula, however, when it is not less than 0.1, the value is 0.1 and if it is not more than 0.035, it is to be taken as 0.035.

$$S = P - qT$$

T = rolling period of ship (sec)

P and q = as specified in **Table 3**

N = where the bilge keel is provided, 0.02 may be used. For other cases, it is to be in accordance with the value given by this Society.

Table 3 Coefficient K, P and q

Classification \ Coefficient	K	P	q
Ships engaging over coastal area	0.0514	0.151	0.0072
Ships having estimated voyage time less than $2h$ and engaging over coastal area	0.0274	0.153	0.010

12. Subdivision of passenger ferry and damage stability requirements

(1) Application

(A) For the subdivision of passenger ferry and damage stability requirements are to be in accordance with the relative Articles of "Regulations for the Subdivision of Ship" in Korean Ship Safety Law.

(2) Arrangement

(A) For the passenger ferries, compartments are to be so arranged that limit line is not to be submerged under water, even though one compartment is flooded.

(B) For the passenger ferries having not less than 45 m in length, in addition to (A), compartments are to be so arranged that limit line is not to be submerged under water, even though two compartment, one compartment by the side of the other compartment are flooded.

(C) For the passenger ferries having not less than 79 m in length, in addition to (A), compartments are to be so arranged that limit line is not to be submerged under water, even though any two compartments are flooded.

(3) Damage stability requirements

(A) Damage stability

(a) When the passenger ferries are damaged and any compartments described in (2) are flooded and are treated for equilibrium, the followings are to be complied with.

(i) When compartments are symmetrically flooded, GM is greater than 0.05 m.

(ii) When compartments are unsymmetrically flooded, angle of inclination is not greater than 7°, However, where deemed necessary by this Society, it may be 15°

(iii)Limit line is not be under water.

(b) For all passenger ferries has a necessary stability for the compliance with the above (a) for the all conditions.

(c) For the limit line is submerged under water during the flooding condition (a), ship has to be accomplished proper treatments deemed necessary by this Society.

(d) When the equilibrium is accomplished, maximum angle of inclination is to be approved by this Society.

(B) Damage stability calculation

(a) In damage stability calculation arrangement of flooding compartment, ship's ratio of dimension and property are to be considered in addition to (2) and the following (C), (D).

(b) For the ships having water-tightness deck, longitudinal bulkheads, inside shell, those are to be considered for ship's safety due to heeling when the compartments the parts surrounded by those are flooding.

(C) Flooding ratio of flooding compartment

Flooding ratio is 60 for the area of cargo, ore or stowage loaded, 90 for accommodation area, 85 for machinery space, 0 or 95 for the area where the liquid cargo is loaded whichever is worse. However, when the ships are damaged, more critical calculation is to be conducted for the area where the accommodation equipment or machinery equipment are not provided in due to located in near the water line and cargoes or packages are not stowed.

(D) Damage assumption

(a) The assumed extent of damage should be:

(i) Longitudinal extent : $l = 0.03L + 3.05$ (m) or 10.67 m, whichever is smaller.

(ii) Transverse extent : 0.2B(m) from the ship's side at right angles to the centerline at the level of the summer load line.

(iii) Vertical extent : top of the keel

(b) If any damage of smaller extent than the maximum damage specified in (a) would result in severer condition, such damage should be considered.

(E) Distance between transverse bulkhead

(a) When the distance between two neighbouring compartments, transverse bulkhead is not more than l in the following formula or 10.67 m, (2) is applied by regarding that one of them is not provided.

$$l = 0.03L + 3.05 \quad (\mathrm{m})$$

(b) For the bended area is provided in transverse bulkhead, it is to be in accordance with Article 38 of the "Regulations for the Subdivision of Ships" in Korean Ship Safety Law.

(F) Unsymmetrical flooding

(a) Unsymmetrical flooding is to be avoided as possible.

(b) The equipments for correction of large angle of inclination due to unsymmetrical flooding is to be automatical as possible, and it is approved by the Society.

(c) When the equipments specified in above (b) is cross flooding equipment, they are to be complied with the followings.

(i) When the control devices are provided, they may be controlled upper of bulkhead deck.

(ii) Equilibrium is to be completed in 15 min.

(G) A special example case of application

This Society may properly consider that the ship unusually has a large GZ in intact stability condition. ⚓

Annex 7-4 Guidance for Calculating the Maximum Allowable and Minimum Required Mass of Cargo and Double Bottom Contents with Bulk Carriers

1. The maximum allowable cargo mass W_{MAX} and the minimum allowable cargo mass W_{MIN} for the each cargo hold which are to be described in Loading Manual as specified in **Pt. 3, Annex 3-1, 2.** (4) (A) of the Guidance are to be given by the following as a function of draft in way of the considered cargo hold.

(1) Maximum allowable cargo mass

(A) In the case where the scantlings of structural members of double bottom are determined by the formula prescribed in the requirements of the Rule

(a) The pressure which works on the ships bottom with mass of cargo or ballast water, $9.81\,h_x\gamma\,(\mathrm{kN/m^2})$ is to be not greater than the obtained with the following formula.

$$\max\{a_1n_{f1}, a_2n_{f2}, \cdots, a_nn_{fn}\} + 9.81(d_x - 0.026L'\alpha_R - h_{BST})$$

h_x : Stowage height to the cargo surface from the tank top at the center line (m). In any case, the height of the cargo surface cannot exceed that of the upper deck.

γ : Design specific gravity of cargoes for the cargo hold which is to be taken as $\frac{M_D}{V}$

M_D : Maximum cargo mass of the cargo hold considered (ton)

V : Volume of the cargo hold considered excluding the hatchway ($\mathrm{m^3}$)

a_i : Difference in pressure in loading condition No. i taken from a population with the total of n loading conditions, which works on the center line of the ships bottom with mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draft ($\mathrm{kN/m^2}$), which is obtained from the following formula. The difference in pressure cannot, however, exceed the design pressure given to the local structural member of double bottom where the member is reinforced to enable ship to carry such heavy cargoes as steel coils.

$$\max\{|p_i - 9.81(d_i + 0.026L')|, |p_i - 9.81(d_i - 0.026L')|\}$$

p_i : Pressure in loading condition No. i, which works on the center line of the ship's bottom by the mass of cargo, ballast water and/or double bottom contents ($\mathrm{kN/m^2}$)

d_i : Draft in loading condition No. i, at mid-hold position of cargo hold length l_H (m)

l_H : Length of cargo hold (m) as defined in **Pt 7, Ch 3, 301. 4** of the Rules.

L' : Length of ship (m). Where exceeds 230 m, is to be taken as 230 m.

α_R : 1.0. However, on the water where there are small effects of ocean waves such as port area, that may be reduced to 0.5.

n_{fi} : 0.9 in loading condition No. i, in the case where the considered hold and either of the adjacent holds are loaded or empty simultaneously. In the other case, it is to be 1.0.

d_x : Draught at mid-hold position of cargo hold length l_H (m)

h_{BST} : Water heads of ballast water charged in the double bottom at the center line (m). In any case, it cannot exceed height of the double bottom.

(b) The maximum allowable cargo mass, W_{MAX} (ton), is to be not greater than the obtained with the following formula.

$$\gamma f(h_x)$$

$f(h_x)$: The function with shows the relationship between the stowage height h_x(m) of cargo at the center line and the volume (m^3) of cargo loaded in the hold. In this case, the cargo may be uniformly supposed to be loaded under level surface.

(B) In the case where the scantlings of structural members of double bottom are determined by direct calculations

(a) The pressure which works on the ships bottom with mass of cargo or ballast water, $9.81 h_x \gamma$ (kN/m^2), is not to be greater than the obtained with the following formula.

$$\max\{a_1, a_2, \cdots, a_n\} + 10.0(d_x - 0.25 H_w \alpha_{DC} - h_{BST})$$

h_x, γ, d_x and h_{BST} : as specified in (A)

a_i : Difference in pressure in loading condition No. i taken from a population with the total of n loading conditions, which works on the center line of the ships bottom by mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draft (kN/m^2), which is obtained from the following formula. The difference in pressure cannot, however, exceed the design pressure given to the local structural member of double bottom where the member is reinforced to enable ship to carry such heavy cargoes as steel coils.

$$\max\{|p_i - 10.0(d_i + 0.25 H_w)|, |p_i - 10.0(d_i - 0.25 H_w)|\}$$

p_i : The pressure, in loading condition No. i, which works on the center line of the ships bottom by the mass of cargo, ballast water and/or double bottom contents (kN/m^2). In calculating the pressure which arises by the mass of cargo, the density of cargo and the shape of cargo surface which were applied in direct calculations may be, however, taken into consideration.

d_i : Draught in loading condition No. I, at mid-hold position of cargo hold length l_H (m)

H_w : As obtained with the following formula.

$0.61 L^{1/2}$ where $L \leq 150$m

$1.41 L^{1/3}$ where $150\text{m} < L \leq 250$m

$2.23 L^{1/4}$ where $250\text{m} < L \leq 300$m

9.28 where $300\text{m} < L$

α_{DC} : 1.0. On the waters where there are small effects of ocean waves such as the bay , it may be, however, reduced to one-third.

(b) The maximum allowable cargo mass, W_{MAX}(ton) , is to be not greater than the obtained with the following formula.

$\gamma f(h_x)$

$f(h_x)$: as specified in (A)

(2) Minimum allowable cargo mass

(A) In the case where the scantlings of structural members of double bottom are determined by the prescribed formula in the requirements of the Rule

(a) The pressure which works on the ships bottom with mass of cargo or ballast water, $9.81 h_x \gamma\,(\mathrm{kN/m^2})$, is to be not less than the obtained with the following formula.

$$-\max\{a_1 n_{f1}, a_2 n_{f2}, \cdots, a_n n_{fn}\} + 9.81(d_x + 0.026 L' \alpha_R - h_{BST})$$

h_x, γ, a_i, n_{fi}, d_x, L', α_R and h_{BST} : As specified in (1) (A)

(b) Minimum allowable cargo mass $W_{MIN}(\mathrm{ton})$ is to be not less than the obtained with the following formulas.

$\gamma f(h_x)$

$f(h_x)$: As specified in (1) (A)

(B) In the case where the scantlings of structural members of double bottom are determined by direct calculations

(a) The pressure which works on the ships bottom with mass of cargo or ballast water, $9.81 h_x \gamma\,(\mathrm{kN/m^2})$, is to be not less than the obtained with the following formula.

$$\min\{a_1, a_2, \cdots, a_n\} + 10.0(d_x + 0.25 H_w \alpha_{DC} - h_{BST})$$

h_x, γ, d_x, α_{DC}, h_{BST} and H_w : As specified in (1) (B)

a_i : Difference in pressure in loading condition No. i taken from a population with the total of loading conditions, which works on the center line of the ships bottom by mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draft ($\mathrm{kN/m^2}$), which is obtained from the following formula taking a downward force as a positive value. The difference in pressure cannot, however, exceed the design pressure given to the local structural member of double bottom where the member is reinforced to enable ship to carry such heavy cargoes as steel coils.

$$\min\{(p_i - 10.0(d_i + 0.25 H_w)), (p_i - 10.0(d_i - 0.25 H_w))\}$$

p_i and d_i : As specified in (1) (B)

(b) Minimum allowable cargo mass $W_{MIN}(\mathrm{ton})$ is to be not less than the obtained with the following formula.

$\gamma f(h_x)$

$f(h_x)$: As specified in (1) (B)

2. The maximum allowable cargo mass W_{MAX} and the minimum allowable cargo mass W_{MIN} for the cargo hold and the adjacent cargo hold (hereinafter referred to as "two adjacent holds") which are to be described in Loading Manual as specified in Pt 3, Appendix 3-1, 2.(4)(D) of the Guidance are to be given by the following as a function of draft in way of these holds.

(1) Maximum allowable cargo mass

(A) In the case where in the scantlings of structural members of double bottom are determined by the formula prescribed in the requirements of the Rule

(a) In each hold, the pressure which works on the ships bottom with mass of cargo or ballast water is to be not greater than the obtained with the following formulas.

The pressure, $9.81h_x\gamma\,(\mathrm{kN/m^2})$, which works on the considered hold is;

$$b+9.81(d_x-0.026L'\alpha_R-h_{BST})$$

The pressure, $9.81h'_x\gamma'\,(\mathrm{kN/m^2})$, which works on the adjacent hold is;

$$b'+9.81(d_x-0.026L'\alpha_R-h'_{BST})$$

h_x and h'_x : In each hold, stowage height to the cargo surface from the tank top at the center line (m). In any case, the height of the cargo surface cannot exceed that of the upper deck.

γ and γ' : In each cargo hold, design specific gravity of cargoes for the cargo hold which has the largest value under such loading conditions that two adjacent holds are empty or loaded simultaneously.

b and b' : The case in which a_j and a'_j satisfy the relationship defined by the following formula, b and b' take the absolute value of a_j and a'_j respectively. The absolute value cannot, however, exceed the design pressure given to the local structural member of double bottom where the member is reinforced to enable ship to carry such heavy cargoes as steel coils.

$$a_j a'_j = \max\{a_1 a'_1, a_2 a'_2, \cdots, a_m a'_m\}$$

a_j and a'_j : Differences in pressure of the considered hold and the adjacent hold in loading condition No. j taken from a population with the total of such m loading conditions that two adjacent holds are empty or loaded simultaneously, which work on the center line of the ships bottom by mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draft ($\mathrm{kN/m^2}$). In loading condition No. j, a_j and a'_j take respectively a_{jk} and a'_{jk} as obtained with the following formula if each difference in pressure of the considered hold and the adjacent hold has the same sign (i.e. plus or minus) in both cases where it added the pressure by wave to the pressure by still water and it subtracted the pressure by wave from the pressure by still water. In any case, it takes a downward force as a positive value.

$$a_{jk} a'_{jk} = \max\{a_{j1} a'_{j1}, a_{j2} a'_{j2}\}$$

a_{jk} and a'_{jk} : Differences in pressure of the considered hold and the adjacent hold in loading condition No. j which are obtained from the following formulas. In case where the pressure by wave is added to the pressure by still water, they are defined as a_{j1} and a'_{j1} respectively. The differences in pressure of the considered hold and the adjacent hold in case where the pressure by wave is subtracted from the pressure by still water are also defined as a_{j2} and a'_{j2}.

$$a_{j1} = p_j - 9.81(d_j + 0.026L')$$
$$a'_{j1} = p'_j - 9.81(d'_j + 0.026L')$$
$$a_{j2} = p_j - 9.81(d_j - 0.026L')$$
$$a'_{j2} = p'_j - 9.81(d'_j - 0.026L')$$

p_j and p'_j : In loading condition No. j, the pressure respectively in the considered hold and in the adjacent hold which arises at the center line of the ships bottom by the mass of cargo, ballast water and/or double bottom contents (kN/m^2).

d_j and d'_j : In loading condition No. j, draught at mid-hold position of cargo hold length l_H (m) of the considered hold and the adjacent hold respectively.

l_H, L' and α_R : As specified in 1. (1) (A)

d_x : The average value of d_j and d'_j (m)

h_{BST} and h'_{BST} : In the considered hold and the adjacent hold respectively, water heads of ballast water charged in the double bottom at the center line (m). In any case, they cannot exceed the height of the double bottom

(b) The maximum allowable cargo mass, W_{MAX}(ton), is to be not greater than the obtained with the following formula.

$$\gamma f_1(h_x) + \gamma' f_2(h'_x)$$

$f_1(h_x)$ and $f_2(h'_x)$: Function, in the considered hold and the adjacent hold respectively, which shows the relationship between the stowage height of the cargo (m) at the center line and the volume (m^3) of the cargo loaded in the hold. In this case, the cargo may be uniformly supposed to be loaded under level surface.

(B) In the case where the scantlings of structural members of double bottom are determined by direct calculations;

(a) In each hold, the pressure which works on the ships bottom with mass of cargo or ballast water is to be not greater than the obtained with the following formulas.

The pressure, $9.81 h_x \gamma$ (kN/m^2), which works on the considered hold is;

$$b + 10.0(d_x - 0.25 H_w \alpha_{DC} - h_{BST})$$

The pressure, $9.81 h'_x \gamma'$ (kN/m^2), which works on the adjacent hold is;

$$b' + 10.0(d_x - 0.25 H_w \alpha_{DC} - h'_{BST})$$

h_x, h'_x, γ, γ', d_x, h_{BST} and h'_{BST} : As specified in (A)

b and b' : As specified in (A), in calculating the values of a_{j1}, a'_{j1}, a_{j2} and a'_{j2} the following formulas are applied respectively.

$$a_{j1} = p_j - 10.0(d_j + 0.25H_w)$$
$$a'_{j1} = p'_j - 10.0(d'_j + 0.25H_w)$$

$a_{j2} = p_j - 10.0(d_j - 0.25H_w)$

$a'_{j2} = p'_j - 10.0(d'_j - 0.25H_w)$

p_j and p'_j : As specified in (A). In calculating the pressure which arises by the mass of cargo, the density of cargo and the shape of cargo surface which were applied in direct calculations may be, however, taken into consideration.

d_j and d'_j : As specified in (A)

H_w and α_{DC} : As specified in **1.**(1) (A)

(b) The maximum allowable cargo mass, W_{MAX}(ton), is to be not greater than that obtained from the following formula.

$\gamma f_1(h_x) + \gamma' f_2(h'_x)$

$f_1(h_x)$ and $f_2(h'_x)$: As specified in (A)

(2) Minimum allowable cargo mass

(A) In the case where the scantlings of structural members of double bottom are determined by the formula prescribed in the requirements of the Rule

(a) In each hold, the pressure which works on the ships bottom by mass of cargo or ballast water is be not less than the obtained with the following formulas.

The pressure, $9.81h_x\gamma\,(\mathrm{kN/m^2})$, which works on the considered hold is;

$-b + 9.81(d_x + 0.026L'\alpha_R - h_{BST})$

The pressure, $9.81h'_x\gamma'\,(\mathrm{kN/m^2})$, which works on the adjacent hold is;

$-b' + 9.81(d_x + 0.026L'\alpha_R - h'_{BST})$

h_x, h'_x, γ, γ', b, b', d_x, L', α_R, h_{BST} and h'_{BST} : As specified in (1) (B)

(b) The minimum allowable cargo mass, W_{MIN}(ton), is to be not less than the obtained with the following formula.

$\gamma f_1(h_x) + \gamma' f_2(h'_x)$

$f_1(h_x)$ and $f_2(h'_x)$: As specified in (1) (A)

(B) In the case where the scantlings of structural members of double bottom are determined by direct calculations

(a) In each hold, the pressure which works on the ships bottom with mass of cargo or ballast water is to be not greater than the obtained with the following formulas.

The pressure, $9.81h_x\gamma\,(\mathrm{kN/m^2})$, which works on the considered hold is;

$b + 10.0(d_x + 0.25H_w\alpha_{DC} - h_{BST})$

The pressure, $9.81h'_x\gamma'\,(\mathrm{kN/m^2})$, which works on the adjacent hold is;

$b' + 10.0(d_x + 0.25H_w\alpha_{DC} - h'_{BST})$

h_x, h'_x, γ, γ', d_x H_w, α_{DC}, h_{BST} and h'_{BST} : As specified in (1) (B)

b and b' : In the case where a_j and a'_j satisfy the relationship defined by the following formula, b and b' take the value of a_j and a'_j respectively. The absolute values of b and b' cannot, however, exceed the design pressure given to the local structural member of double bottom where the member is reinforced to enable ship to carry such heavy cargoes as steel coils.

$$|a_j|\, a'_j = \min\{|a_1|a'_1, |a_2|a'_2, \cdots, |a_m|a'_m\}$$

a_j and a'_j : Differences in pressure of the considered hold and the adjacent hold in loading condition No. j taken from a population with the total of such m loading conditions that two adjacent holds are empty or loaded simultaneously, which works on the center line of the ships bottom by mass of cargo, ballast water and/or double bottom contents and by wave and still water corresponding to the draft ($\mathrm{kN/m^2}$). In loading condition No. j, a_j and a'_j take respectively a_{jk} and a'_{jk} as obtained with the following formulas if each difference in pressure of the considered hold and the adjacent hold has the same sign (i.e. plus or minus) in both cases where it added the pressure by wave to the pressure by still water and it subtracted the pressure by wave from the pressure by still water. In any case, it takes a downward force as a positive value.

$$|a_{jk}|\, a'_{jk} = \min\{|a_{j1}|a'_{j1}, |a_{j2}|a'_{j2}\}$$

a_{jk} and a'_{jk} : Differences in pressure of the considered hold and adjacent hold in loading condition No. j, which are obtained from the following formulas. In case where the pressure by wave is added to the pressure by still water they are defined as a_{j1} and a'_{j1} respectively. The differences in pressure of the considered hold and the adjacent hold in case where the pressure by wave is subtracted from the pressure by still water are also defined as a_{j2} and a'_{j2}.

$$a_{j1} = p_j - 10.0(d_j + 0.25H_w)$$
$$a'_{j1} = p'_j - 10.0(d'_j + 0.25H_w)$$
$$a_{j2} = p_j - 10.0(d_j - 0.25H_w)$$
$$a'_{j2} = p'_j - 10.0(d'_j - 0.25H_w)$$

p_j and p'_j : As specified in (1)(B). In calculating the pressure which arises by the mass of cargo, the density of cargo and the shape of cargo surface which were applied in direct calculations may be, however, taken into consideration.

d_j and d'_j : As specified in (1)(B)

(b) The minimum allowable cargo mass, W_{MIN}(ton), is to be not less than that obtained from the following formula.

$$\gamma f_1(h_x) + \gamma' f_2(h'_x)$$

$f_1(h_x)$ and $f_2(h'_x)$: As specified in (1) (B)

3. Notwithstanding the provisions of **1.** above, for ships of BC-A, BC-B and BC-C specified in **Pt 7, Ch 3, 201. 3** of the Rules, the maximum allowable cargo mass W_{MAX} and the minimum required cargo mass W_{MIN} for the cargo hold may be determined by the following formulae. (See

Fig 1)

$$W_{MAX} = W_{\max}(0) + 1.025\,V\frac{d_x}{h}\,(\mathrm{ton})$$

However, is in no case to be greater than maximum cargo mass $M_D(\mathrm{ton})$

$$W_{MIN} = W_{\min}(0) + 1.025\,V\frac{d_x}{h}\,(ton)$$ However, is in no case to be less than 0.

$$W_{\max}(0) = \max\left\{ W_{\max}(d_i) - 1.025\,V\frac{d_i}{h} \right\}$$

$$W_{\min}(0) = \min\left\{ W_{\min}(d_i) - 1.025\,V\frac{d_i}{h} \right\}$$

$W_{\max}(d_i)$, $W_{\min}(d_i)$: Maximum allowable cargo mass and minimum required cargo mass corresponding to the draught , d_i determined based on the loading condition No. I of loading conditions applied in accordance with the type of ship (ton)

d_i : Draught in the loading condition No. i, at mid-hold position of cargo hold length (m)

V : Volume of the cargo hold excluding volume of the hatchway part (m^3)

h : Vertical distance from the top of inner bottom plating to upper deck plating at the ships centre line(m)

d_x : As specified in **1.** (1) (A)

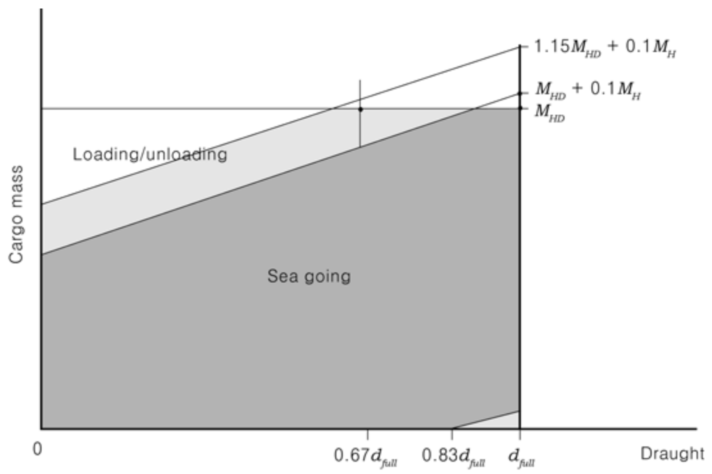


Fig 1 Maximum allowable cargo mass and minimum required cargo mass for a cargo hold(example for a loaded hold in ships of BC-A)

4. Notwithstanding the provisions of **2.** above, for ships of BC-A, BC-B and BC-C specified in **Pt 7, Ch 3, 201. 3** of the Rules, the maximum allowable cargo mass W_{MAX} and the minimum required cargo mass W_{MIN} for the adjacent two holds may be determined by the following formulae. (See **Fig 2**)

$$W_{MAX} = 2M_{Full} + 1.025(V_f + V_d)\frac{d_x - 0.67d}{h}(\mathrm{ton}),$$

However, is in no case to be greater than the maximum cargo mass M_D for each cargo hold.

$W_{MIN} = 1.025(V_f + V_a)\frac{d_x - d_{\min}}{h}(\text{ton})$, However, is in no case to be less than 0.

M_{Full} : the cargo mass in a cargo hold corresponding to cargo with virtual density (homogeneous mass/hold cubic capacity, minimum 1.0 1.0t/m^3) filled to the top of the hatch coaming. M Full is in no case to be less than the actual cargo mass(M_H) in a cargo hold corresponding to a homogeneously loaded condition at maximum draught

V_f and V_a : Volume of the forward and after cargo hold excluding volume of the hatchway part(m^3)

$d_{\min}$: $0.75d$ or draught in ballast conditions with the two adjacent cargo holds empty, whichever is greater(m)

5. In the case specified in **3.** and **4.**, maximum allowable cargo mass and minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15 % of the maximum allowable mass for the cargo hold (in case specified in **4.** the maximum allowable mass for the two adjacent cargo hold) at designed maximum load draught in sea-going condition. However, maximum allowable mass is in no case to be greater than the maximum allowable cargo mass at designed maximum load draught for each cargo hold.

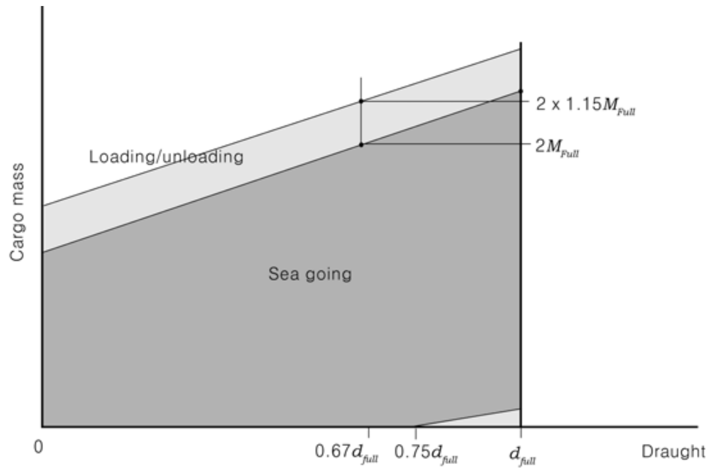


Fig 2 Maximum allowable cargo mass and minimum required cargo mass for two adjacent cargo holds(example)

6. Where, notwithstanding **1.** and **4.** above, the scantling of the double bottom structure is determined for the loading condition other than those given in **1.** or **3.** above, maximum allowable and minimum required mass of cargo may be determined with that condition. Maximum allowable and minimum required mass of cargo being greater or less than the values given in **1.** and **2.**, may be taken when the strength of the double bottom is determined by additional direct calculations and so on.

7. In relation to **1.** to **6.** above, the following notice on referring to maximum allowable and minimum required mass of cargo is to be described in loading manual.

"Where ship engages in a service to carry such hot coils or heavy cargoes that have some adverse effect on the local strength of the double bottom and that the loading is not described as cargo in

Loading Manual, maximum allowable and minimum required mass of cargo are to be considered specially."

8. Typical loading/unloading sequences required in **Pt 3, Appendix 3-1, 3.** (1) (F) of the Guidance, are approved by the Society. Such sequences contain the following loading conditions. However, as for the loading conditions except the following (2), only in case these are specified as ones of the design conditions, these may be included in the loading manual.

(1) Alternate loading condition regulated in **Pt 3, Appendix 3-1**, **3.** (1)(F)(a) of the Guidance
(2) Homogeneous loading condition regulated in **Pt 3, Appendix 3-1, 3.** (1)(F)(b) of the Guidance
(3) Short voyage condition regulated in **Pt 3, Appendix 3-1, 3.** (1)(F)(d) of the Guidance
(4) Multiple port loading/unloading condition regulated in **Pt 3, Appendix 3-1, 3.** (1)(F)(e) of the Guidance
(5) Deck cargo condition regulated in **Pt 3, Appendix 3-1, 3.** (1)(F)(f) of the Guidance
(6) Block loading (partial loading condition; loaded cargo in over two adjacent holds).

9. Each step of a sequence required in **8.** above is specified as follows. A step is defined as each time of changes of the loading equipment position to a new hold.

(1) Each step between commencement of cargo loading in the ballasted condition and the planed loading condition in case of loading cargo.
(2) Each step between commencement of discharging cargo in the planed loading condition and the ballast condition at departure in case of discharging cargo.

10. Each step of sequences specified in **8.** above is acceptable within the allowable limits of longitudinal bending moments and shear forces.

11. In addition to **7.** above, loading manual is to contain the loading/unloading sequence summary forms as specified in **Pt 3, Appendix 3-1, 3.** (1)(F)(g), **Table 4** of Guidance, and to include the following notices.

"Where loading/unloading rather than those included in the design plans or in the loading manual, new loading/unloading sequences are to be developed with the prescribed forms, paying attention to loading rate, the deballasting capability, longitudinal strength, and maximum allowable and minimum required mass of cargo and double bottom contents." ⚓

Annex 7-5 Additional Requirements for Existing Bulk Carriers

1. Scantling of the transverse watertight corrugated bulkhead between cargo holds No.1 and 2, with cargo hold No.1 flooded, for existing bulk carriers

(1) Application and definitions

(A) These requirements apply to all bulk carriers of 150 m in length(L_f) and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1.78 t/m^3, or above, with single deck, topside tanks and hopper tanks, fitted with vertically corrugated transverse watertight bulkheads between cargo holds No. 1 and 2 where:

(a) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998 and have not been constructed in compliance with **Pt 7, Ch 3, Sec 12** of the Rules.

(b) the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with **Pt 7, Ch 3, Sec 12** of the Rules.

(B) The net scantlings of the transverse bulkhead between cargo holds Nos. 1 and 2 are to be calculated using the loads given in (2), the bending moment and shear force given in (3) and the strength criteria given in (4).

(C) Steel renewal and/or reinforcements are required as per (6).

(D) In these requirements, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for the two foremost cargo holds, does not exceed 1.2 to be corrected for different cargo densities.

(2) Load model

(A) General

(a) The loads to be considered as acting on the bulkhead are those given by the combination of the cargo loads with those induced by the flooding of cargo hold No.1.

(b) The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of the bulkhead, depending on the loading conditions included in the loading manual:

(i) homogeneous loading conditions;

(ii) non homogeneous loading conditions.

(c) Non homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements.

(B) Bulkhead corrugation flooding head

The flooding head h_f (See **Fig 1**) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance d_f (m) from the baseline equal to:

(a) For ships less than 50,000 tonnes deadweight with Type B freeboard : $d_f = 0.95D$

(b) For ships other than shown in (a) :

$d_f = D$

(c) For ships to be operated at an assigned load line draught T_r less than the permissible load line draught T, the flooding head defined in (a) and (b) above may be reduced by $T - T_r$.

(C) Pressure in the flooded hold

(a) Bulk cargo loaded hold

Two cases are to be considered, depending on the values of d_1 and d_f, but, d_1 (See **Fig 1**) being a distance from the baseline given, in m, by:

$$d_1 = \frac{M_c}{\rho_c l_c B} + \frac{V_{LS}}{l_c B} + (h_{HT} - h_{DB})\frac{b_{HT}}{B} + h_{DB} \quad (\text{m})$$

where :

M_c = mass of cargo, in hold No.1(ton)

ρ_c = bulk cargo density (t/m^3)

l_c = length of hold No. 1(m)
B = ship's breadth amidship (m)
V_{LS} = volume of the bottom stool above the inner bottom (m^3)
h_{HT} = height of the hopper tanks amidship from the baseline(m)
h_{DB} = height of the double bottom (m)
b_{HT} = breadth of the hopper tanks amidship (m)

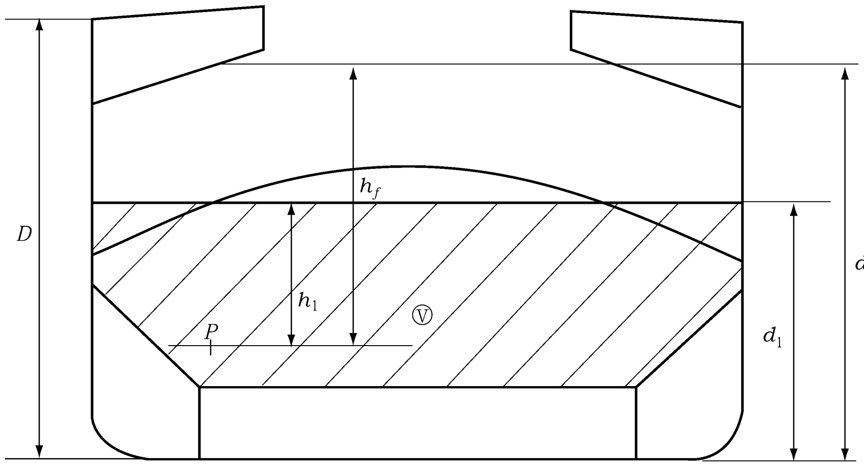


Fig 1 Measurement of d_f, h_1 and h_f

(i) for $d_f \geq d_1$

① At each point of the bulkhead located at a distance between d_1 and d_f from the baseline, the pressure $P_{c,f}$ is given by:

$$P_{c,f} = \rho g h_f \quad (kN/m^2)$$

where :
ρ = 1.025 t/m^3, sea water density (t/m^3)
g = 9.81 m/s^2, gravity acceleration
h_f = flooding head as defined in (B)

② At each point of the bulkhead located at a distance lower than d_1 from the baseline, the pressure $P_{c,f}$ is given by:

$$P_{c,f} = \rho g h_f + [\rho_c - \rho(1 - perm)] g h_1 \tan^2\gamma \quad (kN/m^2)$$

ρ, g, h_f = as given above ①
ρ_c = bulk cargo density (t/m^3)
$perm$ = permeability of cargo, to be taken as 0.3 for ore (corresponding bulk cargo density for iron ore may generally be taken as 3.0 t/m^3),
h_1 = vertical distance, in m, from the calculation point to a level located at a dis-

tance d_1, as defined above, from the base line (See **Fig 1**)

γ = 45° - (ϕ/2)

ϕ = angle of repose of the cargo, in degrees, and may generally be taken as 35° for iron ore and be taken as 25° for cement

③ The force $F_{c,f}$ acting on a corrugation is given by:

$$F_{c,f} = S_1\left[\frac{\rho g(d_f - d_1)^2}{2} + \frac{\rho g(d_f - d_1) + (P_{c,f})_{le}}{2}(d_1 - h_{DB} - h_{LS})\right] \quad \text{(kN)}$$

where :

S_1 = spacing of corrugations(m) (See **Fig 2**)

ρ and g = as specified ② above

d_f = as specified in (B)

$(P_{c,f})_{le}$= pressure at the lower end of the corrugation (kN/mm^2)

d_1 and h_{DB} = as specified in (a)

h_{LS} = height of the lower stool, in m, from the inner bottom.(m)

(ii) for $d_f < d_1$

① At each point of the bulkhead located at a distance between d_f and d_1 from the baseline, the pressure $P_{c,f}$ is given by:

$$P_{c,f} = \rho_c g h_1 \tan^2\gamma \quad \text{(kN/m}^2\text{)}$$

where :

ρ_c, g, h_1 and γ = as specified in (i)

② At each point of the bulkhead located at a distance lower than d_f from the baseline, the pressure $P_{c,f}$ is given by:

$$P_{c,f} = \rho g h_f + [\rho_c h_1 - \rho(1 - perm)h_f] g \tan^2\gamma \quad \text{(kN/m}^2\text{)}$$

where :

ρ, g, h_f, ρ_c, h_1, $perm$ and γ = as specified in (i) above

③ The force $F_{c,f}$ acting on a corrugation is given by:

$$F_{c,f} = S_1\left[\frac{\rho_c g(d_1 - d_f)^2}{2} tan^2\gamma + \frac{\rho_c g(d_1 - d_f)\tan^2\gamma + (P_{c,f})_{le}}{2}(d_1 - h_{DB} - h_{LS})\right] \quad \text{(kN)}$$

where :

S_1, ρ_c, g, γ, $(P_{c,f})_{le}$ and h_{LS} = as specified in (i) above

d_1 and h_{DB} = as specified in (a)

d_f = as specified in (B)

(b) Pressure in the flooded empty hold
At each point of the bulkhead, the hydrostatic pressure P_f induced by the flooding head h_f is to be considered.

$$P_f = \rho g h_f \quad \text{(kN/m}^2\text{)}$$

The force F_f acting on a corrugation is given by the following formulae:

$$F_f = S_1 \rho g \frac{(d_f - d_{DB} - h_{LS})^2}{2} \quad (\text{kN})$$

where :

S_1, g, ρ and h_{LS} = as specified in (i) above

d_1 and h_{DB} = as specified in (a)

d_f = as specified in (B)

(D) Pressure in the non-flooded bulk cargo loaded hold

(a) At each point of the bulkhead, the pressure P_c is given by:

$$P_c = \rho_c g h_1 \tan^2 \gamma \quad (\text{kN/m}^2)$$

where :

ρ_c, g, h_1 and γ = as specified in (C), (a) (i) above

(b) The force F_c acting on a corrugation is given by the following formula:

$$F_c = S_1 \rho_c g \frac{(d_1 - h_{DB} - h_{LS})^2}{2} tan^2 \gamma \quad (\text{kN})$$

where :

ρ_c, g, S_1, h_{LS} and γ = as specified in (C), (a) (i) above

d_1 and h_{DB} = as specified in (C), (a) above

(E) Resultant pressure and load

(a) Homogeneous loading conditions

(i) At each point of the bulkhead structures, the resultant pressure P, to be considered for the scantlings of the bulkhead is given by:

$$P = P_{c,f} - 0.8 P_c \quad (\text{kN/m}^2)$$

(ii) The resultant force F acting on a corrugation is given by:

$$F = F_{c,f} - 0.8 F_c \quad (\text{kN})$$

(b) Non homogeneous loading conditions

(i) At each point of the bulkhead structures, the resultant pressure P to be considered for the scantlings of the bulkhead is given by:

$$P = P_{c,f} \quad (\text{kN/m}^2)$$

(ii) The resultant force F acting on a corrugation is given by:

$$F = F_{c,f} \quad (\text{kN})$$

(iii) In case hold No.1, in non homogeneous loading conditions, is not allowed to be loaded, the resultant pressure P to be considered for the scantlings of the bulkhead and the resultant force F acting on a corrugation is given by:

$$P = P_f \quad (\text{kN/m}^2)$$

$$F = F_f \quad (\text{kN})$$

(3) Bending moment and shear force in the bulkhead corrugations
The bending moment M and the shear force Q in the bulkhead corrugations are obtained using the formulae given in (A) and (B). The M and Q values are to be used for the checks in (4).
(A) Bending moment
The design bending moment M for the bulkhead corrugations is given by:

$$M = \frac{Fl}{8} \quad (\text{kN-m})$$

where :
F = resultant force as specified in (2) (E)
l = span of the corrugation (m) (See **Fig 2** and **3**)
(B) Shear force
The shear force Q at the lower end of the bulkhead corrugations is given by:

$$Q = 0.8F \quad (\text{kN})$$

where :
F and l = as specified in (A) above

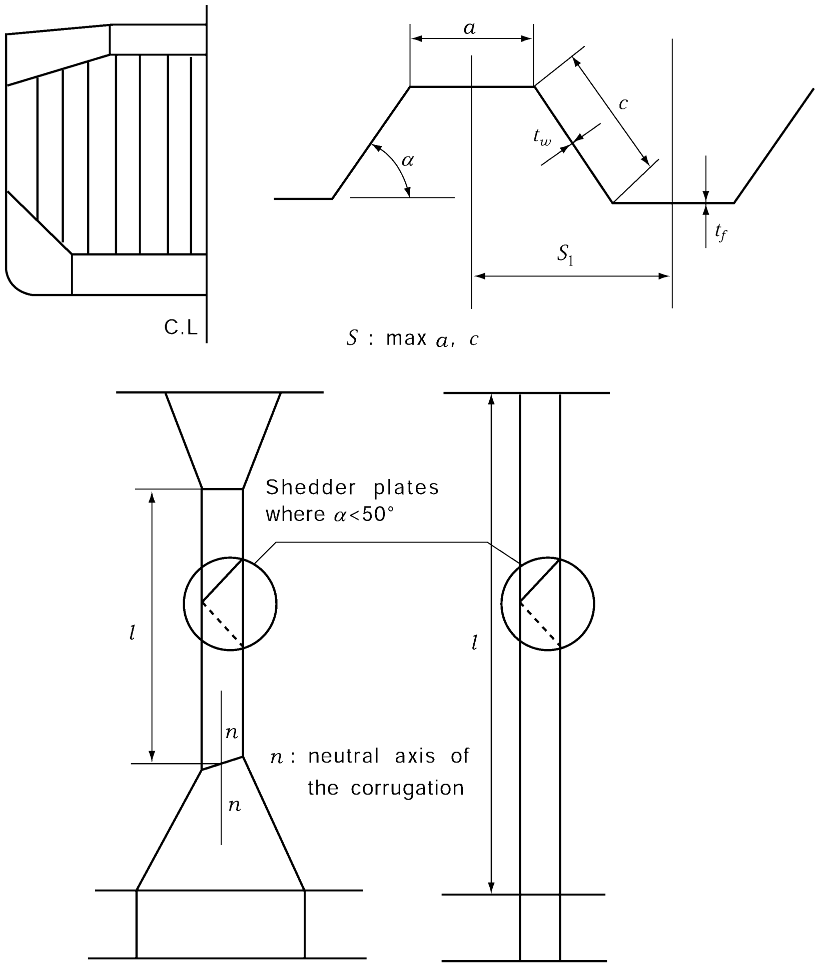
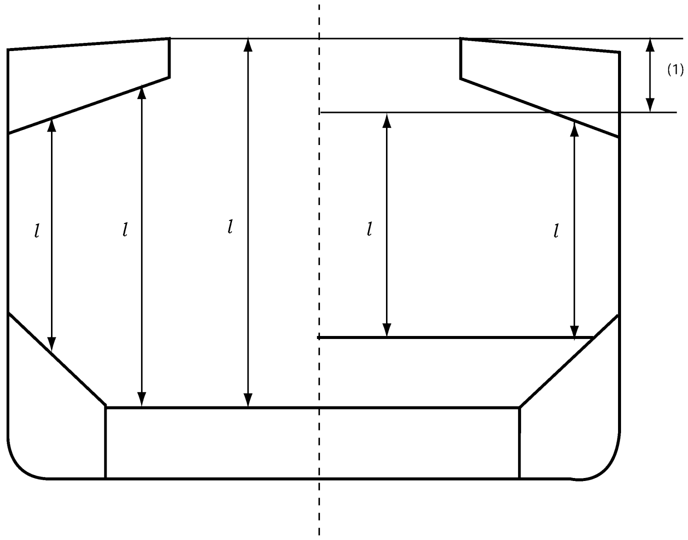


Fig 2 Measurement of S and l



(Note)
(1) For the definition of l, the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to.
(1) For rectangular stool : 2 times the depth of corrugation
(2) For other than shown in (1) : 3 times the depth of corrugation

Fig 3 Measurement of corrugated span l

(4) Strength criteria

(A) General

The following criteria are applicable to transverse bulkheads with vertical corrugations (See **Fig 2**).

(a) Requirements for local net plate thickness are given in (B), (E), (F) and (G).

(b) Where the corrugation angle α shown in **Fig 2** is less than 50°, horizontal row of staggered shedder plates is to be fitted at approximately mid depth of the corrugations to help preserve dimensional stability of the bulkhead under flooding loads. The shedder plates are to be welded to the corrugations by double continuous welding, but they are not to be welded to the side shell.

(c) The thicknesses of the lower part of corrugations considered in the application of (B) and (C) are to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than $0.15l$.

(d) The thicknesses of the middle part of corrugations considered in the application of (B) and (D) are to be maintained to a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than $0.3l$.

(B) Bending capacity and shear stress

(a) The bending capacity is to comply with the following relationship:

$$\frac{M}{0.5Z_{le}\sigma_{a,le} + Z_m\sigma_{a,m}} \times 10^3 \leq 1.0$$

where :

M = bending moment(kN-m), as specified in (3)(A) above.

Z_{le} = section modulus of one half pitch corrugation at the lower end of corrugations, as specified in (C) (cm^3)

Z_m = section modulus of one half pitch corrugation at the mid-span of corrugations as specified in (D) (cm^3)

$\sigma_{a,le}$ = allowable stress at the lower end of corrugations as specified in (E)

$\sigma_{a,m}$ = allowable stress at the mid-span of corrugations as specified in (E).

(i) In no case Z_m is to be taken greater than the lesser of $1.15Z_{le}$ and $1.15Z'_{le}$ for calculation of the bending capacity, Z'_{le} being defined below.

① In case effective shedder plates are fitted:

ⓐ Shedder plates are not knuckled;

ⓑ Shedder plates are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent;

ⓒ Shedder plates are fitted with a minimum slope of 45° and their lower edge is in line with the stool side plating;

② In case effective gusset plates are fitted:

ⓐ Gusset plates are fitted in line with the stool side plating;

ⓑ Gusset plates have material properties at least equal to those provided for the flanges,

(ii) the section modulus Z_{le}, is to be taken not larger than the value Z'_{le} given by :

$$Z'_{le} = Z_g + \frac{Qh_g - 0.5h_g^2 S_1 P_g}{\sigma_a} \times 10^3 \quad (\text{cm}^2)$$

where:

Z_g = section modulus of one half pitch corrugation, according to (D), in way of the upper end of shedder or gusset plates, as applicable

Q = shear force as given in (3)(B)

h_g = height of shedder or gusset plates(m), as applicable (See **Fig 4** (1),(2),(3) and (4))

S_1 = as specified in (2)(C)(a)

P_g = resultant pressure (kN/m^2) as defined in (2)(E), calculated in way of the middle of the shedder or gusset plates, as applicable

σ_a = allowable stress (N/mm^2) as specified in (E).

(b) Stresses τ are obtained by dividing the shear force Q by the shear area. The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by $\sin\alpha$, where α being the angle between the web and the flange. (See **Fig 2**)

(c) When calculating the section moduli and the shear area, the net plate thicknesses are to be used.

(d) The section moduli of corrugations are to be calculated on the basis of the requirements given in (C) and (D).

(C) Section modulus at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width b_{ef}, not larger than as given (F) (a).

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30 % effective.

(a) Provided that effective shedder plates, as defined in (B) are fitted (See **Fig 4** (1) and (2)), when calculating the section modulus of corrugations at the lower end (cross-section in **Fig 4** (1) and (2) ①), the area of flange plates (cm^2), may be increased by not to be taken greater than

$$2.5a\sqrt{t_f t_{sh}}\sqrt{\frac{\sigma_{Fsh}}{\sigma_{Ffl}}}$$

but, it is to be less than $2.5at_f$.

a = width, in m, of the corrugation flange (See **Fig 2**)

t_{sh} = net shedder plate thickness (mm)

t_f = net flange thickness (mm)

σ_{Fsh} = minimum upper yield stress (N/mm^2) of the material used for the shedder plates

σ_{Ffl} = minimum upper yield stress (N/mm^2) of the material used for the corrugation flanges.

(b) Provided that effective gusset plates, as defined in (B), are fitted (See **Fig 4** (3) and (4)), when calculating the section modulus of corrugations at the lower end (cross-section in **Fig 4** (3) and (4) ①), the area of flange plates(cm^2), may be increased by 7 $h_g t_{gu}$.

h_g = height of gusset plate in m, (See **Fig 4** (3) and (4)), not to be taken greater than $\frac{10}{7}S_{gu}$

S_{gu} = width of the gusset plates(m)

t_{gu} = net gusset plate thickness(mm), not to be taken greater than t_f

t_f = net flange thickness based on the as built condition.(m)

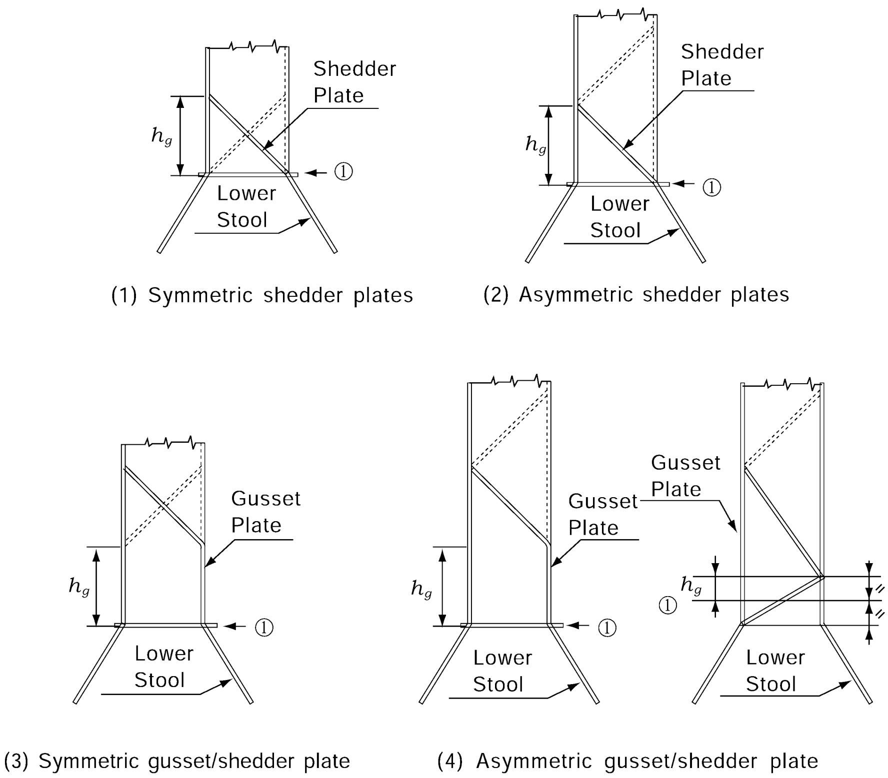


Fig 4 Shedder plates and Gusset plates

(c) If the corrugation webs are welded to a sloping stool top plate, which is at an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in (b) above. No credit can be given to shedder plates only. For angles less than 45° the effectiveness of the web may be obtained by linear interpolation between 30 % for 0° and 100 % for 45°

(D) Section modulus of corrugations at cross-sections other than the lower end. The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, b_{ef}, not larger than as given in (F)(a).

(E) Allowable stress check

The normal and shear stresses σ and τ are not to exceed the allowable values σ_a and τ_a, given by:

$$\sigma_a = \sigma_y \quad (\mathrm{N/mm^2})$$

$$\tau_a = 0.50\sigma_y \quad (\mathrm{N/mm^2})$$

where :

σ_y = minimum upper yield stress of the material.($\mathrm{N/mm^2}$)

(F) Effective compression flange width and shear buckling check

(a) Effective width of the compression flange of corrugations

The effective width b_{ef} of the corrugation flange is given by:

$$b_{ef} = C_e a \quad (\mathrm{m})$$

where :

for $\beta > 1.25$: $C_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2}$

for $\beta \le 1.25$: $C_e = 1.0$

$$\beta = \frac{a}{t_f}\sqrt{\frac{\sigma_y}{E}} \times 10^3$$

t_f = net flange thickness (mm)

a = width of the corrugation flange (m) (See **Fig 2**)

σ_y = minimum upper yield stress of the material ($\mathrm{N/mm^2}$)

E = modulus of elasticity ($\mathrm{N/mm^2}$), to be assumed equal to 2.06 × 10^5 $\mathrm{N/mm^2}$ for steel

(b) Shear

The buckling check is to be performed for the web plates at the corrugation ends. The shear stress τ is not to exceed the critical value τ_c obtained by the following:

$$\tau_c = \tau_E \qquad \text{when : } \tau_E \le 0.5\tau_y$$

$$\tau_c = \tau_y\left(1 - \frac{\tau_y}{4\tau_E}\right) \qquad \text{when : } \tau_E > 0.5\tau_y$$

where :

τ_y = shear stress of the material ($\mathrm{N/mm^2}$)

$$\sigma_y / \sqrt{3}$$

τ_E = elastic buckling stress ($\mathrm{N/mm^2}$)

$$\tau_E = 0.9 k_t E \left(\frac{t}{1000c} \right)^2 \quad (\mathrm{N/mm^2})$$

where :

k_t = 6.34

t = net thickness, in mm, of corrugation web (mm)

c = breadth of corrugation web (See **Fig 2**)

σ_y, E = as specified in (a) above.

(G) Local net plate thickness

(a) The bulkhead local net plate thickness tnet, in mm, is given by:

$$t_{\neq t} = 14.9 S_w \sqrt{\frac{P}{\sigma_y}} \quad (\mathrm{mm})$$

where :

S_w = plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (See **Fig 2**)

P = resultant pressure($\mathrm{kN/m^2}$), as defined in (2)(E), at the bottom of each strake of plating; in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted.

σ_y = minimum upper yield stress of the material.($\mathrm{N/mm^2}$)

(b) When the thicknesses of the flange and web are different :

(i) The net thickness of the narrower plating is not to be taken less than the following values:

$$t_n = 14.9 S_n \sqrt{\frac{P}{\sigma_y}} \quad (\mathrm{mm})$$

where :

S_n = the width of the narrower plating.(m)

P and σ_y = as specified in (a) above.

(ii) The net thickness of the wider plating is not to be taken less than the maximum of the following values:

$$t_{w1} = 14.9 S_w \sqrt{\frac{P}{\sigma_y}} \quad (\mathrm{mm}), \qquad t_{w2} = \sqrt{\frac{440 S_w^2 P}{\sigma_y} - t_{np}^2} \quad (\mathrm{mm})$$

where :

t_{np} = the lesser value of the between actual net thickness of the narrower plating and t_{w1}.

(5) Local details

(A) As applicable, the design of local details is to comply with the Society's requirements for the purpose of transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.

(B) In particular, the thickness and stiffening of gusset and shedder plates, installed for Strengthening purposes, is to comply with the Society's requirements, on the basis of the load model in (2). Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.

(6) Corrosion addition and steel renewal

(A) Steel renewal is required where the gauged thickness is less than $t_{\neq t}+0.5\,\mathrm{mm}$, $t_{\neq t}$ being the thickness used for the calculation of bending capacity and shear stresses as given in (4)(B) or the local net plate thickness as given in (4)(G). Alternatively, reinforcing doubling strips may be used providing the net thickness is not dictated by shear strength requirements for web plates (See (4)(E) and (4)(F)(b)) or by local pressure requirements for web and flange plates (See (4)(G)).

(B) Where the gauged thickness is within the range $t_{\neq t}+0.5\,\mathrm{mm}$, $t_{\neq t}+1.0\,\mathrm{mm}$, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal.

(C) Where steel renewal or reinforcement is required, a minimum thickness of $t_{\neq t}+2.5\,\mathrm{mm}$ is to be replenished for the renewed or reinforced parts.

(D) For $0.8(\sigma_{Ffl} t_{fl}) \geq \sigma_{Fs} t_{st}$

σ_{Ffl} = minimum upper yield stress($\mathrm{N/mm^2}$) of the material used for the corrugation flanges

σ_{Fs} = minimum upper yield stress($\mathrm{N/mm^2}$) of the material used for the lower stool side plating or floors (if no stool is fitted)

t_{fl} = flange thickness, in mm, which is found to be acceptable on the basis of the criteria specified in (A) above or, when steel renewal is required, the replenished thickness according to the criteria specified in (C) above. The above flange thickness dictated by local pressure requirements (See (4)(G)) need not be considered for this purpose

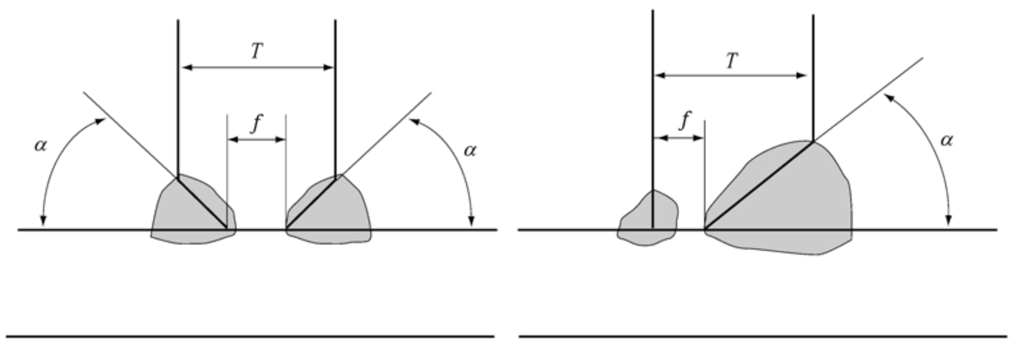
t_{st} = as built thickness of the lower stool side plating or floors (if no stool is fitted) (mm)

(a) Gussets with shedder plates, extending from the lower end of corrugations up to $0.1l$ or reinforcing doubling strips (on bulkhead corrugations and stool side plating) are to be fitted.

(b) If gusset plates are fitted, the material of such gusset plates is to be the same as that of the corrugation flanges. The gusset plates are to be connected to the lower stool shelf plate or inner bottom (if no lower stool is fitted) by deep penetration welds. (See **Fig 5**).

(E) Where steel renewal is required, the bulkhead connections to the lower stool shelf plate or inner bottom (if no stool is fitted) are to be at least made by deep penetration welds.

(F) Where gusset plates are to be fitted or renewed, their connections with the corrugations and the lower stool shelf plate or inner bottom (if no stool is fitted) are to be at least made by deep-penetration welds (See **Fig 5**).



Root Face f : 3mm ~ T/3mm
Groove Angle α : 40° ~ 60°

Fig 5 Deep penetration weld

(G) Guidance on renewal/reinforcement of vertically corrugated transverse watertight bulkhead between cargo holds Nos. 1 and 2

(a) The need for renewal or reinforcement of the vertically corrugated transverse watertight bulkhead between cargo holds Nos. 1 and 2 will be determined by the classification society on a case by case basis using the criteria given in association with the most recent gaugings and findings from survey.

(b) It will take into account the following:

(i) Scantlings of individual vertical corrugations will be assessed for reinforcement / renewal based on thickness measurements obtained in accordance with **Pt 1, Annex 1-5, Table 8** at their lower end, at mid-depth and in way of plate thickness changes in the lower 70 %. These considerations will take into account the provision of gussets and shedder plates and the benefits they offer, provided that they comply with (4)(B) and (A) to (F).

(ii) Permissible levels of diminution will be determined and appropriate measures taken in accordance with (A) and (B).

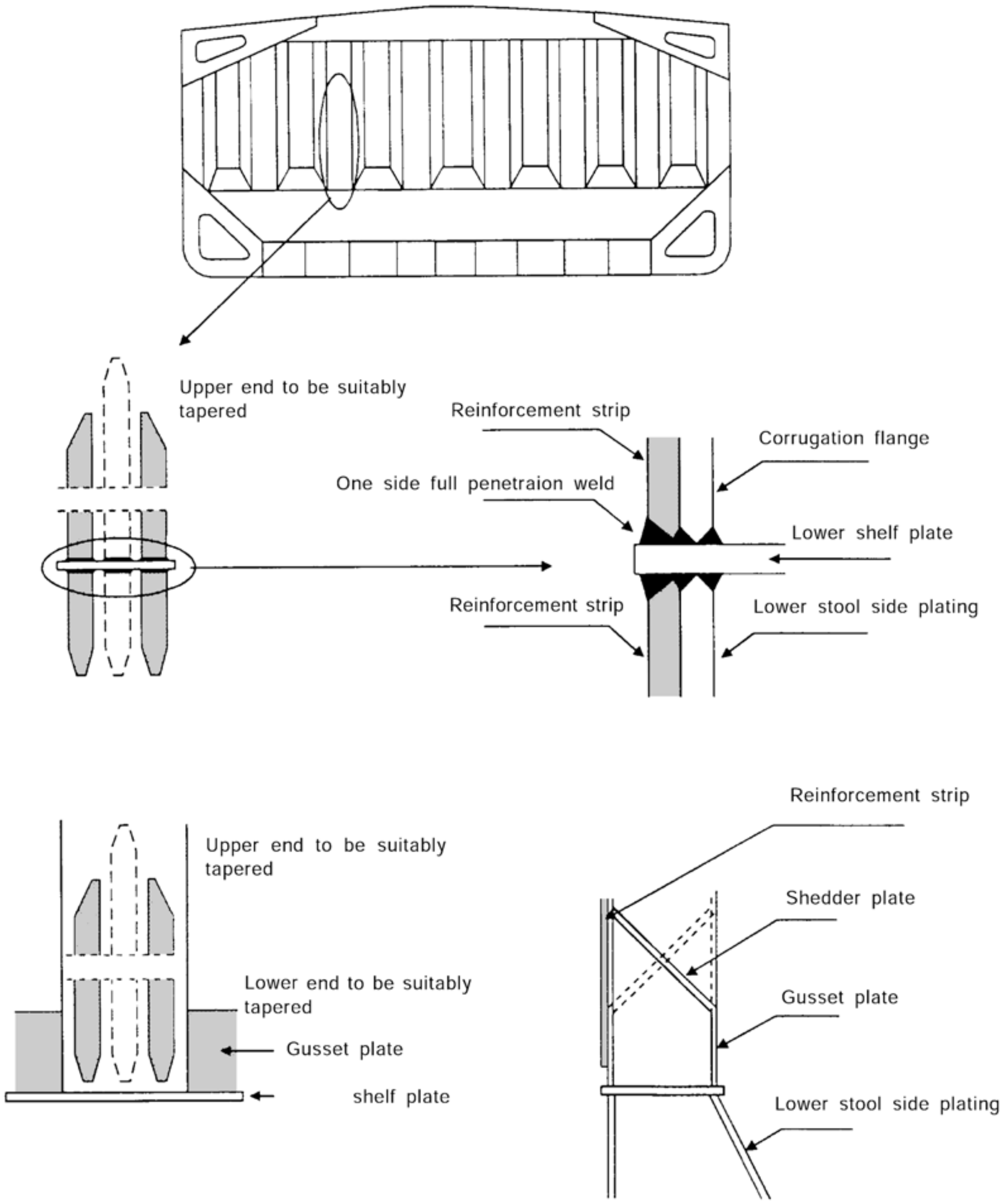
(c) Where renewal is required, the extent of renewal is to be shown clearly in plans. The vertical distance of each renewal zone is to be not less than 15 % of the vertical distance between the upper and lower end of the corrugation measured at the ship's centreline.

(d) Where the reinforcement is accepted by adding strips, the length of the reinforcing strips is to be sufficient to allow it to extend over the whole depth of the diminished plating. In general, the width and thickness of strips should be sufficient to comply with the (A) to (F) requirements. The material of the strips is to be the same as that of the corrugation plating. The strips are to be attached to the existing bulkhead plating by continuous fillet welds. The strips are to be suitably tapered or connected at ends in accordance with Class Society practice. (See **Fig 6**)

(e) Where reinforcing strips are connected to the inner bottom or lower stool shelf plates, one side full penetration welding is to be used. When reinforcing strips are fitted to the corrugation flange and are connected to the lower stool shelf plate, they are normally to be aligned with strips of the same scantlings welded to the stool side plating and having a minimum length equal to the breadth of the corrugation flange.

(f) A general arrangement of structural reinforcement is given by **Fig 6.**

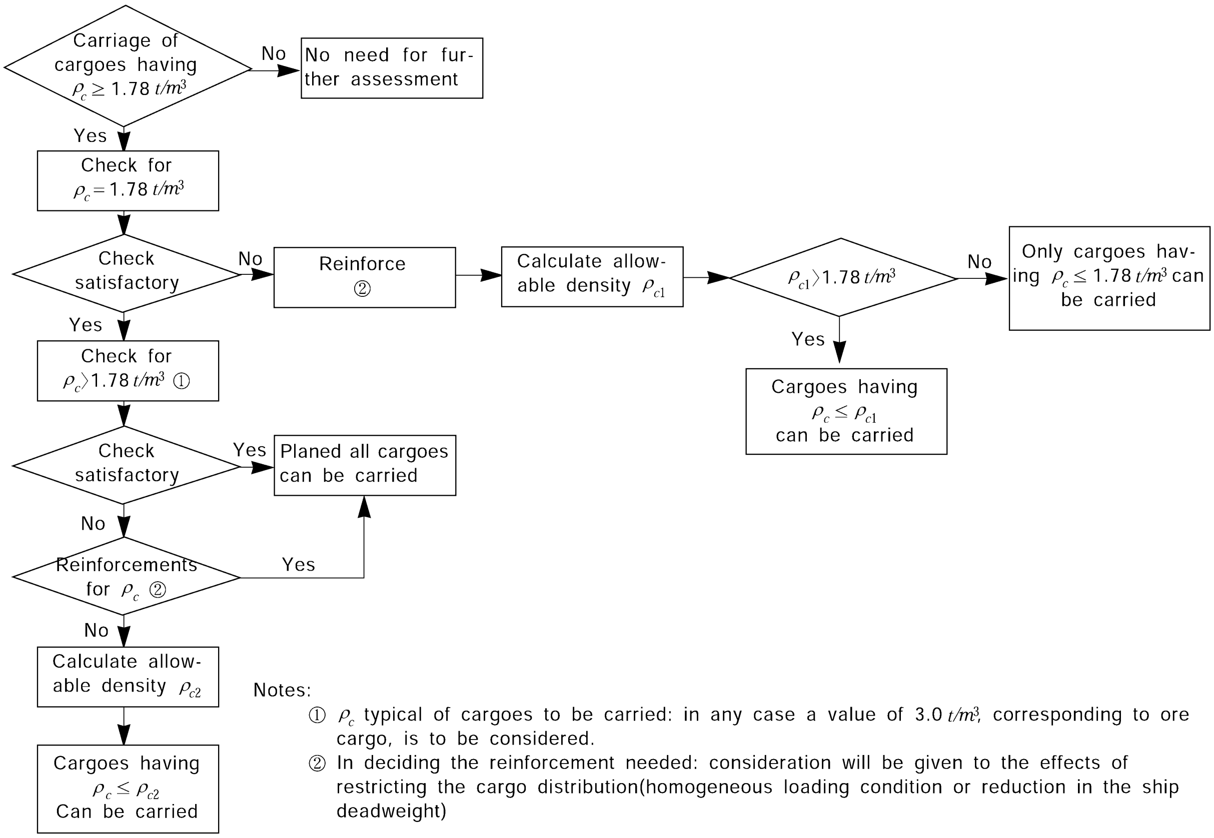
(7) The flow chart to asses capability of carriage of high density cargoes on existing bulk carriers according to the strength of transverse bulkhead between cargo holds Nos. 1 and 2 may refer to the **Fig 7.** However, where the resultant pressure specified in above (2) (E) has the highest value for cargo density(ρ_c) being 1.78 t/m^3, this flow chart may not be applied.



(Note)

1. Square or trapezoidal corrugations are to be reinforced with plate strips fitted to each corrugation flange sufficient to meet the requirements of (A) to (F).
2. The number of strips fitted to each corrugation flange is to be sufficient to meet the requirements (4).
3. The shedder plate may be fitted in one piece or prefabricated with a welded knuckle (gusset plate).
4. Gusset plates, where fitted, are to be welded to the shelf plate in line with the flange of the corrugation, to reduce th stress concentrations at the corrugation corners. Ensure good alignment between gusset plate, corrugation flange and lower stool sloping plate. Use deep penetration welding at all connections. Ensure start and stop of welding is as far away as practically possible from corners of corrugation.
5. Shedder plates are to be attached by on side full penetration welds onto backing bars.
6. Shedder and gusset plates are to have a thickness equal to or greater than the original bulkhead thickness. Gusset plate is to have a minimum height(on the vertical part) equal to half of the width of the corrugation flange. Shedders and gussets are to be same material as flange material.

Fig 6 Example of general arrangement of structural reinforcement



Notes:
① ρ_c typical of cargoes to be carried: in any case a value of $3.0\ t/m^3$, corresponding to ore cargo, is to be considered.
② In deciding the reinforcement needed: consideration will be given to the effects of restricting the cargo distribution(homogeneous loading condition or reduction in the ship deadweight)

Fig 7 Flow chart to assess capability of carriage of high density cargoes on existing bulk carriers according to the strength of transverse bulkhead

2. Evaluation of Allowable Hold Loading of Cargo Hold No. 1 with Cargo Hold No. 1 Flooded, for Existing Bulk Carrier

(1) Application and definitions

(A) These requirements apply to all bulk carriers of 150 m in length and above, in the foremost hold, intending to carry solid bulk cargoes having a density of 1.78 t/m^3, or above, with single deck, topside tanks and hopper tanks, where:

(a) the foremost hold is bounded by the side shell only for ships which were contracted for construction prior to 1 July 1998 and have not been constructed in compliance with **Pt 7, Ch 3, Sec 11** of the Rules.

(b) the foremost hold is double side skin construction of less than 760 mm breadth measured perpendicular to the side shell in ships, the keels of which were laid, or which were at a similar stage of construction, before 1 July 1999 and have not been constructed in compliance with **Pt 7, Ch 3, Sec 11** of the Rules.

(B) Early completion of a special survey coming due after 1 July 1998 to postpone compliance is not allowed.

(C) The loading in cargo hold No. 1 is not to exceed the allowable hold loading in flooded condition, calculated as per (4), using the shear capacity of the double bottom given in (3).

(D) In no case, the allowable hold loading in flooding condition is to be taken greater than the design hold loading in intact condition.

(2) Loading model

(A) General

(a) The loads to be considered as acting on the double bottom are considered by following

(i) the load by the external sea pressures

(ii) the combination of the cargo loads with those induced by the flooding of the hold.

(b) The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

(i) homogeneous loading conditions;
(ii) non homogeneous loading conditions;
(iii) packed cargo conditions (such as steel mill products).

(c) For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculating the allowable hold loading limit.

(B) Inner bottom flooding head

The flooding head h_f (See **Fig 8**) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f, in m, from the baseline equal to:

(a) for ships less than 50,000 tonnes deadweight with Type B freeboard : 0.95D
(b) for ships except for (a) above : D

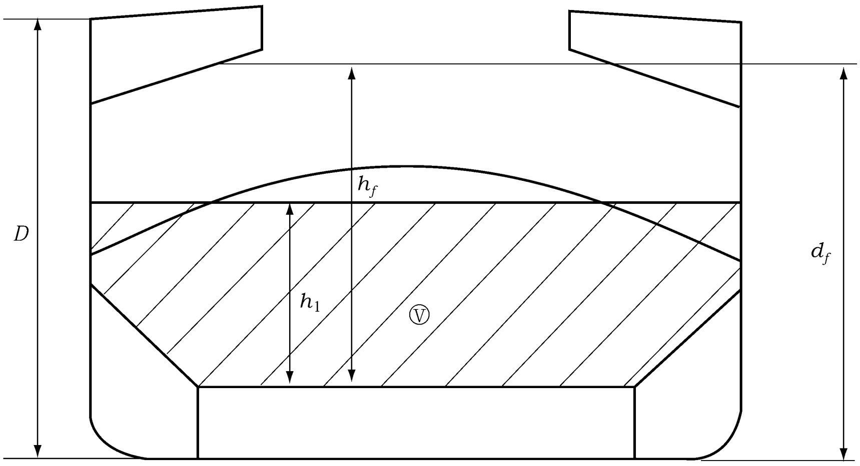


Fig 8 Measurement of d_f, h_1 and h_f

(3) Shear capacity of the double bottom of hold No. 1

(A) The shear capacity C of the double bottom of hold No. 1 is defined as the sum of the shear strength at each end of:

(a) all floors adjacent to both hoppers, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (See **Fig 9**).
(b) all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted.

(B) The strength of girders or floors which run out and are not directly attached to the boundary stool or hopper girder is to be evaluated for the one end only.

(C) Note that the floors and girders to be considered are those inside the hold boundaries formed by the hoppers and stools (or transverse bulkheads if no stool is fitted). The hopper side girders and the floors directly below the connection of the bulkhead stools (or transverse bulkheads if no stool is fitted) to the inner bottom are not to be included.

(D) When the geometry and/or the structural arrangement of the double bottom are such to make the above (A) to (C) inadequate, to the Society's discretion, the shear capacity C of double bottom is to be calculated according to the Society's criteria.

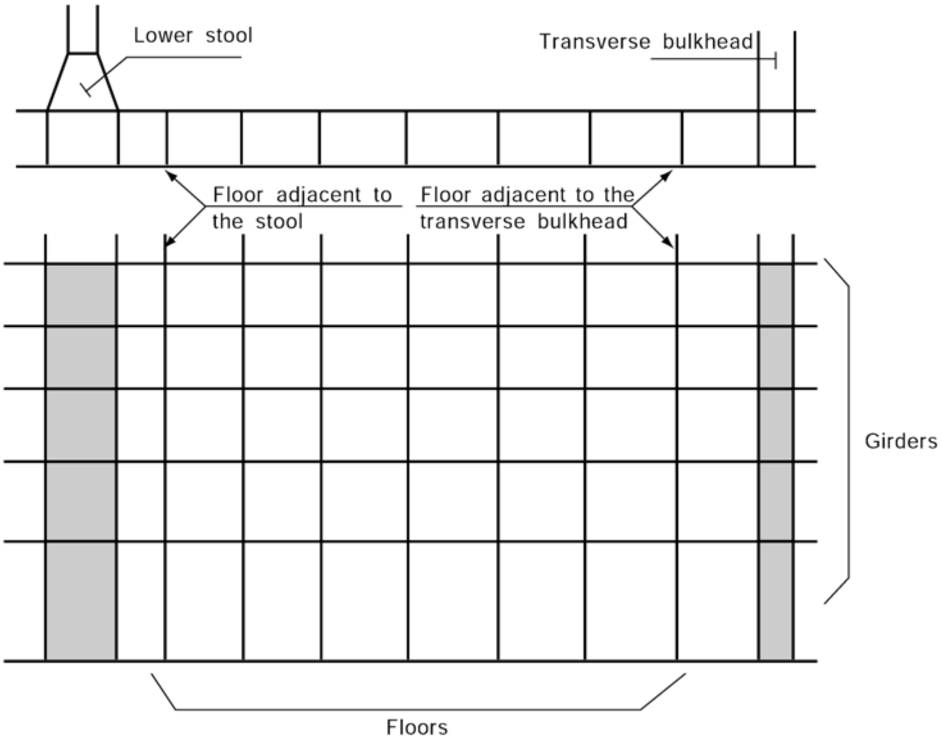


Fig 9 Considering floor and girder

(E) In calculating the shear strength, the net thickness of floors and girders is to be used. The net thickness $t_{\neq t}$, in mm, is given by:

$$t_{\neq t} = t - t_c \quad (\mathrm{mm})$$

where :

t = as built thickness of floors and girders.(mm)

t_c = corrosion diminution, equal to 2 mm, in general ; a lower value of t_c may be adopted, provided that measures are taken, to the Society's satisfaction, to justify the assumption made.

(F) Floor shear strength

The floor shear strength in way of the floor panel adjacent to hoppers S_{f1} and the floor shear strength in way of the openings in the outmost bay (i.e. that bay which is closer to hopper) S_{f2} are given by the following expressions:

$$S_{f1} = A_f \frac{\tau_a}{\eta_1} \times 10^{-3} \quad (\mathrm{kN}), \qquad S_{f2} = A_{f,h} \frac{\tau_a}{\eta_2} \times 10^{-3} \quad (\mathrm{kN})$$

where:

A_f = sectional area of the floor panel adjacent to hoppers (mm^2)

$A_{f,h}$ = net sectional area of the floor panels in way of the openings in the outmost bay(i.e. that bay which is closer to hopper)(mm^2)

τ_a = allowable shear stress ($\mathrm{N/mm}^2$), to be taken equal to $\sigma_y / \sqrt{3}$

σ_y = minimum upper yield stress of the material ($\mathrm{N/mm}^2$)

η_1 = 1.1

η_2 = 1.2, η_2 may be reduced, as the Society's discretion, down to 1.10 where appropriate reinforcements are fitted to the Society's satisfaction

(G) Girder shear strength

The girder shear strength in way of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted) S_{g1} and the girder shear strength in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted) S_{g2} are given by the following expressions:

$$S_{g1} = A_g \frac{\tau_a}{\eta_1} \times 10^{-3} \quad (\mathrm{kN}), \qquad S_{g2} = A_{g,h} \frac{\tau_a}{\eta_2} \times 10^{-3} \quad (\mathrm{kN})$$

where :

A_g = minimum sectional area of the girder panel adjacent to stools(or transverse bulkheads, if no stool is fitted) (mm^2)

$A_{g,h}$ = net sectional area of the girder panels in way of the largest opening in the outmost bay (i.e. that bay which is closest to stool, or transverse bulkhead, if no stool is fitted)(mm^2)

τ_a = allowable shear stress($\mathrm{N/mm}^2$), as given in (F) above.

η_1 = 1.10

η_2 = 1.15, η_2 may be reduced, at the Society's discretion, down to 1.10 where appropriate reinforcements are fitted to the Society's satisfaction

(4) Allowable hold loading

The allowable hold loading W is given by:

$$W = \rho_c V \frac{1}{F} \quad (\mathrm{ton})$$

where :

F = 1.05, however, 1.0 for steel mill products

ρ_c = cargo density for bulk cargoes , for steel products, ρ_c is to be taken as the density of steel ($\mathrm{t/m}^3$)

V = volume occupied by cargo at a level h_1 (m^3)

$$h_1 = \frac{X}{\rho_c g}$$

X is as follows.

(A) for bulk cargoes the lesser of X_1 and X_2 given by:

$$X_1 = \frac{Z + \rho g (E - h_f)}{1 + \frac{\rho}{\rho_c}(perm - 1)}, \qquad X_2 = Z + \rho g (E - h_f perm)$$

ρ = sea water density ($\mathrm{t/m}^3$)

g = 9.81 $\mathrm{m/s}^2$, gravity acceleration

E = ship immersion for flooded hold condition, $d_f - 0.1D$

d_f = as specified in (2)(B)

h_f = flooding head as defined in (2)(B)
$perm$ = cargo permeability, to be taken as 0.3 for ore
Z = the lesser of Z_1 and Z_2 given by

$$Z_1 = \frac{C_h}{A_{DB,h}}, \quad Z_2 = \frac{C_e}{A_{DB,e}}$$

C_h = shear capacity of the double bottom as defined in (3), considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (See (3)(F)) and, for each girder, the lesser of the shear strengths S_{f1} and S_{f2} (See (3)(G))
C_e = shear capacity of the double bottom as defined in (3), considering, for each floor, the shear strength S_{f1} (See (3)(F)) and, for each girder, the lesser of the shear strengths S_{f1} and S_{f2} (See (3)(G))

$$A_{DB,h} = \sum_{i=1}^{i=n} S_i B_{DB,i}$$
$$A_{DB,e} = \sum_{i=1}^{i=n} S_i (B_{DB} - S)$$

n = number of floors between stools (or transverse bulkheads, if no stool is fitted)
S_i = space of ith-floor(m)
$B_{DB,i}$ = $B_{DB} - S$ for floors whose shear strength is given by S_{f1} (See (3)(F)) $B_{DB,h}$ for floors whose shear strength is given by S_{f2} (See (3)(F))
B_{DB} = breadth of double bottom between hoppers (m) (See **Fig 10**)
$B_{DB,h}$ = distance between the two considered opening (m) (See **Fig 10**)
S = spacing of double bottom longitudinals adjacent to hoppers (m)

(B) for steel products, X may be taken as X_1, using $perm$ = 0

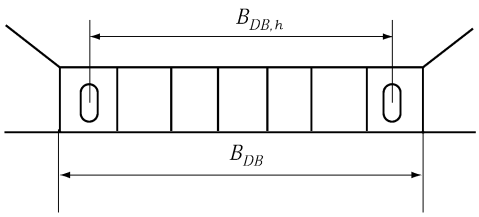


Fig 10 Measurement of $B_{DB,h}$ and B_{DB}

3. Damage Stability

(1) Bulk carriers which are subject to compliance with **Pars 1** and **2** shall, when loaded to the summer loadline, be able to withstand flooding of the foremost cargo hold in all loading conditions and remain afloat in a satisfactory condition of equilibrium, as specified in **SOLAS regulation XII 4.2** to **4.6.**
(2) A ship having been built with an insufficient number of transverse watertight bulkheads to satisfy this requirement may be exempted form the application of **Pars 1** and **2** and this requirement provided the ship fulfills the requirement in **SOLAS XII Reg. 9.** ⚓

Annex 7-6 Water Level Detection & Alarms and Drainage & Pumping Systems for Bulk Carriers and Single Hold Cargo Ships

I. Water level detection & alarms

1. General

(1) The plans containing details on installation, welding and electrical equipment of the water ingress alarm system specified in this Annex to be submitted to the Society for approval.
After installation on board, this system is to be tested and inspected by the attending Surveyor.

(2) Any water level detection & alarm is to be approved by the Society in accordance with the requirements of the relevant regulations.

2. Definitions

(1) **Water level detector** means a system comprising sensors and indication devices that detect and warn of water ingress in cargo holds and other spaces as required in **Pt 7 Ch 3 1403. 1** and **3** of the Rule.

(2) **Sensor** means a unit fitted at the location being monitored that activates a signal to identify the presence of water at the location in **Pt 7 Ch 3 1403. 1** and **3** of the Rule

(3) **Pre-alarm level** means the lower level(0.5 m, single hold cargo ships : not less than 0.3 m) at which the sensor(s) in the cargo hold space will operate.

(4) **Main alarm level** means the higher level($0.15D$ and above, however not exceed the maximum 2 m, single hold cargo ships : not more than $0.15D$) at which the sensor(s) in the cargo hold space will operate or the sole level in spaces other than cargo holds

(5) **Overriding device** means a device to make keeping the current function of an equipment, though a set alarm signal in it would be taken place.

(6) **Depth of ship** means the distance from bottom of cargo hold to hatch coaming. (See **Fig 1**)

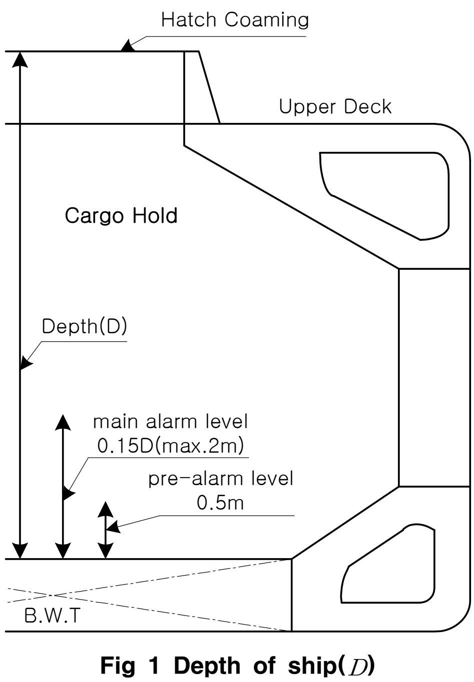


Fig 1 Depth of ship(D)

3. Installation requirements

(1) Bulk Carriers

(A) For cargo holds

(a) In each cargo hold, giving audible and visual alarms, one when the water level above the inner bottom in any hold reaches a height of 0.5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m. On bulk carriers to which **SOLAS Reg.XII/9.2** applies, detectors with only the latter alarm need be installed.

(b) The water level detectors are to be fitted in the aft end of the cargo hold. For cargo holds which are used for water ballast, an alarm overriding device may be installed. The visual alarms are to clearly discriminate between the two different water levels detected in each hold. The illustrations for application and location of installation are showing in Fig **2** to Fig **5.**

(c) The sensors may be installed inside of stools, where the ship has stools in cargo hold. In this case, the character of each sensor is to be considered in conjunction with installation.

(d) In case where the direct contact type detectors will be used, the inspection holes or the equivalent means are to be provided to remove the cargo/water mixture. The mesh size of filter element on inspection holes is to be decided by considering of the diameter of cargo particles and provided a spare filter element for each detector. Any filter element fitted to detectors is to be capable of being cleaned before new loading.

(B) In any ballast tank forward of the collision bulkhead required, giving an audible and visual alarm when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.

(C) In any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, giving an audible and visual alarm at a water level of 0.1 m above the deck. Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume.

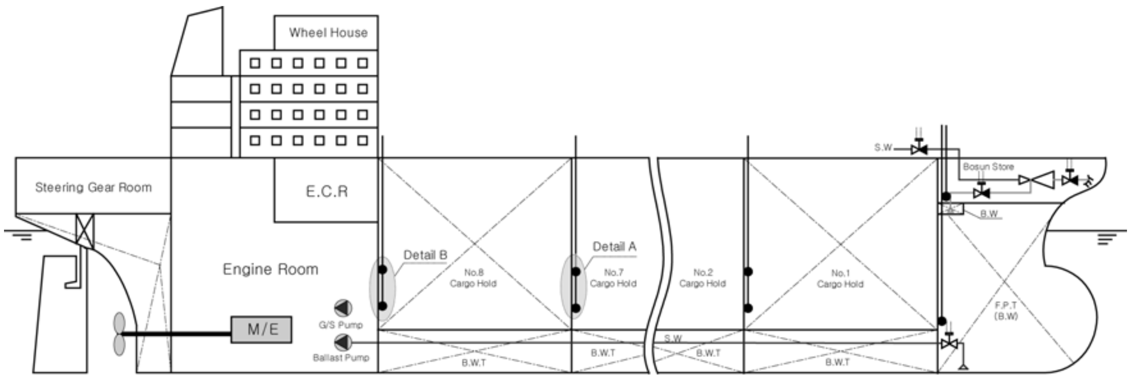


Fig 2 Installation position of water level detector

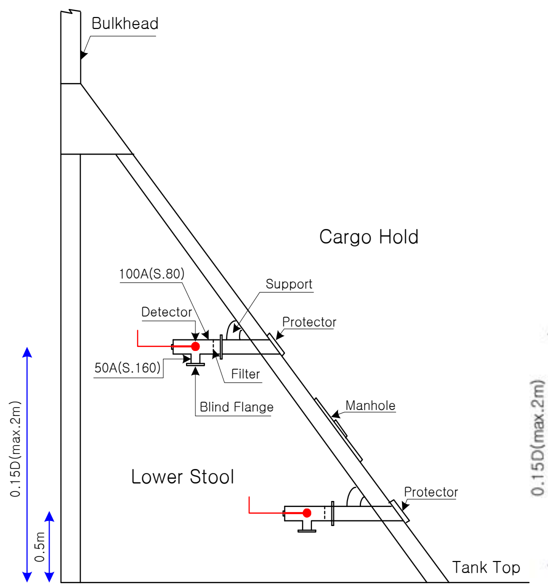


Fig 3 (Detail A)

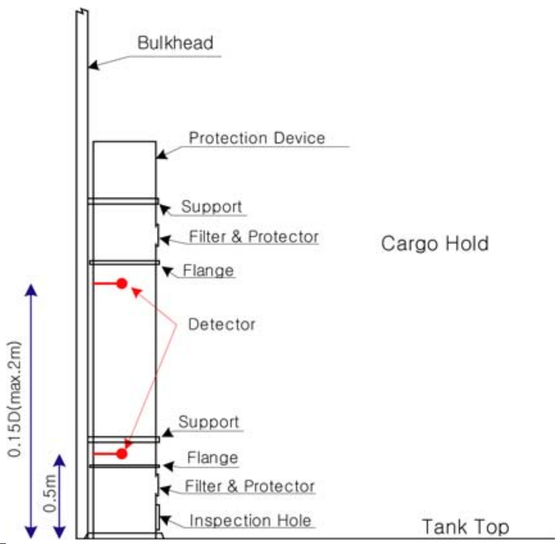


Fig 4 (Detail A)

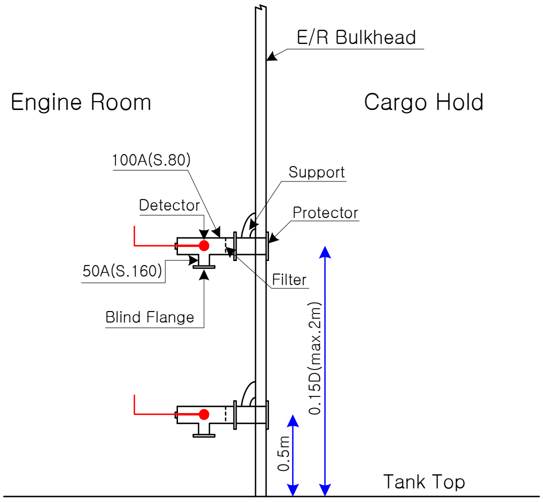


Fig 5 (Detail B)

(2) Single Hold Cargo Ships

(A) Those are to be fitted in such space with water level detectors which give an audible and visual alarm at the navigation bridge when the water level above the inner bottom in the cargo hold reaches a height of not less than 0.3 m, and another when such level reaches not more than 15 % of the mean depth of the cargo hold.

(B) Those are to be fitted at the aft end of the hold(above its lowest part where the inner bottom is not parallel to the designed waterline). Where webs or partial watertight bulkheads are fitted above the inner bottom, additional detectors are to be fitted.

4. Detector system requirements

(1) General

(A) This detecting system is to provide a reliable indication of water reaching a preset level. The audible and visual alarms are to be suitable for location on the navigation bridge.

(B) Protection of the enclosures of electrical components installed in cargo holds, ballast tanks and dry spaces are to be satisfied the requirements of **IP68** in accordance with **(KS C) IEC 60529.**

(C) Protection of the enclosures of electrical components installed above ballast and cargo spaces are to be satisfied the requirements of **IP56** in accordance with **(KS C) IEC 60529.**

(D) The water level detector system is to be capable of being supplied with electrical power from two independent electrical supplies. Failure of one electrical power supply of them is to activate an alarm, both visual and audible.

(2) For cargo holds

An alarm, both visual and audible, is to be activated each when the level of water reaches the pre-alarm level or main alarm level in the cargo hold being monitored. The visual alarm is to identify the cargo hold and the audible main alarm is not to be the same as that for the pre-alarm level.

(3) For compartments other than cargo holds

An alarm, both visual and audible, is to be activated when the level of water in the space being monitored is detected on sensor. The characteristics of the visual and audible alarm is to be the same as those for the main alarm level in a cargo hold.

5. Functional requirements

(1) Means of detecting water level

The method of detecting water level may be by direct or indirect means. A direct means determines the presence of water by physical contact of the water with detection device and indirect means of detection include devices such as the air purge or ultrasonic type sensor.

(2) Functional requirements

(A) The system of detecting water level is to be capable of continuous operation while the ship is at sea.

(B) Detection equipment is to be suitably corrosion resistant for all intended cargoes.

(C) The detector indicating the water level is to be capable of activating to an accuracy of

±100 mm.

(D) The part of the system which has circuitry in the cargo area, is to be intrinsically safe type and at least a **IIB T3** in accordance with **(KS C) IEC** publication **60079.**

(E) Detectors serving a cargo hold is to be capable of being functionally tested in situation when the hold is empty using either direct or indirect methods.

(3) Installation of sensors

(A) The sensors are to be located in a protected position that is communication with the aft part of the cargo hold such that position of the sensor detects the level that is representative of the levels in the actual hold space. These sensors are to be located either as close to the centerline as practicable, or at both the port and starboard sides of the cargo hold.

(B) The detector installation should not inhibit the use of any sounding pipe or other water level gauging device for cargo holds or other spaces and detectors and equipment are to be installed where they are accessible for survey, maintenance and repair.

(C) Electrical cables and any associated equipment installed in cargo holds are to be protected from damage by cargoes or mechanical handling equipment associated with bulk carrier operations, such as in tubes of robust construction or in similar protected locations.

6. Alarm system requirements

(1) The visual and audible alarms are to be suitable for location on the navigation bridge. These alarms are to be complied with the requirements of the **SOLAS Chap.V/Reg.17&18** and also the **Code on Alarms and Indicators.**

(2) Visual indication using a light of a distinct colour, or digital display that is clearly visible in all expected light levels, which does not seriously interfere with other activities necessary for the safe operation of the ship. The visual indication is to be capable of remaining visible until the condition activating it has returned below the level of the relevant sensor. The visual indication is not to be capable of being extinguished by the operator. In case of the system with a flickering function, that flicker is to be capable of being muted by the operator, but, at that time, the visual indication is not to be extinguished.

(3) In conjunction with the visual indication for the same sensor, the system is to be capable of providing audible indication and alarms in the space in which the indicator is situated. The audible indication is to be capable of being muted by the operator.

(4) Time delays may be incorporated into the alarm system to prevent spurious alarms due to sloshing effects associated with ship motions.

(5) The system may be provided with a capability of overriding indication and alarms for the detection systems installed only in tanks and holds that have been designed for carriage of water ballast. An override visual indication capability should be provided throughout deactivation of the water level detector for the holds or tanks. However, where such an override capability is provided, cancellation of the override condition and reactivation of the alarm should automatically occur after the hold or tank has been de-ballasted to a level below the lowest alarm indicator level.

(6) Alarms are to continuously monitor the system and activate a visual and audible alarm on detecting a fault. The audible alarm is to be capable of being muted by manual operation but the visual indication should remain active until the malfunction is cleared. The alarm for malfunction is distinguishable from the alarm for water level detecting, but it may be substituted the system fail alarm.

(7) Alarm systems are to be complied with the requirements of **(KS C) IEC 60092-504**. A test switch for visual indication and audible alarm is to be fitted on alarm panel and the switch is to be returned to the off position automatically after any use.

7. System test requirements

(1) Alarm system

(A) The visual indication is not to be extinguished by the operator.

(B) It is to be set at a level that alerts operators and tested, but does not interfere with the safe operation of the ship.

(C) That they are distinguishable from other alarms.

(2) Water level detectors

(A) After installation on board, a functionality test for detectors is to be carried out. The test is to be represented the presence of water at the detectors for every level monitored, but simulation methods may be used where the direct use of eater is impracticable.

(B) Each detector alarm should be tested to verify that the pre-alarm(0.5 m, single hold cargo ships : not less than 0.3 m) and main alarm levels[0.15 D (max. 2 m), single hold cargo ships : not more than 0.15 D] operate for every space where they are installed and indicate correctly. Also, the fault monitoring arrangements should be tested as far as practicable.

(C) Records of testing of alarm systems should be retained on board.

8. Manuals

Documented operating and maintenance procedures for water level detection containing the following informations are to be kept on board and readily accessible and the procedures are to be written in working language of the master and officers:

- A description of the equipment for detection and alarm arrangements
- Evidence that the equipment has been type tested
- Line diagrams of the detection and alarm system showing the positions of equipment.
- Installation instructions for setting, securing, protecting and testing.
- List of cargoes for which the detector is suitable for operating in a 50% seawater slurry mixture
- Procedures to be followed in the event of equipment not functioning correctly.
- Maintenance requirements for equipment and system.

II. Drainage and pumping system

1. General

The plans containing piping diagram of drainage and pumping systems specified in this Annex are to be submitted for approval by the Society and after installation on board, a functionality test for the pumping system is to be carried out.

2. Position for installation

(1) Ballast tanks forward of the collision bulkhead

(2) Dry spaces other than chain lockers, any part of which extends forward of the foremost cargo hold and the volume of which exceeds 0.1% of the ship's maximum displacement volume.

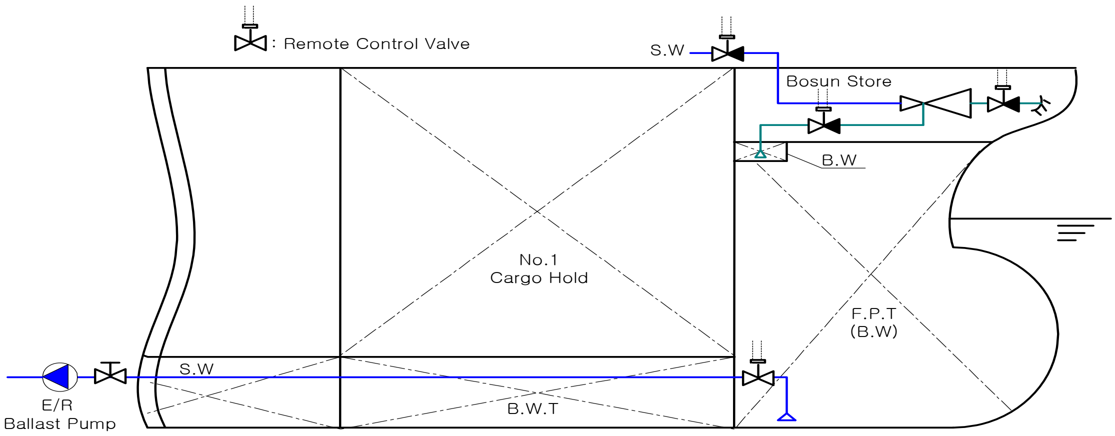


Fig 6 Application example

3. Requirements for installation

(1) The means for draining and pumping ballast tanks forward of the collision bulkhead and bilges of dry spaces any part of which extends forward of the foremost cargo hold shall be capable of being brought into operation from a readily accessible enclosed space, the location of which accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks.

(2) Where the piping arrangements for dewatering closed dry spaces are connected to the piping arrangements for the drainage of water ballast tanks, two non-return valves are to be provided to

prevent the ingress of water into dry spaces from those intended for the carriage of water ballast. One of these non-return valves is to be fitted with shut-off isolation arrangement. The non-return valves are to be located in readily accessible positions. The shut-off isolation arrangement are to be capable of being controlled from the navigation bridge, the propulsion machinery control position or enclosed space which is readily accessible from the navigation bridge or the propulsion machinery control position without travelling exposed freeboard or superstructure decks. In this context, a position which is accessible via an under deck passage, a pipe trunk or other similar means of access is not to be taken as being in the "readily accessible enclosed space".

(3) Where pipes serving such tanks or bilges pierce the collision bulkhead, valve operation by means of remotely operated actuators may be accepted provided that the location of such valve controls complies with this regulation **3** (1).

(4) The remote control valve is not to move from the demanded position in the case of failure of the control system power or actuator power.

(5) Positive indication is to be provided at the remote control station to show that the valve is fully open or closed.

(6) The dewatering arrangements are to be such that when they are in operation, other systems essential for the safety of the ship including fire-fighting and bilge systems remain available and ready for immediate use. The systems for normal operation of electric power supplies, propulsion and steering are not to be affected by the operation of the dewatering systems.

(7) Bilge wells in dry space are to be provided with gratings or strainers that will prevent blockage of the dewatering system with debris.

(8) The enclosures of electrical equipment for the dewatering system installed in any of the forward dry spaces are to provide protection to IPX8 standard as defined in **Pt 6, Ch 1, 103. 2** (1) (B) of the Guidance, **Table 6.1.3** and (KS C) (KS C) IEC Publication 60529 for a water head equal to the height of the space in which the electrical equipment is installed for a time duration of at least 24 hours.

(9) The dewatering system for ballast tanks located forward of the collision bulkhead and for bilges of dry spaces any part of which extends forward of the foremost cargo hold is to be such that any accumulated water can be drained directly by a pump or eductor and to be designed to remove water from the forward spaces at a rate of not less than the following formula.

$$Q = 320 \times A$$

where :

Q : Capacity of the dewatering system (m^3/h)

A : Cross-sectional area of the largest air pipe or ventilator pipe connected from the exposed deck to a closed forward space that is required to be dewatered by these arrangements (m^2) ⚓

Annex 7-7 Unified Interpretation of Convention

(Unless expressly specified otherwise, the requirements in these Annex apply in accordance with keeling date based on SOLAS Convention)

1. UI SC 207 (Structural Strength of Bulk Carriers in case of Accidental Hold Flooding)

(1) This is to clarify the implementation date between SOLAS XII/5.2 and IACS UR S17, S18 and S20, these structural requirements are to be complied with in respect of the flooding of any cargo hold of bulk carriers of 150 m in length and above, intending to carry solid bulk cargoes 1.0 t/m^3 density or above.

(2) Unified Interpretation
Regardless of the date of contract for construction, or the cargo hold cross section configuration, of ships which shall comply with SOLAS XII/5.2, such ships are to comply with IACS Unified Requirements(UR) S17(rev.7), S18(rev.7) for corrugated transverse bulkheads, where fitted, and S20(rev.4), if they do not comply with the IACS CSR for bulk carriers.

3) This is uniformly implemented from 1 July 2006.

2. UI SC 208 (Protection of Cargo Holds Loading/Unloading Equipment)

(1) This is to clarify the implementation date between SOLAS XII/6.4.1 (SLS. 14 / Circ. 250) and IACS CSR, in terms of protection of cargo holds from loading/discharge equipment of bulk carriers of 150 m in length and above, intending to carry solid bulk cargoes 1.0 t/m^3 density or above.

(2) Unified Interpretation
Bulk carriers which shall comply with SOLAS regulation XII/6.4.1 and which do not comply with the IACS CSR for Bulk Carriers, are to comply with the following:
(A) The grab requirements of **Pt 3,** of the Rules.
(B) Wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders(i.e. upper portion of top side tank plates)/hatch end beams in cargo hold and upper portion of hatch coamings.

(3) The requirements of (A) and (B) are satisfied, "Grab" notation of our Society is to be imposed.

(4) This is uniformly implemented from 1 July 2006.

3. UI SC 209 (Failure of Cargo Hold Structural Members and Panels)

(1) This is to bridge the gap
- The 1 April 2006 contract for construction date associated with CSR for bulk carriers and the 1 July 2006 keel laying date associated with the entry into force of the amended SOLAS XII/6.5.3.
- The definition of bulk carriers according to UR and the new definition of the amended SOLAS XII/6.5.3.

and to give an equivalent criteria regarding lateral buckling of ordinary stiffeners for ships which shall comply with SOLAS XII/6.5.3, but are not designed according to CSR for bulk carriers.

(2) Unified Interpretation
Ships which shall comply with SOLAS XII/6.5.3 are to satisfy either (A) or (B) as given below.
(A) CSR for bulk carriers, **Ch 3, Sec 1** "Material" and **Ch 6, Sec 3** "Buckling & ultimate strength of ordinary stiffeners and stiffened panels.
(B) For ships not designed according to CSR for Bulk Carriers (**Ch 3, Sec 1** and **Ch 6, Sec 3**):
(a) For ships with single side structures the material grade shall not be less than grade D/DH for :
- lower bracket of side frame
- side shell plate between two points located to 0.125 l above and 0.125 l below the intersection of side shell and bilge hopper sloping plate or inner bottom plate. The

span of the side frame, l, is defined as the distance between the supporting structures.

In case of side frames built with multiple spans, the above requirements apply to the lower part only. (See **Fig 1**)

(b) The safety factor with respect to lateral buckling of longitudinal and transverse ordinary stiffeners is to be increased by a factor at least 1.15(allowable utilization factor to be reduced by at least 1/1.15=0.87) for the following areas.

- hatchway coaming
- inner bottom
- sloped stiffened panel of topside tanks and hopper tanks (if any)
- inner side (if any)
- top stool and bottom stool of transverse bulkhead (if any)
- stiffened transverse bulkhead (if any)
- side shell (if directly bounding the cargo hold)

The lateral buckling requirements of ordinary stiffeners shall be in accordance with the Rules of the Society.

(3) This is uniformly implemented from 1 July 2006 at the time of the assessment of concerned parts. ⚓

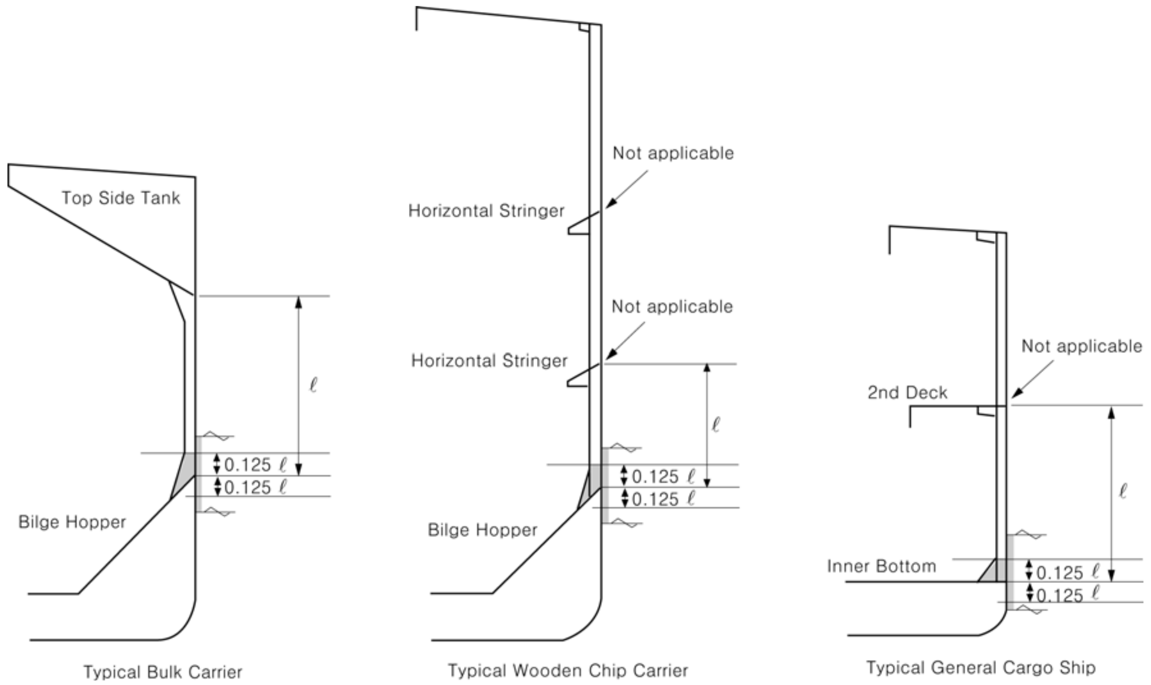


Fig 1 Typical configuration

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 7 SHIPS OF SPECIAL SERVICE

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2011

Rules for the Classification of Steel Ships

Part 7 Ships of Special Service (Ch 5, 6)

Rules

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Guidance

KOREAN REGISTER

2011

Rules for the Classification of Steel Ships

Part 7

Ships of Special Service

Chapter 5 Ships Carrying Liquefied Gases in Bulk
Chapter 6 Ships Carrying Dangerous Chemicals in Bulk

RA-07B-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 7 "SHIPS OF SPECIAL SERVICE(CH 5, 6)"

1. Unless expressly specified otherwise, the requirements in the Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.

2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date 1 July 2011

CHAPTER 5 SHIPS CARRYING LIQUEFIED GASES IN BULK

Section 5 Process Pressure Vessels and Liquid, Vapour, and Pressure Piping Systems

- 503. has been amended.

CHAPTER 6 SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

Section 11 Fire Protection and Fire Extinction

- 1101. has been amended.

CONTENTS

CHAPTER 5 SHIPS CARRYING LIQUEFIED GASES IN BULK

Section 1 General

101. Application (IGC Code 1.1)

1. The requirements in this Chapter apply to ships constructed on or after 1 July 1998. Ships constructed before 1 July 1998 are subject to the requirements of IMO Res. MSC. 5(48) adopted on 17 June 1983 and its additional amendments. Ships constructed before 1 July 1986 are subject to the requirements of IMO Res. A. 328(IX) and its additional amendments and ships constructed before 1 November 1976 are to comply with the requirements of IMO Res. A. 329(IX). **802. 18** and **Sec 15** apply to all ships carrying liquefied gases in bulk regardless of the date of construction. Ships constructed before 1 July 1986 and not having the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, are to comply with the special requirements given by the Society.

2. The requirements in this Chapter apply to ships carrying liquefied gases in bulk (hereinafter referred to as a "ship" in this Chapter) intended to be registered and classed with the Society. The term "liquefied gases" means liquefied gases having an absolute vapour pressure exceeding 0.28 MPa at a temperature of 37.8°C, and other similar flammable products as shown in **Sec 19.**

3. The construction and equipment of ships for carriage of such liquefied gases which are not designated in **Sec 19** are to be to the satisfaction of the Society.

4. For ships to be classed for restricted service and ships not provided with propulsive machinery, the requirements may be modified as appropriate.

5. The ship's hull, machinery and equipment not specified in this Chapter are generally to comply with the requirements in the relevant Chapters of these Rules.

6. When it is intended to carry products covered by this Chapter and products covered by **Ch 6,** the ship should comply with the requirements of both Chapters appropriate to the products carried. However, when a ship is designed and constructed for the carriage of the products listed exclusively in **Sec 19,** the requirements of this Chapter should take precedence.

7. The Society may be subject to IMO decisions which would be different from the requirements of this Chapter.

102. Approval for plans

For classification survey during construction, the following plans and documents as may be required depending upon the products intended to be loaded, condition of cargo storage, construction of cargo containment system and other design conditions are to be submitted in triplicate before the work is commenced.

1. Plans and data for approval

(1) Manufacturing specifications for cargo tanks, insulations and secondary barriers (including welding procedures, inspection and testing procedures for weld and cargo tanks, properties of insulation materials and secondary barriers and their processing manual and working standards)
(2) Details of cargo tank construction
(3) Arrangement of cargo tank accessories including details of fittings inside the tanks
(4) Details of cargo tank supports, deck portions through which cargo tanks penetrate, and their sealing devices
(5) Details of secondary barriers
(6) Specifications and standards of materials (including insulations) used for cargo piping system in connection with design pressure and/or temperature
(7) Specifications and standards of materials of cargo tanks, insulations, secondary barriers and cargo tank supports
(8) Layout and details of attachment for insulations
(9) Constructions of cargo pumps, cargo compressors and their prime movers
(10) Constructions of main parts of refrigeration systems

(11) Piping diagrams of cargo and instrument
(12) Piping diagrams of refrigerant for refrigeration systems
(13) Bilge arrangements and ventilation systems in hold spaces or interbarrier spaces, cargo pump room, cargo compressor room and cargo control room
(14) Arrangement of sensors for gas detectors, temperature indicators, and pressure gauges
(15) Diagrams of inert gas lines and details of pressure adjusting devices, where hold spaces or interbarrier spaces are filled by inert gases
(16) Details of pressure relief devices and drainage systems for leakage of liquefied cargo in hold spaces or interbarrier spaces
(17) Sectional assembly, details of nozzles, fitting arrangement and details of fittings for various pressure vessels
(18) Details of valves for special purpose, cargo hoses, expansion joints, filters, etc., for cargo piping system
(19) Piping diagram, constructions and particulars of utilization units, where cargo is used as fuel
(20) Electric wiring plans and a table of electrical equipment in dangerous spaces
(21) Arrangement of earth connections for cargo tanks, pipe lines, machinery, equipment, etc.
(22) Plans showing dangerous spaces
(23) Fire extinguishing system stipulated in **Sec 11.**

2. Plans and data for reference

(1) Principal basic design and technical reports of cargo containment systems
(2) Data of test method and its result, where model test is carried out in compliance with the requirements of **Sec 4.**
(3) Data for notch toughness, corrosiveness, physical and mechanical properties of materials and welded parts at the minimum design temperature and room temperature, where new materials or welding methods are adopted for constructing the cargo tanks, secondary barriers, insulations and others
(4) Data of design loads stipulated in **403.**
(5) Calculation sheets of cargo tanks and supports stipulated in **404.** to **406.**
(6) Data of the test method and the results, where model tests were carried out to demonstrate the strength and performance of cargo tanks, insulations, secondary barriers, cargo tank supports
(7) Calculation sheets of heat transfer on the main parts of cargo tank under various condition of loading, where considered necessary by the Society.
(8) Calculation sheets of the thermal stress on the main parts of cargo tank at the condition of the temperature distribution stipulated in (7), where considered necessary by the Society
(9) Calculation sheets of temperature distribution on hull structure, where considered necessary by the Society
(10) Specifications of cargo handling systems
(11) Composition and physical properties of cargoes (including a saturated vapour pressure diagram within the necessary temperature range)
(12) Calculation sheets of relieving capacity for pressure relief valves of cargo tank (including calculation of the back pressure in cargo vent system)
(13) Calculation sheets for capacity of refrigeration systems
(14) Cargo piping arrangement
(15) Calculation sheets of filling limits for cargo tanks
(16) Arrangement of access manholes stipulated in **305.** in cargo tank area and the guide for access through these manholes.
(17) Operation manual stipulated in **Sec 18.**
(18) Calculation for ship survival capability stipulated in **Sec 2.**
(19) Equipment for personnel protection stipulated in **Sec 14.**

103. Equivalents

The construction and equipment, etc. which do not fall under the provisions of this Chapter but are considered to be equivalent to those required in this Chapter will be accepted by the Society.

104. National regulations

For the construction and equipment of the ship, attention is to be paid to the requirements of the national regulations of the country in which the ship is registered and/or of the port which the ship intendes to visit.

105. Hazards (IGC Code 1.2)

Hazards of gases covered by this Chapter include fire, toxicity, corrosivity, reactivity, low temperature and pressure.

106. Definitions (IGC Code 1.3)

The definitions of terms are to be as specified in the following and **Sec 4,** unless otherwise specified elsewhere.

1. "**Accommodation spaces**" are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces. Public spaces are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

2. "**A class divisions**" are those divisions formed by bulkheads and decks which comply with the following criteria:

(1) they are constructed of steel or other equivalent material;
(2) they are suitably stiffened;
(3) they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140 ℃ above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180 ℃ above the original temperature, within the time listed below:

class "A-60" 60 min
class "A-30" 30 min
class "A-15" 15 min
class "A-0" 0 min

(4) they are constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test; and
(5) the Society has required a test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code to ensure that it meets the requirements above for integrity and temperature rise.

3. (1) "**Administration**" means the Government of the State whose flag the ship is entitled to fly.

(2) "**Port Administration**" means the appropriate authority of the country in the Port of which the ship is loading or unloading.

4. "**Boiling point**" is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure.

5. "**Breadth (B)**" means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material. The breadth (B) should be measured in metres.

6. "**Cargo area**" is that part of the ship which contains the cargo containment system and cargo pump and compressor rooms and includes deck areas over the full length and breadth of the part of the ship over the above-mentioned spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space are excluded from the cargo area.

7. "**Cargo containment system**" is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the hold space.

8. "**Cargo control room**" is a space used in the control of cargo handling operations and complying with the requirements of **304.**

9. "**Cargoes**" are products listed in **Sec 19** carried in bulk by ships subject to this Chapter.

10. "**Cargo service spaces**" are spaces within the cargo area used for workshops, lockers and store-rooms of more than 2 m^2 in area, used for cargo handling equipment.

11. "**Cargo tank**" is the liquid-tight shell designed to be the primary container of the cargo and includes all such containers whether or not associated with insulation or secondary barriers or both.

12. "**Cofferdam**" is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

13. "**Control stations**" are those spaces in which ships" radio or main navigating equipment or the emergency source of power is located or where the fire-recording or fire-control equipment is centralized. This does not include special fire-control equipment which can be most practically located in the cargo area.

14. "**Flammable products**" are those identified by an "F" in column "f" in the table of **Sec 19.**

15. "**Flammability limits**" are the conditions defining the state of fuel-oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

16. "**Gas carrier**" is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in the table of **Sec 19.**

17. "**Gas-dangerous space or zone**" is:

(1) a space in the cargo area which is not arranged or equipped in an approved manner to ensure that its atmosphere is at all times maintained in a gas-safe condition;
(2) an enclosed space outside the cargo area through which any piping containing liquid or gaseous products passes, or within which such piping terminates, unless approved arrangements are installed to prevent any escape of product vapour into the atmosphere of that space;
(3) a cargo containment system and cargo piping;
(4) (a) a hold space where cargo is carried in a cargo containment system requiring a secondary barrier;
(b) a hold space where cargo is carried in a cargo containment system not requiring a secondary barrier;
(5) a space separated from a hold space described in (4) (a) by a single gastight steel boundary;
(6) a cargo pump room and cargo compressor room;
(7) a zone on the open deck, or semi-enclosed space on the open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo pipe flange or cargo valve or of entrances and ventilation openings to cargo pump rooms and cargo compressor rooms;
(8) the open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2.4 m above the weather deck;
(9) a zone within 2.4 m of the outer surface of a cargo containment system where such surface is exposed to the weather;
(10) an enclosed or semi-enclosed space in which pipes containing products are located. A space which contains gas detection equipment complying with **1306. 5** and a space utilizing boil-off gas as fuel and complying with **Sec 16** are not considered gas-dangerous spaces in this context;
(11) a compartment for cargo hoses; or
(12) an enclosed or semi-enclosed space having a direct opening into any gas-dangerous space or zone.

18. "**Gas-safe space**" is a space other than a gas-dangerous space.

19. "**Hold space**" is the space enclosed by the ship's structure in which a cargo containment system is situated.

20. "**Independent**" means that a piping or venting system, for example, is in no way connected to another system and there are no provisions available for the potential connection to other systems.

21. "**Insulation space**" is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation.

22. "**Interbarrier space**" is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material.

23. "**Length (L)**" means 96 % of the total length on a waterline at 85 % of the least moulded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel, the waterline on which this length is measured should be parallel to the designed waterline. The length (L)

should be measured in metres.

24. ″**Machinery spaces of category A**″ are those spaces and trunks to such spaces which contain:

(1) internal combustion machinery used for main propulsion; or
(2) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(3) any oil-fired boiler or oil fuel unit.

25. ″**Machinery spaces**″ are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces; and trunks to such spaces.

26. ″**MARVS**″ is the maximum allowable relief valve setting of a cargo tank.

27. ″**Oil fuel unit**″ is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0.18 MPa gauge.

28. ″**Organization**″ is the International Maritime Organization (IMO).

29. ″**Permeability**″ of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

30. (1) ″**Primary barrier**″ is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.

(2) ″**Secondary barrier**″ is the liquid-resisting outer element of a cargo containment system designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level. Types of secondary barrier are more fully defined in **Sec 4.**

31. ″**Relative density**″ is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.

32. ″**Separate**″ means that a cargo piping system or cargo vent system, for example, is not connected to another cargo piping or cargo vent system. This separation may be achieved by the use of design or operational methods. Operational methods should not be used within a cargo tank and should consist of one of the following types:

(1) removing spool pieces or valves and blanking the pipe ends;
(2) arrangement of two spectacle flanges in series with provisions for detecting leak age into the pipe between the two spectacle flanges.

33. ″**Service spaces**″ are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store-rooms, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

34. ″**SOLAS**″ means the International Convention for the Safety of Life at Sea,1974, as amended.

35. ″**1983 SOLAS amendments**″ means amendments to the 1974 SOLAS Convention adopted by the Maritime Safety Committee of the Organization at its forty-eighth session on 17 June 1983 by resolution MSC. 6(48).

36. ″**Tank cover**″ is the protective structure intended to protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.

37. ″**Tank dome**″ is the upward extension of a portion of a cargo tank. In the case of below-deck cargo containment systems the tank dome protrudes through the weather deck or through a tank cover.

38. ″**Toxic products**″ are those identified by a "T" in column "f" in the table of **Sec 19.**

39. ″**Vapour pressure**″ is the equilibrium pressure of the saturated vapour above the liquid expressed in bar absolute at a specified temperature.

40. ″**Void space**″ is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, fuel oil tank, cargo pump or compressor room, or any space in normal use by personnel.

41. "**Recognized standards**" are applicable international or national standards acceptable to the Society or standards laid down and maintained by the Society which complies with the standards adopted by the organization.

Section 2 Ship Survival Capability and Location of Cargo Tanks

201. General (IGC Code 2.1)

1. Ships subject to this Chapter should survive the normal effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship and the environment, the cargo tanks should be protected from penetration in the case of minor damage to the ship resulting, for example, from contact with a jetty or tug, and given a measure of protection from damage in the case of collision or stranding, by locating them at specified minimum distances inboard from the ship's shell plating. Both the damage to be assumed and the proximity of the tanks to the ship's shell should be dependent upon the degree of hazard presented by the product to be carried.

2. Ships subject to this Chapter should be designed to one of the following standards:

(1) A type 1 G ship is a gas carrier intended to transport products indicated in **Sec 19** which require maximum preventive measures to preclude the escape of such cargo.
(2) A type 2 G ship is a gas carrier intended to transport products indicated in **Sec 19** which require significant preventive measures to preclude the escape of such cargo.
(3) A type 2 PG ship is a gas carrier of 150 m in length or less intended to transport products indicated in Sec 19 which require significant preventive measures to preclude escape of such cargo, and where the products are carried in independent type C tanks designed (see **402. 4** (4)) for a MARVS of at least 0.7 MPa gauge and a cargo containment system design temperature of -55°C or above. Note that a ship of this description but over 150 m in length is to be considered a type 2 G ship.
(4) A type 3 G ship is a gas carrier intended to carry products indicated in **Sec 19** which require moderate preventive measures to preclude the escape of such cargo.

Thus a type 1 G ship is a gas carrier intended for the transportation of products considered to present the greatest overall hazard and types 2 G/2 PG and type 3 G for products of progressively lesser hazards. Accordingly, a type 1 G ship should survive the most severe standard of damage and its cargo tanks should be located at the maximum prescribed distance inboard from the shell plating.

3. The ship type required for individual products is indicated in column "c" in the table of **Sec 19.**

4. If a ship is intended to carry more than one product listed in **Sec 19,** the standard of damage should correspond to that product having the most stringent ship type requirement. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.

202. Freeboard and intact stability (IGC Code 2.2)

1. Ships subject to this Chapter may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment should not be greater than the maximum draught otherwise permitted by this Chapter.

2. The stability of the ship in all seagoing conditions and during loading and unloading cargo should be to a standard which is acceptable to the Society.

3. When calculating the effect of free surfaces of consumable liquids for loading conditions it should be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface and the tank or combination of tanks to be taken into account should be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments should be calculated by a method acceptable to the Society.

4. Solid ballast should not normally be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, then its disposition should be governed by the need to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

5. The master of the ship should be supplied with a Loading and Stability Information booklet. This booklet should contain details of typical service conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the ship's survival capabilities. In addition, the booklet should contain sufficient information to enable the master to load and operate the ship in a safe and seaworthy manner.

203. Shipside discharges below the freeboard deck (IGC Code 2.3)

1. The provision and control of valves fitted to discharges led through the shell from spaces below the freeboard deck or from within the superstructures and deckhouses on the freeboard deck fitted with weathertight doors should comply with the requirements of the relevant regulation of the International Convention on Load Lines in force, except that the choice of valves should be limited to:

(1) one automatic non-return valve with a positive means of closing from above the freeboard deck; or

(2) where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0.01 L, two automatic non-return valves without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions.

2. For the purpose of this Section "**summer load waterline**" and "**freeboard deck**", have the meanings defined in the International Convention on Load Lines in force.

3. The automatic non-return valves referred to in **Par 1** (1) and (2) should comply with recognized standards and should fully effective in preventing admission of water into the ship, taking into account the sinkage, trim and heel in survival requirements in **209.**

204. Conditions of loading (IGC Code 2.4)

Damage survival capability should be investigated on the basis of loading information submitted to the Society for all anticipated conditions of loading and variations in draught and trim. The survival requirements need not be applied to the ship when in the ballast condition, provided that any cargo retained on board is solely used for cooling, circulation or fuelling purposes.

205. Damage assumptions (IGC Code 2.5)

1. The assumed maximum extent of damage should be:

(1) Side damage:

(a) Longitudinal extent: 1/3 $L^{2/3}$ or 14.5 m, whichever is less

(b) Transverse extent: B/5 or 11.5 m, whichever is less
measured inboard from the ship's side at right angles to the centreline at the level of the summer load line

(c) Vertical extent: upwards without limit
from the moulded line of the bottom shell plating at centreline.

(2) Bottom damage:

	For 0.3 L from the forward perpendicular of the ship	Any other part of the ship
(a) Longitudinal extent:	1/3 $L^{2/3}$ or 14.5 m, whichever is less	1/3$L^{2/3}$ or 5 m, whichever is less
(b) Transverse extent:	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
(c) Vertical extent:	B/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline. (see **206. 3**)	B/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline. (see **206. 3**)

2. Other damage:

(1) If any damage of a lesser extent than the maximum damage specified in **Par 1** would result in a more severe condition, such damage should be assumed.

(2) Local side damage anywhere in the cargo area extending inboard 760 mm measured normal to the hull shell should be considered and transverse bulkheads should be assumed damaged when also required by the applicable subparagraphs of **208.1.**

206. Location of cargo tanks (IGC Code 2.6)

1. Cargo tanks should be located at the following distances inboard:

(1) Type 1 G ships: from the side shell plating not less than the transverse extent of damage specified in **205.1** (1) (b) and from the moulded line of the bottom shell plating at centreline not less than the vertical extent of damage specified in **205.1** (2) (c) and nowhere less than 760 mm from the shell plating.

(2) Types 2 G/2 PG and 3 G ships: from the moulded line of the bottom shell plating at centre-line not less than the vertical extent of damage specified in **205. 1** (2) (c) and nowhere less than 760 mm from the shell plating.

2. For the purpose of tank location, the vertical extent of bottom damage should be measured to the inner bottom when membrane or semi-membrane tanks are used, otherwise to the bottom of the cargo tanks. The transverse extent of side damage should be measured to the longitudinal bulkhead when membrane or semi-membrane tanks are used, otherwise to the side of the cargo tanks (see **Fig 7.5.1**). For internal insulation tanks the extent of damage should be measured to the supporting tank plating.

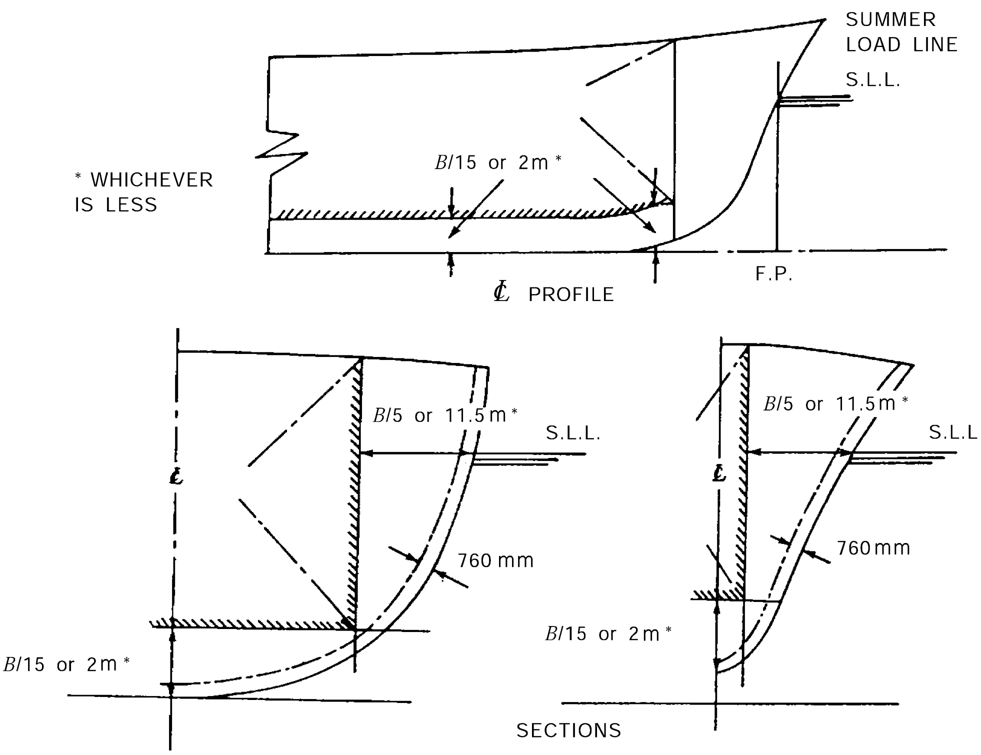


Fig 7.5.1 Tank location requirements as set out in 206.

3. Except for type 1 G ships, suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in **205. 1** (2) (c) provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25 % of the depth of the double bottom or 350 mm, whichever is less. Where there is no double bottom, the protrusion below the upper limit of bottom damage should not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored in determining the compartments affected by damage.

207. Flooding assumptions (IGC Code 2.7)

1. The requirements of **209.** should be confirmed by calculations which take into consideration the design characteristics of the ship; the arrangements, configuration and contents of the damaged compartments; the distribution, relative densities and the free surface effects of liquids; and the draught and trim for all conditions of loading.

2. The permeabilities of spaces assumed to be damaged should be as follows:

Spaces	Permeabilities
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Voids	0.95
Intended for consumable liquids	0 to 0.95
Intended for other liquids	0 to 0.95

3. Wherever damage penetrates a tank containing liquids, it should be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.

4. Where the damage between transverse watertight bulkheads is envisaged as specified in **208. 1** (4), (5) and (6), transverse bulkheads should be spaced at least at a distance equal to the longitudinal extent of damage specified in **205. 1** (1) (a) in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage should be assumed as non-existent for the purpose of determining flooded compartments. Further, any portion of a transverse bulkhead bounding side compartments or double bottom compartments should be assumed damaged if the watertight bulkhead boundaries are within the extent of vertical or horizontal penetration required by **205.** Also, any transverse bulkhead should be assumed damaged if it contains a step or recess of more than 3 m in length located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and after peak tank top should not be regarded as a step for the purpose of this paragraph.

5. The ship should be so designed as to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

6. Equalization arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, should not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of **209. 1** and sufficient residual stability should be maintained during all stages where equalization is used. Spaces which are linked by ducts of large cross-sectional area may be considered to be common.

7. If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in **205.,** arrangements should be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

8. The buoyancy of any superstructure directly above the side damage should be disregarded. The unflooded parts of superstructures beyond the extent of damage, however, may be taken into consideration provided that:

(1) they are separated from the damaged space by watertight divisions and the requirements of **209. 1** (1) in respect of these intact spaces are complied with; and

(2) openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in **209. 2** (1); however the immersion of any other openings capable of being closed weathertight may be permitted.

208. Standard of damage (IGC Code 2.8)

1. Ships should be capable of surviving the damage indicated in **205.** with the flooding assumptions in **207.** to the extent determined by the ship's type according to the following standards:

(1) A type 1 G ship should be assumed to sustain damage anywhere in its length;

(2) A type 2 G ship of more than 150 m in length should be assumed to sustain damage anywhere in its length;

(3) A type 2 G ship of 150 m in length or less should be assumed to sustain damage anywhere in

its length except involving either of the bulkheads bounding a machinery space located aft;

(4) A type 2 PG ship should be assumed to sustain damage anywhere in its length except involving transverse bulkheads spaced further apart than the longitudinal extent of damage as specified in **205. 1** (1) (a);

(5) A type 3 G ship of 125 m in length or more should be assumed to sustain damage anywhere in its length except involving transverse bulkheads spaced further apart than the longitudinal extent of damage specified in **205. 1** (1) (a);

(6) A type 3 G ship less than 125 m in length should be assumed to sustain damage anywhere in its length except involving transverse bulkheads spaced further apart than the longitudinal extent of damage specified in **205.1** (1) (a) and except damage involving the machinery space when located aft. However, the ability to survive the flooding of the machinery space should be considered by the Society.

2. In the case of small type 2 G/2 PG and 3G ships which do not comply in all respects with the appropriate requirements of **Par 1** (3), (4) and (6), special dispensations may only be considered by the Society provided that alternative measures can be taken which maintain the same degree of safety. The nature of the alternative measures should be approved and clearly stated and be available to the Port Administration. Any such dispensation should be duly noted on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

209. Survival requirements (IGC Code 2.9)

Ships subject to this Chapter should be capable of surviving the assumed damage specified in **205.** to the standard provided in **208.** in a condition of stable equilibrium and should satisfy the following criteria.

1. In any stage of flooding:

(1) the waterline, taking into account sinkage, heel and trim, should be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings should include air pipes and openings which are closed by means of weathertight doors or hatch covers and may exclude those openings closed by menas of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and sidescuttles of the non-opening type;

(2) the maximum angle of heel due to unsymmetrical flooding should not exceed 30°; and

(3) the residual stability during intermediate stages of flooding should be to the satisfaction of the Society. However, it should never be significantly less than that required by **Par 2** (1).

2. At final equilibrium after flooding:

(1) the righting lever curve should have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0.1 m within the 20° range; the area under the curve within this range should not be less than 0.0175 m·rad. Unprotected openings should not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in **Par 1** (1) and other openings capable of being closed weathertight may be permitted; and

(2) the emergency source of power should be capable of operating.

Section 3 Ship Arrangements

301. Segregation of the cargo area (IGC Code 3.1)

1. Hold spaces should be segregated from machinery and boiler spaces, accommodation spaces, service spaces and control stations, chain lockers, drinking and domestic water tanks and from stores. Hold spaces should be located forward of machinery spaces of category A, other than those deemed necessary by the Society for the safety or navigation of the ship.

2. Where cargo is carried in a cargo containment system not requiring a secondary barrier, segregation of hold spaces from spaces referred to in **Par 1** or spaces either below or outboard of the hold spaces may be effected by cofferdams, fuel oil tanks or a single gastight bulkhead of all-welded construction forming an A-60 class division. A gastight A-0 class division is satisfactory if there is no source of ignition or fire hazard in the adjoining spaces.

3. Where cargo is carried in a cargo containment system requiring a secondary barrier, segregation of hold spaces from spaces referred to in **Par 1** or spaces either below or outboard of the hold spaces which contain a source of ignition or fire hazard should be effected by cofferdams or fuel oil tanks. If there is no source of ignition or fire hazard in the adjoining space, segregation may be by a single A-0 class division which is gastight.

4. When cargo is carried in a cargo containment system requiring a secondary barrier:

(1) at temperatures below -10°C, hold spaces should be segregated from the sea by a double bottom; and

(2) at temperatures below -55°C, the ship should also have a longitudinal bulkhead forming side tanks.

5. Any piping system which may contain cargo or cargo vapour should:

(1) be segregated from other piping systems, except where inter-connections are required for cargo-related operations such as purging, gas-freeing or inerting. In such cases, precautions should be taken to ensure that cargo or cargo vapour cannot enter such other piping systems through the inter-connections;

(2) except as provided in **Sec 16,** not pass through any accommodation space, service space or control station or through a machinery space other than a cargo pump room or cargo compressor space;

(3) be connected into the cargo containment system directly from the open deck except that pipes installed in a vertical trunk-way or equivalent may be used to traverse void spaces above a cargo containment system and except that pipes for drainage, venting or purging may traverse cofferdams;

(4) except for bow or stern loading and unloading arrangements in accordance with **308.** and emergency cargo jettisoning piping systems in accordance with **Par 6,** and except in accordance with **Sec 16,** be located in the cargo area above the open deck; and

(5) except for thwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning piping systems, be located inboard of the transverse tank location requirements of **206.1.**

6. Any emergency cargo jettisoning piping system should comply with **Par 5** as appropriate and may be led aft externally to accommodation spaces, service spaces or control stations or machinery spaces, but should not pass through them. If an emergency cargo jettisoning piping system is permanently installed a suitable means of isolation from the cargo piping should be provided within the cargo area.

7. Arrangements should be made for sealing the weather decks in way of openings for cargo containment systems.

302. Accommodation, service and machinery spaces and control stations (IGC Code 3.2)

1. No accommodation space, service space or control station should be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations which face the cargo area should be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship having a containment system requiring a secondary barrier.

2. In order to guard against the danger of hazardous vapours, due consideration should be given to the location of air intakes and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements.

3. Access through doors, gastight or otherwise, should not be permitted from a gas-safe space to a gas-dangerous space, except for access to service spaces forward of the cargo area through air-locks as permitted by **306. 1** when accommodation spaces are aft.

4. Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations should not face the cargo area. They should be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4 % of the length (L) of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m. Windows and sidescuttles facing the cargo area and on the sides of the superstructure or deckhouse within the distance mentioned above should be of the fixed (non-opening) type. Wheelhouse windows may be non-fixed and wheelhouse doors may be located within the above limits so long as they are so designed that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured. For ships dedicated to the carriage of cargoes which have neither flammable nor toxic hazards, the Society may approve relaxations from the above requirements.

5. Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse should be of the fixed (non-opening) type.

6. All air intakes and openings into the accommodation spaces, service spaces and control stations should be fitted with closing devices. For toxic gases they should be operated from inside the space.

303. Cargo pump rooms and cargo compressor rooms (IGC Code 3.3)

1. (1) Cargo pump rooms and cargo compressor rooms should be situated above the weather deck and located within the cargo area unless specially approved by the Society. Cargo compressor rooms should be treated as cargo pump rooms for the purpose of fire protection according to SOLAS chapter II-2/9.2.4.

(2) When cargo pump rooms and cargo compressor rooms are permitted to be fitted above or below the weather deck at the after end of the aftermost hold space or at the forward end of the forwardmost hold space, the limits of the cargo area as defined in **106. 6** should be extended to include the cargo pump rooms and cargo compressor rooms for the full breadth and depth of the ship and deck areas above those spaces.

(3) Where the limits of the cargo area are extended by (2), the bulkhead which separates the cargo pump rooms and cargo compressor rooms from accommodation and service spaces, control stations and machinery spaces of category A should be so located as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

2. Where pumps and compressors are driven by shafting passing through a bulkhead or deck, gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal should be fitted in way of the bulkhead or deck.

3. Arrangements of cargo pump rooms and cargo compressor rooms should be such as to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. All valves necessary for cargo handling should be readily accessible to personnel wearing protective clothing. Suitable arrangements should be made to deal with drainage of pump and compressor rooms.

304. Cargo control rooms (IGC Code 3.4)

1. Any cargo control room should be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation spaces, service spaces or control stations provided the following conditions are complied with:

(1) the cargo control room is a gas-safe space; and

(2) (a) if the entrance complies with **302. 4,** the control room may have access to the spaces de-

scribed above;

(b) if the entrance does into comply with **302. 4,** the control room should have no access to the spaces described above and the boundaries to such spaces should be insulated to A-60 class integrity

2. If the cargo control room is designed to be a gas-safe space, instrumentation should, as far as possible, be by indirect reading systems and should in any case be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detector within the cargo control room will not violate the gas-safe space if installed in accordance with **1306. 5.**

3. If the cargo control room for ships carrying flammable cargoes is a gas-dangerous space, sources of ignition should be excluded. Consideration should be paid to the safety characteristics of any electrical installations.

305. Access to spaces in the cargo area (IGC Code 3.5)

1. Visual inspection should be possible of at least one side of the inner hull structure without the removal of any fixed structure or fitting. If such a visual inspection, whether combined with those inspections required in **Par 2, 407. 7** or **410. 16** or not, is only possible at the outer face of the inner hull, the inner hull should not be a fuel-oil tank boundary wall.

2. Inspection of one side of any insulation in hold spaces should be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.

3. Arrangements for hold spaces, void spaces and other spaces that could be considered gas-dangerous and cargo tanks should be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and in the event of injury to allow unconscious personnel to be removed from the space and should comply with the following:

(1) Access should be provided:

(A) to cargo tanks direct from the open deck;

(B) through horizontal openings, hatches or manholes, the dimensions of which should be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space; the minimum clear opening should be not less than 600 mm by 600 mm; and

(C) through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening of which should be not less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided.

(2) the dimensions referred to in (1) (B) and (C) may be decreased if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

(3) The requirements of (1) (B) and (C) do not apply to spaces described in **106. 17** (5). Such spaces should be provided only with direct or indirect access from the open weather deck, not including an enclosed gas-safe space.

4. Access from the open weather deck to gas-safe spaces should be located in a gas-safe zone at least 2.4 m above the weather deck unless the access is by means of an air-lock in accordance with **306.**

306. Air locks (IGC Code 3.6)

1. An air-lock should only be permitted between a gas-dangerous zone on the open weather deck and a gas-safe space and should consist of two steel doors substantially gastight spaced at least 1.5 m but not more than 2.5 m apart.

2. The doors should be self-closing and without any holding back arrangements.

3. An audible and visual alarm system to give a warning on both sides of the air lock should be provided to indicate if more than one door is moved from the closed position.

4. In ships carrying flammable products, electrical equipment which is not of the certified safe type in spaces protected by air locks should be de-energized upon loss of overpressure in the space (see also **1001.** 4). Electrical equipment which is not of the certified safe type for manoeuvring, anchoring and mooring equipment as well as the emergency fire pumps should not be located in spaces to be protected by air locks.

5. The air lock space should be mechanically ventilated from a gas-safe space and maintained at an overpressure to the gas-dangerous zone on the open weather deck.

6. The air-lock space should be monitored for cargo vapour.

7. Subject to the requirements of the International Convention on Load Lines in force, the door still should not be less than 300 mm in height.

307. Bilge, ballast and fuel oil arrangements (IGC Code 3.7)

1. (1) Where cargo is carried in a cargo containment system not requiring a secondary barrier, hold spaces should be provided with suitable drainage arrangements not connected with the machinery space. Means of detecting any leakage should be provided.

(2) Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through adjacent ship structure should be provided. The suction should not be led to pumps inside the machinery space. Means of detecting such leakage should be provided.

2. (1) The hold or interbarrier spaces of Type A independent tank ships should be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements should provide for the return of any cargo leakage to the liquid cargo piping.

(2) Arrangements referred to in (1) should provided with a removable spool piece. This paragraph applies to ships constructed on or after 1 July 2002.

3. In case of internal insulation tanks, means of detecting leakage and drainage arrangements are not required for interbarrier spaces and spaces between the secondary barrier and the inner hull or independent tank structure which are completely filled by insulation material complying with **409. 7** (2).

4. Ballast spaces, including wet duct keels used as ballast piping, fuel-oil tanks and gas-safe spaces may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through, may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps and the discharge from the pumps lead directly overboard with no valves or manifolds in either line which could connect the line from the duct keel to lines serving gas-safe spaces. Pump vents should not be open to machinery spaces.

308. Bow or stern loading and unloading arrangements (IGC Code 3.8)

1. Subject to the requirements in **308.,** cargo piping may be arranged to permit bow or stern loading and unloading.

Bow or stern loading and unloading lines which are led past accommodation spaces, service spaces or control stations should not be used for the transfer of products requiring a type 1G ship. Bow or stern loading and unloading lines should not be used for the transfer of toxic products as specified in **106. 38** unless specifically approved by the Society.

2. Portable arrangements should not be permitted.

3. In addition to the requirements of **Sec 5** the following provisions apply to cargo piping and related piping equipment:

(1) Cargo piping and related piping equipment outside the cargo area should have only welded connections. The piping outside the cargo area should run on the open deck and should be at least 760 mm inboard except for thwartships shore connection piping. Such piping should be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location, it should also be capable of being separated by means of a removable spool piece and blank flanges when not in use.

(2) The piping is to be full penetration butt welded, and fully radiographed regardless of pipe diameter and design temperature. Flange connections in the piping are only permitted within the cargo area and at the shore connection.

(3) Arrangements should be made to allow such piping to be purged and gas-freed after use When not in use, the spool pieces should be removed and the pipe ends be blank-flanged. The vent pipes connected with the purge should be located in the cargo area.

4. Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations should not face the cargo shore connection location of bow or stern loading and unloading arrangements. They should be located on the outboard side of the superstructure or deckhouse at a distance of at least 4 % of the length of the ship but not less than 3 m from the end of the superstructure or deck house facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Sidescuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above should be of the fixed (non-opening) type. In addition. during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side should be kept closed. Where, in the case of small ships, compliance with **302. 4** and this paragraph is not possible, the Society may approve relaxations from the above requirements.

5. Deck openings and air inlets to spaces within distances of 10 m from the cargo shore connection location should be kept closed during the use of bow or stern loading or unloading arrangements.

6. Electrical equipment within a zone of 3 m from the cargo shore connection location should be in accordance with **Sec 10.**

7. Fire-fighting arrangements for the bow or stern loading and unloading areas should be in accordance with **1103. 1** (3) and **1104. 7.**

8. Means of communication between the cargo control station and the shore connection location should be provided and if necessary certified safe.

Section 4 Cargo Containment

401. General (IGC Code 4.1)

1. The Society should take appropriate steps to ensure uniformity in the implementation and application of the provisions of this Section.

2. In addition to the definitions in **106.,** the definitions given in this Section apply throughout this Chapter.

402. Definitions (IGC Code 4.2)

1. Integral tanks

(1) Integral tanks form a structural part of the ship's hull and are influenced in the same manner and by the same loads which stress the adjacent hull structure.
(2) The design vapour pressure P_0 as defined in **Par 6** should not normally exceed 0.025 MPa. If, however, the hull scantlings are increased accordingly, P_0 may be increased to a higher value but less than 0.007 MPa.
(3) Integral tanks may be used for products provided the boiling point of the cargo is not below -10°C. A lower temperature may be accepted by the Society subject to special consideration.

2. Membrane tanks

(1) Membrane tanks are non-self-supporting tanks which consist of a thin layer (membrane) supported through insulation by the adjacent hull structure. The membrane is designed in such a way that thermal and other expansion or contraction is compensated for without undue stressing of the membrane.
(2) The design vapour pressure P_0 should not normally exceed 0.025 MPa. If, however, the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting insulation, P_0 may be increased to a higher value but less than 0.07 MPa.
(3) The definition of membrane tanks does not exclude designs such as those in which nonmetallic membranes are used or in which membranes are included or incorporated in insulation. Such designs require, however, special consideration by the Society. In any case the thickness of the membranes should normally not exceed 10 mm.

3. Semi-membrane tanks

(1) Semi-membrane tanks are non-self-supporting tanks in the loaded condition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure, whereas the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.
(2) The design vapour pressure P_0 should not normally exceed 0.025 MPa. If, however, the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting insulation, P_0 may be increased to a higher value but less than 0.07 MPa.

4. Independent tanks

(1) Independent tanks are self-supporting; they do not form part of the ship's hull and are not essential to the hull strength. There are three categories of independent tanks referred to in (2) to (4).
(2) Type A independent tanks are tanks which are designed primarily using recognized standards of classical ship-structural analysis procedures. Where such tank are primarily constructed of plane surfaces (gravity tanks), the design vapour pressure P_0 should be less than 0.07 MPa.
(3) Type B independent tanks are tanks which are designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (gravity tanks) the design vapour pressure P_0 should be less than 0.07 MPa.
(4) Type C independent tanks (also referred to as pressure vessels) are tanks meeting pressure vessel criteria and having a design vapour pressure not less than:

$P_0 = 0.2 + A\,C(\rho_r)^{\frac{3}{2}}$ (MPa)

where : $A = 0.00185\left(\dfrac{\sigma_m}{\triangle\sigma_A}\right)^2$

with

σ_m = design primary membrane stress

$\triangle\sigma_A$ = allowable dynamic membrane stress (double amplitude at probability level $Q = 10^{-8}$)

55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steels

25 N/mm^2 for aluminium alloy (5083-0)

C = a characteristic tank dimension to be taken as the greatest of the following:

h, $0.75b$ or $0.45l$

with

h = height of tank (dimension in ship's vertical direction) (m)

b = width of tank (dimension in ship's transverse direction) (m)

l = length of tank (dimension in ship's longitudinal direction) (m)

ρ_r = the relative density of the cargo (ρ_r = 1 for fresh water) at the design temperature.

However, the Society may allocate a tank complying with the criterion of this subparagraph to type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

5. Internal insulation tanks

(1) Internal insulation tanks are non-self-supporting and consist of thermal insulation materials which contribute to the cargo containment and are supported by the structure of the adjacent inner hull or of an independent tank. The inner surface of the insulation is exposed to the cargo.

(2) The two categories of internal insulation tanks are:

(a) Type 1 tanks which are tanks in which the insulation or a combination of the insulation and one or more liners functions only as the primary barrier. The inner hull or an independent tank structure should function as the secondary barrier when required.

(b) Type 2 tanks which are tanks in which the insulation or a combination of the insulation and one or more liners functions as both the primary and the secondary barrier and where these barriers are clearly distinguishable.

The terms "liner" means a thin, non-self-supporting, metallic, nonmetallic or composite material which forms part of an internal insulation tank in order to enhance its fracture resistance or other mechanical properties. A liner differs from a membrane in that it is not intended to function alone as a liquid barrier.

(3) Internal insulation tanks should be of suitable materials enabling the cargo containment system to be designed using model tests and refined analytical methods as required in **404. 7.**

(4) The design vapour pressure P_0 should not normally exceed 0.025 MPa. If, however, the cargo containment system is designed for a higher vapour pressure, P_0 may be increased to such higher value, but not exceeding 0.07 MPa if the internal insulation tanks are supported by the inner hull structure. However, a design vapour pressure of more than 0.07 MPa may be accepted by the Society provided the internal insulation tanks are supported by suitable independent tank structures.

6. Design vapour pressure

(1) The design vapour pressure P_0 is the maximum gauge pressure at the top of the tank which has been used in the design of the tank.

(2) For cargo tanks where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P_0 should not be less than the gauge vapour pressure of the cargo at a temperature of 45°C. However, lesser values of this temperature may be accepted by the Society for ships operating in restricted areas or on voyages of restricted duration and account may be taken in such cases of any insulation of the tanks. Conversely, higher values of this temperature may be required for ships permanently operating in areas of high am-

bient temperature.

(3) In all cases, including (2), P_0 should not be less than MARVS.

(4) Subject to special consideration by the Society and to the limitations given in **Pars 1** to **5** for the various tank types, a vapour pressure higher than P_0 may be accepted in harbour conditions, where dynamic loads are reduced.

7. Design temperature

The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported in the cargo tanks. Provision to the satisfaction of the Society should be made to ensure that the tank or cargo temperature cannot be lowered below the design temperature.

403. Design loads (IGC Code 4.3)

1. General

(1) Tanks together with their supports and other fixtures should be designed taking into account proper combinations of the following loads:
- internal pressure
- external pressure
- dynamic loads due to the motions of the ship
- thermal loads sloshing loads
- loads corresponding to ship deflection
- tank and cargo weight with the corresponding reactions in way of supports
- insulation weight
- loads in way of towers and other attachment

The extent to which these loads should be considered depends on the type of tank, and is more fully detailed in the following paragraphs.

(2) Account should be taken of the loads corresponding to the pressure test referred to in **410.**

(3) Account should be taken of an increase of vapour pressure in harbour conditions referred to in **402. 6** (4).

(4) The tanks should be designed for the most unfavourable static heel angle within the range 0° to 30° without exceeding allowable stresses given in **405. 1.**

2. Internal pressure

(1) The internal pressure P_{eq} in bars gauge resulting from the design vapour pressure P_0 and the internal liquid pressure P_{gd} defined in (2), but not including effects of liquid sloshing, should be calculated as follows:

$$P_{eq} = P_0 + (P_{gd})\,\mathrm{max} \quad (\mathrm{MPa})$$

Equivalent calculation procedures may be applied.

(2) The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship referred to in **Par 4** (1). The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:

$$P_{gd} = a_\beta Z_\beta \frac{\rho}{1.02 \times 10^5} \quad (\mathrm{MPa})$$

where:

a_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β (see **Fig 7.5.2**).

Z_β = largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see **Fig 7.5.3**). Tank domes considered to be part of the accepted total tank volume should be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t\left(\frac{100 - FL}{FL}\right)$$

where:

V_t = tank volume without any domes.

FL = filling limit (%) according to **Sec 15**

ρ = maximum cargo density (kg/m^3) at the design temperature.

The direction which gives the maximum value $(P_{gd})\max$ of P_{gd} should be considered. Where acceleration components in three directions need to be considered, an ellipsoid should be used instead of the ellipse in **Fig. 7.5.2.** The above formula applies only to full tanks.

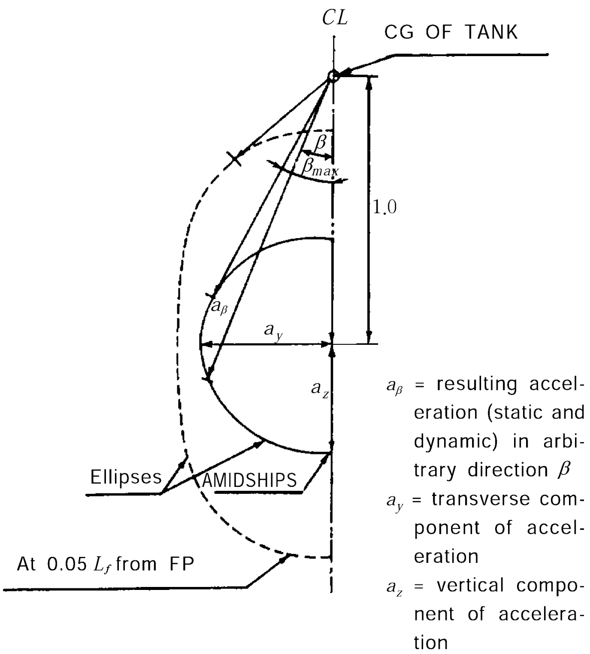


Fig. 7.5.2 Acceleration Ellipse

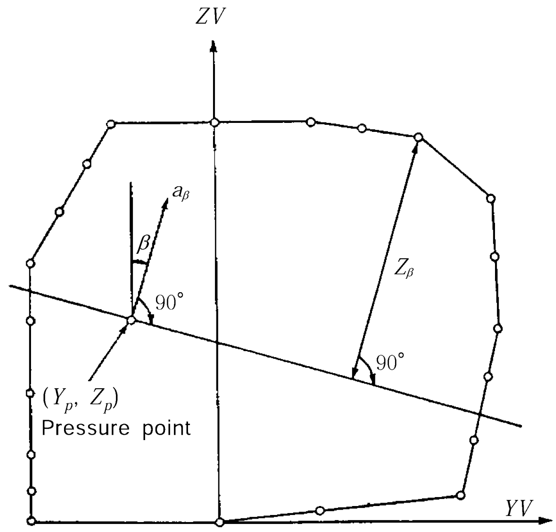


Fig. 7.5.3 Determination of Internal Pressure Heads

3. External pressure

External design pressure loads should be based on the difference between the minimum internal pressure (maximum vacuum) and the maximum external pressure to which any portion of the tank may be subjected simultaneously.

4. Dynamic loads due to ship motions

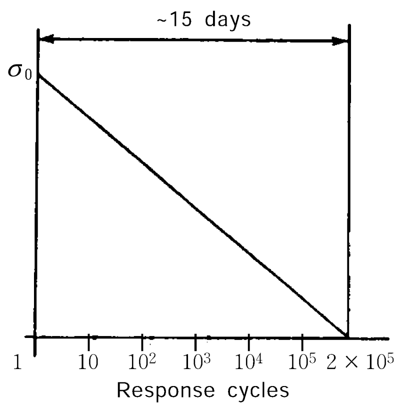
(1) The determination of dynamic loads should take account of the long-term distribution of ship motions, including the effects of surge, sway, heave, roll, pitch and yaw on irregular seas which the ship will experience during its operating life (normally taken to correspond to 10^8 wave encounters). Account may be taken of reduction in dynamic loads due to necessary speed reduction and variation of heading when this consideration has also formed part of the hull strength assessment.

(2) For design against plastic deformation and buckl ing the dynamic loads should be taken as the most probable largest loads the ship will encounte during its operating life (normally taken to correspond to a probability level of 10^{-8}). Guidance formulae for acceleration components are

given in **412.**

(3) When design against fatigue is to be considered the dynamic spectrum should be determined by long-term distribution calculation based on the operating life of the ship (normally taken to correspond to 10^8 wave encounters). If simplified dynamic loading spectra are used for the estimation of the fatigue life, those should be specially considered by the Society.

(4) For practical application of crack propagation estimates, simplified load distribution over a period of 15 days may be used. Such distributions may be obtained as indicated in **Fig 7.5.4.**



σ_0 = most probable maximum stress over the life of the ship

Response cycle scale is logarithmic; the value of 2×10^5 is given as an example of estimate.

Fig 7.5.4 Simplified Load Ditribution

(5) Ships for restricted service may be given special consideration.

(6) The accelerations acting on tanks are estimated at their centre of gravity and include the following components :

vertical acceleration : motion accelerations of heave, pitch and, possibly, roll (normal to the ship base);

transverse acceleration : motion accelerations of sway, yaw and roll; and gravity component of roll;

longitudinal acceleration : motion accelerations of surge and pitch; and gravity component of pitch.

5. Sloshing loads

(1) When partial filling is contemplated, the risk of significant loads due to sloshing induced by any of the ship motions referred to in **Par 4** (6) should be considered.

(2) When risk of significant sloshing-induced loads in found to be present, special tests and calculations should be required.

6. Thermal loads

(1) Transient thermal loads during cooling down periods should be considered for tanks intended for cargo temperatures below -55°C.

(2) Stationary thermal loads should be considered for tanks where design supporting arrangement and operating temperature may given rise to significant thermal stresses.

7. Loads on supports

The loads on supports are covered by **406.**

404. Structural analyses (IGC Code 4.4)

1. Integral tanks

The structural analysis of integral tanks should be in accordance with the requirements of **Pt 3, Ch 15** of the Rules. The tank boundary scantlings should meet at least the requirements for deep tanks taking into account the internal pressure as indicated in **403. 2,** but the resulting scantlings should not be less than normally required by such standards.

2. Membrane tanks

(1) For membrane tanks, the effects of all static and dynamic loads should be considered to determine the suitability of the membrane and of the associated insulation with respect to plastic deformation and fatigue.

(2) Before approval is given, a model of both the primary and secondary barriers, including corners and joints, should normally be tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. Test conditions should represent the most extreme service conditions the cargo containment system will see in its life. Material tests should ensure that ageing is not liable to prevent the materials from carrying out their intended function.

(3) For the purpose of the test referred to in (2), a complete analysis of the particular motions, accelerations and response of ships and cargo containment systems should be performed, unless these data are available from similar ships.

(4) Special attention should be paid to the possible collapse of the membrane due to an overpressure in the interbarrier space, to a possible vacuum in the cargo tank, to the sloshing effects and to hull vibration effects.

(5) A structural analysis of the hull should be to the satisfaction of the Society, taking into account the internal pressure as indicated in **403. 2.** Special attention, however, should be paid to deflections of the hull and their compatibility with the membrane and associated insulation. Inner hull plating thickness should meet at least the requirements of **Pt 3, Ch 15** of the Rules for deep tanks taking into account the internal pressure as indicated in **403. 2.** The allowable stress for the membrane, membrane-supporting material and insulation should be determined in each particular case.

3. Semi-membrane tanks

A structural analysis should be performed in accordance with the requirements for membrane tanks or independent tanks as appropriate, taking into account the internal pressure as indicated in **403. 2.**

4. Type A independent tanks

(1) A structural analysis should be performed to the satisfaction of the Society taking into account the internal pressure as indicated in **403. 2.** The cargo tank plating thickness should meet at least the requirements of **Pt 3, Ch 15** of the Rules for deep tanks taking into account the internal pressure as indicated in **403. 2** and any corrosion allowance required by **405. 2.**

(2) For parts such as structure in way of supports not otherwise covered by the requirements of **Pt 3, Ch 15** of the Rules, stresses should be determined by direct calculations, taking into account the loads referred to in **403.** as far as applicable, and the ship deflection in way of supports.

5. Type B independent tanks

For tanks of this type the following applies :

(1) The effects of all dynamic and static loads should be used to determine the suitability of the structure with respect to:
- plastic deformation
- buckling
- fatigue failure
- crack propagation

Statistical wave load analysis in accordance with **403. 4,** finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, should be carried out.

(2) A three-dimensional analysis should be carried out to evaluate the stress levels contributed by the ship's hull. The model for this analysis should include the cargo tank with its supporting and keying system as well as a reasonable part of the hull.

(3) A complete analysis of the particular ship accelerations and motions in irregular waves and of the response of the ship and its cargo tanks to these forces and motions should be performed unless these data are available from similar ships.
(4) A buckling analysis should consider the maximum construction tolerances.
(5) Where deemed necessary by the Society, model tests may be required to determine stress concentration factors and fatigue life of structural elements.
(6) The cumulative effect of the fatigue load should comply with:

$$\Sigma\frac{n_i}{N_i}+\frac{10^3}{N_j}\le C_w$$

where:

n_i = number of stress cycles at each stress level during the life of the ship

N_i = number of cycles to fracture for the respective stress level according to the Wöhler ($S-N$) curve

N_j = number of cycles to fracture for the fatigue loads due to loading and unloading

C_w should be less than or equal to 0.5, except that the Society may give special consideration to the use of a value greater than 0.5 but not greater than 1.0, dependent on the test procedure and data used to establish the Wöhler ($S-N$) curve.

6. Type C independent tanks

(1) Scantlings based on internal pressure should be calculated as follows :
(a) The thickness and form of pressure-containing parts of pressure vessels under internal pressure, including flanges should be determined according to the requirements of **Pt 5, Ch 5** of the Rules. These calculations in all cases should be based on generally accepted pressure vessel design theory, Openings in pressure-containing parts of pressure vessels should be reinforced in accordance with the requirements of **Pt 5, Ch 5** of the Rules.
(b) The design liquid pressure defined in **403. 2** should be taken into account in the above calculations.
(c) The welded joint efficiency factor to be used in the calculation according to (a) should be 0.95 when the inspection and the non-destructive testing referred to in **410. 9** are carried out. This figure may be increased up to 1.0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels the Society may accept partial nondestructive examinations, but not less than those of **410. 9** (2) (b) depending on such factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated, the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 should be adopted. For special materials, the above-metioned factors should be reduced depending on the specified mechanical properties of the welded joint.
(2) Buckling criteria should be as follows:
(a) The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses should be to a standard acceptable to the Society. These calculations in all cases should be based on generally accepted pressure vessel buckling theory and should adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.
(b) The design external pressure P_e used for verifying the buckling of the pressure vessels should not be less than that given by:

$$P_e=P_1+P_2+P_3+P_4\,(\mathrm{MPa})$$

where:

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P_1 should be specially considered, but should not in general be taken as less than 0.025 MPa.

P_2 = the set pressure of the pressure relief valves for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere P_2 = 0.

P_3 = compressive actions in the shell due to the weight and contraction of insulation, weight of shell, including corrosion allowance, and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition the local effect of external or internal pressure or both should be taken into account.

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks;
elsewhere P_4 = 0.

(3) Stress analysis in respect of static and dynamic loads should be performed as follows:
(a) Pressure vessel scantlings should be determined in accordance with (1) and (2).
(b) Calculations of the loads and stresses in way of the supports and the shell attachment of the support should be made. Loads referred to in **403.** should be used, as applicable. Stresses in way of the supports should be to a standard acceptable to the Society. In special cases a fatigue analysis may be required by the Society.
(c) If required by the Society, secondary stresses and thermal stresses should be specially considered.

(4) For pressure vessels, the thickness calculated according to (1) or the thickness required by (2) plus the corrosion allowance, if any, should be considered as a minimum without any negative tolerance.

(5) For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, should not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.

7. Internal insulation tanks

(1) The effects of all static and dynamic loads should be considered to determine the suitability of the tank with respect to:
- fatigue failure
- crack propagation from both free and supported surfaces
- adhesive and cohesive strength
- compressive, tensile and shear strength.

Statistical wave load analysis in accordance with **403. 4,** finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach should be carried out.

(2) (a) Special attention should be given to crack resistance and to deflections of the inner hull or independent tank structure and their compatibility with the insulation materials. A three-dimensional structural analysis should be carried out to the satisfaction of the Society. This analysis is to evaluate the stress levels and deformations contributed either by the inner hull or by the independent tank structure or both and should also take into account the internal pressure as indicated in **403. 2.** Where water ballast spaces are adjacent to the inner hull forming the supporting structure of the internal insulation tank, the analysis should take account of the dynamic loads caused by water ballast under the influence of ship motions.
(b) The allowable stresses and associated deflections for the internal insulation tank and the inner hull structure or independent tank structure should be determined in each particular case.
(c) Thicknesses of plating of the inner hull or of an independent tank should at least comply with the requirements of Recognized Standards, taking into account the internal pressure as indicated in **403. 2.** Tanks constructed of plane surfaces should at least comply with the requirements of **Pt 3, Ch 15** of the Rules for deep tanks.

(3) A complete analysis of the response of ship, cargo and any ballast to accelerations and motions in irregular waves of the particular ship should be performed to the satisfaction of the Society unless such analysis is available for a similar ship.

(4) (a) In order to confirm the design principles, prototype testing of composite models including

structural elements should be carried out under combined effects of static, dynamic and thermal loads.

(b) Test conditions should represent the most extreme service conditions the cargo containment system will be exposed to during the lifetime of the ship, including thermal cycles. For this purpose, 400 thermal cycles are considered to be a minimum, based upon 19 round voyages per year; where more than 19 round voyages per year are expected, a higher number of thermal cycles will be required. These 400 thermal cycles may be divided into 20 full cycles (cargo temperature to 45°C) and 380 partial cycles (cargo temperature to that temperature expected to be reached in the ballast voyage).

(c) Models should be representative of the actual construction including corners, joints, pump mounts, piping penetrations and other critical areas, and should take into account variations in any material properties, workmanship and quality control.

(d) Combined tension and fatigue tests should be carried out to evaluate crack behaviour of the insulation material in the case where a through crack develops in the inner hull or independent tank structure. In these tests, where applicable the crack area should be subjected to the maximum hydrostatic pressure of the ballast water.

(5) The effects of fatigue loading should be determined in accordance with **Par 5** (6) or by an equivalent method.

(6) For internal insulation tanks, repair procedures should be developed during the prototype testing programme for both the insulation material and the inner hull or the independent tank structure.

405. Allowable stresses and corrosion allowances (IGC Code 4.5)

1. Allowable stresses

(1) For integral tanks, allowable stresses should normally be those given for hull structure in the requirements of **Pt 3, Ch 1, 206.** of the Rules.

(2) For membrane tanks, reference is made to the requirements of **404. 2.** (5).

(3) For type A independent tanks primarily constructed of plane surfaces, the stresses for primary and secondary members (stiffeners, webframes, stringers, girders) when calculated by classical analysis procedures should not exceed the lower of $R_m/2.66$ or $R_e/1.33$ for carbon-manganese steels and aluminium alloys, where R_m and R_e are defined in (7). However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c as defined in (8) may be increased over that indicated above to a stress acceptable to the Society; calculations should take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.

(4) For type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses should not exceed:

$$\sigma_m \leq f$$

$$\sigma_L \leq 1.5f$$

$$\sigma_b \leq 1.5F$$

$$\sigma_L + \sigma_b \leq 1.5F$$

$$\sigma_m + \sigma_b \leq 1.5F$$

where:

σ_m = equivalent primary general membrane stress

σ_L = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

f = the lesser of R_m/A or R_e/B

F = the lesser of R_m/C or R_e/D

with R_m and R_e as defined in (7). With regard to the stresses σ_m, σ_L and σ_b see also the definition of stress categories in **413.** The values of A, B, C and D should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and should have at least the minimum values of **Table 7.5.1.**

(5) For type B independent tanks, primarily constructed of plane surfaces, the Society may require compliance with additional or other stress criteria.

(6) For type C independent tanks the maximum allowable membrane stress to be used in calculation according to **404. 6** (1) (a) should be the lower of:

R_m/A or R_e/B

where:

R_m and R_e are as defined in (7).

The values of A and B should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, and should have at least the minimum values indicated in the **Table 7.5.1.**

Table 7.5.1 Values of A, B, C and D

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3.5	4
B	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5

(7) For the purpose of (3), (4) and (6) the following apply:

(a) R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress strain curve does not show a defined yield stress, the 0.2 % proof stress applies.

R_m = specified minimum tensile strength at room temperature (N/mm^2).

For welded connections in aluminium alloys the respective values of R_e or R_m in annealed conditions should be used.

(b) The above properties should correspond to the minimum specified mechanical properties of the material, including the weld metal in the as-fabricated condition. Subject to special consideration by the Society, account may be taken of enhanced yield stress and tensile strength at low temperature. The temperature on which the material properties are based should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

(8) The equivalent stress σ_c (von Mises, Huber) should be determined by:

$$\sigma_c = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$

where:

σ_x = total normal stress in x-direction

σ_y = total normal stress in y-direction

τ_{xy} = total shear stress in x-y plane.

(9) When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified, the total stresses should be calculated according to:

$$\sigma_x = \sigma_{x \cdot st} \pm \sqrt{\Sigma(\sigma_{x \cdot dyn})^2}$$

$$\sigma_y = \sigma_{y \cdot st} \pm \sqrt{\Sigma(\sigma_{y \cdot dyn})^2}$$

$$\tau_{xy} = \tau_{xy \cdot st} \pm \sqrt{\Sigma(\tau_{xy \cdot dyn})^2}$$

where:

$\sigma_{x \cdot st}$, $\sigma_{y \cdot st}$ and $\tau_{xy \cdot st}$ = static stresses

$\sigma_{x \cdot dyn}$, $\sigma_{y \cdot dyn}$ and $\tau_{xy \cdot dyn}$ = dynamic stresses

all determined separately from acceleration components and hull strain components due to deflection and torsion.

(10) For internal insulation tanks, reference is made to the requirements of **404. 7** (2).

(11) Allowable stresses for materials other than those covered by **Sec 6** should be subject to approval by the Society in each case.

(12) Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

2. Corrosion allowances

(1) No corrosion allowance should generally be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control around the cargo tank, such as inerting, or where the cargo is of a corrosive nature, the Society may require a suitable corrosion allowance.

(2) For pressure vessels no corrosion allowance is generally required if the contents of the pressure vessel are non-corrosive and the external surface is protected by inert atmosphere or by an appropriate insulation with an approved vapour barrier. Paint or other thin coatings should not be credited as protection. Where special alloys are used with acceptable corrosion resistance, no corrosion allowance should be required. If the above conditions are not satisfied, the scantiings calculated according to **404. 6** should be increased as appropriate.

406. Supports (IGC Code 4.6)

1. Cargo tanks should be supported by the hull in a manner which will prevent bodily movement of the tank under static and dynamic loads while allowing contraction and expansion of the tank under temperature variation sand hull deflections without undue stressing of the tank and of the hull.

2. The tanks with supports should also be designed for a static angle of heel of 30° without exceeding allowable stresses given in **405. 1.**

3. The supports should be calculated for the most probable largest resulting acceleration, taking into account rotational as well as translational effects. This acceleration in a given direction may be determined as shown in **Fig 7.5.2.** The half axes of the "**acceleration ellipse**" should be determined according to **403. 4** (2).

4. Suitable supports should be provided to withstand a collision force acting on the tank corresponding to one half the weight of the tank and cargo in the forward direction and one quarter the weight of the tank and cargo in the aft direction without deformation likely to endanger the tank structure.

5. The loads mentioned in **Pars 2** and **4** need not be combined with each other or with wave-induced loads.

6. For independent tanks and, where appropriate, for membrane and semi-membrane tanks, provision should be made to key the tanks against the rotational effects referred to in **Par 3.**

7. Antiflotation arrangements should be provided for independent tanks. The antiflotation arrangements should be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the summer load draught of the ship, without plastic deformation likely to endanger the hull structure.

407. Secondary barrier (IGC Code 4.7)

1. Where the cargo temperature at atmospheric pressure is below -10°C, a secondary barrier should be provided when required by **Par 3** to act as a temporary containment for any envisaged leakage of liquid cargo through the primary barrier.

2. Where the cargo temperature at atmospheric pressure is not below -55°C, the hull structure may act as a secondary barrier. In such a case:

(1) the hull material should be suitable for the cargo temperature at atmospheric pressure as required by **409. 2;** and

(2) the design should be such that this temperature will not result in unacceptable hull stresses.

3. Secondary barriers in relation to tank types should normally be provided in accordance with **Table 7.5.2.** For tanks which differ from the basic tank types as defined in **402.** the secondary barrier requirements should be decided by the Society in each case.

Table 7.5.2 Secondary Barriers in Relation to Tank Types

Cargo temperature at atmospheric pressure	-10°C and above	Below -10°C down to -55°C	Below -55°C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral		Tank type not normally allowed(1)	
Membrane		Complete secondary barrier	
Semi-membrane		Complete secondary barrier(2)	
Independent			
Type A		Complete secondary barrier	
Type B		Partial secondary barrier	
Type C		No secondary barrier required	
Internal insulation			
Type 1		Complete secondary barrier	
Type 2		Complete secondary barrier is incorporated	

Notes:

(1) A complete secondary barrier should normally be required if cargoes with a temperature at atmospheric pressure below -10° are permitted in accordance with **402.1**(3).

(2) In the case of semi-membrane tanks which comply in all respects with the requirements applicable to type independent tanks, except for the manner of support the Society may, after special consideration, accept a partial secondary barrier.

4. The secondary barrier should be so designed that:

(1) it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different requirements apply for particular voyages, taking into account the load spectrum referred to in **403. 4** (4);

(2) it will prevent lowering of the temperature of the ship structure to an unsafe level in the case of leakage of the primary barrier as indicated in **408. 2;** and

(3) the mechanism of failure for the primary barrier does not also cause the failure of the secondary barrier and vice versa.

5. The secondary barrier should fulfil its functions at a static angle of heel of 30°.

6. (1) Where a partial secondary barrier is required, its extent should be determined on the basis of cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in **403. 4** (4) after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors. In all cases, however, the inner bottom adjacent to cargo tanks should be protected against liquid cargo.

(2) Clear of the partial secondary barrier, provision such as a spray shield should be made to deflect any liquid cargo down into the space between the primary and secondary barriers and to keep the temperature of the hull structure to a safe level.

7. The secondary barrier should be capable of being periodically checked for its effectiveness, by means of a pressure/vacuum test, a visual inspection or another suitable method acceptable to the Society. The method should be submitted to the Society for approval.

408. Insulation (IGC Code 4.8)

1. Where a product is carried at a temperature below -10°C suitable insulation should be provided to ensure that the temperature of the hull structure does not fall below the minimum allowable design temperature given in **Sec 6** for the grade of steel concerned, as detailed in **409.,** when the cargo tanks are at their design temperature and the ambient temperatures are 5°C for air and 0°C for seawater. These conditions may generally be used for world-wide service. However, higher values of the ambient temperatures may be accepted by the Society for ships operated in restricted areas. Conversely, lesser values of the ambient temperatures may be fixed by the Society for ships trading occasionally or regularly to areas in latitudes where such lower temperatures are expected during the winter months. The ambient temperatures used in the design should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases on Bulk.

2. Where a complete or partial secondary barrier is required, calculations should be made with the assumptions in **Par 1** to check that the temperature of the hull structure does not fall below the minimum allowable design temperature given in **Sec 6** for the grade of steel concerned, as detailed in **409.** The complete or partial secondary barrier should be assumed to be at the cargo temperature at atmospheric pressure.

3. Calculations required by **Pars 1** and **2** should be made assuming still air and still water, and except as permitted by **Par 4,** no credit should be given for means of heating. In the case referred to in **Par 2,** the cooling effect of the rising boil-off vapour from the leaked cargo should be considered in the heat transmission studies. For structural members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

4. In all cases referred to in **Pars 1** and **2** and for ambient temperature conditions of 5°C for air and 0°C for seawater, approved means of heating transverse hull structural material may be used to ensure that the temperatures of this material do not fall below the minimum allowable values. If lower ambient temperatures are specified, approved means of heating may also be used for longitudinal hull structural material, provided this material remains suitable for the temperature conditions of 5°C for air and 0°C for seawater without heating. Such means of heating should comply with the following requirements:

(1) sufficient heat should be available to maintain the hull structure above the minimum allowable temperature in the conditions referred to in **Pars 1** and **2;**
(2) the heating system should be so arranged that, in the event of a failure in any part of the system, stand-by heating could be maintained equal to not less than 100 % of the theoretical heat load;
(3) the heating system should be considered as an essential auxiliary; and
(4) the design and construction of the heating system should be to the satisfaction of the Society.

5. In determining the insulation thickness, due regard should be paid to the amount of acceptable boil-off in association with the reliquefaction plant on board, main propulsion machinery or other temperature control system.

409. Materials (IGC Code 4.9)

1. The shell and deck plating of the ship and all stiffeners attached thereto should be in accordance with the requirements of **Pt 3** of the Rules, unless the calculated temperature of the material in the design condition is below -5°C due to the effect of the low temperature cargo, in which case the material should be in accordance with **Table 7.5.7** assuming the ambient sea and air temperature of 0°C and 5°C respectively. In the design condition, the complete or partial secondary barrier should be assumed to be at the cargo temperature at atmospheric pressure and for tanks without secondary barriers, the primary barrier should be assumed to be at the cargo temperature.

2. Hull material forming the secondary barrier should be in accordance with **Table 7.5.4.** Metallic materials used in secondary barriers not forming part of the hull structure should be in accordance with **Table 7.5.4** or **7.5.5** as applicable. Insulation materials forming a secondary barrier should comply with the requirements of **Par 7.** Where the secondary barrier is formed by the deck or side shell plating, the material grade required by **Table 7.5.4** should be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

3. Materials used in the construction of cargo tanks should be in accordance with **Table 7.5.3, 7.5.4** or **7.5.5.**

4. Materials other than those referred to in **Pars 1, 2** and **3** used in the construction of the ship which are subject to reduced temperature due to the cargo and which do not form part of the secondary barrier should be in accordance with **Table 7.5.7** for temperatures as determined by **408.** This includes inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

5. The insulation materials should be suitable for loads which may be imposed on them by the adjacent structure.

Table 7.5.3

PLATES, PIPES (SEAMLESS AND WELDED)(1), SECTIONS AND FORGINGS FOR CARGO TANKS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES NOT LOWER THAN 0°C.		
CHEMICAL COMPOSITION AND HEAT TREATMENT		
CARBON-MANGANESE STEEL	Fully killed	
Fine grain steel where thickness exceeds 20 mm		
Small additions of alloying elements by agreement with the Society Composition limits to be approved by the Society		
Normalized, or quenched and tempered(2)		
TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS		
Plates	Each "piece" to be tested	
Sections and forgings	Batch test	
Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 (3)	
CHARPY V-NOTCH TEST		
Plates	Transverse test pieces. Minimum average energy value (E) 27 J	
Sections and forgings	Longitudinal test pieces. Minimum average energy value (E) 41 J	
Test temperature	Thickness t (mm)	Test temperature (°C)
	$t \leq 20$	0
	$20 < t \leq 40$	-20

Notes:
(1) For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes should be specially approved by the Society.
(2) A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Society.
(3) Materials with specified minimum yield stress exceeding 410 N/mm^2 may be specially approved by the Society. For these materials, particular attention should be given to the hardness of the weld and heat affected zone.

Table 7.5.4

PLATES, SECTIONS AND FORGINGS(1) FOR CARGO TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO -55°C
Maximum thickness 25 mm(2)

CHEMICAL COMPOSITION AND HEAT TREATMENT
CARBON-MANGANESE STEEL Fully killed Aluminium treated fine grain steel

Chemical composition (ladle analysis)

C	Mn	Si	S	P
0.16 % max.(3)	0.70 -1.60 %	0.10-0.50 %	0.035 % max.	0.035 % max.

Optional additions: Alloys and grain refining elements may be generally in accordance with the following:

Ni	Cr	Mo	Cu	Nb	V
0.80 % max.	0.25 % max.	0.08 % max.	0.35 % max	0.05 % max.	0.10 % max.

Normalized or quenched and tempered(4)

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

Plates	Each "piece" to be tested
Sections and forgings	Batch test
CHARPY V-NOTCH TEST	Test temperature 5°C below the design temperature or -20°C whichever is lower
Plates	Transverse test pieces. Minimum average energy value (E) 27 J
Sections and forgings(1)	Longitudinal test pieces. Minimum average energy value (E) 41 J

Notes:
(1) The Charpy V-notch and chemistry requirements for forgings may be specially considered by the Society.
(2) For material thickness of more than 25 mm, Charpy V-notch tests should be conducted as follows:

Material thickness(mm)	Test temperature
$25 < t \leq 30$	10°C below design temperature or -20°C whichever is lower
$30 < t \leq 35$	15°C below design temperature or -20°C whichever is lower
$35 < t \leq 40$	20°C below design temperature

The impact energy value should be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values should be specially considered.
Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or-20°C whichever is lower.
For thermally stress relieved reinforcements and other fittings, the test temperature should be the same as that required for the adjacent tank-shell thickness.
(3) By special agreement with the Society, the carbon content may be increased to 0.18 % maximum provided the design temperature is not lower than -40°C.
(4) A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Society.
Guidance: For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with **Table 7.5.5** may be necessary.

Table 7.5.5

PLATES, SECTIONS AND FORGINGS[1] FOR CARGO TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW -55°C AND DOWN TO -165°C[2]
Maximum thickness 25 mm[3]

Minimum design temp. (°C)	Chemical composition[4] and heat treatment	Impact test temp.(°C)
-60	1.5 % nickel steel-normalized	-65
-65	2.25 % nickel steel-normalized or normalized and tempered[5]	-70
-90	3.5 % nickel steel-normalized or normalized and tempered[5]	-95
-105	5 % nickel steel-normalized or normalized and tempered[5][6]	-110
-165	9 % nickel steel-double normalized and tempered or quenched and tempered	-196
-165	Austenitic steels, such as types 304, 304 L, 316, 316 L, 321 and 347 solution treated[7]	-196
-165	Aluminium alloys; such as type 5083 annealed	Not required
-165	Austenitic Fe-Ni alloy (36 % nickel).Heat treatment as agreed	Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS

Plates	Each "piece" to be tested
Sections and forgings	Batch test

CHARPY V-NOTCH TEST

Plates	Transverse test pieces. Minimum average energy value (E) 27 J
Sections and forgings	Longitudinal test pieces. Minimum average energy value (E) 41 J

Notes:
(1) The impact test required for forgings used in critical applications should be subject to special consideration by the Society.
(2) The requirements for design temperatures below -165°C should be specially agreed with the Society.
(3) For materials 1.5 % Ni, 2.25 % Ni, 3.5 % Ni and 5 % Ni, with thicknesses greater than 25 mm, the impact tests should be conducted as follows:

Material thickness (mm)	Test temperature
$25 < t \leq 30$	10°C below design temperature
$30 < t \leq 35$	15°C below design temperature
$35 < t \leq 40$	20°C below design temperature

In no case should the test temperature be above that indicated in this table. The energy value should be in accordance with this table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values should be specially considered. For 9 % Ni, austenitic stainless steels and aluminium alloys, thicknesses greater than 25 mm may be used at the discretion of the Society.
(4) The chemical composition limits should be approved by the Society.
(5) A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Society.
(6) A specially heat treated 5 % nickel steel, for example triple heat treated 5 % nickel steel, may be used down to -165°C upon special agreement with the Society, provided that the impact tests are carried out at -196°C.
(7) The impact test may be omitted subject to agreement with the Society.

Teble 7.5.6

PIPES (SEAMLESS AND WELDED)(1), FORGINGS(2) AND CASTINGS(2) FOR CARGO AND PROCESS PIPING FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO -165°C(3)
Maximum thickness 25 mm

Minimum design temp. (°C)	Chemical composition(5) and heat treatment	Impact test	
		Test temp.(°C)	Minimum average energy (E)(J)
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed(6)	(4)	27
-65	2.25 % nickel steel. Normalized or normalized and tempered(6)	-70	34
-90	3.5 % nickel steel. Normalized or normalized and tempered(6)	-95	34
-165	9 % nickel steel(7) Double normalized and tempered or quenched and tempered	-196	41
	Austenitic steels, such as types 304, 304 L, 316, 316 L, 321 and 347. Solution treated(8)	-196	41
	Aluminium alloys, such as type 5083 annealed	-	Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS
Each batch to be tested
IMPACT TEST Longitudinal test pieces

Notes:
(1) The use of longitudinally or spirally welded pipes should be specially approved by the Society.
(2) The requirements for forgings and castings may be subject to special consideration by the Society.
(3) The requirements for design temperatures below-165°C should be specially agreed with the Society.
(4) The test temperature should be 5°C below the design temperature or -20°C whichever is lower.
(5) The composition limits should be approved by the Society.
(6) A lower design temperature may be specially agreed with the Society for quenched and tempered materials.
(7) This chemical composition is not suitable for castings.
(8) Impact tests may be omitted subject to agreement with the Society.

Table 7.5.7

PLATES AND SECTIONS FOR HULL STRUCTURES REQUIRED BY **409. 1** AND **409. 4**

Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades in accordance with **601. 9**						
	A	B	D	E	AH	DH	EH
0 and above(1) -5 and above(2)	Normal practice						
down to -5	15	25	30	50	25	45	50
down to -10	×	20	25	50	20	40	50
down to -20	×	×	20	50	×	30	50
down to -30	×	×	×	40	×	20	40
Below -30	In accordance with **Table 7.5.4** except that the thickness limitation given in **Table 7.5.4** and in footnote (2) of that table does not apply.						

Notes: "x" means steel grade not to be used.
(1) For the purpose of **409. 4**
(2) For the purpose of **409. 1**

6. Where applicable, due to location or environmental conditions, insulation materials should have suitable properties of resistance to fire and flame spread and should be adequately protected against penetration of water vapour and mechanical damage.

7. (1) Materials used for thermal insulation should be tested for the following properties as applicable, to ensure that they are adequate for the intended service:

(a) compatibility with the cargo
(b) solubility in the cargo
(c) absorption of the cargo
(d) shrinkage
(e) ageing
(f) closed cell content
(g) density
(h) mechanical properties
(i) thermal expansion
(j) abrasion
(k) cohesion
(I) thermal conductivity
(m) resistance to vibrations
(n) resistance to fire and flame spread

(2) In addition to meeting the above requirements, insulation materials which form part of the cargo containment as defined in **402. 5** should be tested for the following properties after simulation of ageing and thermal cycling to ensure that they are adequate for the intended service:

(a) bonding (adhesive and cohesive strength)
(b) resistance to cargo pressure
(c) fatigue and crack propagation properties
(d) compatibility with cargo constituents and any other agent expected to be in contact with the insulation in normal service.
(e) where applicable the influence of presence of water and water pressure on the insulation properties should be taken into account.
(f) gas de-absorbing.

(3) The above properties, where applicable, should be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than -196°C.

8. The procedure for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials should be to the satisfaction of the Society.

9. Where powder or granulated insulation is used, the arrangements should be such as to prevent compacting of the material due to vibrations. The design should incorporate means to ensure that the material remains sufficiently buoyant to maintain the required thermal conductivity and also prevent any undue increase of pressure on the cargo containment system.

410. Construction and testing (IGC Code 4.10)

1. (1) All welded joints of the shells of independent tanks should be of the butt weld, full penetration type. For dome-to-shell connections, the Society may approve tee welds of the full penetration type. Except for small penetrations on domes, nozzle welds are also generally to be designed with full penetration.

(2) Welding joint details for type C independent tanks should be as follows:

(a) All longitudinal and circumferential joints of pressure vessels should be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds should be obtained by double welding or by the use of backing rings. If used, backing rings should be removed, unless specifically approved by the Society for very small process pressure vessels. Other edge preparations may be allowed by the Society depending on the results of the tests carried out at the approval of the welding procedure.
(b) The bevel preparation of the joints between the pressure vessel body and domes and between domes and relevant fittings should be designed according to a standard for pressure vessels acceptable to the Society. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles should be full pene-

tration welds extending through the entire thickness of the vessel wall or nozzle wall, unless specially approved by the Society for small nozzle diameters.

2. Workmanship should be to the satisfaction of the Society. Inspection and non-destructive testing of welds for tanks other than type C independent tanks should be in accordance with the requirements of **603. 7.**

3. For membrane tanks, quality assurance measures, weld procedure qualification, design details, materials, construction, inspection and production testing of components, should be to standards developed during the prototype testing programme.

4. For semi-membrane tanks the relevant requirements in this Article for independent tanks or for membrane tanks should be applied as appropriate.

5. (1) For internal insulation tanks, in order to ensure uniform quality of the material, quality control procedures including environmental control, application procedure qualification, corners, penetrations and other design details, materials specification, installation and production testing of components should be to standards developed during the prototype test programme.

(2) A quality control specification including maximum permissible size of constructional defects, tests and inspections during the fabrication, installation and also sampling tests at each of these stages should be to the satisfaction of the Society.

6. Integral tanks should be hydrostatically or hydropneumatically tested to the satisfaction of the Society. The test in general should be so performed that the stresses approximate, as fas as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.

7. In ships fitted with membrane or semi-membrane tanks, cofferdams and all spaces which may normally contain liquid and are adjacent to the hull structure supporting the membrane should be hydrostatically or hydropneumatically tested in accordance with Recognized Standards. In addition, any other hold structure supporting the membrane should be tested for tightness. Pipe tunnels and other compartments which do not normally contain liquid need not be hydrostatically tested.

8. (1) In ships fitted with internal insulation tanks where the inner hull is the supporting structure, all inner hull structure should be hydrostatically or hydropheumatically tested in accordance with Recognized Standards, taking into account the MARVS.

(2) In ships fitted with internal insulation tanks where independent tanks are the supporting structure, the independent tanks should be tested in accordance with **Par 10** (1).

(3) For internal insulation tanks where the inner hull structure or an independent tank structure acts as a secondary barrier, a tightness test of those structures should be carried out using techniques to the satisfaction of the Society.

(4) These tests should be performed before the application of the materials which will form the internal insulation tank.

9. For type C independent tanks, inspection and nondestructive testing should be as follows:

(1) Manufacture and workmanship - The tolerances relating to manufacture and workmanship such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, should comply with standards acceptable to the Society. The tolerances should also be related to the buckling analysis referred to in **404. 6** (2).

(2) Non-destructive testing - As far as completion and extension of non-destructive testing of welded joints are concerned, the extent of non-destructive testing should be total or partial according to standards acceptable to the Society, but the controls to be carried out should not be less than the following:

(a) Total non-destructive testing referred to in **404. 6** (1) (c):
Radiography : butt welds 100 % and
Surface crack detection : all welds 10 %;
reinforcement rings around holes, nozzles, etc. 100 %.
As an alternative, ultrasonic testing may be accepted as a partial substitute for the radiographic testing, if specially allowed by the Society. In addition, the Society may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

(b) Partial non-destructive testing referred to in **404. 6** (1) (c):
Radiography : butt welds: all welded crossing joints and at least 10 % of the full length at selected positions uniformly distributed and

Surface crack detection : reinforcement rings around holes, nozzles, etc. 100 %
Ultrasonic testing : as may be required by the Society in each instance.

10. Each independent tank should be subjected to hydrostatic or hydropneumatic test as follows:

(1) For type A independent tanks, this test should be so performed that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions should simulate, as far as practicable, the actual loading of the tank and of its supports.

(2) For type B independent tanks, the test should be performed as required in (1) for type A independent tanks. In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions should not exceed 90 % of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75 % of the yield strength, the prototype test should be monitored by the use of strain gauges or other suitable equipment.

(3) Type C independent tanks should be tested as follows:

(a) Each pressure vessel, when completely manufactured, should be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 P_0, but in no case during the pressure test should the calculated primary membrane stress at any point exceed 90 % of the yield stress of the material. The definition of P_0 is given in **402. 6**. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype test should be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

(b) The temperature of the water used for the test should be at least 30°C above the nil ductility transition temperature of the material as fabricated.

(c) The pressure should be held for 2 h per 25 mm of thickness but in no case less than 2 h.

(d) Where necessary for cargo pressure vessels, and with the specific approval of the Society, a hydropneumatic test may be carried out under the conditions prescribed in (a), (b) and (c).

(e) Special consideration may be given by the Society to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of (a) should be fully complied with.

(f) After completion and assembly, each pressure vessel and its related fittings should be subjected to an adequate tightness test.

(g) Pneumatic testing of pressure vessels other than cargo tanks should be considered on an individual case basis by the Society. Such testing should be permitted only for those vessels which are so designed or supported that they cannot be safely filled with water, or for those vessels which cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

11. All tanks should be subjected to a tightness test which may be performed in combination with the pressure test referred to in **Par 10** or separately.

12. Requirements with respect to inspection of secondary barriers should be decided by the Society in each case.

13. In ships fitted with type B independent tanks, at least one tank and its support should be instrumented to confirm stress levels unless the design and arrangement for the size of ship involved are supported by full-scale experience. Similar instrumentation may be required by the Society for type C independent tanks dependent on their configuration and on the arrangement of their supports and attachments.

14. The overall performance of the cargo containment system should be verified for compliance with the design parameters during the initial cool-down, loading and discharging of the cargo. Records of the performance of the components and equipment essential to verify the design parameters should be maintained and be available to the Society.

15. Heating arrangements, if fitted in accordance with **408. 4,** should be tested for required heat output and heat distribution.

16. The hull should be inspected for cold spots following the first loaded voyage.

17. The insulation materials of internal insulation tanks should be subjected to additional inspection in order to verify their surface conditions after the third loaded voyage of the ship, but not later than the first 6 months of the ship's service after building or a major repair work is undertaken on the internal insulation tanks.

18. For type C independent tanks, the required marking of the pressure vessel should be achieved by a method which does not cause unacceptable local stress raisers.

411. Stress relieving for type C independent tanks (IGC Code 4.11)

1. For type C independent tanks of carbon and carbon-manganese steel, post-weld heat treatment should be performed after welding if the design temperature is below -10°C. Post-weld heat treatment in all other cases and for materials other than those mentioned above should be to the satisfaction of the Society. The soaking temperature and holding time should be to the satisfaction of the Society.

2. In the case of large cargo pressure vessels of carbon or carbon-manganese steel for which it is difficult to perform the heat treatment, mechanical stress relieving by pressurizing may be carried out as an alternative to the heat treatment subject to the following conditions:

(1) Complicated welded pressure vessel parts, such as sumps or domes with nozzles, with adjacent shell plates should be heat treated before they are welded to larger parts of the pressure vessel.

(2) The mechanical stress relieving process should preferably be carried out during the hydrostatic pressure test required by the requirement in **410. 10** (3), by applying a higher pressure than the test pressure required by **410. 10** (3) (a). The pressurizing medium should be water.

(3) For the water temperature, the requirement in **410.10** (3) (b) applies.

(4) Stress relieving should be performed while the tank is supported by its regular saddles or supporting structure or, when stress relieving cannot be carried out on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure.

(5) The maximum stress relieving pressure should be held for two hours per 25 mm of thickness but in no case less than two hours.

(6) The upper limits placed on the calculated stress levels during stress relieving should be the following:

- equivalent general primary membrane stress: 0.9 R_e
- equivalent stress composed of primary bending stress plus membrane stress: 1.35 R_e

  where Re is the specific lower minimum yield stress or 0.2 % proof stress at test temperature of the steel used for the tank.

(7) Strain measurements will normally be required to prove these limits for at least the first tank of a series of identical tanks built consecutively. The location of strain gauges should be included in the mechanical stress relieving procedure to be submitted in accordance with **411. 2** (14).

(8) The test procedure should demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again up to the design pressure.

(9) High stress areas in way of geometrical discontinuities such as nozzles and other openings should be checked for cracks by dye penetrant or magnetic particle inspection after mechanical stress relieving. Particular attention in this respect should be given to plates exceeding 30 mm in thickness.

(10) Steels which have a ratio of yield stress to ultimate tensile strength greater than 0.8 should generally not be mechanically stress relieved. If however the yield stress is raised by a method giving high ductility of the steel, slightly higher rates may be accepted upon consideration in each case.

(11) Mechanical stress relieving cannot be substituted for heat treatment of cold formed parts of tanks if the degree of cold forming exceeds the limit above which heat treatment is required.

(12) The thickness of the shell and heads of the tank should not exceed 40 mm. Higher thicknesses may be accepted for parts which are thermally stress relieved.

(13) Local buckling should be guarded against particularly when tori-spherical heads are used for tanks and domes.

(14) The procedure for mechanical stress relieving should be submitted beforehand to the Society for approval.

412. Guidance formulae for acceleration components (IGC Code 4.12)

The following formulae are given as guidance for the components of acceleration due to ship's motions corresponding to a probability level of 10^{-8} in the North Atlantic and apply to ships with a length exceeding 50 m.

Vertical acceleration as defined in **403. 4** (6) : $a_z = \pm a_0 \sqrt{1 + \left(5.3 - \frac{45}{L_0}\right)^2 \left(\frac{x}{L_0} + 0.05\right)^2 \left(\frac{0.6}{C_b}\right)^{1.5}}$

Transverse acceleration as defined in **403. 4** (6) : $a_y = \pm a_0 \sqrt{0.6 + 2.5\left(\frac{x}{L_0} + 0.05\right)^2 + K\left(1 + 0.6K\frac{z}{B}\right)^2}$

Longitudinal acceleration as defined in **403. 4** (6) : $a_x = \pm a_0 \sqrt{0.06 + A^2 - 0.25A}$

with:

$$A = \left(0.7 - \frac{L_0}{1200} + 5\frac{z}{L_0}\right)\left(\frac{0.6}{C_b}\right)$$

where:

L_0 = length of the ship for determination of scantlings as defined in Recognized Standards (m)

C_b = block coefficient

B = greatest moulded breadth of the ship (m)

x = longitudinal distance (m) from amidships to the centre of gravity of the tank with contents; x is positive forward of amidships, negative aft of amidships

z = vertical distance (m) from the ship's actual water-line to the centre of gravity of tank with contents; z is positive above and negative below the waterline.

$$a_0 = 0.2\frac{V}{\sqrt{L_0}} + \frac{34 - \frac{600}{L_0}}{L_0}$$

where: V = service speed (knots)

K = 1 in general. For particular loading conditions and hull forms, determination of K according to the formula below may be necessary.

K = 13 GM/B, where $K \geq$ 1.0 and GM = metacentric height (m)

a_x, a_y and a_z = maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions and they are considered as acting separately for calculation purposes. a_z does not include the component due to the static weight, a_y includes the component due to the static weight in the transverse direction due to rolling and a_x includes the component due to the static weight in the longitudinal direction due to pitching.

413. Stress categories (IGC Code 4.13)

For the purpose of stress evaluation referred to in **405. 1** (4), stress categories are defined in this Article.

1. Normall stress is the component of stress normal to the plane of reference.

2. Membrane stress is the component of normal stress which is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

3. Bending stress is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

4. Shear stress is the component of the stress acting in the plane of reference.

5. Primary stress is a stress produced by the imposed loading and which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses which considerably exceed the yield strength will result in failure or at least in gross deformations.

6. Primary general membrane stress is a primary membrane stress which is so distributed in the structure that no redistribution of load occurs as a result of yielding.

7. Primary local membrane stress arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress although it has some characteristics of a secondary stress. A stress region may be considered as local if :

$$S_1 \leq 0.5\sqrt{Rt}$$
$$S_2 \geq 2.5\sqrt{Rt}$$

where:

S_1 = distance in the meridional direction over which the equivalent stress exceeds 1.1 f

S_2 = distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded

R = mean radius of the vessel

t = wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded

f = allowable primary general membrane stress.

8. Secondary stress is a normal stress or shear stress developed by constraints of adjacent parts or by self constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions which cause the stress to occur.

Section 5 Process Pressure Vessels and Liquid, Vapour, and Pressure Piping Systems

501. General (IGC Code 5.1)

1. The Society should take appropriate steps to ensure uniformity in the implementation and application of the provisions of this Section.

2. The requirements for type C independent tanks in **Sec 4** may also apply to process pressure vessels if required by the Society. If so required the term "pressure vessels" as used in **Sec 4** covers both type C independent tanks and process pressure vessels.

502. Cargo and process piping (IGC Code 5.2)

1. General

(1) The requirements of **502.** to **505.** apply to product and process piping including vapour piping and vent lines of safety valves or similar piping. Instrument piping not containing cargo is exempt from these requirements.
(2) Provision should be made by the use of offsets, loops, bends, mechanical expansion joints such as bellows, slip joints and ball joints or similar suitable means to protect the piping, piping system components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. Where mechanical expansion joints are used in piping they should be held to a minimum and, where located outside cargo tanks, should be of the bellows type.
(3) Low-temperature piping should be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections and at pump seals, protection for the hull beneath should be provided.
(4) Where tanks or piping are separated from the ship's structure by thermal isolation, provision should be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections should be electrically bonded.
(5) Suitable means should be provided to relieve the pressure and remove liquid contents from cargo loading and discharging crossover headers and cargo hoses to the cargo tanks or other suitable location, prior to disconnecting the cargo hoses.
(6) All pipelines or components which may be isolated in a liquid full condition should be provided with relief valves.
(7) Relief valves discharging liquid cargo from the cargo piping system should discharge into the cargo tanks; alternatively they may discharge to the cargo vent mast if means are provided to detect and dispose of any liquid cargo which may flow into the vent system. Relief valves on cargo pumps should discharge to the pump suction.

2. Scantlings based on internal pressure

(1) Subject to the conditions stated in **Par 4,** the wall thickness of pipes should not be less than:

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}}$$

where:

t_0 = theoretical thickness (mm)

$$t_0 = \frac{PD}{2Ke + P}$$

with:

P = design pressure (MPa) referred to in **Par 3**

D = outside diameter (mm)

K = allowable stress (N/mm^2) referred to in **Par 4**

e = efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with Recognized Standards. In other cases an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process.

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be:

$$b = \frac{Dt_0}{2.5r}$$

with :

r = mean radius of the bend (mm)

c = corrosion allowance (mm). If corrosion or erosion is expected, the wall thickness of the piping should be increased over that required by other design requirements. This allowance should be consistent with the expected life of the piping.

a = negative manufacturing tolerance of thickness (%).

3. Design pressure

(1) The design pressure P in the formula for t_0 in **Par 2** (1) is the maximum gauge pressure to which the system may be subjected in service.

(2) The greater of the following design conditions should be used for piping, piping systems and components as appropriate:

(a) for vapour piping systems or components which may be separated from their relief valves and which may contain some liquid: the saturated vapour pressure at 45°C, or higher or lower if agreed upon by the Society (see **402. 6** (2));

(b) for systems or components which may be separated from their relief valves and which contain only vapour at all times: the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Society (see **402. 6** (2)), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

(c) the MARVS of the cargo tanks and cargo processing systems; or

(d) the pressure setting of the associated pump or compressor discharge relief valve; or

(e) the maximum total discharge or loading head of the cargo piping system; or

(f) the relief valve setting on a pipeline system.

(3) The design pressure should not be less than 1.0 MPa gauge except for open ended lines where it should be not less than 0.5 MPa gauge.

4. Permissible stresses

(1) For pipes, the permissible stress to be considered in the formula for t in **Par 2** (1) is the lower of the following values:

$$R_m/A \quad \text{or} \quad R_e/B$$

where:

R_m = specified minimum tensile strength at room temperature (N/mm^2)

R_e = specified minimum yield stress at room temperature (N/mm^2)

If the stress-strain curve does not show a defined yield stress, the 0.2 % proof stress applies. The values of A and B should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and have values of at least A = 2.7 and B = 1.8.

(2) The minimum wall thickness should be in accordance with Recognized Standards.

(3) Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads from supports, ship deflection or other causes, the wall thickness should be increased over that required by **Par 2,** or, if this is impracticable or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

(4) Flanges, valves and other fittings should comply with recognized standards, taking into account the design pressure defined in **Par 3.** For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted by the Society.

(5) For flanges not complying with a standard, the dimensions of flanges and related bolts should be to the satisfaction of the Society.

5. Stress analysis

When the design temperature is -110°C or lower, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system should be submitted to the Society. For temperatures of above -110°C, a stress analysis may be required by the Society in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration should be given to thermal stresses, even though calculations are not submitted. The analysis may be carried out according to a code of practice acceptable to the Society.

6. Materials

(1) The choice and testing of materials used in piping systems should comply with the requirements of **Sec 6** taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open ended vent piping, provided the temperature of the cargo at the pressure relief valve setting is -55°C or greater and provided no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi-membrane tanks.

(2) Materials having a melting point below 925°C should not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation should be provided.

503. Tests of piping components and pumps prior to installation on board (IGC Code 5.3)

1. Each type of piping component and pump should be subject to the following tests.

(1) Valves

(A) Type tests

Each size and type of valve intended to be used at a working temperature below -55°C is to be type approved. Type tests to the minimum design temperature or lower and to a pressure not lower than the maximum design pressure foreseen for the valves is to be witnessed in the presence of the Surveyor. Type tests are to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure, seat and stem leakage test at a pressure equal to 1.1 times the design pressure, and cryogenic testing consisting of valve operation and leakage verification at the design temperature.

For valves intended to be used at a working temperature above -55°C, type approval is not required.

(B) Production tests

All valves are to be tested at the plant of manufacturer in the presence of the Surveyor. Testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure, seat and stem leakage test at a pressure equal to 1.1 times the design pressure.

In addition, cryogenic testing consisting of valve operation and leakage verification at the design temperature for a minimum of 10% of each type and size of valve for valves intended to be used at a working temperature below -55°C.

As an alternative to the above, the manufacturer may request the Society to certify a valve subject to the following:

(a) The valve has been type approved as required by **Ch 5, 503. 1** (1) (A) for valves intended to be used at a working temperature below -55°C, and
(b) The manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and
(c) The quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure and seat and stem leakage test at a pressure equal to 1.1 times the design pressure. The manufacturer is to maintain records of such tests, and
(d) Cryogenic testing consisting of valve operation and leakage verification at the design temperature for a minimum of 10 % of each type and size of valve for valves intended to be used at a working temperature below -55 °C in the presence of the Society' representative.

(2) Expansion Bellows

Each type of expansion bellows intended for use on cargo piping outside the cargo tank and, where required, on those expansion bellows installed within the cargo tanks is to be type approved by the following tests:

(A) A type element of the bellows, not precompressed, should be pressure tested at not less than 5 times the design pressure without bursting. The duration of the test should not be less than 5 min.
(B) A pressure test should be performed on a type expansion joint complete with all the accessories such as flanges, stays and articulations, at twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation. Depending on the materials used, the Society may require the test to be at the minimum design temperature.
(C) A cyclic test (thermal movements) should be performed on a complete expansion joint, which is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. Testing at ambient temperature is permitted, when this testing is at least as severe as testing at the service temperature.
(D) A cyclic fatigue test (ship deformation) should be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 cycles/s. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.
(E) The Society may waive performance of the tests referred to in this paragraph provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 0.1 MPa gauge this documentation is to include sufficient test data to justify the design method used, with particular reference to correlation between calculation and test results.

(3) Cargo Pumps

(A) Each size and type of pumps is subject to design approval and the tests of following (a) to (c) in the presence of the Surveyor. However, for the pump designed the same as an existing pump approved by the Society and having satisfactory in-service experience, consideration may be given to waiving the tests.
  (a) hydrostatic test of the pump body equal to 1.5 times the design pressure
  (b) the following capacity tests
    (i) For submerged pumps, the capacity test is to be carried out with the design medium or with a medium below the design temperature.
    (ii) For deep well pumps, the capacity test may be carried out with water. In addition, for deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the design temperature.
  (c) After completion of tests, the pump is to be opened out for examination.
(B) All pumps of the same size and type which have been granted design approval are subject to the tests of following (a) and (b) at the plant of manufacturer in the presence of the

Surveyor.
(a) hydrostatic test of the pump body equal to 1.5 times the design pressure
(b) the capacity tests in compliance with the special requirements given by the Society.
The manufacturer may request the Society to waive the above tests subject to the following:
(c) The pump has been tested as required by **Ch 5, 503. 1** (3) (A) and
(d) The manufacturer has a recognised quality system that has been assessed and certified by the Society subject to periodic audits, and
(e) The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

504. Piping fabrication and joining details (IGC Code 5.4)

1. The requirements of this Article apply to piping inside and outside the cargo tanks. Relaxations from these requirements may be accepted, in accordance with recognized standards, for piping inside cargo tanks and open-ended piping.

2. The following direct connection of pipe lengths, without flanges, may be considered:
(1) Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures below -10°C, butt welds should be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of -10°C or lower, backing rings should be removed.
(2) Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, should only be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.
(3) Screwed couplings complying with recognized standards only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

3. (1) Flanges in flange connections should be of the welded neck, slip-on or socket welded type.
(2) Flanges should comply with recognized standards as to their type, manufacture and test. In particular, for all piping except open ended, the following restrictions apply:
(a) For design temperatures lower than -55°C, only welded neck flanges should be used.
(b) For design temperatures lower than -10°C, slip-on flanges should not be used in nominal sizes above 100 mm and socket welded flanges should not be used in nominal sizes above 50 mm.

4. Piping connections, other than those mentioned in **Pars 2** and **3,** may be accepted by the Society in each case.

5. Bellows and expansion joints should be provided to allow for expansion of piping.
(1) If necessary, bellows should be protected against icing.
(2) Slip joints should not be used except within the cargo tanks.

6. Welding, post-weld heat treatment and non-destructive testing.
(1) Welding should be carried out in accordance with **603.**
(2) Post-weld heat treatment should be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Society may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.
(3) In addition to normal controls before and during the welding and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the requirements of this paragraph, the following tests should be required:
(a) 100 % radiographic inspection of butt welded joints for piping systems with design temperatures lower than -10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm. When such butt welded joints of piping sections are made by automatic welding procedures in the pipe fabrication shop, upon special approval by the Society, the extent of radiographic inspection may be progressively reduced but in no case to less than 10 % of each joint, If defects are revealed, the extent of examination should be increased to 100 % and should include inspection of previously accepted welds. This special

approval can only be granted if well-documented quality assurance procedures and records are available to enable the Society to assess the ability of the manufacturer to produce satisfactory welds consistently.

(b) For other butt-welded joints of pipes not covered by (a), spot radiographic tests or other non-destructive tests should be carried out at the discretion of the Society depending upon service, position and materials. In general, at least 10 % of butt-welded joints of pipes should be radiographed.

505. Testing of piping on board (IGC Code 5.5)

1. The requirements of this Article apply to piping inside and outside the cargo tanks. However, the Society may accept relaxations from these requirements for piping inside cargo tanks and open-ended piping.

2. After assembly, all cargo and process piping should be subjected to a hydrostatic test to at least 1.5 times the design pressure. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board should be hydrostatically tested to at least 1.5 times the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing means should be submitted to the Society for approval.

3. After assembly on board, each cargo and process piping system should be subjected to a leak test using air, halides, or other suitable medium to a pressure depending on the leak detection method applied.

4. All piping systems including valves, fittings and associated equipment for handling cargo or vapours should be tested under normal operating conditions not later than at the first loading operation.

506. Cargo system valving requirements (IGC Code 5.6)

1. Every cargo piping system and cargo tank should be provided with the following valves, as applicable:

(1) For cargo tanks with a MARVS not exceeding 0.07 MPa gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, should have shutoff valves located as close to the tank as practicable. These valves may be remotely controlled but should be capable of local manual operation and provide full closure. One or more remotely controlled emergency shutdown valves should be provided on the ship for shutting down liquid and vapour cargo transfer between ship and shore. Such valves may be arranged to suit the ship's design and may be the same valve as required in **Par 3** and should comply with the requirements of **Par 4.**

(2) For cargo tanks with a MARVS exceeding 0.07 MPa gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, should be equipped with a manually operated stop valve and a remotely controlled emergency shutdown valve. These valves should be located as close to the tank as practicable. Where the pipe size does not exceed 50 mm in diameter, excess flow valves may be used in lieu of the emergency shutdown valve. A single valve may be substituted for the two separate valves provided the valve complies with the requirements of **Par 4,** is capable of local manual operation and provides full closure of the line.

(3) Cargo pumps and compressors should be arranged to shutdown automatically if the emergency shutdown valves required by **Par 1** (1) and (2) are closed by the emergency shutdown system required by **Par 4.**

2. Cargo tank connections for gauging or measuring devices need not be equipped with excess flow or emergency shutdown valves provided that the devices are so constructed that the outward flow of tank contents cannot exceed that passed by a 1.5 mm diameter circular hole.

3. One remotely operated emergency shutdown valve should be provided at each cargo hose connection in use. Connections not used in transfer operations may be blinded with blank flanges in lieu of valves.

4. The control system for all required emergency shutdown valves should be so arranged that all such valves may be operated by single controls situated in at least two remote locations on the ship.

One of these locations should be the control position required by **1301. 3** or cargo control room. The control system should also be provided with fusible elements designed to melt at temperatures between 98°C and 104°C which will cause the emergency shutdown valves to close in the event of fire. Locations for such fusible elements should include the tank domes and loading stations. Emergency shutdown valves should be of the fail-closed (closed on loss of power) type and be capable of local manual closing operation. Emergency shutdown valves in liquid piping should fully close under all serivce conditions within 30 s of actuation. Information about the closing time of the valves and their operating characteristics should be available on board and the closing time should be verifiable and reproducible. Such valves should close smoothly.

5. The closure time of 30 s for the emergency shutdown valve referred to in **506. 4** should be measured from the time of manual or automatic initiation to final closure. This is called the total shutdown time and is made up of a signal response time and a valve closure time. The valve closure time should be such as to avoid surge pressure in pipelines. Such valves should close in such a manner as to cut off the flows smoothly. This paragraph applies to ships constructed on or after 1 July 2002.

6. Excess flow valves should close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping including fittings, valves, and appurtenances protected by an excess flow valve, should have a greater capacity than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding an area of 1.0 mm diameter circular opening to allow equalization of pressure, after an operating shutdown.

507. Ship's cargo hoses (IGC Code 5.7)

1. Liquid and vapour hoses used for cargo transfer should be compatible with the cargo and suitable for the cargo temperature.

2. Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, should be designed for a bursting pressure not less than 5 times the maximum pressure the hose will be subjected to during cargo transfer.

3. For cargo hoses installed on board ships on or after 1 July 2002, each new type of cargo hose, complete with end-fittings, should be prototype-tested at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test should demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the extreme service temperature. Hoses used for prototype testing should not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced should be hydrostatically tested at ambient temperature to a pressure not less than 1.5 times its specified maximum working pressure but not more than two-fifths of its bursting pressure. The hose should be stencilled or otherwise marked with the date of testing, its specified maximum working pressure and, if used in services other than the ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure should not be less than 1.0 MPa gauge.

508. Cargo transfer methods (IGC Code 5.8)

1. Where cargo transfer is by means of cargo pumps not accessible for repair with the tanks in service, at least two separate means should be provided to transfer cargo from each cargo tank and the design should be such that failure of one cargo pump, or means of transfer, will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.

2. The procedure for transfer of cargo by gas pressurization should preclude lifting of the relief valves during such transfer. Gas pressurization may be accepted as a means of transfer of cargo for those tanks so designed that the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation.

509. Vapour return connections (IGC Code 5.9)

Connections for vapour return lines to the shore installations should be provided.

Section 6 Materials of Construction

601. General (IGC Code 6.1)

1. The Society should take appropriate steps to ensure uniformity in the implementation and application of the provisions of this Section.

2. This Section gives the requirements for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping, secondary barriers and contiguous hull structures associated with the transportation of the products. The requirements for rolled materials, forgings and castings are given in **602.** and **Tables 7.5.3** to **7.5.7.** The requirements for weldments are given in **603.**

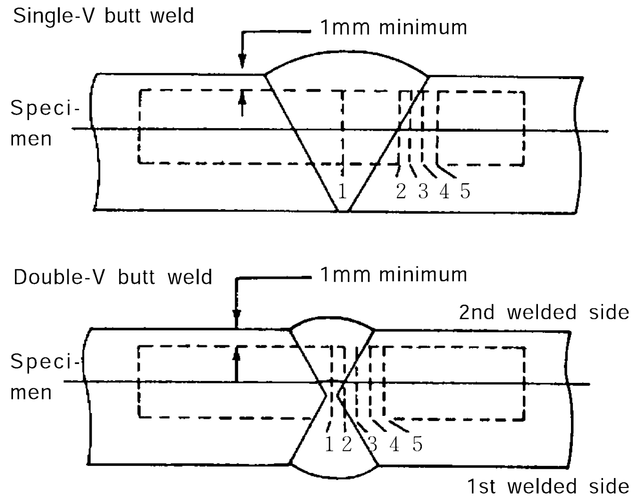
3. The manufacture, testing, inspection and documentation should be in accordance with the requirements of **Pt 2** of the Rules and the specified requirements given in this Chapter.

4. (1) Acceptance tests should include Charpy V-notch toughness tests unless otherwise specified by the Society. The specified Charpy V-notch requirements are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens should be in accordance with Recognized Standards. The testing and requirements for specimens smaller than 5.0 mm size should be in accordance with the requirements of **Pt 2** of the Rules. Minimum average values for subsized specimens should be:

Charpy V-notch specimen size	Minimum energy average of three specimens
10 x 10 mm	E
10 x 7.5 mm	5/6 E
10 x 5.0 mm	2/3 E
where: E = the energy values (J) specified in **Tables 7.5.3** to **7.5.6**	

Only one individual value may be below the specified average value provided it is not less than 70 % of that value.

(2) In all cases, the largest size Charpy specimens possible for the material thickness should be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the suface (see **Fig. 7.5.5**). If the average value of the three initial Charpy V-notch specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen,three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted. At the discretion of the Society other types of toughness tests, such as a drop weight test, may be used. This may be in addition to or in lieu of the Charpy V-notch test.



Notch location:
1. Centre of weld
2. On fusion line
3. In HAZ, 1mm from fusion line
4. In HAZ, 3mm from fusion line
5. In HAZ, 5mm from fusion line
HAZ = heat-affected zone

The largest size Charpy specimens possible for the material thickness should be machined with the centre of the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen should be approximately 1mm or greater In addition for double-V butt welds, specimens should be machined closer to the surface of the second welded side.

Fig 7.5.5 Orientation of Weld Test Specimen

5. Tensile strength, yield stress and elongation should be to the satisfaction of the Society. For carbon-manganese steel and other materials with definitive yield points, consideration should be given to the limitation of the yield to tensile ratio.

6. The bend test may be omitted as a material acceptance test, but is required for weld tests.

7. Materials with alternative chemical composition or mechanical properties may be accepted by the Society.

8. Where post-weld heat treatment is specified or required, the properties of the base material should be determined in the heat treated condition in accordance with the applicable table of this Section and the weld properties should be determined in the heat treated condition in accordance with **603.** In cases where a post-weld heat treatment is applied, the test requirements may be modified at the discretion of the Society.

9. Where reference is made in this Section to *A, B, D, E, AH, DH* and *EH* hull structural steels, these steel grades are the grades of steel according to **Pt 2** of the Rules.

602. Material requirements (IGC Code 6.2)

The requirements for materials of construction are shown in the tables as follows **(Refer to Table 409.)**:

Table 7.5.3: Plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 7.5.4: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to -55°C.

Table 7.5.5: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C.

Table 7.5.6: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to -165°C.

Table 7.5.7: Plates and sections for hull structures required by **409. 1** and **409. 4.**

603. Welding and non-destructive testing (IGC Code 6.3)

1. General

The requirements of this Article are those generally employed for carbon, carbon-managanese, nickel alloy and stainless steels, and may form the basis for acceptance testing of other material. At the discretion of the Society, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

2. Welding consumables

Welding consumables intended for welding of cargo tanks should be in accordance with Recognized Standards unless otherwise agreed with the Society. Deposited weld metal tests and butt weld tests should be required for all welding consumables, unless otherwise specially agreed with the Society. The results obtained from tensile and Charpy V-notch impact tests should be in accordance with Recognized Standards. The chemical composition of the deposited weld metal should be recorded for information and approval.

3. Welding procedure tests for cargo tanks and process pressure vessels

(1) Welding procedure tests for cargo tanks and process pressure vessels are required for all butt welds and the test assemblies should be representative of:
- each base material
- each type of consumable and welding process
- each welding position.

For butt welds in plates, the test assemblies should be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test should be in accordance with Recognized Standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator or the Society. Procedure tests for consumables intended for fillet welding procedure tests should be in accordance with Recognized Standards. In such cases consumables should be selected which exhibit satisfactory impact properties.

(2) The following welding procedure tests for cargo tanks and process pressure vessels should be made from each test assembly:

(a) Cross-weld tensile tests.

(b) Transverse bend tests which may be face, root or side bends at the discretion of the Society. However, longitudinal bend test may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

(c) One set of three Charpy V-notch impacts, generally at each of the following locations, as shown in **Fig. 7.5.5**:
- Centreline of the welds
- Fusion line (F.L.)
- 1 mm from the F.L.
- 3 mm from the F.L.
- 5 mm from the F.L

(d) Macrosection, microsection and hardness survey may also be required by the Society.

4. Test requirements

(1) Tensile tests: Generally, tensile strength should not be less than the specified minimum tensile strength for the appropriate parent materials. The Society may also require that the transverse weld tensile strength should not be less than the specified minimum tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture is to be reported for information.

(2) Bend tests: No fracture is acceptable after a 180° bend over a former of a diameter 4 times the thickness of the test pieces, unless otherwise specially required by or agreed with the Society.

(3) Charpy V-notch impact tests: Charpy tests should be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (E), should be no less than 27 J. The weld metal requirements for subsize specimens and single energy values should be in accordance with **601. 4.** The results of fusion line and heat affected zone impact tests should show a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever is applicable, and for subsize specimens, the minimum average energy (E) should be in accordance with **601. 4.** If the material thickness does not permit machining either full-size or standard subsize specimens, the testing procedure and acceptance standards should be in accordance with Recognized Standards.

5. Welding procedure tests for piping

Welding procedure tests for piping should be carried out and should be similar to those detailed for cargo tanks in **Par 3.** Unless otherwise specially agreed with the Society, the test requirements should be in accordance with **Par 4.**

6. Production weld tests

(1) For all cargo tanks and process pressure vessels except integral and membrane tanks, production weld tests should generally be performed for approximately each 50 m of butt weld joints and should be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks should be performed except that the number of tests may be reduced subject to agreement with the Society. Tests, other than those specified in (2), (3) and (4), may be required for cargo tanks or secondary barriers at the discretion of the Society.

(2) The production tests for types A and B independent tanks and semi-membrane tanks should include the following tests:

(a) Bend tests, and where required for procedure tests one set of three Charpy V-notch tests should be made for each 50 m of weld. The Charpy V-notch tests should be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches should be in the centre of the weld.

(b) The test requirements are the same as the applicable test requirements listed in **Par 4,** except that impact tests that do not meet the prescribed energy requirements may still be accepted, upon special consideration by the Society, by passing a drop weight test. In such cases, two drop weight specimens should be tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.

(3) In addition to those tests listed in (2) (a) for type C independent tanks and process pressure vessels transverse weld tensile tests are required. The test requirements are listed in **Par 4** except that impact tests that do not meet the prescribed energy requirements may still be accepted upon special consideration by the Society, by passing a drop weight test. In such cases, two drop weight specimens should be tested for each set of Charpy specimens that failed, and both must show "no break" performance at the temperature at which the Charpy tests were conducted.

(4) Production tests for integral and membrane tanks should be in accordance with Recognized Standards.

7. Non-destructive testing

(1) For type A independent tanks and semi-membrane tanks where the design temperature is -20°C or less, and for type B independent tanks regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks should be subjected to 100 % radiographic inspection.

(a) Where the design temperature is higher than -20°C, all full penetration butt welds in way of intersections and at least 10 % of the remaining full penetration welds of tank structures should be subjected to radiographic inspection.

(b) In each case the remaining tank structure including the welding of stiffeners and other fittings and attachments should be examined by magnetic particle or dye penetrant methods as considered necessary by the Society.

(c) All test procedures and acceptance standards should be in accordance with Recognized Standards. The Society may accept an approved ultrasonic test procedure in lieu of radiographic inspection, but may in addition require supplementary inspection by radiography at selected locations. Further, the Society may require ultrasonic testing in addition to normal radiographic inspection.

(2) Inspection of type C independent tanks and process pressure vessels should be carried out in accordance with **410. 9.**

(3) For integral and membrane tanks, special weld inspection procedures and acceptance criteria should be in accordance with Recognized Standards.

(4) The inspection and non-destructive testing of the inner hull or the independent tank structures supporting internal insulation tanks should take into account the design criteria given in **404. 7.** The schedule for inspection and non-destructive testing should be to the satisfaction of the Society.

(5) Inspection of piping should be carried out in accordance with the requirements of **Sec 5.**

(6) The secondary barrier should be radiographed as considered necessary by the Society. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell should be tested by radiography.

Section 7 Cargo Pressure/Temperature Control

701. General (IGC Code 7.1)

1. Unless the entire cargo system is designed to withstand the full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, maintenance of the cargo tank pressure below the MARVS should be provided by one or more of the following means, except as otherwise provided in this Article:

(1) a system which regulates the pressure in the cargo tanks by the use of mechanical refrigeration;
(2) a system whereby the boil-off vapours are utilized as fuel for shipboard use or waste heat system subject to the provisions of **Sec 16.** This system may be used at all times, including while in port and while manoeuvring, provided that a means of disposing of excess energy is provided, such as a steam dump system, that is satisfactory to the Society;
(3) a system allowing the product to warm up and increase in pressure. The insulation or cargo tank design pressure or both should be adequate to provide for a suitable margin for the operating time and temperatures involved. The system should be acceptable to the Society in each case;
(4) other systems acceptable to the Society;
(5) in addition to the above means, the Society may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea. This may also be permitted in port with the permission of the port Administration;

2. The systems required by **Par 1** should be constructed, fitted and tested to the satisfaction of the Society. Materials used in their construction should be suitable for use with the cargoes to be carried. For normal service, the upper ambient design temperature should be:

- sea : 32°C
- air : 45°C

For service in especially hot or cold zones these design temperatures should be increased or reduced, as appropriate, by the Society.

3. For certain highly dangerous cargoes specified in **Sec 17,** the cargo containment system should be capable of withstanding the full vapour pressure of the cargo under condition of the upper ambient design temperature irrespective of any system provided for dealing with boil-off gas.

702. Refrigeration systems(IGC Code 7.2)

1. A refrigeration system should consist of one or more units capable of maintaining the required cargo pressure/temperature under conditions of the upper ambient design temperatures. Unless an alternative means of controlling the cargo pressure/temperature is provided to the satisfaction of the Society, a stand-by unit (or units) affording spare capacity at least equal to the largest required single unit should be provided. A stand-by unit should consist of a compressor with its driving motor, control system and any necessary fittings to permit operation independently of the normal service units. A stand-by heat exchanger should be provided unless the normal heat exchanger for the unit has an excess capacity of at least 25 % of the largest required capacity. Separate piping systems are not required.

2. (1) Where two or more refrigerated cargoes which may react chemically in a dangerous manner are carried simultaneously, special consideration should be given to the refrigeration systems to avoid the possibility of mixing cargoes. For the carriage of such cargoes, separate refrigeration systems, each complete with a stand-by unit as specified in **Par 1,** should be provided for each cargo. However, where cooling is provided by an indirect or combined system and leakage in the heat exchangers cannot cause mixing of the cargoes under any envisaged condition, separate refrigeration units need not be fitted.

(2) Where two or more refrigerated cargoes are not mutually soluble under the conditions of carriage, so that their vapour pressures would be additive on mixing, special consideration should be given to the refrigeration systems to avoid the possibility of mixing cargoes.

3. Where cooling water is required in refrigeration systems, an adequate supply should be provided by a pump or pumps used exclusively for this purpose. This pump or these pumps should have at least two sea suction lines, where practicable leading from sea-chests, one port and one starboard.

A spare pump of adequate capacity should be provided, which may be a pump used for other services so long as its use for cooling would not interfere with any other essential service.

4. The refrigeration system may be arranged in one of the following ways:

(1) a direct system where evaporated cargo is compressed, condensed and returned to cargo tanks. For certain cargoes specified in **Sec 17** this system should not be used;
(2) an indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed;
(3) a combined system where evaporated cargo is compressed and condensed in a cargo/refrigerant heat exchanger and returned to the cargo tanks. For certain cargoes specified in **Sec 17** this system should not be used.

5. All primary and secondary refrigerants must be compatible with each other and with the cargo with which they come into contact. The heat exchange may take place either remotely from the cargo tank or by cooling coils fitted inside or outside the cargo tank.

Section 8 Cargo Tank Vent Systems

801. General (IGC Code 8.1)

All cargo tanks should be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold spaces, interbarrier spaces and cargo piping which may be subject to pressures beyond their design capabilities should also be provided with a suitable pressure relief system. The pressure relief system should be connected to a vent piping system so designed as to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition. Pressure control systems specified by **Sec 7** should be independent of the pressure relief valves.

802. Pressure relief systems (IGC Code 8.2)

1. Each cargo tank with a volume exceeding 20 m^3 should be fitted with at least two pressure relief valves of approximately equal capacity, suitably designed and constructed for the prescribed service. For cargo tanks with a volume not exceeding 20 m^3, a single relief valve may be fitted.

2. Interbarrier spaces should be provided with pressure relief devices complying with recognized standards.

3. In general, the setting of the pressure relief valves should not be higher than the vapour pressure which has been used in the design of the tank. However, where two or more pressure relief valves are fitted, valves comprising not more than 50 % of the total relieving capacity may be set at a pressure up to 5 % above MARVS.

4. Pressure relief valves should be connected to the highest part of the cargo tank above deck level. Pressure relief valves on cargo tanks with a design temperature below 0°C should be arranged to prevent their becoming inoperative due to ice formation when they are closed. Due consideration should be given to the construction and arrangement of pressure relief valves on cargo tanks subject to low ambient temperatures. Valves should be constructed of materials with a melting point above 925°C. Consideration should be given to lower melting point materials for internal parts and seals if their use will yield a significant improvement in the general operation of the valve.

5. Pressure relief valves should be prototype tested to ensure that the valves have the capacity required. Each valve should be tested to ensure that it opens at the prescribed pressure setting with an allowance not exceeding ±10 % for 0 to 0.15 MPa, ± 6 % for 0.15 to 0.3 MPa, ± 3 % for 0.3 MPa and above. Pressure relief valves should be set and sealed by a competent authority acceptable to the Society and a record of this action, including the values of set pressure, should be retained aboard the ship.

6. In the case of cargo tanks permitted to have more than one relief valve setting this may be accomplished by:

(1) installing two or more properly set and sealed valves and providing means as necessary for isolating the valves not in use from the cargo tank; or

(2) installing relief valves whose settings may be changed by the insertion of previously approved spacer pieces or alternative springs or by other similar means not requiring pressure testing to verify the new set pressure. All other valve adjustment should be sealed.

7. The changing of the set pressure under the provisions of **802. 6**, and the corresponding resetting of the alarms referred to in **1304. 1**, should be carried out under the supervision of the master in accordance with procedures approved by the Society and specified in the ship's operating manual. Changes in set pressures should be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.

8. Stop valves or other means of blanking off pipes between tanks and pressure relief valves to facilitate maintenance should not be fitted unless all the following arrangements are provided:

(1) suitable arrangements to prevent more than one pressure relief valve being out of service at the same time;

(2) a device which automatically and in a clearly visible way indicates which one of the pressure relief valves is out of service; and

(3) pressure relief valve capacities such that if one valve is out of service the remaining valves have the combined relieving capacity required by **805.** However, this capacity may be provided by the combined capacity of all valves, if a suitably maintained spare valve is carried on board.

9. Each pressure relief valve installed on a cargo tank should be connected to a venting system, which should be so constructed that the discharge of gas will be unimpeded and directed vertically upwards at the exit and so arranged as to minimize the possibility of water or snow entering the vent system. The height of vent exits should not be less than $B/3$ or 6 m, whichever is the greater, above the weather deck and 6 *m* above the working area, the fore and aft gangway, deck storage tanks and cargo liquid lines.

10. Cargo tank pressure relief valve vent exits should be arranged at a distance at least equal to B or 25 m, whichever is less, from the nearest air intake or opening to accommodation spaces, service spaces and control stations, or other gas-safe spaces. For ships less than 90 m in length, smaller distances may be permitted by the Society. All other vent exits connected to the cargo containment system should be arranged at a distance of at least 10 m from the nearest air intake or opening to accommodation spaces, service spaces and control stations, or other gas-safe spaces.

11. All other cargo vent exits not dealt with in other sections should be arranged in accordance with **Pars 9** and **10.**

12. If cargoes which react in a hazardous manner with each other are carried simultaneously, a separate pressure relief system should be fitted for each cargo carried.

13. In the vent piping system, means for draining liquid from places where it may accumulate should be provided. The pressure relief valves and piping should be so arranged that liquid can under no circumstances accumulate in or near the pressure relief valves.

14. Suitable protection screens should be fitted on vent outlets to prevent the ingress of foreign objects.

15. All vent piping should be so designed and arranged that it will not be damaged by temperature variations to which it may be exposed, or by the ship's motions.

16. The back pressure in the vent lines from the pressure relief valves should be taken into account in determining the flow capacity required by **805.** The pressure drop in the vent line from the tank to the pressure relief valve inlet should not exceed 3 % of the valve set pressure. For unbalanced pressure relief valves the back pressure in the discharge line should not exceed 10 % of the gauge pressure at the relief valve inlet with the vent lines under fire exposure as referred to in **805. 2.**

17. Pressure relief valves should be positioned on the cargo tank so that they will remain in the vapour phase under conditions of 15° list and 0.015 L trim, where L is as defined in **106. 23** at the maximum allowable filling limit(FL).

18. The adequacy of the vent system fitted on tanks loaded in accordance with **1501. 5** is to be demonstrated using the special guidelines. A relevant certificate should be permanently kept on board the ship. For the purposes of this paragraph, vent system means :

(1) the tank outlet and the piping to the pressure relief valve;
(2) the pressure relief valve;
(3) the piping from the pressure relief valve to the location of discharge to the atmosphere and including any interconnections and piping which joins other tanks.

This paragraph may apply to all ships regardless of the date of construction.

803. Additional pressure relieving system for liquid level control (IGC Code 8.3)

1. Where required by **1501. 4** (2), an additional pressure relieving system to prevent the tank from becoming liquid full at any time during relief under the fire exposure conditions referred to in **805.** should be fitted to each tank. This pressure relieving system should consist of:

(1) one or more relief valves set at a pressure corresponding to the gauge vapour pressure of the cargo at the reference temperature defined in **1501. 4** (2); and
(2) an override arrangement, whenever necessary, to prevent its normal operation. This arrangement should include fusible elements designed to melt at temperatures between 98°C and 104°C and to cause relief valves specified in (1) to become operable. The fusible elements should be lo-

cated, in particular, in the vicinity of relief valves. The system should become operable upon loss of system power if provided. The override arrangement should not be dependent on any source of ship's power.

2. The total relieving capacity of the additional pressure relieving system at the pressure mentioned in **Par 1** (1) should not be less than:

$$Q' = FG'A^{0.82}\ (\mathrm{m^3/s})$$

where:

Q' = minimum required rate of discharge of air at standard conditions of 273K and 0.1013MPa.

$$G' = \frac{12.4}{(L+\rho_r m)D}\sqrt{\frac{ZT}{M}}$$

with:

ρ_r : relative density of liquid phase of product at relieving conditions (ρ_r = 1.0 for fresh water)

m = $-di/d\rho_r$: gradient of decrease of liquid phase enthalpy against increase of liquid phase density (KJ/kg) at relieving conditions. For set pressures not higher than 0.2 MPa the value in **Table 7.5.8** may be used. For products not listed in the table and for higher set pressures, the value of m should be calculated on the basis of the thermodynamic data of the product itself

Table 7.5.8 Factor m

Product	$m = -di/d\rho_r$ (KJ/kg)
Ammonia, anhydrous	3,400
Butadiene	1,800
Butane	2,000
Butylenes	1,900
Ethane	2,100
Ethylene	1,500
Methane	2,300
Methyl chloride	816
Nitrogen	400
Propane	2,000
Propylene	1,600
Propylene oxide	1,550
Vinyl chloride	900
The values in this table may be used for set pressures not higher than 0.2 MPa.	

i : enthalpy of liquid (KJ/kg)

T' : temperature in kelvins (K) at relieving conditions, i.e. at the pressure at which the additional pressure relieving system is set

F, A, L, D, Z and M are defined in **805. 2.**

3. Compliance with **Par 1** (1) requires changing of the setting of the relief valves provided for in this Article. This should be accomplished in accordance with the provisions of **802. 6** and **7.**

4. Relief valves mentioned under **Par 1** (1) above may be the same as the pressure relief valves mentioned in **802.,** provided the setting pressure and the relieving capacity are in compliance with the requirements of this Article.

5. The exhaust of such pressure relief valves may be led to the venting system referred to in **802. 9.** If separate venting arrangements are fitted these should be in accordance with the requirements of **802. 9** to **15.**

804. Vacuum protection systems (IGC Code 8.4)

1. Cargo tanks designed to withstand a maximum external pressure differential exceeding 0.025 MPa and capable of withstanding the maximum external pressure differential which can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, need no vacuum protection systems.

2. Cargo tanks designed to withstand a maximum external pressure differential not exceeding 0.025 MPa, or tanks which cannot withstand the maximum external pressure differential that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by sending boil-off vapour to the machinery spaces, should be fitted with:

(1) two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank, and refrigeration equipment if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank; or
(2) vacuum relief valves with a gas flow capacity at least equal to the maximum cargo discharge rate per cargo tank, set to open at a pressure sufficiently below the external design differential pressure of the cargo tank; or
(3) other vacuum relief systems acceptable to the Society.

3. Subject to the requirements of **Sec 17,** the vacuum relief valves should admit an inert gas, cargo vapour or air to the cargo tank and should be arranged to minimize the possibility of the entrance of water or snow. If cargo vapour is admitted, it should be from a source other than the cargo vapour lines.

4. The vacuum protection system should be capable of being tested to ensure that it operates at the prescribed pressure.

805. Size of valves (IGC Code 8.5)

Pressure relief valves should have a combined relieving capacity for each cargo tank to discharge the greater of the following with not more than a 20 % rise in cargo tank pressure above the MARVS:

1. the maximum capacity of the cargo tank inerting system if the maximum attainable working pressure of the cargo tank inerting system exceeds the MARVS of the cargo tanks; or

2. vapours generated under fire exposure computed using the following formula:

$$Q = FGA^{0.82} \quad (\mathrm{m^3/s})$$

where:

Q = minimum required rate of discharge of air at standard conditions of 273 K and 0.1013 MPa.

F = fire exposure factor for different cargo tank types:

F = 1.0 for tanks without insulation located on deck;

F = 0.5 for tanks above the deck when insulation is approved by the Society (Approval will be based on the use of an approved fireproofing material, the thermal conductance of insulation, and its stability under fire exposure);

F = 0.5 for uninsulated independent tanks installed in holds;

F = 0.2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

F = 0.1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds);

F = 0.1 for membrane and semi-membrane tanks.

For independent tanks partly protruding through the open deck, the fire exposure factor should be determined on the basis of the surface areas above and below deck.

G = gas factor

$$G = \frac{12.4}{LD}\sqrt{\frac{ZT}{M}}$$

with:

T = temperature in kelvins (K) at relieving conditions, i.e. 120 % of the pressure at which the pressure relief valve is set.

L = latent heat of the material being vaporized at relieving conditions, in KJ/kg.

D = constant based on relation of specific heats k, shown in **Table 7.5.9;** if k is not known, D = 0.606 should be used. The constant D may also be calculated by the following formula:

Table 7.5.9 Constant D

k	D	k	D
1.00	0.606	1.52	0.704
1.02	0.611	1.54	0.707
1.04	0.615	1.56	0.710
1.06	0.620	1.58	0.713
1.08	0.624	1.60	0.716
1.10	0.628	1.62	0.719
1.12	0.633	1.64	0.722
1.14	0.637	1.66	0.725
1.16	0.641	1.68	0.728
1.18	0.645	1.70	0.731
1.20	0.649	1.72	0.734
1.22	0.652	1.74	0.736
1.24	0.656	1.76	0.739
1.26	0.660	1.78	0.742
1.28	0.664	1.80	0.745
1.30	0.667	1.82	0.747
1.32	0.671	1.84	0.750
1.34	0.674	1.86	0.752
1.36	0.677	1.88	0.755
1.38	0.681	1.90	0.758
1.40	0.685	1.92	0.760
1.42	0.688	1.94	0.763
1.44	0.691	1.96	0.765
1.46	0.695	1.98	0.767
1.48	0.698	2.00	0.770
1.50	0.701	2.02	0.772
		2.20	0.792

$$D=\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

Z = compressibility factor of the gas at relieving conditions; if not known, Z = 1.0 should be used.

M = molecular mass of the product

A = external surface area of the tank (m^2) for different tank types :

for body-of-revolution type tanks : A = external surface area;

for other than body-of-revolution type tanks : A = external surface area less the projected bottom surface area ;

for tanks consisting of an array of pressure vessel tanks:

insulation on the ship's structure:

A = external surface area of the hold less its projected bottom area;

insulation on the tank structure:

A = external surface area of the array of pressure vessels excluding insulation, less the projected bottom area as shown in **Fig 7.5.6.**

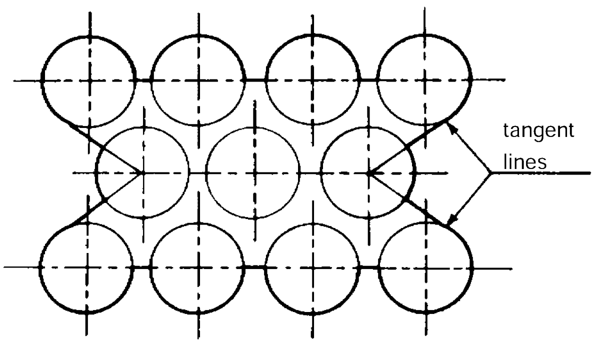


Fig. 7.5.6 Determination of the Projected Bottom Area for Tanks Consisting of an Array

Section 9 Environmental Control

901. Environmental control within cargo tanks and cargo piping systems (IGC Code 9.1)

1. A piping system should be provided to enable each cargo tank to be safely gas-freed, and to be safely purged with cargo gas from a gas-free condition. The system should be arranged to minimize the possibility of pockets of gas or air remaining after gas-freeing or purging.

2. A sufficient number of gas sampling points should be provided for each cargo tank in order to adequately monitor the progress of purging and gas-freeing. Gas sampling connections should be valved and capped above the main deck.

3. For flammable gases, the system should be arranged to minimize the possibility of a flammable mixture existing in the cargo tank during any part of the gas-freeing operation by utilizing an inerting medium as an intermediate step. In addition, the system should enable the cargo tank to be purged with an inerting medium prior to filling with cargo vapour or liquid, without permitting a flammable mixture to exist at any time within the cargo tank.

4. Piping systems which may contain cargo should be capable of being gas-freed and purged as provided in **Pars 1** and **3.**

5. Inert gas utilized in these procedures may be provided from the shore or from the ship.

902. Environmental control within the hold spaces (cargo containment systems other than type C independent tanks) (IGC Code 9.2)

1. Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full secondary barriers should be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage which should be sufficient for normal consumption for at least 30 days.

2. (1) Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring partial secondary barriers should be inerted with suitable dry inert gas and kept inerted with makeup gas provided by a shipboard inert gas generation system or by shipboard storage which should be sufficient for normal consumption for at least 30 days.

(2) Alternatively, subject to the restrictions specified in **Sec 17,** the Society may allow the spaces referred to in (1) to be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces; and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensure that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand should be provided.

3. For non-flammable gases, the spaces referred to in **Par 1** and **Par 2** (1) may be maintained with a suitable dry air or inert atmosphere.

4. In case of internal insulation tanks, environmental control arrangements are not required for interbarrier spaces and spaces between the secondary barrier and the inner hull or independent tank structures completely filled with insulation materials complying with **409. 7** (2).

903. Environmental control of spaces surrounding type C independent tanks (IGC Code 9.3)

Spaces surrounding refrigerated cargo tanks not having secondary barriers should be filled with suitable dry inert gas or dry air and be maintained in this condition with make-up inert gas provided by a ship-board inert gas generation system, shipboard storage of inert gas, or dry air provided by suitable air drying equipment.

904. Inerting (IGC Code 9.4)

1. Inerting refers to the process of providing a noncombustible environment by the addition of compatible gases, which may be carried in storage vessels or produced on board the ship or supplied from the shore. The inert gases should be compatible chemically and operationally, at all temperatures likely to occur within the spaces to be inerted, with the materials of construction of the spaces and the cargo. The dew points of the gases should be taken into consideration.

2. Where inert gas is also stored for fire-fighting purposes, it should be carried in separate containers and should not be used for cargo services.

3. Where inert gas is stored at temperature below 0°C, either as a liquid or as a vapour, the storage and supply system should be so designed that the temperature of the ship's structure is not reduced below the limiting values imposed on it.

4. Arrangements suitable for the cargo carried should be provided to prevent the backflow of cargo vapour into the inert gas system.

5. The arrangements should be such that each space being inerted can be isolated and the necessary controls and relief valves etc. should be provided for controlling pressure in these spaces.

905. Inert gas production on board (IGC Code 9.5)

1. The equipment should be capable of producing inert gas with an oxygen content at no time greater than 5 % by volume subject to the special requirements of **Sec 17.** A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5 % oxygen content by volume subject to the requirements of **Sec 17.** Additionally, where inert gas is made by an on-board process of fractional distillation of air which involves the storage of the cryogenic liquefied nitrogen for subsequent release, the liquefied gas entering the storage vessel should be monitored for traces of oxygen to avoid possible initial high oxygen enrichment of the gas when released for inerting purposes.

2. An inert gas system should have pressure controls and monitoring arrangements appropriate to the cargo containment system. A means acceptable to the Society, located in the cargo area, of preventing the backflow of cargo gas should be provided.

3. Spaces containing inert gas generating plants should have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves, or equivalent devices should be fitted in the inert gas main in the cargo area as required in **Par 2.** Inert gas piping should not pass through accommodation spaces, service spaces or control stations. When not in use, the inert gas system should be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

4. Flame burning equipment for generating inert gas should not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using the catalytic combustion process.

Section 10 Electrical Installations

1001. General (IGC Code 10.1)

1. The provisions of the Section are applicable to ships carrying flammable products and should be applied in conjunction with part D of chapter II-1 of the 1983 SOLAS amendments.

2. Electrical installations should be such as to minimize the risk of fire and explosion from flammable products. Electrical installations complying with this Section need not be considered as a source of ignition for the purposes of **Sec 3.**

3. The Society should take appropriate steps to ensure uniformity in the implementation and application of the provisions of this Section in respect of electrical installations.

4. Electrical equipment, cables and wiring shall not be installed in hazardous locations unless it conforms with the standards not inferior to those acceptable to the Organization. Refer to the standards published by the International Electrotechnical Commission, IEC 60092-502:1999" Electrical installation in ships - tankers. However, for locations not covered by such standards, electrical equipments, cables and wiring which do not conform to the standards may be installed in hazardous locations based on a risk assessment to the satisfaction of the Society to ensure that an equivalent level of safety is assured.

5. Where electrical equipment is installed in gas dangerous spaces or zones as provided in **Par 4,** it should be to the satisfaction of the Society and approved by the relevant authorities recognized by the Society for operation in the flammable atmosphere concerned.

Section 11 Fire Protection and Fire Extinction

1101. Fire safety requirements (IGC Code 11.1)

1. The requirements for tankers in SOLAS chapter II-2 should apply to ships covered by this Chapter, irrespective of tonnage including ships of less than 500 tons gross tonnage, except that:

(1) regulations 4.5.1.6 and 4.5.10 do not apply ;
(2) regulation 10.2 as applicable to cargo ships and regulations 10.4 and 10.5 should apply as they would apply to tankers of 2,000 gross tonnage and over ;.
(3) regulation 10.5.6 should apply to ships of 2,000 gross tonnage and over ;
(4) the following regulations of SOLAS chapter II-2 related to tankers do not apply and are replaced by Sections and articles of this Chapter as detailed below :

SOLAS Regulation	Replaced by
10.10	**1106.**
4.5.1.1 and 4.5.1.2	**Sec 3**
4.5.5 and 10.8	**1103.** and **1104.**
10.9	**1105.**

(5) regulation 13.3.4 and 13.4.3 should apply to ships of 500 gross tonnage and over ;

2. All sources of ignition should be excluded from spaces where flammable vapour may be present except as otherwise provided in **Secs 10** and **16.**

3. The provisions of this article apply in conjunction with **Sec 3.**

4. For the purposes of fire fighting, any open deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forward most hold space should be included in the cargo area.

1102. Fire water main equipment (IGC Code 11.2)

1. All ships, irrespective of size, carrying products which are subject to this Chapter should comply with the requirements of SOLAS regulations II-2/10.2, 10.4 and 10.5, except that the required fire pump capacity and fire main and water service pipe diameter should not be limited by the provisions of regulations II-2/10.2.2.4.1 and II-2/10.2.1.3 when the fire pump and fire main are used as part of the water spray system as permitted by **1103. 3.** In addition, the requirements of regulation II-2/10.2.1.6 should be met at a pressure of at least 0.5 MPa gauge.

2. The arrangements should be such that at least two jets of water can reach any part of the deck in the cargo area and those portions of the cargo containment system and tank covers above the deck. The necessary number of fire hydrants should be located to satisfy the above arrangements and to comply with the requirements of SOLAS regulations II-2/10.2.1.5.1 and II-2/10.2.3.3, with hose lengths as specified in regulation II-2/10.2.3.1.1.

3. Stop valves should be fitted in any crossover provided and in the fire main or mains at the poop front and at intervals of not more than 40 m between hydrants on the deck in the cargo area for the purpose of isolating damaged sections of the main.

4. All water nozzles provided for fire-fighting use should be of an approved dual-purpose type capable of producing either a spray or a jet. All pipes, valves, nozzles and other fittings in the fire-fighting systems should be resistant to the effects of fire and to corrosion by water.

5. Where the ship's engine-room is unattended, arrangements should be made to start and connect to the fire main at least one fire pump by remote control from the navigating bridge or other control station outside the cargo area.

1103. Water spray system (IGC Code 11.3)

1. On ships carrying flammable or toxic products or both, a water spray system for cooling, fire prevention and crew protection should be installed to cover:

(1) exposed cargo tank domes and any exposed parts of cargo tanks;
(2) exposed on-deck storage vessels for flammable or toxic products;
(3) cargo liquid and vapour discharge and loading manifolds and the area of their control valves and any other areas where essential control valves are situated and which should be at least equal to the area of the drip trays provided; and
(4) boundaries of superstructures and deckhouses normally manned, cargo compressors rooms, cargo pump rooms, store-rooms containing high fire risk items and cargo control rooms, all facing the cargo area. Boundaries of unmanned forecastle structures not containing high fire risk items or equipment do not require water spray protection.

2. The system should be capable of covering all areas mentioned in **Par 1** with a uniformly distributed water spray of at least 10 l/m^2 per minute for horizontal projected surfaces and 4 l/m^2 per minute for vertical surfaces. For structures having no clearly defined horizontal or vertical surfaces, the capacity of the water spray system should be the greater of the following:

(1) projected horizontal surface multiplied by 10 l/m^2 per minute; or
(2) actual surface multiplied by 4 l/m^2 per minute.
On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves should be fitted at intervals in the spray main for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections which may be operated independently provided the necessary controls are located together, aft of the cargo area. A section protecting any area included in **Par 1** (1) and (2) should cover the whole of the athwartship tank grouping which includes that area.

3. The capacity of the water spray pumps should be sufficient to deliver the required amount of water to all areas simultaneously or where the system is divided into sections, the arrangements and capacity should be such as to supply water simultaneously to anyone section and to the surfaces specified in **Par 1** (3) and (4). Alternatively, the main fire pumps may be used for this service provided that their total capacity is increased by the amount needed for the spray system. In either case, a connection, through a stop valve, should be made between the fire main and water spray main outside the cargo area.

4. Subject to the approval of the Society, water pumps normally used for other services may be arranged to supply the water spray main.

5. All pipes, valves, nozzles and other fittings in the water spray systems should be resistant to corrosion by seawater, for which purpose galvanized pipe, for example, may be used, and to the effect of fire.

6. Remote starting of pumps supplying the water spray system and remote operation of any normally closed valves in the system should be arranged in suitable locations outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

1104. Dry chemical powder fire-extinguishing systems (IGC Code 11.4)

1. Ships in which the carriage of flammable products is intended should be fitted with fixed dry chemical powder type extinguishing systems for the purpose of fighting fire on the deck in the cargo area and bow or stern cargo handling areas if applicable. The system and the dry chemical powder should be adequate fo this purpose and satisfactory to the Society.

2. The system should be capable of delivering powder from at least two hand hose lines or combination monitor/hand hose lines to any part of the above-deck exposed cargo area including above-deck product piping. The system should be activated by an inert gas such as nitrogen, used exclusively for this purpose and stored in pressure vessels adjacent to the powder containers.

3. The system for use in the cargo area should consist of at least two independent self-contained dry chemical powder units with associated controls, pressurizing medium fixed piping, monitors or hand hose lines. For ships with a cargo capacity of less than 1,000 m^3 only one such unit need be fitted, subject to approval by the Society. A monitor should be provided and so arranged as to protect the cargo loading and discharge manifold areas and be capable of actuation and discharge locally and remotely. The monitor is not required to be remotely aimed if it can deliver the necessary powder to all required areas of coverage from a single position. All hand hose lines and monitors should be capable of actuation at the hose storage reel or monitor. At least one hand hose line or monitor should be situated at the after end of the cargo area.

4. A fire-extinguishing unit having two or more monitors, hand hose lines, or combinations thereof, should have independent pipes with a manifold at the powder container, unless a suitable alternative means is provided to ensure proper performance as approved by the Society. Where two or more pipes are attached to a unit the arrangement should be such that any or all of the monitors and hand hose lines should be capable of simultaneous or sequential operation at their rated capacities.

5. The capacity of a monitor should be not less than 10 kg/sec. Hand hose lines should be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3.5 kg/sec. The maximum discharge rate should be such as to allow operation by one man. The length of a hand hose line should not exceed 33 m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping should not exceed that length which is capable of maintaining the powder in a fluidized state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles should be of weather-resistant construction or stored in water-resistant housing or covers and be readily accessible.

6. A sufficient quantity of dry chemical powder should be stored in each container to provide a minimum 45 seconds discharge time for all monitors and hand hose lines attached to each powder unit. Coverage from fixed monitors should be in accordance with **Table 7.5.10.**

Table 7.5.10 Coverage from Fixed Monitors

Capacity of fixed monitors(kg/sec) each	10	25	45
Maximum distance of coverage(m)	10	30	40

Hand hose lines should be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration should be given where areas to be protected are substantially higher than the monitor or hand hose reel locations.

7. Ships fitted with bow or stern loading and discharge arrangements should be provided with an additional dry chemical powder unit complete with at least one monitor and one hand hose line complying with the requirements of **Pars 1** to **6.** This additional unit should be located to protect the bow or stern loading and discharge arrangements. The area of the cargo line forward or aft of the cargo area should be protected by hand hose lines.

1105. Cargo compressor and pump rooms (IGC Code 11.5)

1. The cargo compressor and pump rooms of any ship should be provided with a carbon dioxide system as specified in SOLAS regulation II-2/10.9.1.1. A notice should be exhibited at the controls stating that the system is only to be used for fire-extinguishing and not for inerting purposes, due to the electrostatic ignition hazard. The alarms referred to in SOLAS regulation II-2/10.9.1.1.1 should be safe for use in a flammable cargo vapour-air mixture. For the purpose of this requirement, an extinguishing system should be provided which would be suitable for machinery spaces. However, the amount of carbon dioxide gas carried should be sufficient to provide a quantity of free gas equal to 45 % of the gross volume of the cargo compressor and pump rooms in all cases.

2. Cargo compressor and pump rooms of ships which are dedicated to the carriage of a restricted number of cargoes should be protected by an appropriate fire-extinguishing system approved by the Society.

1106. Fire-fighter's outfits (IGC Code 11.6)

1. Every ship carrying flammable products should carry fire-fighter's outfits complying with the requirements of SOLAS regulation II-2/10.10 as follows:

Total cargo capacity	Number of outfits
5,000 m^3 and below	4
above 5,000 m^3	5

2. Additional requirements for safety equipment are given in **Sec 14.**

3. Any breathing apparatus required as part of a fire-fighter's outfit should be a self-contained air-breathing apparatus having a capacity of at least 1,200 l of free air.

Section 12 Mechanical Ventilation in the Cargo Area

The requirements of this Section should be substituted for SOLAS regulations II-2/4.5.2.6 and II-2/4.5.4.

1201. Spaces required to be entered during normal cargo handling operations (IGC Code 12.1)

1. Electric motor rooms, cargo compressor and pump rooms, other enclosed spaces which contain cargo handling equipment and similar spaces in which cargo handling operations are performed should be fitted with mechanical ventilation systems capable of being controlled from outside such spaces. Provision should be made to ventilate such spaces prior to entering the compartment and operating the equipment and a warning notice requiring the use of such ventilation should be placed outside the compartment.

2. Mechanical ventilation inlets and outlets should be arranged to ensure sufficient air movement through the space to avoid the accumulation of flammable or toxic vapours and to ensure a safe working environment, but in no case should the ventilation system have a capacity of less than 30 changes of air per hour based upon the total volume of the space. As an exception, gas-safe cargo control rooms may have eight changes of air per hour.

3. Ventilation systems should be fixed and, if of the negative pressure type, permit extraction from either the upper or the lower parts of the spaces, or from both the upper and the lower parts, depending on the density of the vapours of the products carried.

4. In rooms housing electric motors driving cargo compressors or pumps, spaces except machinery spaces containing inert gas generators, cargo control rooms if considered as gas-safe spaces and other gas-safe spaces within the cargo area, the ventilation should be of the positive pressure type.

5. In cargo compressor and pump rooms and in cargo control rooms if considered gas-dangerous, the ventilation should be of the negative pressure type.

6. Ventilation exhaust ducts from gas-dangerous spaces should discharge upwards in locations at least 10 m in the horizontal direction from ventilation intakes and openings to accommodation spaces, service spaces and control stations and other gas-safe spaces.

7. Ventilation intakes should be so arranged as to minimize the possibility of re-cycling hazardous vapours from any ventilation discharge opening.

8. Ventilation ducts from gas-dangerous spaces should not be led through accommodation, service and machinery spaces or control stations, except as allowed in **Sec 16.**

9. Electric motors driving fans should be placed outside the ventilation ducts if the carriage of flammable products is intended. Ventilation fans should not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, for gas-dangerous spaces should be of non sparking construction defined as:

(1) impellers or housing of nonmetallic construction, due regard being paid to the elimination of static electricity;
(2) impellers and housing of nonferrous materials;
(3) impellers and housing of austenitic stainless steel; and
(4) ferrous impellers and housing with not less than 13 mm design tip clearance.
Any combination or an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

10. Spare parts should be carried for each type of fan on board referred to in this Section.

11. Protection screens of not more than 13 mm square mesh should be fitted in outside openings of ventilation ducts.

1202. Spaces not normally entered (IGC Code 12.2)

Hold spaces, interbarrier spaces, void spaces, cofferdams, spaces containing cargo piping and other spaces where cargo vapour may accumulate, should be capable of being ventilated to ensure a safe environment when entry into the spaces is necessary. Where a permanent ventilation system is not provided for such spaces, approved means of portable mechanical ventilation should be provided. Where necessary owing to the arrangement of spaces, such as hold spaces and interbarrier spaces, essential ducting for such ventilation should be permanently installed. Fans or blowers should be clear of personnel access openings, and should comply with **1201. 9.**

Section 13 Instrumentation (Gauging, Gas Detection)

1301. General (IGC Code 13.1)

1. Each cargo tank should be provided with means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices should be installed in the liquid and vapour piping systems, in cargo refrigerating installations and in the inert gas systems as detailed in this Section.

2. Where a secondary barrier is required, permanently installed instrumentation should be provided to detect when the primary barrier fails to be liquid tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation should consist of appropriate gas detecting devices according to **1306.** However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.

3. If the loading and unloading of the ship is performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank should be concentrated in one control position.

4. Instruments should be tested to ensure reliability in the working conditions and recalibrated at regular intervals. Test procedures for instruments and the intervals between recalibration should be approved by the Society.

1302. Level indicators for cargo tanks (IGC Code 13.2)

1. Each cargo tank should be fitted with at least one liquid level gauging device, designed to operate at pressures not less than the MARVS of the cargo tank and at temperatures within the cargo operating temperature range. Where only one liquid level gauge is fitted it should be so arranged that any necessary maintenance can be carried out while the cargo tank is in service.

2. Cargo tank liquid level gauges may be of the following types subject to any special requirement for particular cargoes shown in column "g" in the table of **Sec 19:**

(1) indirect devices, which determine the amount of cargo by means such as weighing or pipe flow meters;

(2) closed devices, which do not penetrate the cargo tank, such as devices using radioisotopes or ultrasonic devices;

(3) closed devices, which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If a closed gauging device is not mounted directly on the tank it should be provided with a shutoff valve located as close as possible to the tank; and

(4) restricted devices, which penetrate the tank and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices should be kept completely closed. The design and installation should ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices should be so designed that the maximum opening does not exceed 1.5 mm diameter or equivalent area unless the device is provided with an excess flow valve.

3. Sighting ports with a suitable protective cover and situated above the liquid level with an internal scale may be allowed by the Society as a secondary means of gauging for cargo tanks having a design vapour pressure not higher than 0.07 MPa.

4. Tubular gauge glasses should not be fitted. Gauge glasses of the robust type as fitted on high-pressure boilers and fitted with excess flow valves may be allowed by the Society for deck tanks, subject to any provisions of **Sec 17.**

1303. Overflow control (IGC Code 13.3)

1. Except as provided in **Par 2,** each cargo tank should be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated. Another sensor operating independently of the high liquid level alarm should automatically actuate a shutoff valve in a manner which will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full. The emergency shutdown valve referred to in **506. 1** and **506. 3** may be used for this purpose. If another valve is used for this purpose, the same information as referred to in **506. 4** should be available on board.

2. A high liquid level alarm and automatic shutoff of cargo tank filling need not be required when the cargo tank:

(1) is a pressure tank with a volume not more than 200 m^3; or
(2) is designed to withstand the maximum possible pressure during the loading operation and such pressure is below that of the start-to-discharge pressure of the cargo tank relief valve.

3. Electrical circuits, if any, of level alarms should be capable of being tested prior to loading.

1304. Pressure gauges (IGC Code 13.4)

1. The vapour space of each cargo tank should be provided with a pressure gauge which should incorporate an indicator in the control position required by **1301. 3.** In addition, a high-pressure alarm and, if vacuum protection is required, a low-pressure alarm should be provided on the navigating bridge. Maximum and minimum allowable pressures should be marked on the indicators. The alarms should be activated before the set pressures are reached. For cargo tanks fitted with pressure relief valves, which can be set at more than one set pressure in accordance with **802. 6,** high-pressure alarms should be provided for each set pressure.

2. Each cargo pump discharge line and each liquid and vapour cargo manifold should be provided with at least one pressure gauge.

3. Local-reading manifold pressure gauges should be provided to indicate the pressure between stop valves and hose connections to the shore.

4. Hold spaces and interbarrier spaces without open connection to the atmosphere should be provided with pressure gauges.

1305. Temperature indicating devices (IGC Code 13.5)

1. Each cargo tank should be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level. The temperature indicating devices should be marked to show the lowest temperature for which the cargo tank has been approved by the Society.

2. When a cargo is carried in a cargo containment system with a secondary barrier at a temperature lower than -55°C, temperature indicating devices should be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices should give readings at regular intervals and, where applicable, audible warning of temperatures approaching the lowest for which the hull steel is suitable.

3. If cargo is to be carried at temperatures lower than -55°C, the cargo tank boundaries, if appropriate for the design of the cargo containment system, should be fitted with temperature indicating devices as follows:

(1) A sufficient number of devices to establish that an unsatisfactory temperature gradient does not occur.
(2) On one tank a number of devices in excess of those required in (1) in order to verify that the initial cool down procedure is satisfactory. These devices may be either temporary or permanent. When a series of similar ships is built, the second and successive ships need not comply with the requirements of this subparagraph.

4. The number and position of temperature indicating devices should be to the satisfaction of the Society.

1306. Gas detection requirements (IGC Code 13.6)

1. Gas detection equipment acceptable to the Society and suitable for the gases to be carried should be provided in accordance with column "f" in the table of **Sec 19.**

2. In every installation, the positions of fixed sampling heads should be determined with due regard to the density of the vapours of the products intended to be carried and the dilution from compartment purging or ventilation.

3. Pipe runs from sampling heads should not be led through gas-safe spaces except as permitted by **Par 5.**

4. Audible and visual alarms from the gas detection equipment, if required by this Article, should be located on the navigating bridge, in the control position required by **1301. 3,** and at the gas detector readout location.

5. Gas detection equipment may be located in the control position required by **1301. 3,** on the navigating bridge or at other suitable locations. When such equipment is located in a gas-safe space the following conditions should be met:

(1) gas-sampling lines should have shutoff valves or an equivalent arrangement to prevent cross-communication with gas-dangerous spaces; and
(2) exhaust gas from the detector should be discharged to the atmosphere in a safe location.

6. Gas detection equipment should be so designed that it may readily be tested. Testing and calibration should be carried out at regular intervals. Suitable equipment and span gas for this purpose should be carried on board. Where practicable, permanent connections for such equipment should be fitted.

7. A permanently installed system of gas detection and audible and visual alarms should be provided for:

(1) cargo pump rooms;
(2) cargo compressor rooms;
(3) motor rooms for cargo handling machinery;
(4) cargo control rooms unless designated as gas-safe;
(5) other enclosed spaces in the cargo area where vapour may accumulate including hold spaces and interbarrier spaces for independent tanks other than type C;
(6) ventilation hoods and gas ducts where required by **Sec 16;** and
(7) air locks.

8. The gas detection equipment should be capable of sampling and analysing from each sampling head location sequentially at intervals not exceeding 30 min, except that in the case of gas detection for the ventilation hoods and gas ducts referred to in **1306. 7** (6) sampling should be continuous. Common sampling lines to the detection equipment should not be fitted.

9. In the case of products which are toxic or both toxic and flammable, the Society except when column "i" in the table of **Sec 19** refers to **1709.,** may authorize the use of portable equipment for detection of toxic products as an alternative to a permanently installed system, if such equipment is used before personnel enter the spaces listed in **Par 7** and at 30 min intervals while they remain therein.

10. For the spaces listed in **Par 7,** alarms should be activated for flammable products when the vapour concentration reaches 30 % of the lower flammable limit.

11. In the case of flammable products, where cargo containment systems other than independent tanks are used, hold spaces and interbarrier spaces should be provided with a permanently installed gas detection system capable of measuring gas concentrations of 0 % to 100 % by volume. The detection equipment, equipped with audible and visual alarms, should be capable of monitoring from each sampling head location sequentially at intervals not exceeding 30 min. Alarms should be activated when the vapour concentration reaches the equivalent of 30 % of the lower flammable limit in air or such other limit as may be approved by the Society in the light of particular cargo containment arrangements. Common sampling lines to the detection equipment should not be fitted.

12. In the case of toxic gases, hold spaces and interbarrier spaces should be provided with a permanently installed piping system for obtaining gas samples from the spaces. Gas from these spaces should be sampled and analysed from each sampling head location by means of fixed or portable equipment at intervals not exceeding 4 h and in any event before personnel enter the space and at 30 min intervals while they remain therein.

13. Every ship should be provided with at least two sets of portable gas detection equipment acceptable to the Society and suitable for the products to be carried.

14. A suitable instrument for the measurement of oxygen levels in inert atmospheres should be provided.

Section 14 Personnel Protection

1401. Protective equipment (IGC Code 14.1)

Suitable protective equipment including eye protection should be provided for protection of crew members engaged in loading and discharging operations, taking into account the character of the products.

1402. Safety equipment (IGC Code 14.2)

1. Sufficient, but not less than two complete sets of safety equipment in addition to the firmen's outfits required by **1106. 1** each permitting personnel to enter and work in a gas-filled space, should be provided.

2. One complete set of safety equipment should consist of:

(1) one self-contained air-breathing apparatus not using stored oxygen, having a capacity of at least 1,200 l of free air;
(2) protective clothing, boots, gloves and tight fitting goggles;
(3) steel-cored rescue line with belt; and
(4) explosion-proof lamp.

3. An adequate supply of compressed air should be provided and should consist either of:

(1) one set of fully charged spare air bottles for each breathing apparatus required by **Par 1;** a special air compressor suitable for the supply of high-pressure air of the required purity; and a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by **Par 1;** or
(2) fully charged spare air bottles with a total free air capacity of at least 6,000 l for each breathing apparatus required by **Par 1.**

4. Alternatively, the Society may accept a low-pressure air line system with hose connection suitable for use with the breathing apparatus required by **Par 1.** This system should provide sufficient high-pressure air capacity to supply, through pressure reduction devices, enough low-pressure air to enable two men to work in a gas-dangerous space for at least 1 h without using the air bottles of the breathing apparatus. Means should be provided for recharging the fixed air bottles and the breathing apparatus air bottles from a special air compressor suitable for the supply of high-pressure air of the required purity.

5. Protective equipment required in **1401.** and safety equipment required in **Par 1** should be kept in suitable, clearly marked lockers located in readily accessible places.

6. The compressed air equipment should be inspected at least once a month by a responsible officer and the inspection recorded in the ship's log-book, and inspected and tested by an expert at least once a year.

1403. First-aid equipment (IGC Code 14.3)

1. A stretcher which is suitable for hoisting an injured person from spaces below deck should be kept in a readily accessible location.

2. The ship should have on board medical first-aid equipment, including oxygen resuscitation equipment and antidotes for cargoes to be carried. Medical First Aid Guide for Use in Accidents Involving Dangerous Goods(MFAG) numbers related to products covered by the code are given in the table of minimum requirements(**Sec 19**)

1404. Personnel protection requirements for individual products (IGC Code 14.4)

1. Provisions of **1404.** are applicable to ships carrying products for which those paragraphs are listed in column "i" in the table of **Sec 19.**

2. Respiratory and eye protection suitable for emergency escape purposes should be provided for every person on board subject to the following:

(1) (a) filter type respiratory protection is unacceptable;

(b) self-contained breathing apparatus should normally have a duration of service of at least 15 min;

(2) emergency escape respiratory protection should not be used for fire-fighting or cargo handling purposes and should be marked to that effect;

(3) two additional sets of the above respiratory and eye protection should be permanently located in the navigating bridge.

3. Suitably marked decontamination showers and an eyewash should be available on deck in convenient locations. The showers and eyewash should be operable in all ambient conditions.

4. In ships of a cargo capacity of 2,000 m^3 and over, two complete sets of safety equipment should be provided in addition to the equipment required by **1106. 1** and **1402. 1.** At least three spare charged air bottles should be provided for each self-contained air breathing apparatus required in this paragraph.

5. Personnel should be protected against the effects of a major cargo release by the provision of a space within the accommodation area designed and equipped to the satisfaction of the Society.

6. For certain highly dangerous products, cargo control rooms should be of the gas-safe type only.

Section 15 Filling Limits for Cargo Tanks

1501. General (IGC Code 15.1)

1. No cargo tanks should have a higher filling limit(FL) than 98 % at the reference temperature, except as permitted by **Par 3.**

2. The maximum loading limit(LL) to which a cargo tank may be loaded should be determined by the following formula:

$$LL = FL\frac{\rho_R}{\rho_L}$$

where:

LL = loading limit expressed as a percentage, being the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded(%)

FL = filling limit as specified in **Par 1** or **3**

ρ_R = relative density of cargo at the reference temperature

ρ_L = relative density of cargo at the loading temperature and pressure.

3. The Society may allow a higher filling limit(FL) than the limit of 98 % specified in **Par 1** at the reference temperature, taking into account the shape of the tank, arrangements of pressure relief valves, accuracy of level and temperature gauging and the difference between the loading temperature and the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves, provided the conditions in **802. 17** are maintained.

4. For the purposes of this Section only, "reference temperature" means:

(1) the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves when no cargo vapour pressure/temperature control as referred to in **Sec 7** is provided.

(2) the temperature of the cargo upon termination of loading, during transport, or at unloading, whichever is the greatest, when a cargo vapour pressure/temperature control as referred to in **Sec 7** is provided. If this reference temperature would result in the cargo tank becoming liquid full before the cargo reaches a temperature corresponding to the vapour pressure of the cargo at the set pressure of the relief valves required in **802.**, an additional pressure relieving system complying with **803.** should be fitted.

5. The Society may allow type C tanks to be loaded according to the following formula, provided that the tank vent system has been approved in accordance with **802. 18:**

$$LL = FL\frac{\rho_R}{\rho_L}$$

where:

LL = loading limit as specified in **Par 2;**

FL = filling limit as specified in **Par 1** or **3;**

ρ_R = relative density of cargo at the highest temperature which the cargo may reach upon termination or loading, during transport, or at unloading, under the ambient design temperature conditions described in **701. 2;** and

ρ_L = as specified in **Par 2.**

This paragraph does not apply to products requiring a type 1 G ship.

6. This Section applies to all ships regardless of the date of construction.

1502. Information to be provided to the master (IGC Code 15.2)

The maximum allowable loading limits for each cargo tank should be indicated for each product which may be carried, for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Society. Pressures at which the pressure relief valves, including those valves required by **803.**, have been set should also be stated on the list. A copy of the list should be permanently kept on board by the master.

Section 16 Use of Cargo as Fuel

1601. General (IGC Code 16.1)

1. Methane (LNG) is the only cargo whose vapour or boil-off gas may be utilized in machinery spaces of category A and in such spaces may be utilized only in boilers, inert gas generators, and combustion engines and gas turbines.

2. These provisions do not preclude the use of gas fuel for auxiliary services in other locations, provided that such other services and locations should be subject to special consideration by the Society.

1602. Arrangement of machinery spaces of category A (IGC Code 16.2)

1. Spaces in which gas fuel is utilized should be fitted with a mechanical ventilation system and should be arranged in such a way as to prevent the formation of dead spaces. Such ventilation should be particularly effective in the vicinity of electrical equipment and machinery or of other equipment and machinery which may generate sparks. Such a ventilation system should be separated from those intended for other spaces.

2. Gas detectors should be fitted in these spaces, particularly in the zones where air circulation is reduced. The gas detection system should comply with the requirements of **Sec 13.**

3. Electrical equipment located in the double wall pipe or duct specified in **1603. 1** should be of the intrinsically safe type.

1603. Gas fuel supply (IGC Code 16.3)

1. Gas fuel piping should not pass through accommodation spaces, service spaces or control stations. Gas fuel piping may pass through or extend into other spaces provided they fulfil one of the following:

(1) the gas fuel piping should be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes; or

(2) the gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the inner wall of this pipe or duct should be equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour. The ventilation system should be arranged to maintain a pressure less than the atmospheric pressure. The fan motors should be placed outside the ventilated pipe or duct. The ventilation outlet should be placed in a position where no flammable gas-air mixture may be ignited. The ventilation should always be in operation when there is gas fuel in the piping. Continuous gas detection should be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with **Par 10**. The master gas fuel valve required by **Par 7** should close automatically, if the required air flow is not established and maintained by the exhaust ventilation system.

2. If a gas leak occurs, the gas fuel supply should not be restored until the leak has been found and repaired. Instructions to this effect should be placed in a prominent position in the machinery spaces.

3. The double wall piping system or the ventilated pipe or duct provided for the gas fuel piping should terminate at the ventilation hood or casing required by **Par 4.**

4. A ventilation hood or casing should be provided for the areas occupied by flanges, valves, etc., and for the gas fuel piping, at gas fuel utilization units, such as boilers, diesel engines and gas turbines. If this ventilation hood or casing is not served by the exhaust ventilation fan serving the ventilated pipe or duct as specified in **Par 1** (2), then it should be equipped with an exhaust ventilation system and continuous gas detection should be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with **Par 10.** The master gas fuel valve required by **Par 7** should close automatically if the required air flow is not established and maintained by the exhaust ventilation system. The ventilation hood or casing should be installed or mounted to permit the ventilating air to sweep across the gas utilization unit and be exhausted at the top of the ventilation hood or casing.

5. The ventilation inlet and discharge for the required ventilation systems should be respectively from and to a safe location.

6. Each gas utilization unit should be provided with a set of three automatic valves. Two of these valves should be in series in the gas fuel pipe to the consuming equipment. The third valve should be in a pipe that vents, to a safe location in the open air, that portion of the gas fuel piping that is between the two valves in series. These valves should be so arranged that failure of the necessary forced draft, loss of flame on boiler burners, abnormal pressure in the gas fuel supply line, or failure of the valve control actuating medium will cause the two gas fuel valves which are in series to close automatically and cause the vent valve to open automatically. Alternatively, the function of one of the valves in series and of the valve in the vent line can be incorporated into one valve body so arranged that, when one of the above conditions occurs, flow to the gas utilization unit will be blocked and the vent opened. The three shut-off valves should be arranged for manual reset.

7. A master gas fuel valve that can be closed from within the machinery space should be provided within the cargo area. The valve should be arranged so as to close automatically if leakage of gas is detected, or loss of ventilation for the duct or casing or loss of pressurization of the double wall gas fuel piping occurs.

8. Gas fuel piping in machinery spaces should comply with **502.** to **505.** as far as found applicable. The piping should, as far as practicable, have welded joints. Those parts of the gas fuel piping, which are not enclosed in a ventilated pipe or duct according to **Par 1** and are on the open deck outside the cargo area should have full penetration butt-welded joints and should be fully radiographed.

9. Provision should be made for inerting and gas-freeing that portion of the gas fuel piping system located in the machinery space.

10. Gas detection systems provided in accordance with the requirements of **Pars 1** and **4** should comply with **1306. 2** and **1306. 4** through **1306. 8** as applicable; they should activate the alarm at 30 % of the lower flammable limit and shut down the master gas fuel valve referred to in **Par 7** before the gas concentration reaches 60 % of the lower flammable limit.

1604. Gas make-up plant and related storage tanks (IGC Code 16.4)

1. All equipment (heaters, compressors, filters, etc.) for making up the gas for its use as fuel, and the related storage tanks should be located in the cargo area in accordance with the requirement of **301. 5** (4). If the equipment is in an enclosed space, the space should be ventilated according to **1201.** and be equipped with a fixed fire-extinguishing system according to **1105.** and with a gas detection system according to **1306.,** as applicable.

2. The compressors should be capable of being remotely stopped from a position which is always and easily accessible, and also from the engine-room. In addition, the compressors should be capable of automatically stopping when the suction pressure reaches a certain value depending on the set pressure of the vacuum relief valves of the cargo tanks. The automatic shut-down device of the compressors should have a manual resetting. Volumetric compressors should be fitted with pressure relief valves discharging into the suction line of the compressor. The size of the pressure relief valves should be determined in such a way that, with the delivery valve kept closed, the maximum pressure does not exceed by more than 10 % the maximum working pressure, The requirements of **506. 1** (3) apply to these compressors.

3. If the heating medium for the gas fuel evaporator or heater is returned to spaces outside the cargo area it should first go through a degassing tank. The degassing tank should be located in the cargo area. Provisions should be made to detect and alarm the presence of gas in the tank. The vent outlet should be in a safe position and fitted with a flame screen.

4. Piping and pressure vessels in the gas fuel conditioning system should comply with **Sec 5.**

1605. Special requirements for main boilers (IGC Code 16.5)

1. Each boiler should have a separate uptake.

2. A system suitable to ensure the forced draught in the boilers should be provided. The particulars of such a system should be to the satisfaction of the Society.

3. Combustion chambers of boilers should be of suitable form such as not to present pockets where gas may accumulate.

4. The burner systems should be of dual type, suitable to burn either oil fuel or gas fuel alone or oil and gas fuel simultaneously. Only oil fuel should be used during manoeuvring and port operations unless automatic transfer from gas to oil burning is provided in which case the burning of a combination of oil and gas or gas alone may be permitted provided the system is demonstrated to the satisfaction of the Society. It should be possible to change over easily and quickly from gas fuel operation to oil fuel operation. Gas nozzles should be fitted in such a way that gas fuel is ignited by the flame of the oil fuel burner. A flame scanner should be installed and arranged to assure that gas flow to the burner is cut off unless satisfactory ignition has been established and maintained. On the pipe of each gas burner a manually operated shut-off valve should be fitted. An installation should be provided for purging the gas supply piping to the burners by means of inert gas or steam, after the extinguishing of these burners.

5. Alarm devices should be fitted in order to monitor a possible decrease in liquid fuel oil pressure or a possible failure of the related pumps.

6. Arrangements should be made that, in case of flame failure of all operating burners for gas or oil or for a combination thereof, the combustion chambers of the boilers are automatically purged before relighting. Arrangements should also be made to enable the boilers to be manually purged.

1606. Special requirements for gas-fired internal combustion engines and gas-fired turbines (IGC Code 16.6)

Special provisions for gas-fuelled internal combustion engines and for gas turbines will be considered by the Society in each case.

Section 17 Special Requirements

1701. General (IGC Code 17.1)

The provisions of this Section are applicable where reference is made in column "i" in the table of **Sec 19.** These are requirements additional to the general requirements of this Chapter.

1702. Materials of construction (IGC Code 17.2)

Materials which may be exposed to cargo during normal operations should be resistant to the corrosive action of the gases. In addition, the following materials of construction for cargo tanks, and associated pipelines, valves, fittings and other items of equipment should not be used for certain products as specified in column "i" in the table of **Sec 19**:
(1) mercury, copper and copper-bearing alloys, and zinc;
(2) copper, silver, mercury, magnesium and other acetylide-forming metals;
(3) aluminium and aluminium-bearing alloys;
(4) copper, copper alloys, zinc and galvanized steel;
(5) aluminium, copper and alloys of either;
(6) copper and copper-bearing alloys with greater than 1% copper.

1703. Independent tanks (IGC Code 17.3)

1. Products should be carried in independent tanks only.

2. Products should be carried in type C independent tanks and the provisions of **701. 3** apply. The design pressure of the cargo tank should take into account any padding pressure or vapour discharge unloading pressure.

1704. Refrigeration systems (IGC Code 17.4)

1. Only the indirect system described in **702. 4** (2) should be used.

2. For a ship engaged in the carriage of products which readily form dangerous peroxides, recondensed cargo should not be allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:
(1) using the indirect system described in **702. 4** (2) with the condenser inside the cargo tank; or
(2) using the direct system or combined system described in **702. 4** (1) and (3) respectively, or the indirect system described in **702. 4** (2) with the condenser outside the cargo tank, and designing the condensate system to avoid any places in which liquid could collect and be retained. Where this is impossible inhibited liquid should be added upstream of such a place.

3. If the ship is to carry consecutively products as specified in **Par 2** with a ballast passage between, all uninhibited liquid should be removed prior to the ballast voyage. If a second cargo is to be carried between such consecutive cargoes, the reliquefaction system should be thoroughly drained and purged before loading the second cargo. Purging should be carried out using either inert gas or vapour from the second cargo, if compatible. Practical steps should be taken to ensure that polymers or peroxides do not accumulate in the cargo system.

1705. Deck cargo piping (IGC Code 17.5)

One hundred per cent radiography of all butt-welded joints in cargo piping exceeding 75 mm in diameter is required.

1706. Exclusion of air from vapour spaces (IGC Code 17.6)

Air should be removed from the cargo tanks and associated piping before loading and then subsequently excluded by:
(1) introducing inert gas to maintain a positive pressure. Storage or production capacity of the inert gas should be sufficient to meet normal operating requirements and relief valve leakage. The oxygen content of inert gas should at no time be greater than 0.2 % by volume; or

(2) control of cargo temperatures such that a positive pressure is maintained at all times.

1707. Moisture control (IGC Code 17.7)

For gases which are non-flammable and may become corrosive or react dangerously with water, moisture control should be provided to ensure that cargo tanks are dry before loading and that during discharge, dry air or cargo vapour is introduced to prevent negative pressures. For the purposes of this paragraph, dry air is air which has a dew point of -45°C or below at atmospheric pressure.

1708. Inhibition (IGC Code 17.8)

Care should be taken to ensure that the cargo is sufficiently inhibited to prevent polymerization at all times during the voyage. Ships should be provided with a certificate from the manufacturer stating:

(1) Name and amount of inhibitor added;
(2) date inhibitor was added and the normally expected duration of its effectiveness;
(3) any temperature limitations affecting the inhibitor;
(4) the action to be taken should be length of the voyage exceed the effective lifetime of the inhibitors.

1709. Permanently installed toxic gas detectors (IGC Code 17.9)

1. Gas sampling lines should not be led into or through gas-safe spaces. Alarms referred to in **1306. 7** should be activated when the vapour concentration reaches the threshold limiting value.

2. The alternative of using portable equipment in accordance with **1306. 9** should not be permitted.

1710. Flame screens on vent outlets (IGC Code 17.10)

Cargo tank vent outlets should be provided with readily renewable and effective flame screens or safety heads of an approved type when carrying a cargo referenced to this Article. Due attention should be paid in the design of flame screens and vent heads to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Ordinary protection screens should be fitted after removal of the flame screens.

1711. Maximum allowable quantity of cargo per tank (IGC Code 17.11)

When carrying a cargo referenced to this Article the quantity of the cargo should not exceed 3,000 m^3 in any one tank.

1712. Submerged electric cargo pumps (IGC Code 17.12)

The vapour space of cargo tanks equipped with submerged electric motor pumps should be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.

1713. Ammonia (IGC Code 17.13)

1. Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon-manganese steel or nickel steel. To minimize the risk of this occurring, measures detailed in **Pars 2** to **8** should be taken as appropriate.

2. Where carbon-manganese steel is used, cargo tanks, process pressure vessels and cargo piping should be made of fine-grained steel with a specified minimum yield strength not exceeding 355 N/mm^2 and with an actual yield strength not exceeding 440 N/mm^2. One of the following constructional or operational measures should also be taken:

(1) lower strength material with a specified minimum tensile strength not exceeding 410 N/mm^2 should be used; or
(2) cargo tanks, etc., should be post-weld stress relief heat treated; or
(3) carriage temperature should be maintained preferably at a temperature close to the product's boiling point of -33°C but in no case at a temperature above -20°C; or

(4) the ammonia should contain not less than 0.1 % w/w water.

3. If carbon-manganese steels with higher yield properties are used other than those specified in **Par 2,** the completed cargo tanks, piping, etc., should be given a post-weld stress relief heat treatment.

4. Process pressure vessels and piping of the condensate part of the refrigeration system should be given a post-weld stress relief heat treatment when made of materials mentioned in **Par 1.**

5. The tensile and yield properties of the welding consumables should exceed those of the tank or piping material by the smallest practical amount.

6. Nickel steel containing more than 5 % nickel and carbon-manganese steel not complying with the requirements of **Pars 2** and **3** are particularly susceptible to ammonia stress corrosion cracking and should not be used for containment and piping systems for the carriage of this product.

7. Nickel steel containing not more than 5 % nickel may be used provided the carriage temperature complies with the requirements specified in **2** (3).

8. In order to minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2.5 ppm w/w. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature T in the table below:

T (°C)	O_2 (%, v/v)
-30 and below	0.90
-20	0.50
-10	0.28
0	0.16
10	0.10
20	0.05
30	0.03

Oxygen percentages for intermediate temperatures may be obtained by direct interpolation.

1714. Chlorine (IGC Code 17.14)

1. Cargo containment system

(1) The capacity of each tank should not exceed 600 m^3 and the total capacity of all cargo tanks should not exceed 1,200 m^3.
(2) The tank design vapour pressure should not be less than 1.35 MPa (see also **701. 3** and **1703. 2**).
(3) Parts of tanks protruding above the upper deck should be provided with protection against thermal radiation taking into account total engulfment by fire.
(4) Each tank should be provided with two pressure relief valves. A bursting disc of appropriate material should be installed between the tank and the pressure relief valves. The rupture pressure of the bursting disc should be 0.1 MPa lower than the opening pressure of the pressure relief valve, which should be set at the design vapour pressure of the tank but not less than 1.35 MPa gauge. The space between the bursting disc and the relief valve should be connected through an excess flow valve to a pressure gauge and a gas detection system. Provision should be made to keep this space at or near the atmospheric pressure during normal operation.
(5) Outlets from pressure relief valves should be arranged in such a way as to minimize the hazards on board the ship as well as to the environment. Leakage from the relief valves should be led through the absorption plant to reduce the gas concentration as far as possible. The relief valve exhaust line should be arranged at the forward end of the ship to discharge outboard at deck level with an arrangement to select either port or starboard side, with a mechanical interlock to ensure that one line is always open.
(6) The Society and the port Administration may require that chlorine is carried in refrigerated state at a specified maximum pressure.

2. Cargo piping systems

(1) Cargo discharge should be performed by means of compressed chlorine vapour from shore, dry air or another acceptable gas or fully submerged pumps. The pressure in the vapour space of the tank during discharging should not exceed 1.05 MPa gauge. Cargo discharge compressors on board ships should not be accepted by the Society.
(2) The design pressure of the cargo piping system should be not less than 2.1 MPa gauge. The internal diameter of the cargo pipes should not exceed 100 mm. Only pipe bends should be accepted for compensation of pipeline thermal movement. The use of flanged joints should be restricted to a minimum, and when used the flanges should be of the welding neck type with tongue and groove.
(3) Relief valves of the cargo piping system should discharge to the absorption plant (see also **802. 16**).

3. Materials

(1) The cargo tanks and cargo piping systems should be made of steel suitable for the cargo and for a temperature of -40°C, even if a higher transport temperature is intended to be used.
(2) The tanks should be thermally stress-relieved. Mechanical stress relief should not be accepted as an equivalent.

4. Instrumentation-safety devices

(1) The ship should be provided with a chlorine absorbing plant with connections to the cargo piping system and the cargo tanks. The absorbing plant should be capable of neutralizing at least 2 % of the total cargo capacity at a reasonable absorption rate.
(2) During the gas-freeing of cargo tanks, vapours should not be discharged to the atmosphere.
(3) A gas detecting system should be provided capable of monitoring chlorine concentrations of at least 1 ppm by volume. Suction points should be located:
(a) near the bottom of the hold spaces;
(b) in the pipes from the safety relief valves;
(c) at the outlet from the gas absorbing plant;
(d) at the inlet to the ventilation systems for the accommodation, service and machinery spaces and control stations;
(e) on deck at the forward end, in the middle and at the after end of the cargo area. (Only required to be used during cargo handling and gas-freeing operations).
The gas detection system should be provided with an audible and visual alarm with a set point of 5 ppm.
(4) Each cargo tank should be fitted with a high pressure alarm giving an audible alarm at a pressure equal to 1.05 MPa gauge.

5. Personnel protection

In addition to the requirements given in **Sec 14** the following requirements should be met:

(1) The enclosed space required by **1404. 5** should be easily and quickly accessible from the open deck and from accommodation spaces and should be capable of being rapidly closed gastight. Access to this space from the deck and from the accommodation spaces should be by means of an air lock. The space should be so designed as to accommodate the entire crew of the ship and be provided with a source of uncontaminated air for a period of not less than 4 h. One of the decontamination showers required by **1404. 3** should be located near the air lock to the space.
(2) A compressor and the necessary equipment for filling the air bottles should be provided.
(3) One set of oxygen therapy equipment should be carried in the space referred to in (1).

6. Filling limits for cargo tanks

(1) The requirements of **1501. 4** (2) do not apply when it is intended to carry chlorine.
(2) The chlorine content of the gas in the vapour space of the cargo tank after loading should be greater than 80 % by volume.

1715. Diethyl ether and vinyl ethyl ether (IGC Code 17.15)

1. The cargo should be discharge only by deepwell pumps or by hydraulically operated submerged pumps. These pumps should be of a type designed to avoid liquid pressure against the shaft gland.

2. Inert gas displacement may be used for discharging cargo from type C independent tanks provided the cargo system is designed for the expected pressure.

1716. Ethylene oxide (IGC Code 17.16)

1. For the carriage of ethylene oxide the requirements of **1720.** apply, with the additions and modifications as given in this Article.

2. Deck tanks should not be used for the carriage of ethylene oxide.

3. Stainless steels types 416 and 442 as well as cast iron should not be used in ethylene oxide cargo containment and piping systems.

4. Before loading, tanks should be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been ethylene oxide, propylene oxide or mixtures of these products. Particular care should be taken in the case of ammonia in tanks made of steel other than stainless steel.

5. Ethylene oxide should be discharged only by deepwell pumps or inert gas displacement. The arrangement of pumps should comply with **1720. 5** (3).

6. Ethylene oxide should be carried refrigerated only and maintained at temperatures of less than 30°C.

7. Pressure relief valves should be set at a pressure of not less than 0.55 MPa gauge. The maximum set pressure should be specially approved by the Society.

8. The protective padding of nitrogen gas as required by **1720. 15** should be such that the nitrogen concentration in the vapour space of the cargo tank will at no time be less than 45 % by volume.

9. Before loading and at all times when the cargo tank contains ethylene oxide liquid or vapour, the cargo tank should be inerted with nitrogen.

10. The water spray system required by **1720. 17** and that required by **1103.** should operate automatically in a fire involving the cargo containment system.

11. A jettisoning arrangement should be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.

1717. Isopropylamine and monoethylamine (IGC Code 17.17)

Separate piping systems should be provided as defined in **106. 32.**

1718. Methyl acetylene-propadiene mixtures (IGC Code 17.18)

1. Methyl acetylene-propadiene mixtures should be suitable stabilized for transport. Additionally, upper limits of temperature and pressure during the refrigeration should be specified for the mixtures.

2. Examples of acceptable, stabilized compositions are:

(1) Composition 1
- (a) maximum methyl acetylene to propadiene molar ratio of **3** to **1**;
- (b) maximum combined concentration of methyl acetylene and propadiene of 65 mol per cent,
- (c) minimum combined concentration of propane, butane, and isobutane of 24 mol per cent, of which at least one third (on a molar basis) must be butanes and one third propane; and
- (d) maximum combined concentration of propylene and butadiene of 10 mol per cent.

(2) Composition 2
- (a) maximum methyl acetylene and propadiene combined concentration of 30 mol per cent;
- (b) maximum methyl acetylene concentration of 20 mol per cent;
- (c) maximum propadiene concentration of 20 mol per cent;
- (d) maximum propylene concentration of 45 mol per cent;
- (e) maximum butadiene and butylenes combined concentration of **2** mol per cent;
- (f) minimum saturated C_4 hydrocarbon concentration of **4** mol per cent; and
- (g) minimum propane concentration of 25 mol per cent.

3. Other compositions may be accepted provided the stability of the mixture is demonstrated to the satisfaction of the Society.

4. A ship carrying methyl acetylene-propadiene mixtures should preferably have an indirect refrigeration system as specified in **702. 4** (2). Alternatively, a ship not provided with indirect refrigeration may utilize direct vapour compression refrigeration subject to pressure and temperature limitations depending on the composition. For the example compositions given in **Par 2,** the following features should be provided:

(1) A vapour compressor that does not raise the temperature and pressure of the vapour above 60°C and 1.75 MPa gauge during its operation, and that does not allow vapour to stagnate in the compressor while it continues to run.
(2) Discharge piping from each compressor stage or each cylinder in the same stage of a reciprocating compressor should have:
(a) two temperature-actuated shutdown switches set to operate at 60°C or less;
(b) a pressure-actuated shutdown switch set to operate at 1.75 MPa gauge or less; and
(c) a safety relief valve set to relieve at 1.8 MPa gauge or less.
(3) The relief valve required by **Par 4** (2) (c) should vent to a mast meeting the requirements of **802. 9, 10, 13** and **14** and should not relieve into the compressor suction line.
(4) An alarm that sounds in the cargo control position and in the navigating bridge when a high pressure switch, or a high-temperature switch operates.

5. The piping system, including the cargo refrigeration system, for tanks to be loaded with methyl acetylene-propadiene mixtures should be either independent (as defined in **106. 20**) or separate (as defined in **106. 32**) from piping and refrigeration systems for other tanks. This segregation applies to all liquid and vapour vent lines and any other possible connections, such as common inert gas supply lines.

1719. Nitrogen (IGC Code 17.19)

Materials of construction and ancillary equipment such as insulation should be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system. Due consideration should be given to ventilation in such areas where condensation might occur to avoid the stratification of oxygen-enriched atmosphere.

1720. Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide content of not more than 30% by weight (IGC Code 17.20)

1. Products transported under the provisions of this Article should be acetylene-free.

2. (1) Unless cargo tanks are properly cleaned, these products should not be carried in tanks which have contained as one of the three previous cargoes any product known to catalyse polymerization, such as:
(a) anhydrous ammonia and ammonia solutions;
(b) amines and amine solutions;
(c) oxidizing substances (e.g. chlorine).
(2) Before loading, tanks should be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been propylene oxide or ethylene oxide-propylene oxide mixtures. Particular care should be taken in the case of ammonia in tanks made of steel other than stainless steel.
(3) In all cases, the effectiveness of cleaning procedures for tanks and associated pipework should be checked by suitable testing or inspection to ascertain that no traces of acidic or alkaline materials remain that might create a hazardous situation in the presence of these products.
(4) Tanks should be entered and inspected prior to each initial loading of these products to ensure freedom from contamination, heavy rust deposits and any visible structural defects. When cargo tanks are in continuous service for these products, such inspections should be performed at intervals of not more than 2 years.
(5) Tanks for the carriage of these products should be of steel or strainless steel construction.
(6) Tanks which have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

3. (1) All valves, flanges, fittings and accessory equipment should be of a type suitable for use with these products and should be constructed of steel or stainless steel in accordance with recognized standards. Discs or disc faces, seats and other wearing parts of valves should be made of stainless steel containing not less than 11 % chromium.

(2) Gaskets should be constructed of materials which do not react with, dissolve in, or lower the autoignition temperature of these products and which are fire-resistant and possess adequate mechanical behaviour. The surface presented to the cargo should be polytetrafluorethylene (PTFE) or materials giving a similar degree of safety by their inertness. Spirally-wound stainless steel with a filler of PTFE or similar fluorinated polymer may be accepted by the Society.

(3) Insulation and packing if used should be of a material which does not react with, dissolve in, or lower the autoignition temperature of these products.

(4) The following materials are generally found unsatisfactory for gaskets, packing and similar uses in containment systems for these products and would require testing before being approved by the Society.

(a) Neoprene or natural rubber if it comes into contact with the products;

(b) Asbestos or binders used with asbestos;

(c) Materials containing oxides of magnesium, such as mineral wools.

4. Filling and discharge piping should extend to within 100 mm of the bottom of the tank or any sump.

5. (1) The products should be loaded and discharge in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product should be independent of all other containment systems.

(2) During discharging operations, the pressure in the cargo tank should be maintained above 0.07 MPa gauge.

(3) The cargo should be discharged only by deepwell pumps, hydraulically operated submerged pumps, or inert gas displacement. Each cargo pump should be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.

6. Tanks carrying these products should be vented independently of tanks carrying other products. Facilities should be provided for sampling the tank contents without opening the tank to atmosphere.

7. Cargo hoses used for transfer of these products should be marked "FOR ALKYLENE OXIDE TRANSFER ONLY".

8. Hold spaces should be monitored for these products. Hold spaces surrounding type A and B independent tanks should also be inerted and monitored for oxygen. The oxygen content of these spaces should be maintained below 2 %. Portable sampling equipment is satisfactory.

9. Prior to disconnecting shore-lines, the pressure in liquid and vapour lines should be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines should not be discharged to atmosphere.

10. Tanks should be designed for the maximum pressure expected to be encountered during loading, carriage or unloading of cargo.

11. Tanks for the carriage of propylene oxide with a design vapour pressure of less than 0.06 MPa and tanks for the carriage of ethylene oxide-propylene oxide mixtures with a design vapour pressure of less than 0.12 MPa should have a cooling system to maintain the cargo below the reference temperature. For reference temperature see **1501. 4** (1).

12. Pressure relief valve settings should not be less than 0.02 MPa gauge and for type C independent cargo tanks not greater than 0.7 MPa gauge for the carriage of propylene oxide and not greater than 0.53 MPa gauge for the carriage of ethylene oxide-propylene oxide mixtures.

13. (1) The piping system for tanks to be loaded with these products should be completely separate from piping systems for all other tanks, including empty tanks, and from all cargo compressors. If the piping system for the tanks to be loaded with these products is not independent as defined in **106. 20** the required piping separation should be accomplished by the removal of spool pieces, valves, or other pipe sections and the installation of blank flanges at these locations. The required separation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connections such as common inert gas supply lines.

(2) The products should be transported only in accordance with cargo handling plans that have been approved by the Society. Each intended loading arrangement should be shown on a separate cargo handling plan. Cargo handling plans should show the entire cargo piping system and the locations for installation of blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan should be kept on board the ship. The International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk should be endorsed to include reference to the approved cargo handling plans.

(3) Before each initial loading of these products and before every subsequent return to such services, certification verifying that the required piping separation has been achieved should be obtained from a responsible person acceptable to the port Administration and carried on board the ship. Each connection between a blank flange and pipeline flange should be fitted with a wire and seal by the responsible person to ensure that inadvertent removal of the blank flange is impossible.

14. The maximum allowable tank loading limits for each cargo tank should be indicated for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Society. A copy of the list should be permanently kept on board by the master.

15. The cargo should be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system should be installed to prevent the tank pressure falling below 0.007 MPa gauge in the event of product temperature fall due to ambient conditions or malfunctioning of refrigeration system. Sufficient nitrogen should be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99.9 % by valume) should be used for padding. A battery of nitrogen bottles connected to the cargo tanks through a pressure reduction valve satisfies the intention of the expression "automatic" in this context.

16. The cargo tank vapour space should be tested prior to and after loading to ensure that the oxygen content is 2 % by volume or less.

17. A water spray system of sufficient capacity should be provided to blanket effectively the area surrounding the loading manifold, the exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles should be such as to give a uniform distribution rate of 10 l/m^2 per minute. The water spray system should be capable of both local and remote manual operation and the arrangement should ensure that any spilled cargo is washed away. Remote manual operation should be arranged such that remote starting of pumps supplying water spray system and remote operation of any normally closed valves in the system can be carried out from a suitable location outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected. Additionally, a water hose with pressure to the nozzle, when ambient temperatures permit, should be connected ready for immediate use during loading and unloading operation.

1721. Vinyl chloride (IGC Code 17.21)

In cases where polymerization of vinyl chloride is prevented by addition of an inhibitor, **1708.** is applicable. In cases where no or insufficient inhibitor has been added, any inert gas used for the purposes of **1706.** should contain not more oxygen than 0.1 %. Before loading is started, inert gas samples from the tanks and piping should be analysed. When vinyl chloride is carried, a positive pressure should always be maintained in the tanks, also during ballast voyages between successive carriages.

Section 18 Operating Requirements

1801. Cargo information (IGC Code 18.1)

1. Information should be on board and available to all concerned, giving the necessary data for the safe carriage of cargo. Such information should include for each product carried:

(1) a full description of the physical and chemical properties necessary for the safe containment of the cargo;
(2) action to be taken in the event of spills or leaks;
(3) counter-measures against accidental personal contact;
(4) fire-fighting procedures and fire-fighting media;
(5) procedures for cargo transfer, gas-freeing, ballasting, tank cleaning and changing cargoes;
(6) special equipment needed for the safe handling of the particular cargo;
(7) minimum allowable inner hull steel temperatures; and
(8) emergency procedures.

2. Products required to be inhibited should be refused if the certificate required by **1708.** is not supplied.

3. A copy of this Chapter or national regulations incorporating the provisions of this Chapter should be on board every ship covered by this Chapter.

1802. Compatibility (IGC Code 18.2)

1. The master should ascertain that the quantity and characteristics of each product to be loaded are within the limits indicated in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and in the Loading and Stability Information booklet provided for in **202. 5** and that products are listed in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk as required under **Sec 3** of the Certificate.

2. Care should be taken to avoid dangerous chemical reactions if cargoes are mixed. This is of particular significance in respect of:

(1) tank cleaning procedures required between successive cargoes in the same tank; and
(2) simultaneous carriage of cargoes which react when mixed. This should be permitted only if the complete cargo systems including, but not limited to, cargo pipework, tanks, vent systems and refrigeration systems are separated as defined in **106. 32.**

1803. Personnel training (IGC Code 18.3)

1. Personnel involved in cargo operations should be adequately trained in handling procedures.

2. All personnel should be adequately trained in the use of protective equipment provided on board and have basic training in the procedures, appropriate to their duties, necessary under emergency conditions.

3. Officers should be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo, and a sufficient number of them should be instructed and trained in essential first aid for cargoes carried.

1804. Entry into spaces (IGC Code 18.4)

1. Personnel should not enter cargo tanks, hold spaces, void spaces, cargo handling spaces or other enclosed spaces where gas may accumulate, unless:

(1) the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and the absence of toxic atmosphere; or
(2) personnel wear breathing apparatus and other necessary protective equipment and the entire operation is under the close supervision of a responsible officer.

2. Personnel entering any space designated as gas dangerous on a ship carrying flammable products should not introduce any potential source of ignition into the space unless it has been certified gas-free and is maintained in that condition.

3. (1) For internal insulation tanks, special fire precautions should be taken in the event of hot work carried out in the vicinity of the tanks. For this purpose, gas absorbing and deabsorbing characteristics of the insulation material should be taken into account.

(2) For internal insulation tanks, repairs should be carried out in accordance with the procedures provided for in **404. 7** (6).

1805. Carriage of cargo at low temperature (IGC Code 18.5)

1. When carrying cargoes at low temperatures:

(1) if provided, the heating arrangements associated with cargo containment systems should be operated in such a manner as to ensure that the temperature does not fall below that for which the materials of the hull structure is designed;
(2) loading should be carried out in such a manner as to ensure that unsatisfactory temperature gradients do not occur in any cargo tank, piping, or other ancillary equipment; and
(3) when cooling down tanks from temperatures at or near ambient, the cool-down procedure laid down for that particular tank, piping and ancillary equipment should be followed closely.

1806. Protective equipment (IGC Code 18.6)

Personnel should be made aware of the hazards associated with the cargo being handled and should be instructed to act with care and use the appropriate protective equipment as mentioned in **1401.** during cargo handling.

1807. Systems and controls (IGC Code 18.7)

Cargo emergency shutdown and alarm systems involved in cargo transfer should be tested and checked before cargo handling operations begin. Essential cargo handling controls should also be tested and checked prior to transfer operations.

1808. Cargo transfer operations (IGC Code 18.8)

1. Transfer operations including emergency procedures should be discussed between ship personnel and the persons responsible at the shore facility prior to commencement and communications maintained throughout the transfer operations.

2. The closing time of the valve referred to in **1303.1** (i.e. time from shutdown signal initiation to complete valve closure) should not be greater than:

$$\frac{3{,}600\,U}{LR} \quad \text{(sec)}$$

where:

U = ullage volume at operating signal level (m^3)

LR = maximum loading rate agreed between ship and shore facility (m^3/h).

The loading rate should be adjusted to limit surge pressure on valve closure to an acceptable level taking into account the loading hose or arm, the ship and the shore piping systems where relevent.

1809. Additional operating requirements (IGC Code 18.9)

Additional operating requirements will be found in the following paragraphs of this Chapter: **308. 4, 308.5, 701.1** (5), **802. 5, 802. 7, 904. 2, 1201.1, 1201.10, 1301.4, 1402. 5, 1402.6, 1403.1, 1501., 1502., 1602. 2, 1704. 2, 1706., 1707., 1712., 1713., 1714., 1715., 1716., 1717., 1718., 1720.**

Section 19 Summary of Minimum Requirements

EXPLANATORY NOTES

UN Number (column b)

The UN numbers as listed in the table of **Sec 19** are intended for information only.

Vapour detection required (column f)

F - Flammable vapour detection
T - Toxic vapour detection
O - Oxygen analyser
F+T- Flammable and toxic vapour detection

Gauging-types permitted (column g)

I - Indirect, or closed, as described in **1302. 2** (1) and (2)
C - Indirect, or closed, as described in **1302. 2** (1), (2) and (3)
R - Indirect, closed or restricted, as described in **1302. 2** (1), (2), (3) and (4).

Refrigerant gases

Non-toxic and non-flammable gases such as:
dichlorodifIuoromethane (1028)
dichloromonofluoromethane (1029)
dichlorotetrafIuoroethane (1958)
monochlorodifIuoromethane (1018)
monochlorotetrafluoroethane (1021)
monochlorotrifluoromethane (1022)

Unless otherwise specified, gas mixtures containing less than 5 % total acetylenes may be transported with no further requirements than those provided for the major components.

MFAG table No. (column h)

MFAG numbers are provided for information on the emergency procedures to be applied in the event of an incident with the products covered by the IGC Code. Where any of the products listed are carried at low temperature from which frostbite may occur MFAG No. 620 is also applicable.

a	b	c	d	e	f	g	h	i
Product name	UN number	Ship type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging	MFAG table No.	Special requirements
Acetaldehyde	1089	2 G/2 PG	-	Inert	F+T	C	300	**1404.3, 1404.4, 1704.1, 1706.1**
Ammonia, anhydrous	1005	2 G/2 PG	-	-	T	C	725	**1404.2, 1404.3, 1404.4, 1702.1, 1713.**
Butadiene	1010	2 G/2 PG	-	-	F+T	R	310	**1702.2, 1704.2, 1704.3, 1706., 1708.**
Butane	1011	2 G/2 PG	-	-	F	R	310	
Butane-propane mixtures	1011/ 1978	2 G/2 PG	-	-	F	R	310	
Butylenes	1012	2 G/2 PG	-	-	F	R	310	
Carbon dioxide	-	3 G	Yes	-	-	C	-	
Chlorine	1017	1 G	Yes	Dry	T	I	740	**1404., 1703.2, 1704.1, 1705., 1707., 1709., 1714.**
Diethyl ether*	1155	2G/2PG	-	Inert	F+T	C	330	**1404.2, 1404.3, 1702.6, 1703.1, 1706.1, 1710., 1711., 1715.**
Dimethylamine	1032	2 G/2 PG	-	-	F+T	C	320	**1404.2, 1404.3, 1404.4, 1702.1**
Dimethyl ether	-	2 G/2 PG	-	-	F+T	C	-	
Ethane	1961	2 G	-	-	F	R	310	
Ethyl chloride	1037	2 G/2 PG	-	-	F+T	R	340	
Ethylene	1038	2 G	-	-	F	R	310	
Ethylene oxide	1040	1 G	Yes	Inert	F+T	C	365	**1404.2, 1404.3, 1404.4, 1404.6, 1702.2, 1703.2, 1704.1, 1705., 1706.1, 1716.**
Ethyene oxide-propylene oxide mixtures with ethylene oxide content of not more than 30% by weight*	2983	2 G/2 PG	-	Inert	F+T	C	365	**1404.3, 1703.1, 1704.1, 1706.1, 1710., 1711., 1720.**
Isoprene*	1218	2 G/2 PG	-	-	F	R	310	**1404.3, 1708., 1710., 1712.**
Isopropylamine*	1221	2 G/2 PG	-	-	F+T	C	320	**1404.2, 1404.3, 1702.4, 1710., 1711., 1712., 1717.**

a	b	c	d	e	f	g	h	i
Product name	UN number	Ship type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging	MFAG table No.	Special requirements
Methane (LNG)	1972	2 G	-	-	F	C	620	
Methyl acetylene-propadiene mixtures	1060	2 G/2 PG	-	-	F	R	310	**1718.**
Methyl bromide	1062	1 G	Yes	-	F+T	C	345	**1404., 1702.3, 1703.2, 1704.1, 1705., 1709.**
Methyl chloride	1063	2 G/2 PG	-	-	F+T	C	340	**1702.3**
Monoethylamine*	1036	2 G/2 PG	-	-	F+T	C	320	**1404.2, 1404.3, 1404.4, 1702.1, 1703.1, 1710., 1711., 1712., 1717.**
Nitrogen	2040	3 G	-	-	O	C	620	**1719.**
Pentanes (all isomers)*	1265	2 G/2 PG	-	-	F	R	310	**1404.4, 1710., 1712.**
Pentene (all isomers)*	1265	2 G/2 PG	-	-	F	R	310	**1404.4, 1710., 1712.**
Propane	1978	2 G/2 PG	-	-	F	R	310	
Propylene	1077	2 G/2 PG	-	-	F	R	310	
Propylene oxide*	1280	2 G/2 PG	-	Inert	F+T	C	365	**1404.3, 1703.1, 1704.1, 1706.1, 1710., 1711., 1720.**
Refrigerant gases (see notes)	-	3 G	-	-	-	R	350	
Sulphur dioxide	1079	1 G	Yes	Dry	T	C	635	**1404., 1703.2, 1704.1, 1705., 1707., 1709.**
Vinyl chloride	1086	2 G/2 PG	-	-	F+T	C	340	**1404.2, 1404.3, 1702.2, 1702.3, 1703.1, 1706., 1721.**
Vinyl ethyl ether*	1302	2 G/2 PG	-	Inert	F+T	C	330	**1404.2, 1404.3, 1702.2, 1703.1, 1706.1, 1708., 1710., 1711., 1715.**
Vinylidene chloride*	1303	2 G/2 PG	-	Inert	F+T	R	340	**1404.2, 1404.3, 1702.5, 1706.1, 1708., 1710., 1711.**

* This cargo is covered also by the IBC Code.

CHAPTER 6 SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

Section 1 General

101. Application (IBC Code 1.1)

1. The requirements in this Chapter apply to ships constructed on or after 1 July 1986, unless expressly provided otherwise. The requirements are also to comply with the requirements of IMO Res. MSC. 4 (48), MSC. 176 (79) and its additional amendments. Ships constructed before 1 July 1986 are to comply with the requirements of IMO Res. A.212 (VII), MEPC. 144 (54) and its additional amendments.

2. The requirements in this Chapter apply to ships, including those of less than 500 gross tonnage, engaged in the carriage of bulk cargoes of dangerous chemicals or noxious liquid substances, other than petroleum or similar flammable products as follows:

(1) Products having significant fire hazards in excess of those of petroleum products and similar flammable products.
(2) Products having significant hazards in addition to or other than flammability.

3. Products that have been reviewed and determined not to present safety and pollution hazards to such an extent as to warrant the application of the Rules are found in **Sec 18.**

4. Liquids covered of this Chapter are those having a vapour pressure not exceeding 0.28 MPa absolute at a temperature of 37.8 ℃.

5. For the purpose of MARPOL 73/78, the requirements applies only to NLS tanker defined thereof, which are engaged in the carriage of Noxious Liquid Substances identified as such by an entry of X, Y or Z in column c of Sec 17.

6. For a product for carriage in bulk, but not listed in **Secs 17** or **18,** the Administration shall prescribe the preliminary suitable conditions for the carriage, having regard to the criteria for hazard evaluation of bulk chemicals. For the evaluation of the pollution hazard of such a product and assignment of its pollution category, the procedure specified in regulation 6.3 of Annex II of MARPOL 73/78 is to be followed.

7. The ship's hull, machinery and equipment not specified in this Chapter are generally to comply with the requirements in the relevant Chapters of these Rules.

8. The ships carrying flammable dangerous chemicals in bulk are also to be in compliance with the requirements in **Pt 7, Ch 1** and **Pt 8** unless otherwise required in this Chapter.

9. For ships to be classed for restricted service and ships not provided with propulsive machinery, the requirements may be modified as appropriate.

10. When it is intended to carry products covered by this Chapter and products covered by **Ch 5,** the ship shall comply with the requirements of both Chapters appropriate to the products carried, However, when a ship is designed and constructed for the carriage of the products listed exclusively in **Sec 17**, the requirements of this Chapter should take precedence.

102. Approval for plans

For classification survey during construction, the following plans and informations as may be necessary depending upon the products intended to be loaded, condition of cargo storage, construction of cargo containment system and other design conditions are to be submitted in triplicate before the work is commenced.

1. Plans and data for approval

(1) Manufacturing specifications for independent cargo tanks (including materials to be used, welding procedures and inspection and testing procedures for weld and cargo tanks).
(2) Details of cargo tank construction.
(3) Arrangements of cargo tank accessories (including details of fittings inside the tanks).
(4) Details of independent cargo tank supports, deck portions through which cargo tanks penetrate

and their sealing devices when provided.
(5) Plans showing arrangement and the methods of attachment of the insulation together with the working procedure concerned.
(6) When the cargoes are required to be cooled, the plans and informations in accordance with **Ch 5, 102. 1** (1), (6), (7), (8) and (16) are to be submitted depending upon the cargo storage plan and the type of cargo tank construction.
(7) Cargo pump construction plan including list of materials to be used and their specifications.
(8) Piping arrangement in cargo tank area.
(9) Cargo tank ventilation arrangement.
(10) Ventilation plan of cargo pump rooms, cofferdams, double bottoms and others.
(11) Diagram of monitoring and measurement system for cargo level, cargo temperature and others and the detail construction of their equipment.
(12) Control system for cargo temperature.
(13) Details of environmental control system such as inerting, padding, drying or ventilation including the piping diagram and the construction of their equipment.
(14) Instruments for cargo vapour detection.
(15) Electrical wiring plans and a table of electrical equipment used in dangerous spaces.
(16) Arrangement of earth connections for cargo tanks, pipe lines, machinery and equipment, only when flammable cargoes are intended to be loaded.
(17) Plans showing dangerous spaces.
(18) Fire extinguishing system.

2. Plans and data for reference

(1) Lists showing chemical and physical properties and other special properties of the all cargoes intended to be loaded. Loading plans of the dangerous chemicals coming within the scope of this Chapter and other chemicals to be loaded simultaneously with these dangerous chemicals.
(2) Guide of reactivity hazard defined by reactivity with other chemicals, water or the chemical itself including polymerization and, where deemed necessary, with the heating or cooling media. The chemicals not intended to be loaded simultaneously with the dangerous chemicals coming within the scope of this Chapter may be excluded from these guides.
(3) Data of reactivity hazard between intended cargoes and coating or lining in cargo tanks and of piping and equipment that may come into contact with cargo liquid or vapour.
(4) Data of suitability of corrosion-resistance materials for the cargoes having corrosive properties.
(5) Strength calculation of each cargo tanks and, where deemed necessary, thermal stress calculation.
(6) Capacity calculation of heating system as required cargoes to be heated.
(7) Plans and documents in accordance with **Ch 5, 102. 2** (1), (6), (8) and (10) depending upon the cargo storage plan and the type of cargo tank construction when the cargoes require to be cooled.
(8) Arrangements of access manholes stipulated in 304. in cargo tank area and the guide for access through these manholes.
(9) Operation manual stipulated in **Sec 16.**
(10) Calculation for ship survival capability stipulated in **Sec 2.**
(11) Equipment for personnel protection.

103. Equivalents

The construction, equipment, etc., which do not fall under the provisions of this Chapter but is considered to be equivalent to those required in this Chapter will be accepted by the Society.

104. National regulations

For the construction and equipment of the ship, attention is to be paid to the requirements of national regulations of the country in which the ship is registered and/or of the port which the ship intends to visit.

105. Hazards (IBC Code 1.2)

Hazards of products covered by this Chapter include as follows :

1. Fire hazard, defined by flashpoint, explosive/flammability limits/range and autoignition temperature of the chemical.

2. Health hazard, defined by:

(1) corrosive effects on the skin in the liquid state ; or
(2) acute toxic effect, taking into account values of :
LD_{50} (oral): a dose which is lethal to 50 % of the test subjects when administered orally;
LD_{50} (skin): a dose which is lethal to 50 % of the test subjects when administered to the skin;
LC_{50} (inhalation): the concentration which is lethal by inhalation to 50 % of the test subjects; or
(3) Other health effects such as carcinogenicity and sensitization.

3. Reactivity hazard, defined by reactivity:

(1) with water ;
(2) with air;
(3) with other products; or
(4) of the product itself (e.g. polymerization)

4. Marine pollution hazard, as defined :

(1) bioaccumulation ;
(2) lack of ready biodegradibility ;
(3) acute toxicity to aquatic organisms ;
(4) chronic toxity to acquatic organisms ;
(5) long term human health effect; and
(6) physical properties resulting in the product floating or sinking and so adversely affecting marine life.

106. Definitions (IBC Code 1.3)

The definitions of terms are to be as specified in the following and **Sec 4,** unless otherwise specified elsewhere.

1. "**Accommodation spaces**" are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, barber shops, pantries containing no cooking appliances and similar spaces. "**Public spaces**" are those portions of the accommodation spaces which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

2. "**Administration**" means the Government of the State whose flag the ship is entitled to fly.

3. "**Anniversary date**" means the day and the month of each year, which will correspond to the date of expiry of the International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk.

4. "**Boiling point**" is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure.

5. "**Breadth (B)**" means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material. The breadth (B) should be measured in metres.

6. "**Cargo area**" is that part of the ship that contains cargo tanks, slop tanks, cargo pump rooms including pump rooms, cofferdams, ballast or void spaces adjacent to cargo tanks or slop tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above-mentioned spaces. Where independent tanks are installed in hold spaces, cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forward hold space are excluded from the cargo area.

7. "**Cargo pump room**" is a space containing pumps and their accessories for the handling of products covered by this Chapter.

8. "**Cargo service spaces**" are spaces within the cargo area used for workshops, lockers and store-rooms of more than 2 m^2 in area, used for cargo handling equipment.

9. "**Cargo tank**" is the envelope designed to contain the cargo.

10. "**Chemical tanker**" is a cargo ship constructed or adapted and used for the carriage in bulk of any liquid product listed in **Sec 17.**

11. "**Cofferdam**" is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

12. "**Control stations**" are those spaces in which ship's radio or main navigating equipment or the emergency source of power is located or where the fire-recording or fire-control equipment is centralized. This does not include special fire control equipment which can be most practically located in the cargo area.

13. "**Dangerous chemicals**" means any liquid chemicals designated as presenting a safety hazard, based on the safety criteria for assigning products to chapter 17.

14. "**Density**" is the ratio of the mass to the volume of a product, expressed in terms of kilograms per cubic meter. This applies to liquid, gases and vapours.

15 "**Explosive/flammability limits/range**" are the conditions defining the state of fuel-oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

16. "**Flash point**" is the temperature in degrees Celsius at which a product will give off enough flammable vapour to be ignited. Values given in this Chapter are "closed cup test" determined by an approved flash point apparatus.

17. "**Hold space**" is the space enclosed by the ship's structure in which an independent cargo tank is situated.

18. "**Independent**" means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems.

19. "**Length (L)**" means 96 % of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or the length from the forside of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel, the waterline on which this length is measured should be parallel to the designed waterline. The length (L) should be measured in metres.

20. "**Machinery spaces of category A**" are those spaces and trunks to such spaces which contain:

(1) internal combustion machinery used for main propulsion; or
(2) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(3) any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

21. "**Machinery spaces**" are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.

22. "**MARPOL 73/78**" means the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, as amended.

23. "**Noxious liquid substance**" means any substance indicated in the pollution Category column of chapter 17 or 18 of the International Chemical Code, or the current MEPC.2/Circular or provisionally assessed under the provisions of regulation 6.3 of MARPOL Annex II as falling into category X, Y or Z.

24. "**Oil fuel unit**" is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil al a pressure of more than 0.18 MPa gauge.

25. "**Organization**" is the International Maritime Organization (IMO).

26. "**Permeability**" of a space means the ratio of the volume within the space which is assumed to be occupied by water to the total volume of that space.

27 "**Port Administration**" means the appropriate authority of the country in the port of which the ship is loading or unloading.

28. "**Products**" is the collective term used to cover both Noxious Liquid Substances and Dangerous Chemicals

29. "**Pump room**" is a space, located in the cargo area, containing pumps and their accessories for the handling of ballast and oil fuel.

30. "**Recognized standards**" are applicable international or national standards acceptable to the Society or standards laid down and maintained by the Society which complies with the standards adopted by the organization.

31. "**Recognized temperature**" is the temperature at which the vapour pressure of the cargo corresponds to the set pressure of the pressure-relief valve.

32. "**Separate**" means that a cargo piping system or cargo vent system, for example, is not connected to another cargo piping or cargo vent system.

33. "**Service spaces**" are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store-rooms, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

34. " **SOLAS** " means the International Convention for the Safety of Life at Sea, 1974.

35. "**Vapour pressure**" is the equilibrium pressure of the saturate vapour above the liquid expressed in bars absolute at a specified temperature.

36. "**Void space**" is an enclosed space in the cargo area external to a cargo tank, other than a hold space, ballast space, oil fuel tank, cargo pump room, pump room, or any space in normal use by personnel.

Section 2 Ship Survival Capability and Location of Cargo Tanks

201. General (IBC Code 2.1)

1. Ships subject to this Chapter should survive the normal effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship and the environment, the cargo tanks of certain types of ships should be protected from penetration in the case of minor damage to the ship resulting, for example, from contact with a jetty or tug, and given a measure of protection from damage in the case of collision or stranding, by locating them at specified minimum distances inboard from the ship's shell plating. Both the damage to be assumed and the proximity of the cargo tanks to the ship's shell should be dependent upon the degree of hazard presented by the products to be carried.

2. Ships subject to this Chapter should be designed to one of the following standards:

(1) A "**type 1 ship**" is a chemical tanker intended to transport **Sec 17** products with very severe environmental and safety hazards which require maximum preventive measures to preclude an escape of such cargo.

(2) A "**type 2 ship**" is a chemical tanker intended to transport **Sec 17** products with appreciably severe environmental and safety hazards which require significant preventive measures to preclude an escape of such cargo.

(3) A "**type 3 ship**" is a chemical tanker intended to transport **Sec 17** products with sufficiently severe environmental and safety hazards which require a moderate degree of containment to increase survival capability in a damaged condition.

Thus a type 1 ship is a chemical tanker intended for the transportation of products considered to present the greatest overall hazard and type 2 and type 3 ships for products of progressively lesser hazards. Accordingly, a type 1 ship should survive the most severe standard of damage and its cargo tanks should be located at the maximum prescribed distance inboard from the shell plating.

3. The ship type required for individual products is indicated in column "e" in the table of **Sec 17.**

4. If a ship is intended to carry more than one product listed in **Sec 17,** the standard of damage should correspond to that product having the most stringent ship type requirement. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.

202. Freeboard and intact stability (IBC Code 2.2)

1. Ships subject to this Chapter may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment should not be greater than the maximum draught otherwise permitted by this Chapter.

2. The stability of the ship in all seagoing conditions should be to a standard which is acceptable to the Society.

3. When calculating the effect of free surfaces of consumable liquids for loading conditions it should be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface and the tank or combination of tanks to be taken into account should be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments should be calculated by a method acceptable to the Society.

4. Solid ballast should not normally be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, then its disposition should be governed by the need to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

5. The master of the ship should be supplied with a Loading and Stability Information booklet. This booklet should contain details of typical service and ballast conditions, provisions for evaluating other conditions of loading and a summary of the ship's survival capabilities. In addition, the booklet should contain sufficient information to enable the master to load and operate the ship in a safe and seaworthy manner.

203. Shipside discharges below the freeboard deck (IBC Code 2.3)

1. The provision and control of valves fitted to discharges led through the shell from spaces below the freeboard deck or from with in the superstructures and deckhouses on the freeboard deck fitted with weathertight doors should comply with the requirements of the relevant regulation of the International Convention on Load Lines in force, except that the choice of valves should be limited to:

(1) one automatic non-return valve with a positive means of closing from above the freeboard deck; or

(2) where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0.01 L, two automatic non-return valves without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions.

2. For the purpose of this Section "**summer load waterline**" and "**freeboard deck**", have the meanings as defined in the International Convention on Load Lines in force.

3. The automatic non-return valves referred to in **Par 1** (1) and (2) should be of a type acceptable to the Society and should be fully effective in preventing admission of water into the ship, taking into account the sinkage, trim and heel in survival requirements in **209.** and should comply with recognized standards.

204. Conditions of loading (IBC Code 2.4)

Damage survival capability should be investigated on the basis of loading information submitted to the Society for all anticipated conditions of loading and variations in draught and trim. Ballast conditions where the chemical tanker is not carrying products covered by this Chapter, or is carrying only residues for such products, need not be considered.

205. Damage assumptions (IBC Code 2.5)

1. The assumed maximum extent of damage should be:

(1) Side damage:

(a) Longitudinal extent: 1/3 $L^{2/3}$ or 14.5 m, whichever is less

(b) Transverse extent: B/5 or 11.5 m, whichever is less, measured inboard from the ship's side at right angles to the centreline at the level of the summer load line

(c) Vertical extent: upwards without limit, from the moulded line of the bottom shell plating at centreline.

(2) Bottom damage:

	For 0.3 L from the forward perpendicular of the ship	Any other part of the ship
(a) Longitudinal extent:	1/3 $L^{2/3}$ or 14.5 m, whichever is less	1/3 $L^{2/3}$ or 5 m, whichever is less
(b) Transverse extent:	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
(c) Vertical extent:	B/15 or 2 m, whichever is less, measured from the moulded line of the bottom shell plating at centreline. (see **206. 2**)	B/15 or 2 m, whichever is less, measured from the moulded line of the bottom shell plating at centreline. (see **206. 2**)

2. Other damage:

If any damage of a lesser extent than the maximum damage specified in **Par 1** would result in a more severe condition, such damage should be considered.

206. Location of cargo tanks (IBC Code 2.6)

1. Cargo tanks should be located at the following distances inboard.

(1) Type 1 ships: from the side shell plating not less than the transverse extent of damage specified in **205. 1** (1) (b) and from the moulded line of the bottom shell plating at centreline not less than the vertical extent of damage specified in **205. 1** (2) (c) and nowhere less than 760 mm from the shell plating. This requirement does not apply to the tanks for diluted slops arising from tank washing.
(2) Type 2 ships: from the moulded line of the bottom shell plating at centreline not less than the vertical extent of damage specified in **205. 1** (2) (c) and nowhere less than 760 mm from the shell plating. This requirement does not apply to the tanks for diluted slops arising from tank washing.
(3) Type 3 ships: no requirement.

2. Except for type 1 ships, suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in **205. 1** (2) (c) provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25 % of the depth of the double bottom or 350 mm, whichever is less. Where there is no double bottom, the protrusion of the suction well of independent tanks below the upper limit of bottom damage should not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored in determining the compartments affected by damage.

207. Flooding assumptions (IBC Code 2.7)

1. The requirements of **209.** should be confirmed by calculations which take into consideration the design characteristics of the ship; the arrangements, configuration and contents of the damaged compartments; the distribution, relative densities and the free surface effects of liquids; and the draught and trim for all conditions of loading.

2. The permeabilities of spaces assumed to be damaged should be as follows:

Spaces	Permeabilities
Appropriated to stores	0.60
Occupied by accommodation	0.95
Occupied by machinery	0.85
Voids	0.95
Intended for consumable liquids	0 to 0.95
Intended for other liquids	0 to 0.95

3. Wherever damage penetrates a tank containing liquids it should be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.

4. Every watertight division within the maximum extent of damage defined in **205. 1** and considered to have sustained damage in positions given in **208. 1** should be assumed to be penetrated. Where damage less than the maximum is being considered in accordance with **205. 2,** only watertight divisions or combinations of watertight divisions within the envelope of such lesser damage should be assumed to be penetrated.

5. The ship should be so designed as to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

6. Equalization arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, should not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of **209.** and sufficient residual stability should be maintained during all stages where equalization is used. Spaces which are linked by ducts of large cross-sectional area may be considered to be common.

7. If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in **205.,** arrangements should be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

8. The buoyancy of any superstructure directly above the side damage should be disregarded. The unflooded parts of superstructures beyond the extent of damage, however, may be taken into consideration provided that:

(1) they are separated from the damaged space by watertight divisions and the requirements of **209. 3** in respect of these intact spaces are complied with; and
(2) openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in **209.;** however the immersion of any other openings capable of being closed weathertight may be permitted.

208. Standard of damage (IBC Code 2.8)

1. Ships should be capable of surviving the damage indicated in **205.** with the flooding assumptions in **207.** to the extent determined by the ship's type according to the following standards:

(1) A type 1 ship should be assumed to sustain damage anywhere in its length;
(2) A type 2 ship of more than 150 m in length should be assumed to sustain damage anywhere in its length;
(3) A type 2 ship of 150 m in length or less should be assumed to sustain damage anywhere in its length except involving either of the bulkheads bounding a machinery space located aft;
(4) A type 3 ship of more than 225 m in length should be assumed to sustain damage anywhere in its length;
(5) A type 3 ship of 125 m in length or more but not exceeding 225 m in length should be assumed to sustain damage anywhere in its length except involving either of the bulkheads bounding a machinery space located aft;
(6) A type 3 ship below 125 m in length should be assumed to sustain damage anywhere in its length except involving damage to the machinery space when located aft. However, the ability to survive the flooding of the machinery space should be considered by the Society.

2. In the case of small type 2 and type 3 ships which do not comply in all respects with the appropriate requirements of **Par 1** (3) and (6), special dispensation may only be considered by the Society provided that alternative measures can be taken which maintain the same degree of safety.

209. Survival requirements (IBC Code 2.9)

1. Ships subject to this Chapter should be capable of surviving the assumed damage specified in **205.** to the standard provided in **208.** in a condition of stable equilibrium and should satisfy the following criteria.

2. In any stage of flooding:

(1) the waterline, taking into account sinkage, heel and trim, should be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings should include air pipes and openings which are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and sidescuttles of the non-opening type;
(2) the maximum angle of heel due to unsymmetrical flooding should not exceed 25° except that this angle may be increased up to 30° if no deck immersion occurs;
(3) the residual stability during intermediate stages of flooding should be to the satisfaction of the Society. However, it should never be significantly less than that required by **Par 3.**

3. At final equilibrium after flooding:

(1) the righting lever curve should have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0.1 m within the 20° range; the area under the curve within this range should not be less than 0.0175 m · rad. Unprotected openings should not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in **Par 2** (1) and other openings capable of being closed weathertight may be permitted; and
(2) the emergency source of power should be capable of operating.

Section 3 Ship Arrangements

301. Cargo segregation (IBC Code 3.1)

1. Unless expressly provided otherwise, tanks containing cargo or residues of cargo subject to this Chapter should be segregated from accommodation, service and machinery spaces and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump room, pump room, empty tank, oil fuel tank or other similar space.

2. Cargoes, residues of cargoes or mixtures containing cargoes which react in a hazardous manner with other cargoes, residues or mixtures, should:

(1) be segregated from such other cargoes by means of a cofferdam, void space, cargo pump room, pump room, empty tank, or tank containing a mutually compatible cargo;
(2) have separate pumping and piping systems which should not pass through other cargo tanks containing such cargoes, unless encased in a tunnel; and
(3) have separate tank venting systems.

3. Cargo piping should not pass through any accommodation, service or machinery space other than cargo pump rooms or pump rooms.

4. Cargoes subject to this Chapter should not be carried in either the fore or aft peak tank.

5. If cargo piping systems or cargo ventilation systems are to be separated. This separation may be achieved by the use of design or operational methods. Operational methods shall not be used within a cargo tank and shall consist of one of the following type:

(1) removing spool-pieces or valves and blanking the pipe ends.
(2) arrangement of two spectacle flanges in series, with provisions for detecting leakage into the pipe between the two spectacle flanges.

302. Accommodation, service and machinery spaces and control stations (IBC Code 3.2)

1. No accommodation or service spaces or control stations should be located within the cargo area except over a cargo pump room recess or pump room recess that complies with SOLAS regulations II-2/4.5.1 to 4.5.2.4 and no cargo or slop tank should be aft of the forward end of any accommodation.

2. In order to guard against the danger of hazardous vapours, due consideration should be given to the location of air intakes and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping and cargo vent systems.

3. Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations should not face the cargo area. They should be located on the end bulkhead not facing the cargo area and/or on the outboard side of the superstructure or deck house at a distance of at least 4 % of the length (L) of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m. No doors should be permitted within the limits mentioned above, except that doors to those spaces not having access to accommodation and service spaces and control stations, such as cargo control stations and store-rooms may be fitted. Where such doors are fitted, the boundaries of the space should be insulated to "A-60" standard. Bolted plates for removal of machinery may be fitted within the limits specified above. Wheelhouse doors and wheel house windows may be located within the limits specified above so long as they are so designed that a rapid and efficient gas- and vapour-tightening of the wheelhouse can be ensured. Windows and sidescuttles facing the cargo area and on the sides of the super structures and deckhouses within the limits specified above should be of the fixed (non-opening) type. Such sidescuttles in the first tier on the main deck should be fitted with inside covers of steel or equivalent material.

303. Cargo pump rooms (IBC Code 3.3)

1. Cargo pump rooms should be so arranged as to ensure:

(1) unrestricted passage at all times from any ladder platform and from the floor; and
(2) unrestricted access to all valves necessary for cargo handling for a person wearing the required

personnel protective equipment.

2. Permanent arrangements should be made for hoisting an injured person with a rescue line while avoiding any projecting obstacles.

3. Guard railings should be installed on all ladders and platforms.

4. Normal access ladders should not be fitted vertical and should incorporate platforms at suitable intervals.

5. Means should be provided to deal with drainage and any possible leakage from cargo pumps and valves in cargo pump rooms. The bilge system serving the cargo pump room should be operable from outside the cargo pump room. One or more slop tanks for storage of contaminated bilge water or tank washings should be provided. A shore connection with a standard coupling or other facilities should be provided for transferring contaminated liquids to onshore reception facilities.

6. Pump discharge pressure gauges should be provided outside the cargo pump room.

7. Where machinery is driven by shafting passing through a bulkhead or deck, gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal should be fitted in way of the bulkhead or deck.

304. Access to spaces in the cargo area (IBC Code 3.4)

1. Access to cofferdams, ballast tanks, cargo tanks and other spaces in the cargo area should be direct from the open deck and such as to ensure their complete inspection. Access to double bottom spaces may be through a cargo pump room, pump room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

2. For access through horizontal openings, hatches or manholes, the dimensions should be sufficient to allow a person wearing a self-contained air breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening should be not less than 600 mm by 600 mm.

3. For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening should be not less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

4. Smaller dimensions may be approved by the Society in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

305. Bilge and ballast arrangements (IBC Code 3.5)

1. Pumps, ballast lines, vent lines and other similar equipment serving permanent ballast tanks should be independent of similar equipment serving cargo tanks and of cargo tanks themselves. Discharge arrangements for permanent ballast tanks sited immediately adjacent to cargo tanks should be outside machinery spaces and accommodation spaces. Filling arrangements may be in the machinery spaces provided that such arrangements ensure filling from tank deck level and non return valves are fitted.

2. Filling of ballast in cargo tanks may be arranged from deck level by pumps serving permanent ballast tanks, provided that the filling line has no permanent connection to cargo tanks or piping and that non-return valves are fitted.

3. Bilge pumping arrangements for cargo pump rooms, pump rooms, void spaces, slop tanks, double bottom tanks and similar spaces should be situated entirely within the cargo area except for void spaces, double bottom tanks and ballast tanks were such spaces are separated from tanks containing cargo or residues of cargo by a double bulkhead.

306. Pump and pipeline identification (IBC Code 3.6)

Provisions should be made for the distinctive marking of pumps, valves and pipelines to identify the service and tanks which they serve.

307. Bow or stern loading and unloading arrangements (IBC Code 3.7)

1. Cargo piping may be fitted to permit bow or stern loading and unloading. Portable arrangements should not be permitted.

2. Bow or stern loading and unloading lines should not be used for the transfer of products required to be carried in type 1 ships. Bow and stern loading and unloading lines should not be used for the transfer of cargoes emitting toxic vapours required to comply with **1512. 1,** unless specifically approved by the Society.

3. In addition to **501.,** the following provisions apply:

(1) The piping outside the cargo area should be fitted at least 760 mm inboard on the open deck. Such piping should be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location, it should also be capable of being separated by means of a removable spool piece and blank flanges when not in use.
(2) The shore connection should be fitted with a shutoff valve and a blank flange.
(3) The piping should be full penetration butt-welded, and fully radiographed. Flange connections in the piping should only be permitted within the cargo area and at the shore connection.
(4) Spray shields should be provided at the connections specified in (1) as well as collecting trays of sufficient capacity with means for the disposal of drainage.
(5) The piping should be self-draining to the cargo area and preferably into a cargo tank. Alternative arrangements for draining the piping may be accepted by the Society.
(6) Arrangements should be made to allow such piping to be purged after use and maintained gas-safe when not in use. The vent pipes connected with the purge should be located in the cargo area. The relevant connections to the piping should be provided with a shutoff valve and blank flange.

4. Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations should not face the cargo shore connection location of bow or stern loading and unloading arrangements. They should be located on the outboard side of the superstructure or deckhouse at a distance of at least 4 % of the length of the ship but not less than 3 m from the end of the house facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Sidescuttles facing the shore-connection location and on the sides of the superstructure or deckhouse within the distance mentioned above should be of the fixed (non-opening) type. In addition, during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side should be kept closed. Where, in the case of small ships, compliance with **302. 3** and this paragraph is not possible, the Society may approve relaxations from the above requirements.

5. Air pipes and other openings to enclosed spaces not listed in **307. 4** should be shielded from any spray which may come from a burst hose or connection.

6. Escape routes should not terminate within the coamings required by **307. 7** or within a distance of 3 m beyond the coamings.

7. Continuous coamings of suitable height should be fitted to keep any spills on deck and away from the accommodation and service areas.

8. Electrical equipment within the coamings required by **307. 7** or within a distance of 3 m beyond the coamings should be in accordance with the requirements of **Sec 10.**

9. Fire-fighting arrangements for the bow or stern loading and unloading areas should be in accordance with **1103. 16.**

10. Means of communication between the cargo control station and the cargo shore connection location should be provided and certified safe, if necessary. Provision should be made for the remote shutdown of cargo pumps from the cargo shoreconnection location.

Section 4 Cargo Containment

401. Definitions (IBC Code 4.1)

1. "**Independent tank**" means a cargo containment envelope which is not contiguous with, or part of, the hull structure. An independent tank is built and installed so as to eliminate whenever possible (or in any event to minimize) its stressing as a result of stressing or motion of the adjacent hull structure. An independent tank is not essential to the structural completeness of the ship's hull.

2. "**Integral tank**" means a cargo containment envelope which forms part of the ship's hull and which may be stressed in the same manner and by the same loads which stress the contiguous hull structure and which is normally essential to the structural completeness of the ship's hull.

3. "**Gravity tank**" means a tank having a design pressure not greater than 0.07 MPa gauge at the top of the tank. A gravity tank may be independent or integral. A gravity tank should be constructed and tested according to recognized standards taking account of the temperature of carriage and relative density of the cargo.

4. "**Pressure tank**" means a tank having a design pressure greater than 0.07 MPa gauge. A pressure tank should be an independent tank and should be of a configuration permitting the application of pressure vessel design criteria according to recognized standards.

402. Tank type requirements for individual products (IBC Code 4.2)

Requirements for both installation and design of tank types for individual products are shown in column "f" in the table of **Sec 17.**

Section 5 Cargo Transfer

501. Piping scantlings (IBC Code 5.1)

1. Subject to the conditions stated in **Par 4** the wall thickness (t) of pipes should not be less than:

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}} \quad (\mathrm{mm})$$

where:

t_0 = theoretical thickness

$$t_0 = \frac{P \cdot D}{2K \cdot e + P} \quad (\mathrm{mm})$$

with

P = design pressure (MPa) referred to in **Par 2**

D = outside diameter (mm)

K = allowable stress($\mathrm{N/mm^2}$) referred to in **Par 5**

e = efficiency factor; equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by manufacturers approved for making welded pipes, which are considered equivalent to seamless pipes wnen non-destructive testing on welds is carried out in accordance with recognized standards. In other cases, an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process.

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be not less than:

$$b = \frac{D \cdot t_0}{2.5r} \quad (\mathrm{mm})$$

with

r = mean radius of the bend (mm).

c = corrosion allowance (mm). If corrosion or erosion is expected, the wall thickness of piping should be increased over that required by the other design requirements.

a = negative manufacturing tolerance for thickness (%).

2. The design pressure P in the formula for t_0 in **Par 1** is the maximum gauge pressure to which the system may be subjected in service, taking into account the highest set pressure on any relief valve on the system.

3. Piping and piping system components which are not protected by a relief valve, or which may be isolated from their relief valve, should be designed for at least the greatest of:

(1) for piping systems or components which may contain some liquid, the saturated vapour pressure at 45°C;

(2) the pressure setting of the associated pump discharge relief valve;

(3) the maximum possible total pressure head at the outlet of the associated pumps when a pump

discharge relief valve is not installed.

4. The design pressure should not be less than 1.0 MPa gauge except for open-ended lines where it should be not less than 0.5 MPa gauge.

5. For pipes, the allowable stress to be considered in the formula for to in **Par 1** is the lower of the following values:

R_m/A or R_e/B

where:

R_m = specified minimum tensile strength at ambient temperature (N/mm^2)

R_e = specified minimum yield stress at ambient temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0.2 % proof stress applies.

A and B should have values of at least A = 2.7 and B = 1.8

6. (1) The minimum wall thickness should be in accordance with recognized standards.

(2) Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to weight of pipes and content and to superimposed loads from supports, ship deflection or other causes, the wall thickness should be increased over that required by **Par 1** or, if this is impracticable or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

(3) Flanges, valves and other fittings should be in accordance with recognized standards, taking into account the design pressure defined under **Par 2.**

(4) For flanges not complying with a standard the dimensions of flanges and associated bolts should be to the satisfaction of the Society.

502. Piping fabrication and joining details (IBC Code 5.2)

1. The requirements of this Article apply to piping inside and outside the cargo tanks. However, relaxations from these requirements may be accepted in accordance with recognized standards for open-ended piping and for piping inside cargo tanks except for cargo piping serving other cargo tanks.

2. Cargo piping should be joined by welding except:

(1) for approved connections to shutoff valves and expansion joints; and

(2) for other exceptional cases specifically approved by the Society.

3. The following direct connections of pipe lengths, without flanges may be considered:

(1) Butt-welded joints with complete penetration at the root may be used in all applications.

(2) Slip-on welded joints with sleeves and related welding having dimensions in accordance with recognized standards should only be used for pipes with an external diameter of 50 mm or less. This type of joint should not be used when crevice corrosion is expected to occur.

(3) Screwed connections in accordance with recognized standards should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

4. Expansion of piping should normally be allowed for by the provision of expansion loops or bends in the piping system.

(1) Bellows in accordance with recognized standards may be specially considered.

(2) Slip joints should not be used.

5. Welding, post-weld heat treatment and non-destructive testing should be performed in accordance with Recognized Standards.

503. Flange connections (IBC Code 5.3)

1. Flanges should be of the welded neck, slip-on or socket-welded type. However, socket-welded type flanges should not be used in nominal size above 50 mm.

2. Flanges should comply with recognized standards as to their type, manufacture and test.

504. Test requirements for piping (IBC Code 5.4)

1. The test requirements of this Article apply to piping inside and outside cargo tanks. However, relaxations from these requirements may be accepted in accordance with recognized standards for piping inside tanks and open-ended piping.

2. After assembly, each cargo piping system should be subject to a hydrostatic test to at least 1.5 times the design pressure. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard the ship. Joints welded on board should be hydrostatically tested to at least 1.5 times the design pressure.

3. After assembly on board, each cargo piping system should be tested for leaks to a pressure depending on the method applied.

505. Piping arrangements (IBC Code 5.5)

1. Cargo piping should not be installed under deck between the outboard side of the cargo containment spaces and the skin of the ship unless clearances required for damage protection (see **206.**) are maintained; but such distances may be reduced where damage to the pipe would not cause release of cargo provided that the clearance required for inspection purposes is maintained.

2. Cargo piping, located below the main deck, may run from the tank it serves and penetrate tank bulkheads or boundaries common to longitudinally or transversally adjacent cargo tanks, ballast tanks, empty tanks, pump rooms or cargo pump rooms provided that inside the tank it serves it is fitted with a stop valve operable from the weather deck and provided cargo compatibility is assured in the event of piping failure. As an exception, where a cargo tank is adjacent to a cargo pump room, the stop valve operable from the weather deck may be situated on the tank bulkhead on the cargo pump room side, provided an additional valve is fitted between the bulkhead valve and the cargo pump. A totally enclosed hydraulically-operated valve located outside the cargo tank may, however, be accepted, provided that the valve is:

(1) designed to preclude the risk of leakage;
(2) fitted on the bulkhead of the cargo tank which it serves;
(3) suitably protected against mechanical damage;
(4) fitted at a distance from the shell, as required for damage protection; and
(5) operable from the weather deck.

3. In any cargo pump room where a pump serves more than one tank, a stop valve should be fitted in the line to each tank.

4. Cargo piping installed in pipe tunnels should also comply with the requirements of **Pars 1** and **2.** Pipe tunnels should satisfy all tank requirements for construction, location and ventilation and electrical hazard requirements. Cargo compatibility should be assured in the event of a piping failure. The tunnel should not have any other openings except to the weather deck and cargo pump room or pump room.

5. Cargo piping passing through bulkheads should be so arranged as to preclude excessive stresses at the bulkhead and should not utilize flanges bolted through the bulkhead.

506. Cargo transfer control systems (IBC Code 5.6)

1. For the purpose of adequately controlling the cargo, cargo transfer systems should be provided with:

(1) one stop valve capable of being manually operated on each tank filling and discharge line, located near the tank penetration; if an individual deepwell pump is used to discharge the contents of a cargo tank, a stop valve is not required on the discharge line of that tank;
(2) one stop valve at each cargo hose connection;
(3) remote shutdown devices for all cargo pumps and similar equipment.

2. The controls necessary during transfer or transport of cargoes covered by this Chapter other than in cargo pump rooms which have been dealt with elsewhere in this Chapter should not be located below the weather deck.

3. For certain products, additional cargo transfer control requirements are shown in column "o" in the table of **Sec 17.**

507. Ship's cargo hoses (IBC Code 5.7)

1. Liquid and vapour hoses used for cargo transfer should be compatible with the cargo and suitable for the cargo temperature.

2. Hoses subject to tank pressure or the discharge pressure of pumps should be designed for a bursting pressure not less than 5 times the maximum pressure the hose will be subjected to during cargo transfer.

3. For cargo hoses installed on board ships on or after 1 July 2002, each new type of cargo hose, complete with end-fittings, should be prototype-tested at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test should demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the extreme service temperature. Hoses used for prototype testing should not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced should be hydrostatically tested at ambient temperature to a pressure not less than 1.5 times its specified maximum working pressure but not more than two fifths of its bursting pressure. The hose should be stencilled or otherwise marked with its specified maximum working pressure and, if used in other than ambient temperature services, its maximum and minimum service temperature as applicable. The specified maximum working pressure should not be less than 1.0 MPa gauge.

Section 6 Materials of Construction

601. General (IBC Code 6.1)

1. Structural materials used for tank construction, together with associated piping, pumps, valves, vents and their jointing materials, should be suitable at the temperature and pressure for the cargo to be carried in accordance with recognized standards. Steel is assumed to be the normal material of construction.

2. The shipyard is responsible for providing compatibility information to the ship operator and/or master. This must be done in a timely manner before delivery of the ship or on completion of a relevant modification of the material of construction.

3. Where applicable the following should be taken into account in selecting the material of construction:

(1) notch ductility at the operating temperature;
(2) corrosive effect of the cargo;
(3) possibility of hazardous reactions between the cargo and the material of construction; and
(4) suitability of linings.

4. The shipper of the cargo is responsible for providing compatibility information to the ship operator and/or master. This must be done in a timely manner before transportation of the product. The cargo shall be compatible with all materials of construction such that :

(1) no damages to the integrity of the materials of construction is incurred ; and/or
(2) no hazardous, or potentially hazardous reaction is created.

5. When a product is submitted to IMO for evaluation, and where compatibility of the product with materials referred to in paragraph 1 renders special requirements, the BLG Product Data Reporting form shall provide information on the required materials of construction. These requirements shall be reflected in Sec.15 and consequentially be referred to in column o of Sec 17. The reporting form shall also indicate if no special requirements are necessary. The products of the product is responsible for providing the correct information.

Section 7 Cargo Temperature Control

701. General (IBC Code 7.1)

1. When provided, any cargo heating or cooling systems should be constructed, fitted and tested to the satisfaction of the Society. Materials used in the construction of temperature control systems should be suitable for use with the product intended to be carried.

2. Heating or cooling media should be of a type approved for use with the specific cargo. Consideration should be given to the surface temperature of heating coils or ducts to avoid dangerous reactions from localized overheating or overcooling of cargo. (see also **1513. 6**)

3. Heating or cooling systems should be provided with valves to isolate the system for each tank and to allow manual regulation of flow.

4. In any heating or cooling system, means should be provided to ensure that, when in any condition other than empty, a higher pressure can be maintained within the system than the maximum pressure head that could be exerted by the cargo tank contents on the system.

5. Means should be provided for measuring the cargo temperature.

(1) The means for measuring the cargo temperature should be of restricted or closed type, respectively, when a restricted or closed gauging device is required for individual substances as shown in column "j" in the table of **Sec 17.**

(2) A restricted temperature-measuring device is subject to the definition for a restricted gauging device in **1301. 1** (2), e.g. a portable thermometer lowered inside a gauge tube of the restricted type.

(3) A closed temperature measuring device is subject to the definition for closed gauging device in **1301. 1** (3), e.g. a remote-reading thermometer of which the sensor is installed in the tank.

(4) When overheating or overcooling could result in a dangerous condition, an alarm system which monitors the cargo temperature should be provided. (See also operational requirements in **1606**.)

6. When products for which **1512., 1512. 1** or **3** are listed in column "o" in the table of **Sec 17** are being heated or cooled, the heating or cooling medium should operate in a circuit:

(1) which is independent of other ship's services, except for another cargo heating or cooling system, and which does not enter the machinery space; or

(2) which is external to the tank carrying toxic products; or

(3) Where the medium is sampled to check for the presence of cargo before it is recirculated to other services of the ship or into the machinery space. The sampling equipment should be located within the cargo area and be capable of detecting the presence of any toxic cargo being heated or cooled. Where this method is used, the coil return should be tested not only at the commencement of heating or cooling of a toxic product, but also on the first occasion the coil is used subsequent to having carried an unheated or uncooled toxic cargo.

702. Additional requirements (IBC Code 7.2)

For certain products, additional requirements contained in **Sec 15** are shown in column "o" in the table of **Sec 17.**

Section 8 Cargo Tank Venting and Gas-freeing Arrangements

801. Application (IBC Code 8.1)

1. Unless expressly provided otherwise, this section applies to ships constructed on or after 1 January 1994.

2. Ship constructed before 1 January 1994 shall comply with the requirements of Section 8 of the Rules which were in force prior to the said date.

3. Ships constructed on or after 1 July 1986 but before 1 January 1994 which fully comply with the requirements of the Rules at that time may be regarded as complying with the requirements of SOLAS regulation Il-2/4.5.3, 4.5.6, to 4.5.8, 4.5.10 and 11.6.

4. For ships to which this Chapter applies, the requirements of this Section shall apply in lieu of regulation II-2/59.1 and 59.2 of the 1974 SOLAS Convention, as amended.

5. Ships constructed on or after 1 July 1986, but before 1 July 2002 shall comply with the paragraph **803. 3**. However, the Society may approve relaxation of the requirements for ships of less than 500 gross tonnage which were constructed on or after 1 July 1986, but before 1 July 2002.

802. Cargo tank venting (IBC Code 8.2)

1. All cargo tanks should be provided with a venting system appropriate to the cargo being carried and these systems should be independent of the air pipes and venting systems of all other compartments of the ship. Tank venting systems should be designed so as to minimize the possibility of cargo vapour accumulating about the decks, entering accommodation, service and machinery spaces and control stations and in the case of flammable vapours entering or collecting in spaces or areas containing sources of ignition. Tank venting systems should be arranged to prevent entrance of water into the cargo tanks and at the same time, vent outlets should direct the vapour discharge upwards in the form of unimpeded jets.

2. The venting systems should be connected to the top of each cargo tank and as far as practicable the cargo vent lines should be self-draining back to the cargo tanks under all normal operational conditions of list and trim. Where it is necessary to drain venting systems above the level of any pressure/vacuum valve, capped or plugged drain cocks should be provided.

3. Provision should be made to ensure that the liquid head in any tank does not exceed the design head of the tank. Suitable high-level alarms, overflow control systems or spill valves, together with gauging and tank filling procedures may be accepted for this purpose. Where the means of limiting cargo tank overpressure includes an automatic closing valve, the valve should comply with the appropriate provisions of **1519.**

4. Tank venting systems should be designed and operated so as to ensure that neither pressure nor vacuum created in the cargo tanks during loading or unloading exceeds tank design parameters. The main factors to be considered in the sizing of a tank venting system are as follows:

(1) design loading and unloading rate;
(2) gas evolution during loading: this should be taken account of by multiplying the maximum loading rate by a factor of at least 1.25;
(3) density of the cargo vapour mixture;
(4) pressure loss in vent piping and across valves and fittings;
(5) pressure/vacuum settings of relief devices.

5. Tank vent piping connected to cargo tanks of corrosion-resistant material, or to tanks which are lined or coated to handle special cargoes as required by this Chapter, should be similarly lined or coated or constructed of corrosion-resistant material.

6. The master should be provided with the maximum permissible loading and unloading rates for each tank or group of tanks consistent with design of the venting systems.

803. Types of tank venting systems (IBC Code 8.3)

1. An open tank venting system is a system which offers no restriction except for friction losses to the free flow of cargo vapours to and from the cargo tanks during normal operations, An open venting system may consist of individual vents from each tank, or such individual vents may be combined into a common header or headers, with due regard to cargo segregation. In no case should shutoff valves be fitted either to the individual vents or to the header.

2. A controlled tank venting system is a system in which pressure and vacuum relief valves or pressure/vacuum valves are fitted to each tank to limit the pressure or vacuum in the tank. A controlled venting system may consist of individual vents from each tank or such individual vents on the pressure side only as may be combined into a common header or headers with due regard to cargo segregation. In no case should shutoff valves be fitted either above or below pressure or vacuum relief valves or pressure/vacuum valves. Provision may be made for bypassing a pressure or vacuum valve or pressure/vacuum valve under certain operating conditions provided that the requirement of **Par 6** is maintained and that there is suitable indication to show whether or not the valve is bypassed.

3. On ships constructed on or after 1 July 2002, controlled tank venting systems should consist of a primary and a secondary means of allowing full flow relief of vapour to prevent over-pressure or under-pressure in the event of failure of one means. Alternatively, the secondary means may consist of pressure sensors fitted in each tank with a monitoring system in the ship's cargo control room or position from which cargo operations are normally carried out. Such monitoring equipment should also provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

4. The position of vent outlets of a controlled tank venting system should be arranged:

(1) at a height of not less than 6 m above the weather deck or above a raised walkway if fitted within 4 m of the raised walkway;

(2) at a distance of at least 10 m measured horizontally from the nearest air intake or opening to accommodation, service and machinery spaces and ignition sources.

5. The vent outlet height referred to in **4** (1) may be reduced to 3 m above the deck or a raised walkway, as applicable, provided that high velocity venting valves of a type approved by the Society, directing the vapour/air mixture upwards in an unimpeded jet with an exit velocity of at least 30 m/s, are fitted.

6. Controlled tank venting systems fitted to tanks to be used for cargoes having a flashpoint not exceeding 60°C (closed cup test) should be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of the devices should comply with the requirements of the Society, which should contain at least the standards adopted by the Organization.

7. In designing venting systems and in the selection of devices to prevent the passage of flame for incorporation into the tank venting system, due attention should be paid to the possibility of the blockage of these systems and fittings by, for example, the freezing of cargo vapour, polymer build up, atmospheric dust or icing up in adverse weather conditions. In this context it should be noted that flame arresters and flame screens are more susceptible to blockage. Provisions should be made such that the system and fittings may be inspected, operationally checked, cleaned or renewed as applicable.

8. Reference in **Pars 1** and **2** to the use of shutoff valves in the venting lines should be interpreted to extend to all other means of stoppage, including spectacle blanks and blank flanges.

804. Venting requirements for individual products (IBC Code 8.4)

Venting requirements for individual products are shown in column "g", and additional requirements in column "o" in the table of **Sec 17.**

805. Cargo tank gas-freeing (IBC Code 8.5)

1. The arrangements for gas-freeing cargo tanks used for cargoes other than those for which open venting is permitted should be such as to minimize the hazards due to the dispersal of flammable or toxic vapours in the atmosphere and to flammable or toxic vapour mixtures in a cargo tank.

Accordingly, gas-freeing operations should be carried out such that vapour is initially discharged:

(1) through the vent outlets specified in **803. 3** and **803. 4;** or
(2) through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas- freeing operation; or
(3) through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/s which are protected by suitable devices to prevent the passage of flame.
When the flammable vapour concentration at the outlets has been reduced to 30 % of the lower flammable limit and, in the case of a toxic product, the vapour concentration does not present a significant health hazard, gas-freeing may thereafter be continued at cargo tank deck level.

2. The outlets referred to in **1** (2) and **1** (3) may be fixed or portable pipes.

3. In designing a gas-freeing system in conformity with **Par 1,** particularly in order to achieve the required exit velocities of **1** (2) and **1** (3), due consideration should be given to the following:

(1) materials of construction of system;
(2) time to gas-free;
(3) flow characteristics of fans to be used;
(4) the pressure losses created by ducting, piping, cargo tank inlets and outlets;
(5) the pressure achievable in the fan driving medium (e.g. water or compressed air);
(6) the densities of the cargo vapour/air mixtures for the range of cargoes to be carried.

Section 9 Environmental Control

901. General (IBC Code 9.1)

1. Vapour spaces within cargo tanks and, in some cases, spaces surrounding cargo tanks may require to have specially controlled atmospheres.

2. There are four different types of control for cargo tanks, as follows:

(1) Inerting - by filling the cargo tank and associated piping systems and, where specified in **Sec 15,** the spaces surrounding the cargo tanks, with a gas or vapour which will not support combustion and which will not react with the cargo, and maintaining that condition.
(2) Padding- by filling the cargo tank and associated piping systems with a liquid, gas or vapour which separates the cargo from the air, and maintaining that condition.
(3) Drying - by filling the cargo tank and associated piping systems with moisture-free gas or vapour with a dewpoint of -40°C or below at atmospheric pressure, and maintaining that condition.
(4) Ventilation - forced or natural.

3. Where inerting or padding of cargo tanks is required:

(1) An adequate supply of inert gas for use in filling and discharging the cargo tanks should be carried or should be manufactured on board unless a shore supply is available. In addition, sufficient inert gas should be available on the ship to compensate for normal losses during transportation.
(2) The inert gas system on board the ship should be able to maintain a pressure of at least 0.007 MPa gauge within the containment system at all times. In addition, the inert gas system should not raise the cargo tank pressure to more than the tank's relief valve setting.
(3) Where padding is used, similar arrangements for supply of the padding medium should be made as required for inert gas in (1) and (2).
(4) Means should be provided for monitoring ullage spaces containing a gas blanket to ensure that the correct atmosphere is being maintained.
(5) Inerting or padding arrangements or both, where used with flammable cargoes, should be such as to minimize the creation of static electricity during the admission of the inerting medium.

4. Where drying is used and dry nitrogen is used as the medium, similar arrangements for supply of the drying agent should be made to those required in **Par 3.** Where agents are used as the drying medium on all air inlets to the tank, sufficient medium should be carried for the duration of the voyage, taking into consideration the diurnal temperature range and the expected humidity.

902. Environmental control requirements for individual products (IBC Code 9.2)

The required types of environmental control for certain products are shown in column "h" in the table of **Sec 17.**

Section 10 Electrical Installations

1001. General (IBC Code 10.1)

1. The provisions of this Section are applicable to ships carrying cargoes which are inherently, or due to their reaction with other substances, flammable or corrosive to the electrical equipment, and should be applied in conjunction with applicable electrical requirements of part D, chapter II-1 of the 1983 SOLAS amendments.

2. (1) Electrical installations shall be such as to minimize the risk of fire and explosion from flam mable products. Reference is made to the recommendation published the International Electrotechnical Commission, in particular to publication IEC 60079-1-1 : 2002

(2) Where the specific cargo is liable to damage the materials normally used in electrical apparatus, due consideration should be given to the particular characteristics of the materials chosen for conductors, insulation, metal parts, etc. As far as necessary, these components should be protected to prevent contact with gases or vapours liable to be encountered.

3. The Society should take appropriate steps to ensure uniformity in the implementation and the application of the provisions of this Section in respect of electrical installations.

4. Electrical equipment, cables and wiring shall not be installed in the hazardous locations unless it conforms with the standards not inferior to those acceptable to the recommendation published the International Electrotechnical Commission, in particular to publication IEC 60079-1-1 : 2002. However, for locations not covered by such standards, electrical equipment, cables and wiring which do not conform to the standards may be installed in hazardous locations based on a risk assessment to the satisfaction of the Society, to ensure that an equivalent level of safety is assured.

5. Where electrical equipment is installed in hazardous locations, as permitted in this Section, it should be to the satisfaction of the Society and certified by the relevent authorities recognized by the Society for operation in the flammable atmosphere concerned, as indicated in column "i" in the table of **Sec 17.**

6. For guidance, indication is given if the flashpoint of a substance is in excess of 60°C. In the case of heated cargo, carriage conditions might need to be established and the requirements for cargoes having a flashpoint not exceeding 60°C applied.

1002. Bonding (IBC Code 10.2)

Independent cargo tanks should be electrically bonded to the hull. All gasketed cargo pipe joints and hose connections should be electrically bonded.

1003. Electrical requirements for individual products (IBC Code 10.3)

Electrical requirements for individual products are shown in column "i" in the table of **Sec 17.**

Section 11 Fire Protection and Fire Extinction

1101. Application (IBC Code 11.1)

1. The requirements for tankers in chapter II-2 of the 1983 SOLAS amendments shall apply to ships covered by this Chapter, irrespective of tonnage, including ships of less than 500 tons gross tonnages, except that:

(1) regulations 4.5.5, 10.8 and 10.9 shall not apply;
(2) regulation 4.5.1.2 (i.e. the requirements for location of the main cargo control station) need not apply;
(3) regulation 10.2, 10.4 and 10.5 shall apply as they would apply to cargo ships of 2,000 tons gross tonnage and over;
(4) regulation of 10.5.6 shall apply to ships of 2,000 gross tonnage and over;
(5) the provisions of **1103.** shall apply in lieu of regulation 10.8; and
(6) the provisions of **1102.** shall apply in lieu of regulation 10.9.
(7) regulation 4.5.10 shall apply to ships of 500 gross tonnage and over, replacing "hydrocarbon gases" by "flammable vapours" in the regulation; and.
(8) regulations 13.3.4 and 13.4.3 shall apply to ships of 500 gross tonnage and over.

2. Notwithstanding the provisions of **Par 1,** ships engaged solely in the carriage of products which are non-flammable (entry NF in column "i" of the table of minimum requirements) need not comply with the requirements for tanker specified in SOLAS chapter II-2, provided that they comply with the requirements for cargo ships of that chapter, except that regulation 10.7 need not apply to such ships and **1102.** and **1103.** hereunder need not apply.

3. For ships engaged solely in the carriage of products with flashpoint above 60°C (entry "yes" in column "i" of the table of minimum requirements) the requirements of SOLAS chapter II-2 may apply as specified in regulation II-2/1.6.4 in lieu of the provisions of this Section.

4. Monitoring of the concentration of flammable vapour

In lieu of the provisions of SOLAS regulation II-2/1.6.7, the requirements of regulations II-2/4.5.10.1.1 and II-2/4.5.10.1.4 shall apply and a system for continuous monitoring of the concentration of flammable vapours shall be fitted on ships of 500 gross tonnage and over which were constructed before 1 January 2009 by the date of the first scheduled dry-docking after 1 January 2009, but not later than 1 January 2012. Sampling points or detector heads should be located in suitable positions in order that potentially dangerous leakages are readily detected. When the flammable vapour concentration reaches a pre-set level which shall not be higher than 10 % of the lower flammable limit, a continuous audible and visual alarm signal shall be automatically effected in the pump-room and cargo control room to alert personnel to the potential hazard. However, existing monitoring systems already fitted having a pre-set level not greater than 30 % of the lower flammable limit may be accepted. Notwithstanding the above provisions, the Administration may exempt ships not engaged on international voyages from those requirements.

1102. Cargo pump rooms (IBC Code 11.2)

1. The cargo pump room of any ship should be provided with a fixed carbon dioxide fire-extinguishing system as specified in regulation II-2/5.1 and .2 of the 1983 SOLAS amendments. A notice should be exhibited at the controls stating that the system is only to be used for fire-extinguishing and not for inerting purposes, due to the electrostatic ignition hazard. The alarms referred to in regulation II-2/5.1.6 of the 1983 SOLAS amendments should be safe for use in a flammable cargo vapour-air mixture. For the purpose of this requirements, an extinguishing system should be provided which would be suitable for machinery spaces. However, the amount of gas carried should be sufficient to provide a quantity of free gas equal to 45% of the gross volume of the cargo pump room in all cases; or

2. Cargo pump rooms of ships which are dedicated to the carriage of a restricted number of cargoes should be protected by an appropriate fire-extinguishing system approved by the Society.

3. A fire-extinguishing system consisting of either a fixed pressure water-spray system or a high-expansion foam system could be provided for a cargo pump room if cargoes will be carried which are not suited to extinguishment by carbon dioxide or equivalent media. The International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk should reflect this conditional requirement.

1103. Cargo area (IBC Code 11.3)

1. Every ship should be provided with a fixed deck foam system in accordance with the requirements of **Pars 2** to **12.**

2. Only one type of foam concentrate should be supplied, and it should be effective for the maximum possible number of cargoes intended to be carried. For other cargoes for which foam is not effective or is incompatible, additional arrangements to the satisfaction of the Society should be provided. Regular protein foam should not be used.

3. The arrangements for providing foam should be capable of delivering foam to the entire cargo tanks deck area as well as into any cargo tank, the deck of which is assumed to be ruptured.

4. The deck foam system should be capable of simple and rapid operation. The main control station for the system should be suitably located outside of the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fires in the areas protected.

5. The rate of supply of foam solution should be not less than the greatest of the following:

(1) 2 l/min per square metre of the cargo tanks deck area, where cargo tanks deck area means the maximum breadth of the ship times the total longitudinal extent of the cargo tank spaces;
(2) 20 l/min per square metre of the horizontal sectional area of the single tank having the largest such area;
(3) 10 l/min per square metre of the area protected by the largest monitor, such area being entirely forward of the monitor, but not less than 1,250 l/min. For ships of less than 4,000 tonnes deadweight, the minimum capacity of the monitor should be to the satisfaction of the Society.

6. Sufficient foam concentrate should be supplied to ensure at least 30 min of foam generation when using the highest of the solution rates stipulated in **5** (1) to (3).

7. Foam from the fixed foam system should be supplied by means of monitors and foam applicators. At least 50 % of the foam rate required in **Par 5.** (1) or (2) should be delivered from each monitor. The capacity of any monitor should be at least 10 l/min of foam solution per square metre of deck area protected by that monitor, such area being entirely forward of the monitor. Such capacity should be not less than 1,250 l/min. For ships of less than 4,000 tonnes deadweight, the minimum capacity of the monitor should be to the satisfaction of the Society.

8. The distance from the monitor to the farthest extremity of the protected area forward of that monitor should be not more than 75 % of the monitor throw in still air conditions.

9. A monitor and hose connection for a foam applicator should be situated both port and starboard at the poop front or accommodation spaces facing the cargo area.

10. Applicators should be provided for flexibility of action during fire-fighting operations and to cover areas screened from the monitors. The capacity of any applicator should be not less than 400 l/min and the applicator throw in still air conditions should be not less than 15 m. The number of foam applicators provided should be not less than four. The number and disposition of foam main outlets should be such that foam from at least two applicators can be directed to any part of the cargo tanks deck area.

11. Valves should be provided in the foam main, and in the fire main where this is an integral part of the deck foam system, immediately forward of any monitor position to isolate damaged sections of those mains.

12. Operation of a deck foam system at its required output should permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main.

13. Ships which are dedicated to the carriage of a restricted number of cargoes should be protected by alternative provisions to the satisfaction of the Society when they are just as effective for the products concerned as the deck foam system required for the generality of flammable cargoes.

14. Suitable portable fire-extinguishing equipment for the products to be carried should be provided and kept in good operating order.

15. Where flammable cargoes are to be carried all sources of ignition should be excluded from hazardous locations referred to in **1001. 4.**

16. Ships fitted with bow or stern loading and unloading arrangements should be provided with one additional foam monitor meeting the requirements of **Par 7** and one additional applicator meeting the requirements of **Par 10.** The additional monitor should be located to protect the bow or stern loading and unloading arrangements. The area of the cargo line forward or aft of the cargo area should be protected by the above-mentioned applicator.

1104. Special requirements (IBC Code 11.4)

Fire-extinguishing media determined to be effective for certain products are listed in column "l" in the table of **Sec 17.**

Section 12 Mechanical Ventilation in the Cargo Area

For ships to which this Chapter applies, the requirements of this Section replace the requirements of SOLAS regulation II-2/ 4.5.2.6 and 4.5.4. However, for products addressed under **1101. 2** and **1101. 3,** except acids and products for which **1517.** applies, SOLAS regulation II-2/4.5.2.6 and 4.5.4 may apply in lieu of the provisions of this Section.

1201. Spaces normally entered during cargo handling operations (IBC Code 12.1)

1. Cargo pump rooms and other enclosed spaces which contain cargo handling equipment and similar spaces in which work is performed on the cargo should be fitted with mechanical ventilation systems, capable of being controlled from outside such spaces.

2. Provision should be made to ventilate such spaces prior to entering the compartment and operating the equipment and a warning notice requiring the use of such ventilation should be placed outside the compartment.

3. Mechanical ventilation inlets and outlets should be arranged to ensure sufficient air movement through the space to avoid the accumulation of toxic or flammable vapours or both (taking into account their vapour densities) and to ensure sufficient oxygen to provide a safe working environment, but in no case should the ventilation system have a capacity of less than 30 changes of air per hour based upon the total volume of the space. For certain products, increased ventilation rates for cargo pump rooms are prescribed in **1517.**

4. Ventilation systems should be permanent and should normally be of the extraction type. Extraction from above and below the floor plates should be possible. In rooms housing motors driving cargo pumps, the ventilation should be of the positive pressure type.

5. Ventilation exhaust ducts from spaces within the cargo area should discharge upwards in locations at least 10 m in the horizontal direction from ventilation intakes and openings to accommodation, service and machinery spaces and control stations and other spaces outside the cargo area.

6. Ventilation intakes should be so arranged as to minimize the possibility of recycling hazardous vapours from any ventilation discharge opening.

7. Ventilation ducts should not be led through accommodation, service and machinery spaces or other similar spaces.

8. Electric motors driving fans should be placed outside the ventilation ducts if the carriage of flammable products is intended. Ventilation fans and fan ducts, in way of fans only, for hazardous locations referred to in **Sec 10** should be of non sparking construction defined as:

(1) impellers or housing of nonmetallic construction, due regard being paid to the elimination of static electricity;
(2) impellers and housing of nonferrous materials;
(3) impellers and housing of austenitic stainless steel; and
(4) ferrous impellers and housing with not less than 13 mm design tip clearance.
Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

9. Sufficient spare parts should be carried for each type of fan on board, required by this Section.

10. Protection screens of not more than 13 mm square mesh should be fitted in outside openings of ventilation ducts.

1202. Pump rooms and other enclosed spaces normally entered (IBC Code 12.2)

Pump rooms and other enclosed spaces normally entered, which are not covered by **1201. 1,** should be fitted with mechanical ventilation systems, capable of being controlled from outside such spaces and complying with the requirements of **1201. 3,** except that the capacity should not be less than 20 changes of air per hour, based upon the total volume of the space. Provision should be made to ventilate such spaces prior to entering.

1203. Spaces not normally entered (IBC Code 12.3)

Double bottoms, cofferdams, duct keels, pipe tunnels, hold spaces and other spaces where cargo may accumulate, should be capable of being ventilated to ensure a safe environment when entry into the spaces is necessary. Where a permanent ventilation system is not provided for such spaces, approved means of portable mechanical ventilation should be provided. Where necessary owing to the arrangement of spaces, for instance hold spaces, essential ducting for such ventilation should be permanently installed. For permanent installations, the capacity of 8 air changes per hour should be provided and for portable systems the capacity of 16 air changes per hour. Fans or blowers should be clear of personnel access openings, and should comply with **1201. 8.**

Section 13 Instrumentation

1301. Gauging (IBC Code 13.1)

1. Cargo tanks should be fitted with one of the following types of gauging devices:

(1) Open device"which makes use of an opening in the tanks and may expose the gauger to the cargo or its vapour. An example of this is the ullage opening.

(2) Restricted device"which penetrates the tank and which, when in use, permits a small quantity of cargo vapour or liquid to be exposed to the atmosphere. When not in use, the device is completely closed. The design should ensure that no dangerous escape of tank contents (liquid or spray) can take place in opening the device.

(3) Closed device"which penetrates the tank, but which is part of a closed system and keeps tank contents from being released. Examples are the float-type systems, electronic probe, magnetic probe and protected sight glass. Alternatively an indirect device which does not penetrate the tank shell and which is independent of the tank may be used. Examples are weighing of cargo, pipe flow meter.

2. Gauging devices should be independent of the equipment required under **1519.**

3. Open gauging and restricted gauging should be allowed only where:

(1) open venting is allowed by this Chapter; or

(2) means are provided for relieving tank pressure before the gauge is operated.

4. Types of gauging for individual products are shown in column "j" in the table of **Sec 17.**

1302. Vapour detection (IBC Code 13.2)

1. Ships carrying toxic or flammable products or both should be equipped with at least two instruments designed and calibrated for testing for the specific vapours in question. If such instruments are not capable of testing for both toxic concentrations and flammable concentrations, then two separate sets of instruments should be provided.

2. Vapour detection instruments may be portable or fixed. If a fixed system is installed, at least one portable instrument should be provided.

3. When toxic vapour detection equipment is not available for some products which require such detection, as indicated in column "k" in the table of **Sec 17,** the Society may exempt the ship from the requirement, provided an appropriate entry is made on the International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk. When granting such an exemption, the Society should recognize the necessity for additional breathing air supply and an entry should be made on the International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk drawing attention to the provisions of **1402. 4** and **1604. 2** (2).

4. Vapour detection requirements for individual products are shown in column "k" in the table of **Sec 17.**

Section 14 Personnel Protection

1401. Protective equipment (IBC Code 14.1)

1. For the protection of crew members who are engaged in loading and discharging operations, the ship should have on board suitable protective equipment consisting of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant material, and tight-fitting goggles or face shields or both. The protective clothing and equipment should cover all skin so that no part of the body is unprotected.

2. Work clothes and protective equipment should be kept in easily accessible places and in special lockers. Such equipment should not be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. The Society may, however, approve storage rooms for such equipment within accommodation spaces if adequately segregated from living spaces such as cabins, passageways dining rooms, bathrooms, etc.

3. Protective equipment should be used in any operation which may entail danger to personnel.

1402. Safety equipment (IBC Code 14.2)

1. Ships carrying cargoes for which **1512., 1512. 1** or **3** is listed in column "o" in the table of **Sec 17** shall have on board sufficient but not less than three complete sets of safety equipment each permitting personnel to enter a gas-filled compartment and perform work there for at least 20 min. Such equipment shall be in addition to that required by SOLAS regulation II-2/10.10.

2. One complete set of safety equipment should consist of:

(1) one self-contained air-breathing apparatus (not using stored oxygen);
(2) protective clothing, boots, gloves and tightfitting goggles;
(3) fireproof lifeline with belt resistant to the cargoes carried; and
(4) explosion-proof lamp.

3. For the safety equipment required in **Par 1,** all ships should carry the following, either:

(1) one set of fully charged spare air bottles for each breathing apparatus;
(2) a special air compressor suitable for the supply of high-pressure air of the required purity.
(3) a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus; or
(4) fully charged spare air bottles with a total free air capacity of at least 6,000 l for each breathing apparatus on board in excess of the requirements of SOLAS regulation II-2/10.10.

4. A cargo pump room of ships carrying cargoes which are subject to the requirements of **1518.** or cargoes for which in column "k" in the table of **Sec 17** toxic vapour detection equipment is required but is not available should have either:

(1) a low-pressure line system with hose connections suitable for use with the breathing apparatus required by **Par 1.** This system should provide sufficient high-pressure air capacity to supply, through pressure reduction devices, enough low-pressure air to enable two men to work in a gas-dangerous space for at least 1 h without using the air bottles of the breathing apparatus. Means should be provided for recharging the fixed air bottles and breathing apparatus air bottles from a special air compressor suitable for the supply of high-pressure air of the required purity; or
(2) an equivalent quantity of spare bottled air in lieu of the low-pressure air line.

5. At least one set of safety equipment as required by **Par 2** should be kept in a suitable clearly marked locker in a readily accessible place near the cargo pump room. The other sets of safety equipment should also be kept in suitable, clearly marked, easily accessible, places.

6. The breathing apparatus should be inspected at least once a month by a responsible officer, and the inspection recorded in the ship's log-book. The equipment should be inspected and tested by an expert at least once a year.

1403. Emergency equipment (IBC Code 14.3)

1. Ships carrying cargoes for which "Yes" is indicated in column "n" of the Sec 17, shall be provided with suitable respiratory and eye protection sufficient for every person on board for emergency escape purposes, subject to the following:

(1) filter type respiratory protection is unacceptable;
(2) self-contained breathing apparatus shall have normally at least a duration of service of 15 min;
(3) emergency escape respiratory protection shall not be used for fire-fighting or cargo handling purposes and shall be marked to that effect.

2. The ships shall have on board medical first-aid equipment including oxygen resuscitation equipment and antidotes for cargoes carried, based on the guidelines developed by IMO.

3. A stretcher which is suitable for hoisting an injured person up from spaces such as the cargo pump room shall be placed in a readily accessible location.

4. Suitably marked decontamination showers and an eyewash shall be available on deck in convenient locations. The showers and eyewash shall be operable in all ambient conditions.

Section 15 Special Requirements

1501. General

The provisions of this Section are applicable where specific reference is made in column "o" in the table of **Sec 17**. These requirements are additional to the general requirements of this Chapter.

1502. Ammonium nitrate solution, 93 % or less (IBC Code 15.2)

1. The ammonium nitrate solution should contain at least 7 % by weight of water. The acidity (pH) of the cargo when diluted with ten parts of water to one part of cargo by weight should be between 5.0 and 7.0. The solution should not contain more than 10 ppm chloride ions, 10 ppm ferric ions, and should be free of other contaminants.

2. Tanks and equipment for ammonium nitrate solution should be independent of tanks and equipment containing other cargoes or combustible products. Equipment which may in service, or when defective, release combustible products into the cargo, e.g. lubricants, should not be used. Tanks should not be used for seawater ballast.

3. Except where expressly approved by the Society, ammonium nitrate solutions should not be transported in tanks which have previously contained other cargoes unless tanks and associated equipment have been cleaned to the satisfaction of the Society.

4. The temperature of the heat exchanging medium in the tank heating system should not exceed 160°C. The heating system should be provided with a control system to keep the cargo at a bulk mean temperature of 140°C. High-temperature alarms at 145°C and 150°C and a low-temperature alarm at 125°C should be provided. Where the temperature of the heat exchanging medium exceeds 160°C an alarm should also be given. Temperature alarms and controls should be located on the navigating bridge.

5. If the bulk mean cargo temperature reaches 145°C, a cargo sample should be diluted with ten parts of distilled or demineralized water to one part of cargo by weight and the acidity (pH) should be determined by means of a narrow range indicator paper or stick. Acidity (pH) measurements should then be taken every 24 h. If the acidity (pH) is found to be below 4.2, ammonia gas should be injected into the cargo until the acidity (pH) of 5.0 is reached.

6. A fixed installation should be provided to inject ammonia gas into the cargo. Controls for this system should be located on the navigating bridge. For this purpose, 300 kg of ammonia per 1,000 tonnes of ammonium nitrate solution should be available on board.

7. Cargo pumps should be of the centrifugal deepwell type or of the centrifugal type with water-flushed seals.

8. Vent piping should be fitted with approved weatherhoods to prevent clogging. Such weatherhoods should be accessible for inspection and cleaning.

9. Hot work on tanks, piping and equipment which have been in contact with ammonium nitrate solution should only be done after all traces of ammonium nitrate have been removed, inside as well as outside.

1503. Carbon disulphide (IBC Code 15.3)

Carbon disulphide may be carried either under water pad or under suitable inert gas pad as specified in the following paragraphs.

Carriage under water pad

1. Provision should be made to maintain a water pad in the cargo tank during loading, unloading and transit. In addition, an inert gas pad should be maintained in the ullage space during transit.

2. All openings should be in the top of the tank, above the deck.

3. Loading lines should terminate near the bottom of the tank.

4. A standard ullage opening should be provided for emergency sounding.

5. Cargo piping and vent lines should be independent of piping and vent lines used for other cargo.

6. Pumps may be used for discharging cargo, provided they are of the deepwell or hydraulically driven submersible types. The means of driving a deepwell pump should not present a source of ignition for carbon disulphide and should not employ equipment that may exceed a temperature of 80°C.

7. If a cargo discharge pump is used, it should be inserted through a cylindrical well extending from the tank top to a point near the tank bottom. A water pad should be formed in this well before attempting pump removal unless the tank has been certified as gas-free.

8. Water or inert gas displacement may be used for discharging cargo, provided the cargo system is designed for the expected pressure and temperature.

9. Safety relief valves should be of stainless steel construction.

10. Because of its low ignition temperature and close clearances required to arrest its flame propagation, only intrinsically safe system and circuits are permitted in the hazardous location described in **1002. 3.**

Carriage under suitable inert gas pad

11. Carbon disulphide should be carried in independent tanks with a design pressure of not less than 0.06 MPa gauge.

12. All openings should be located on the top of the tank, above the deck.

13. Gaskets used in the containment system should be of a material which does not react with, or dissolve in, carbon disulphide.

14. Threaded joints should not be permitted in the cargo containment system, including the vapour lines.

15. Prior to loading, the tank(s) should be inerted with suitable inert gas until the oxygen level is 2 % by volume or lower. Means should be provided to automatically maintain a positive pressure in the tank using suitable inert gas during loading, transport and discharge. The system should be able to maintain this positive pressure between 0.01 and 0.02 MPa gauge, and should be remotely monitored and fitted with over/underpressure alarms.

16. Hold spaces surrounding an independent tank carrying carbon disulphide should be inerted by a suitable inert gas until the oxygen level is 2 % or less. Means should be provided to monitor and maintain this condition throughout the voyage. Means should also be provided to sample these spaces for carbon disulphide vapour.

17. Carbon disulphide should be loaded, transported and discharged in such a manner that venting to the atmosphere does not occur. If carbon disulphide vapour is returned to shore during loading or to the ship during discharge, the vapour return system should be independent of all other containment systems.

18. Carbon disulphide should be discharged only by submerged deepwell pumps or by a suitable inert gas displacement. The submerged deepwell pumps should be operated in a way that prevents heat build-up in the pump. The pump should also be equipped with a temperature sensor in the pump housing with remote readout and alarm in the cargo control room. The alarm should be set at 80°C. The pump should also be fitted with an automatic shut-down device, if the tank pressure falls below atmospheric pressure during the discharge.

19. Air should not be allowed to enter the cargo tank, cargo pump or lines while carbon disulphide is contained in the system.

20. No other cargo handling, tank cleaning or deballasting should take place concurrent with loading or discharge of carbon disulphide.

21. A water spray system of sufficient capacity should be provided to blanket effectively the area surrounding the loading manifold, the exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles should be such as to give an uniform distribution rate of 10 $l/m^2/min$. Remote manual operation should be arranged such that remote starting of pumps supplying the water-spray system and remote operation of any normally closed valves in the system can be carried out from a suitable location outside the cargo area adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

The water-spray system should be capable of both local and remote manual operation, and the arrangement should ensure that any spilled cargo is washed away. Additionally, a water hose with pressure to the nozzle when atmospheric temperature permits, should be connected ready for immediate use during loading and unloading operations.

22. No cargo tanks should be more than 98 % liquid-full at the reference temperature (R).

23. The maximum volume (V_L) of cargo to be loaded in a tank should be:

$$V_L = 0.98\, V\rho_R / \rho_L$$

where:

V_L : volume of the tank

ρ_R : relative density of cargo at the reference temperature (R)

ρ_L : relative density of cargo at the loading temperature

R : reference temperature, i.e. the temperature at which the vapour pressure of the cargo corresponds to the set pressure of the pressure relief valve.

24. The maximum allowable tank filling limits for each cargo tank should be indicated for each loading temperature which may be applied, and for the applicable maximum reference temperature, on a list approved by the Administration. A copy of the list should be permanently kept on board by the master.

25. Zones on open deck, or semi-enclosed spaces on open deck within three metres of a tank outlet, gas or vapour outlet, cargo pipe flange or cargo valve of a tank certified to carry carbon disulphide, should comply with the electrical equipment requirements specified for carbon disulphide in column "i" in the table of **Sec 17.** Also, within the specified zone, no other heat sources, like steam piping with surface temperatures in excess of 80°C should be allowed.

26. Means should be provided to ullage and sample the cargo without opening the tank or disturbing the positive suitable inert gas blanket.

27. The product should be transported only in accordance with a cargo handling plan that has been approved by the Administration. Cargo handling plans should show the entire cargo piping system. A copy of the approved cargo handling plan should be available on board. The International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk should be endorsed to include reference to the approved cargo handling plan.

1504. Diethyl ether (IBC Code 15.4)

1. Unless inerted, natural ventilation should be provided for the voids around the cargo tanks while the vessel is under way. If a mechanical ventilation system is installed, all blowers should be of non-sparking construction. Mechanical ventilation equipment should not be located in the void spaces surrounding the cargo tanks.

2. Pressure relief valve settings should not be less than 0.02 MPa gauge for gravity tanks.

3. Inert gas displacement may be used for discharging cargo from pressure tanks provided the cargo system is designed for the expected pressure.

4. In view of the fire hazard, provision should be made to avoid any ignition source or heat generation or both in the cargo area.

5. Pumps may be used for discharging cargo, provided that they are of a type designed to avoid liquid pressure against the shaft gland or are of a hydraulically operated submerged type and are suitable for use with the cargo.

6. Provision should be made to maintain the inert gas pad in the cargo tank during loading, unloading and transit.

1505. Hydrogen peroxide solutions (IBC Code 15.5)

1. Hydrogen peroxide solutions over 60 % but not over 70 %

(1) Hydrogen peroxide solutions over 60 % but not over 70 % should be carried in dedicated ships only and no other cargoes should be carried.
(2) Cargo tanks and associated equipment should be either pure aluminium (99.5 %) or solid stainless steel (304 *L*, 316, 316 *L* or 316 *Ti*), and passivated in accordance with approved procedures. Aluminium should not be used for piping on deck. All nonmetallic materials of construction for the containment system should neither be attacked by hydrogen peroxide nor contribute to its decomposition.
(3) Pump rooms should not be used for cargo transfer operations.
(4) Cargo tanks should be separated by cofferdams from oil fuel tanks or any other space containing flammable or combustible materials.
(5) Tanks intended for the carriage of hydrogen peroxide should not be used for seawater ballast.
(6) Temperature sensors should be installed at the top and bottom of the tank. Remote temperature readouts and continuous monitoring should be located on the navigating bridge. If the temperature in the tanks rises above 35°C, visible and audible alarms should be activated on the navigating bridge.
(7) Fixed oxygen monitors (or gas sampling lines) should be provided in void spaces adjacent to tanks to detect leakage of the cargo into these spaces. Remote readouts, continuous monitoring (if gas-sampling lines are used, intermittent sampling is satisfactory) and visible and audible alarms similar to those for the temperature sensors should also be located on the navigating bridge. The visible and audible alarms should be activated if the oxygen concentration in these void spaces exceeds 30 % by volume. Two portable oxygen monitors should also be available as back-up systems.
(8) As a safeguard against uncontrolled decomposition, a cargo jettisoning system should be installed to discharge the cargo overboard. The cargo should be jettisoned if the temperature rise of the cargo exceeds a rate of 2°C per hour over a 5 h period or when the temperature in the tank exceeds 40°C.
(9) Cargo tank venting systems should have pressure/vacuum relief valves for normal controlled venting, and rupture discs or a similar device for emergency venting, should tank pressure rise rapidly as a result of uncontrolled decomposition. Rupture discs should be sized on the basis of tank design pressure, tank size and anticipated decomposition rate.
(10) A fixed water-spray system should be provided for diluting and washing away any concentrated hydrogen peroxide solution spilled on deck. The areas covered by the water-spray should include the manifold/hose connections and the tank tops of those tanks designated for carrying hydrogen peroxide solutions. The minimum application rate should satisfy the following criteria:
  (a) The product should be diluted from the original concentration to 35 % by weight within 5 min of the spill.
  (b) The rate and estimated size of the spill should be based upon maximum anticipated loading and discharge rates, the time required to stop flow of cargo in the vent of tank overfill or a piping/hose failure, and the time necessary to begin application of dilution water with actuation at the cargo control location or on the navigating bridge.
(11) Only those hydrogen peroxide solutions which have a maximum decomposition rate of 1 % per year at 25°C should be carried. Certification from the shipper that the product meets this standard should be presented to the master and kept on board. A technical representative of the manufacturer should be on board to monitor the transfer operations and have the capability tc test the stability of the peroxide. He should certify to the master that the cargo has been loaded in a stable condition.
(12) Protective clothing that is resistant to hydrogen peroxide solutions should be provided for each crew member involved in cargo transfer operations. Protective clothing should include nonflammable coveralls, suitable gloves, boots and eye protection.

2. Hydrogen peroxide solutions over 8 % but not over 60 % by weight

(1) The ship's shell plating should not form any boundaries of tanks containing this product.
(2) Hydrogen peroxide should be carried in tanks thoroughly and effectively cleaned of all traces of previous cargoes and their vapours or ballast. Procedures for inspection, cleaning, passivation and loading of tanks should be in accordance with MSC/Circ. 394. A certificate should be on

board the vessel indicating that the procedures in the circular have been followed. The passivation requirement may be waived by the Society for domestic shipments of short duration. Particular care in this respect is essential to ensure the safe carriage of hydrogen peroxide.
(a) When hydrogen peroxide is carried no other cargoes should be carried simultaneously.
(b) Tanks which have contained hydrogen peroxide may be used for other cargoes after cleaning in accordance with the procedures outlined in MSC/Circ. 394.
(c) Consideration in design should provide minimum internal tank structure, free draining, no entrapment and ease of visual inspection.

(3) Cargo tanks and associated equipment should be either pure aluminium (99.5 %) or solid stainless steel of types suitable for use with hydrogen peroxide (e.g. 304, 304 L, 316, 316 L, 316 Ti). Aluminium should not be used for piping on deck. All nonmetallic materials of construction for the containment system should neither be attacked by hydrogen peroxide nor contribute to its decomposition.

(4) Cargo tanks should be separated by a cofferdam from fuel oil tanks or any other space containing materials incompatible with hydrogen peroxide.

(5) Temperature sensors should be installed at the top and bottom of the tank. Remote temperature readouts and continuous monitoring should be located on the navigating bridge. If the temperature in the tank rises above 35°C, visible and audible alarms should activate on the navigating bridge.

(6) Fixed oxygen monitors (or gas-sampling lines) should be provided in void spaces adjacent to tanks to detect leakage of the cargo into these spaces. The enhancement of flammability by oxygen enrichments should be recognized. Remote readouts, continuous monitoring (if gas-sampling lines are used, intermittent sampling is satisfactory) and visible and audible alarms similar to those for the temperature sensors should also be located on the navigating bridge. The visible and audible alarms should activate if the oxygen concentration in these void spaces exceeds 30 % by volume. Two portable oxygen monitors should also be available as back-up systems.

(7) As a safeguard against uncontrolled decomposition, a cargo jettisoning system should be installed to discharge the cargo overboard. The cargo should be jettisoned if the temperature rise of the cargo exceeds a rate of 2°C per hour over a five-hour period or when the temperature in the tank exceeds 40°C.

(8) Cargo tank venting systems with filtration should have pressure/vacuum relief valves for normal controlled venting, and a device for emergency venting, should have for tank pressure rise rapidly as a result of an uncontrolled decomposition rate, as stipulated in (7). These venting systems should be designed in such a manner that there is no introduction of seawater into the cargo tank even under heavy sea conditions. Emergency venting should be sized on the basis of tank design pressure and tank size.

(9) A fixed water-spray system should be provided for diluting and washing away any concentrated solution spilled on deck. The areas covered by the water-spray should include the manifold/hose connections and the tank tops of those tanks designated for the carriage of hydrogen peroxide solutions. The minimum application rate should satisfy the following criteria:
(a) The product should be diluted from the original concentration to 35 % by weight within 5 minutes of the spill.
(b) The rate and estimated size of the spill should be based upon maximum anticipated loading and discharge rates, the time required to stop flow of the cargo in the event of tank overfill or a piping/hose failure, and the time necessary to begin application of dilution water with actuation at the cargo control location or on the navigating bridge.

(10) Only those hydrogen peroxide solutions which have a maximum decomposition rate of 1 % per year at 25°C should be carried. Certification from the shipper that the product meets this standard should be presented to the master and kept on board. A technical representative of the manufacturer should be on board to monitor the transfer operations and have the capability to test the stability of the hydrogen peroxide. He should certify to the master that the cargo has been loaded in a stable condition.

(11) Protective clothing that is resistant to hydrogen peroxide should be provided for each crew member involved in cargo transfer operations. Protective clothing should include coveralls that are nonflammable, suitable gloves, boots and eye protection.

(12) During transfer of hydrogen peroxide the related piping system should be separated from all other systems. Cargo hoses used for transfer of hydrogen peroxide should be marked "FOR HYDROGEN PEROXIDE TRANSFER ONLY".

3. Procedures for inspection, cleaning, passivation and loading of tanks for the carriage of hydrogen peroxide solutions 8-60%, which have contained other cargoes, or for the carriage of other cargoes after carriage of hydrogen peroxide.

(1) Tanks having contained cargoes other than hydrogen peroxide shall be inspected, cleaned and passivated before re-use for the transport of hydrogen peroxide solutions. The procedures for inspection and cleaning, as given in paragraphs (2) to (8) below, apply to both stainless steel and pure aluminium tanks (see paragraph 2.(2)). Procedures for passivation are given in paragraph (9) for stainless steel and (10) for aluminium. Unless otherwise specified, all steps apply to the tanks and to all associated equipment having been in contact with the other cargo.

(2) After unloading the previous cargo the tank shall be rendered safe and inspected for any residues, scale and rust.

(3) Tanks and associated equipment shall be washed with clean filtered water. The water to be used shall at least have the quality of potable water with a low chlorine content.

(4) Trace residues and vapours of the previous cargo shall be removed by steaming of tank and equipment.

(5) Tank and equipment are washed again with clean water (quality as above) and dried, using filtered, oil-free air.

(6) The atmosphere in the tank shall be sampled and investigated for the presence of organic vapours and oxygen concentration.

(7) The tank shall be checked again by visual inspection for residues of the previous cargo, scale and rust as well as for any smell of the previous cargo.

(8) If inspection or measurements indicate the presence of residues of the previous cargo or its vapours, actions described in paragraphs (3) to (5) shall be repeated.

(9) Tank and equipment made from stainless steel which have contained other cargoes than hydrogen peroxide or which have been under repair shall be cleaned and passivated, regardless of any previous passivation, according to the following procedure:

(a) New welds and other repaired parts shall be cleaned and finished using stainless steel wire brush, chisel, sandpaper or buff. Rough surfaces shall be given a smooth finish. A final polishing is necessary.

(b) Fatty and oily residues shall be removed by the use of appropriate organic solvents or detergent solutions in water. The use of chlorine-containing compounds shall be avoided as they can seriously interfere with passivation.

(c) The residues of the degreasing agent shall be removed, followed by a washing with water.

(d) In the next step, scale and rust shall be removed by the application of acid (e.g. a mixture of nitric and hydrofluoric acids), followed again by a washing with clean water.

(e) All the metal surfaces which can come into contact with hydrogen peroxide shall be passivated by the application of nitric acid of a concentration between 10 and 35% by mass. The nitric acid must be free from heavy metals, other oxidizing agents or hydrogen fluoride. The passivation process shall continue for 8 to 24 h, depending upon the concentration of acid, the ambient temperature and other factors. During this time a continuous contact between the surfaces to be passivated and the nitric acid shall be ensured. In the case of large surfaces this may be achieved by recirculating the acid. Hydrogen gas may be evolved in the passivation process, leading to the presence of an explosive atmosphere in the tanks. Therefore, appropriate measures must be taken to avoid the build-up or the ignition of such an atmosphere.

(f) After passivation the surfaces shall be thoroughly washed with clean filtered water. The washing process shall be repeated until the effluent water has the same pH value as the incoming water.

(g) Surfaces treated according to the above steps may cause some decomposition when coming into contact with hydrogen peroxide for the first time. This decomposition will cease after a short time (usually within two or three days). Therefore an additional flushing with hydrogen peroxide for a period of at least two days is recommended.

(h) Only degreasing agents and acid cleaning agents which have been recommended for this purpose by the manufacturer of the hydrogen peroxide shall be used in the process.

(10) Tanks and equipment made from aluminium and which have contained cargoes other than hydrogen peroxide, or which have been under repair, shall be cleaned and passivated. The following is an example of a recommended procedure:

(a) The tank shall be washed with a solution of a sulphonated detergent in hot water, followed by a washing with water.

(b) The surface shall then be treated for 15 to 20 min with a solution of sodium hydroxide of a concentration of 7% by mass or treated for a longer period with a less concentrated solution (e.g. for 12 h with 0.4 to 0.5% sodium hydroxide). To prevent excessive corrosion at the bottom of the tank when treating with more concentrated solutions of sodium hydroxide, water shall be added continuously to dilute the sodium hydroxide solution which collects there.

(c) The tank shall be thoroughly washed with clean, filtered water. As soon as possible after washing, the surface shall be passivated by the application of nitric acid of a concentration between 30 and 35% by mass. The passivation process shall continue for 16 to 24 h. During this time a continuous contact between the surfaces to be passivated and the nitric acid shall be ensured.

(d) After passivation the surfaces shall be thoroughly washed with clean, filtered water. The washing process shall be repeated until the effluent water has the same pH value as the incoming water.

(e) A visual inspection shall be made to ensure that all surfaces have been treated. It is recommended that an additional flushing is carried out for a minimum of 24 h with dilute hydrogen peroxide solution of a concentration approximately 3% by mass.

(11) The concentration and stability of the hydrogen peroxide solution to be loaded shall be determined.

(12) The hydrogen peroxide is loaded under intermittent visual supervision of the interior of the tank from an appropriate opening.

(13) If substantial bubbling is observed which does not disappear within 15 min after the completion of loading, the contents of the tank shall be unloaded and disposed of in an environmentally safe manner. The tank and equipment shall then be repassivated as described above.

(14) The concentration and stability of the hydrogen peroxide solution shall be determined again. If the same values are obtained within the limits of error as in paragraph (10), the tank is considered to be properly passivated and the cargo ready for shipment.

(15) Actions described in paragraphs (2) to (8) shall be carried out under the supervision of the master or shipper. Actions described in paragraphs (9) to (15) shall be carried out under the on-site supervision and responsibility of a representative of the hydrogen peroxide manufacturer or under supervision and responsibility of another person familiar with the safety-relevant properties of hydrogen peroxide.

(16) The following procedure shall be applied when tanks having contained hydrogen peroxide solution are to be used for other products (unless otherwise specified, all steps apply to the tanks and to all associated equipment having been in contact with hydrogen peroxide):

(a) Hydrogen peroxide cargo residue shall be drained as completely as possible from tanks and equipment.

(b) Tanks and equipment shall be rinsed with clean water, and subsequently thoroughly washed with clean water.

(c) The interior of the tank shall be dried and inspected for any residues. Steps (a) to (c) in (16), shall be carried out under the supervision of the master or the shipper. Step (c) in paragraph (16) shall be carried out by a person familiar with the safety-relevant properties of the chemical to be transported and of hydrogen peroxide.

SPECIAL CAUTIONS :

(1) Hydrogen peroxide decomposition may enrich the atmosphere with oxygen and appropriate precautions shall be observed.

(2) Hydrogen gas may be evolved in the passivation processes described in paragraphs (9)(e), (10)(b) and (10)(d), leading to the presence of an explosive atmosphere in the tank. Therefore, appropriate measures must be taken to avoid the build-up or the ignition of such an atmosphere.

1506. Motor fuel anti-knock compounds (containing lead alkyls) (IBC Code 15.6)

1. Tanks used for these cargoes should not be used for the transportation of any other cargo except those commodities to be used in the manufacturer of motor fuel anti-knock compounds containing lead alkyls.

2. If a cargo pump room is located on deck level according to **1518.,** the ventilation arrangements should be in compliance with **1517.**

3. Entry into cargo tanks used for the transportation of these cargoes is not permitted unless approved by the Society.

4. Air analysis should be made for lead content to determine if the atmosphere is satisfactory prior to allowing personnel to enter the cargo pump room or void spaces surrounding the cargo tank.

1507. Phosphorus, yellow or white (IBC Code 15.7)

1. Phosphorus should, at all times, be loaded, carried and discharged under a water pad of 760 mm minimum depth. During discharge operations, arrangements should be made to ensure that water occupies the volume of phosphorus discharged. Any water discharged from a phosphorus tank should be returned only to a shore installation.

2. Tanks should be designed and tested to a minimum equivalent water head of 2.4 m above the top of the tank, under designed loading conditions, taking into account the depth, relative density and method of loading and discharge of the phosphorus.

3. Tanks should be so designed as to minimize the interfacial area between the liquid phosphorus and its water pad.

4. A minimum ullage space of 1 % should be maintained above the water pad. The ullage space should be filled with inert gas or naturally ventilated by two cowled standpipes terminating at different heights but at least 6 m above the deck and at least 2 m above the pump house top.

5. All openings should be at the top of cargo tanks, and fittings and joints attached thereto should be of materials resistant to phosphorus pentoxide.

6. Phosphorus should be loaded at a temperature not exceeding 60°C.

7. Tank heating arrangements should be external to tank and have a suitable method of temperature control to ensure that the temperature of the phosphorus does not exceed 60°C. A high-temperature alarm should be fitted.

8. A water drench system acceptable to the Society should be installed in all void spaces surrounding the tanks. The system should operate automaticatly in the event of an escape of phosphorus.

9. Void spaces referred to in **Par 8** should be provided with effective means of mechanical ventilation which should be capable of being sealed off quickly in an emergency.

10. Loading and discharge of phosphorus should be governed by a central system on the ship which, in addition to incorporating high-level alarms, should ensure that no overflow of tanks is possible and that such operations can be stopped quickly in an emergency from either ship or shore.

11. During cargo transfer, a water hose on deck should be connected to a water supply and kept flowing throughout the operation so that any spillage of phosphorus may be washed down with water immediately.

12. Ship-to-shore loading and discharge connections should be of a type approved by the Society.

1508. Propylene oxide and mixtures of ethylene oxide/propylene oxide with an ethylene oxide content of not more than 30 % by weight (IBC Code 15.8)

1. Products transported under the provisions of this Article should be acetylene-free.

2. Unless cargo tanks are properly cleaned, these products should not be carried in tanks which have contained as one of the three previous cargoes any products known to catalyse polymerization, such as:

(1) mineral acids (e.g. sulphuric, hydrochloric, nitric);
(2) carboxylic acids and anhydrides (e.g. formic, acetic);
(3) halogenated carboxylic acids (e.g. chloracetic);
(4) sulphonic acids (e.g. benzene sulphonic);
(5) caustic alkalis (e.g. sodium hydroxide, potassium hydroxide);
(6) ammonia and ammonia solutions;
(7) amines and amine solutions;

(8) oxidizing substances.

3. Before loading, tanks should be thoroughly and effectively cleaned, to remove all traces of previous cargoes from tanks and associated pipework, except where the immediately prior cargo has been propylene oxide or ethylene oxide/propylene oxide mixtures. Particular care should be taken in the case of ammonia in tanks made of steel other than stainless steel.

4. In all cases, the effectiveness of cleaning procedures for tanks and associated pipework should be checked by suitable testing or inspection to ascertain that no traces of acidic or alkaline materials remain that might create a hazardous situation in the presence of these products.

5. Tanks should be entered and inspected prior to each initial loading of these products to ensure freedom from contamination, heavy rust deposits and visible structural defects. When cargo tanks are in continuous service for these products, such inspections should be performed at intervals of not more than 2 years.

6. Tanks for the carriage of these products should be of steel or stainless steel construction.

7. Tanks for the carriage of these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

8. All valves, flanges, fittings and accessory equipment should be of a type suitable for use with the products and should be constructed of steel or stainless steel in accordance with recognized standards. Discs or disc faces, seats and other wearing parts of valves should be made of stainless steel containing not less than 11 % chromium.

9. Gaskets should be constructed of materials which do not react with, dissolve in, or lower the autoignition temperature of these products and which are fire-resistant and possess adequate mechanical behaviour. The surface presented to the cargo should be polytetrafluoroethylene (PTFE), or materials giving a similar degree of safety by their inertness. Spirally wound stainless steel with a filler of PTFE or similar fluorinated polymer may be accepted.

10. Insulation and packing, if used, should be of a material which does not react with, dissolve in, or lower the autoignition temperature of these products.

11. The following materials and generally found unsatisfactory for gaskets, packing and similar uses in containment systems for these products and would require testing before being approved by the Society:

(1) Neoprene or nature rubber, if it comes into contact with the products.
(2) Asbestos, or binders used with asbestos.
(3) Materials containing oxides of magnesium, such as mineral wools.

12. Threaded joints should not be permitted in the cargo liquid and vapour lines.

13. Filling and discharge piping should extend to within 100 mm of the bottom of the tank or any sump pit.

14. The containment system for a tank containing these products should have a valved vapour return connection.

15. The products should be loaded and discharged in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product should be independent of all other containment systems.

16. During discharge operations, the pressure in the cargo tank should be maintained above 0.007 MPa gauge.

17. Tanks carrying these products should be vented independently of tanks carrying other products. Facilities should be provided for sampling the tank contents without opening the tank to atmosphere.

18. The cargo should be discharged only by deepwell pumps, hydraulically operated submerged pumps, or inert gas displacement. Each cargo pump should be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.

19. Cargo hoses used for transfer of these products should be marked **"FOR ALKYLENE OXIDE TRANSFER ONLY"**.

20. Cargo tanks, void spaces and other enclosed spaces, adjacent to an integral gravity cargo tank carrying propylene oxide, should either contain a compatible cargo (those cargoes specified in **Par 2** are examples of substances considered incompatible) or be inerted by injection of a suitable inert gas. Any hold space in which an independent cargo tank is located should be inerted. Such inerted spaces and tanks should be monitored for these products and oxygen. Portable sampling equipment is satisfactory. The oxygen content of these spaces should be maintained below 2 %.

21. In no case should air be allowed to enter the cargo pump or piping system while these products are contained within the system.

22. Prior to disconnecting shore-lines, the pressure in liquid and vapour lines should be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines should not be discharged to atmosphere.

23. Propylene oxide may be carried in pressure tanks or in independent or integral gravity tanks. Ethylene oxide/propylene oxide mixtures should be carried in independent gravity tanks or pressure tanks. Tanks should be designed for the maximum pressure expected to be encountered during loading, conveying and discharging cargo.

24. Tanks for the carriage of propylene oxide with a design pressure less than 0.06 MPa gauge and tanks for the carriage of ethylene oxide/propylene oxide mixtures with a design pressure less than 0.12 MPa gauge should have a cooling system to maintain the cargo below the reference temperature.

25. The refrigeration requirement for tanks with a design pressure less than 0.06 MPa gauge may be waived by the Society for ships operating in restricted areas or on voyages of restricted duration, and account may be taken in such cases of any insulation of the tanks. The area and times of year for which such carriage would be permitted should be included in the conditions of carriage on the International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk.

26. Any cooling system should maintain the liquid temperature below the boiling temperature at the containment pressure. At least two complete cooling plants automatically regulated by variations within the tanks should be provided. Each cooling plant should be complete with the necessary auxiliaries for proper operation. The control system should also be capable of being manually operated. An alarm should be provided to indicate malfunctioning of the temperature controls. The capacity of each cooling system should be sufficient to maintain the temperature of the liquid cargo below the reference temperature of the system.

27. An alternative arrangement may consist of three cooling plants, any two of which should be sufficient to maintain the liquid temperatures below the reference temperature.

28. Cooling media which are separated from the products by a single wall only should be nonreactive with the products.

29. Cooling systems requiring compression of the products should not be used.

30. Pressure relief valve settings should not be less than 0.02 MPa gauge and for pressure tanks not greater than 0.7 MPa gauge for the carriage of propylene oxide and not greater than 0.53 MPa gauge for the carriage of propylene oxide/ethylene oxide mixtures.

31. The piping system for tanks to be loaded with these products should be separated from piping systems for all other tanks, including empty tanks. If the piping system for the tanks to be loaded is not independent, the required piping separation should be accomplished by the removal of spool pieces, valves, or other pipe sections, and the installation of blank flanges at these locations. The required separation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connections, such as common inert gas supply lines.

32. These products may be transported only in accordance with cargo handling plans that have been approved by the Society. Each intended loading arrangement should be shown on a separate cargo handling plan. Cargo handling plans should show the entire cargo piping system and the locations for installation of blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan should be maintained on board the ship. The International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk should be endorsed to include reference to the approved cargo handling plans.

33. Before each initial loading of these products and before every subsequent return to such service, certification verifying that the required piping separation has been achieved should be obtained from a responsible person acceptable to the port Administration and carried on board the ship. Each connection between a blank flange and a pipeline flange should be fitted with a wire and seal by the responsible person to ensure that inadvertent removal of the blank flange is impossible.

34. (1) No cargo tanks should be more than 98 % liquid-full at the reference temperature.

(2) The maximum volume (V_L) of cargo to be loaded in a tank should be:

$$V_L = 0.98\,V\frac{\rho_R}{\rho_L}$$

where

V = volume of the tank

ρ_R = relative density of cargo at the reference temperature.

ρ_L = relative density of cargo at the loading temperature and pressure.

(3) The maximum allowable tank filling limits for each cargo tank should be indicated for each loading temperature which may be applied, and for the applicable maximum reference temperature, on a list to be approved by the Society. A copy of the list should be permanently kept on board by the master.

35. The cargo should be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system should be installed to prevent the tank pressure falling below 0.07 MPa gauge in the event of product temperature fall due to ambient conditions or maloperation of refrigeration systems. Sufficient nitrogen should be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99.9 % by volume) should be used for padding. A battery of nitrogen bottles connected to the cargo tanks through a pressure reduction valve satisfies the intention of the expression "automatic" in this context.

36. The cargo tank vapour space should be tested prior to and after loading to ensure that the oxygen content is 2 % by volume or less.

37. A water-spray system of sufficient capacity should be provided to blanket effectively the area surrounding the loading manifold, the exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles should be such as to give a uniform distribution rate of 10 l/min per square metre. Remote manual operation should be arranged such that remote starting of pumps supplying the water- spray system and remote operation of any normally closed valves in the system can be carried out from a suitable location outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected. The water-spray system should be capable of both local and remote manual operation and the arrangement should ensure that any spilled cargo is washed away. Additionally, a water hose with pressure to the nozzle, when atmospheric temperatures permit, should be connected ready for immediate use during loading and unloading operations.

38. A remotely operated, controlled closing-rate, shutoff valve should be provided at each cargo hose connection used during cargo transfer.

1509. Sodium chlorate solution, 50 % or less (IBC Code 15.9)

1. Tanks and associated equipment which have contained this product may be used for other cargoes after thorough cleaning by washing or purging.

2. In the event of spillage of this product, all spilled liquid should be thoroughly washed away without delay. To minimize fire risk, spillage should not be allowed to dry out.

1510. Sulphur, Molten (IBC Code 15.10)

1. Cargo tank ventilation should be provided to maintain the concentration of hydrogen sulphide below one half of its lower explosive limit throughout the cargo tank vapour space for all conditions of carriage, i.e. below 1.85 % by volume.

2. Where mechanical ventilation systems are used for maintaining low gas concentrations in cargo tanks, an alarm system should be provided to give warning if the system fails.

3. Ventilation systems should be so designed and arranged as to preclude depositing of sulphur within the system.

4. Openings to void spaces adjacent to cargo tanks should be so designed and fitted as to prevent the entry of water, sulphur or cargo vapour.

5. Connections should be provided to permit sampling and analysing of vapour in void spaces.

6. Cargo temperature controls should be provided to ensure that the temperature of the sulphur does not exceed 155°C.

7. Sulphur (molten) has a flashpoint above 60°C : however, electrical equipment shall be certificated safe for gases evolved.

1511. Acids (IBC Code 15.11)

1. The ship's shell plating should not form any boundaries of tanks containing mineral acids.

2. Proposals for lining steel tanks and related piping systems with corrosion-resistant materials may be considered by the Society. The elasticity of the lining should not be less than that of the supporting boundary plating.

3. Unless constructed wholly of corrosion-resistant materials or fitted with an approved lining, the plating thickness should take into account the corrosivity of the cargo.

4. Flanges of the loading and discharge manifold connections should be provided with shields, which may be portable, to guard against the danger of the cargo being sprayed; and in addition, drip trays should also be provided to guard against leakage on to the deck.

5. Because of the danger of evolution of hydrogen when these substances are being carried, the electrical arrangements should comply with **1001.4.** The certified safe type equipment should be suitable for use in hydrogen-air mixtures. Other sources of ignition should not be permitted in such spaces.

6. Substances subjected to the requirements of this Article should be segregated from oil fuel tanks, in addition to the segregation requirements in **301. 1.**

7. Provision should be made for suitable apparatus to detect leakage of cargo into adjacent spaces.

8. The cargo pump room bilge pumping and drainage arrangements should be of corrosion-resistant materials.

1512. Toxic products (IBC Code 15.12)

1. Exhaust openings of tank vent systems should be located:

(1) at a height of $B/3$ or 6 m, whichever is greater, above the weather deck or, in the case of a deck tank, the access gangway;
(2) not less than 6 m above the fore-and-aft gangway, if fitted within 6 m of the gangway; and
(3) 15 m from any opening or air intake to any accommodation and service spaces;
(4) the vent height may be reduced to 3 m above the deck or fore-and-aft gangway, as applicable, provided high-velocity vent valves of a type approved by the Society, directing the vapour-air mixture upwards in an unimpeded jet with an exit velocity of at least 30 m/s, are fitted.

2. Tank venting systems should be provided with a connection for a vapour return line to the shore installation.

3. Products should:

(1) not be stowed adjacent to oil fuel tanks;
(2) have separate piping systems; and
(3) have tank vent systems separate from tanks containing nontoxic products. (see also **307. 2**)

4. Cargo tank relief valve settings should be a minimum of 0.02 MPa gauge.

1513. Cargoes protected by additives (IBC Code 15.13)

1. Certain cargoes with a reference in column "o" in the table of **Sec 17** by the nature of their chemical make-up, tend, under certain conditions of temperature, exposure to air or contact with a catalyst, to undergo polymerization, decomposition, oxidation or other chemical changes. Mitigation of this tendency is carried out by introducing small amounts of chemical additives into the liquid cargo or by controlling the cargo tank environment.

2. Ships carrying these cargoes should be so designed as to eliminate from the cargo tanks and cargo handling system any material of construction or contaminants which could act as a catalyst or destroy the inhibitor.

3. Care should be taken to ensure that these cargoes are sufficiently protected to prevent deleterious chemical change at all times during the voyage. Ships carrying such cargoes should be provided with a certificate of protection from the manufacturer and kept during the voyage specifying:

(1) the name and amount of additive present;
(2) whether the additive is oxygen dependent;
(3) date additive was put in the product and duration of effectiveness;
(4) any temperature limitations qualifying the additives" effective lifetime; and
(5) the action to be taken should the length of voyage exceed the effective lifetime of the additives.

4. Ships using the exclusion of air as the method of preventing oxidation of the cargo should comply with **901. 3.**

5. A product containing an oxygen dependent additive should be carried without inertion (in tanks of a size not greater than 3,000 m^3). Such cargoes should not be carried in a tank requiring inertion under the requirements of **SOLAS** chapter II-2.

6. Venting systems should be of a design that eliminates blockage from polymer build-up. Venting equipment should be of a type that can be checked periodically for adequacy of operation.

7. Crystallization or solidification of cargoes normally carried in the molten state can lead to depletion of inhibitor in parts of the tank contents. Subsequent remelting can thus yield pockets of uninhibited, liquid with the accompanying risk of dangerous polymerization. To prevent this, care should be taken to ensure that at no time are such cargoes allowed to crystallize or solidify, either wholly or partially, in any part of the tank. Any required heating arrangements should be such as to ensure that in no part of the tank does cargo become overheated to such an extent that any dangerous polymerization can be initiated. If the temperature from steam coils would induce overheating, an indirect low-temperature heating system should be used.

1514. Cargoes with a vapour pressure greater than 0.1013 MPa absolute at 37.8°C (IBC Code 15.14)

1. For a cargo referenced in column "o" in the table of **Sec 17** to this Article, a mechanical refrigeration system should be provided unless the cargo system is designed to withstand the vapour pressure of the cargo at 45°C. Where the cargo system is designed to withstand the vapour pressure of the cargo at 45°C, and no refrigeration system is provided, a notation should be made in the conditions of carriage on the International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk to indicate the required relief valve setting for the tanks.

2. A mechanical refrigeration system should maintain the liquid temperature below the boiling temperature at the cargo tank design pressure.

3. When ships operate in restricted areas and at restricted times of the year, or on voyages of limited duration, the Society involved may agree to waive requirements for a refrigeration system. A notation of any such agreement, listing geographic area restrictions and times of the year, or voyage duration limitations, should be included in the conditions of carriage on the International Certificate for the Carriage of Dangerous Chemicals in Bulk.

4. Connections should be provided for returning expelled gases to shore during loading.

5. Each tank should be provided with a pressure gauge which indicates the pressure in the vapour space above the cargo.

6. Where the cargo needs to be cooled, thermometers should be provided at the top and bottom of each tank.

7. (1) No cargo tanks should be more than 98 % liquid-full at the reference temperature (R).

(2) The maximum volume (V_L) of cargo to be loaded in a tank should be:

$$V_L = 0.98\,V\frac{\rho_R}{\rho_L}$$

where

V = volume of the tank

ρ_R = relative density of cargo at the reference temperature (R)

ρ_L = relative density of cargo at the loading temperature

R = reference temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valve.

(3) The maximum allowable tank filling limits for each cargo tank should be indicated for each loading temperature which may be applied, and for the applicable maximum reference temperature, on a list approved by the Society. A copy of the list should be permanently kept on board by the master.

1515. Cargoes with low ignition temperature and wide flammability range (IBC Code 15.15)

Deleted.

1516. Cargo contamination (IBC Code 15.16)

1. Where column "o" in the table of **Sec 17** refers to this Article, water should not be allowed to contaminate this cargo. In addition, the following provisions apply:

(1) Air inlets to pressure/vacuum relief valves of tanks containing the cargo should be situated at least 2 m above the weather deck.

(2) Water or steam should not be used as the heat transfer media in a cargo temperature control system required by **Sec 7.**

(3) The cargo should not be carried in cargo tanks adjacent to permanent ballast or water tanks unless the tanks are empty and dry.

(4) The cargo should not be carried in tanks adjacent to slop tanks or cargo tanks containing ballast or slops or other cargoes containing water which may react in a dangerous manner. Pumps, pipes or vent lines serving such tanks should beseparate from similar equipment serving tanks containing the cargo. Pipelines from slop tanks or ballast lines should not pass through tanks containing the cargo unless encased in a tunnel.

1517. Increased ventilation requirements (IBC Code 15.17)

For certain products, the ventilation system as described in **1201.3** should have a minimum capacity of at least 45 changes of air per hour based upon the total volume of space. The ventilation system exhaust ducts should discharge at least 10 m away from openings into accommodation spaces, work areas or other similar spaces, and intakes to ventilation systems, and at least 4 *m* above the tank deck.

1518. Special cargo pump room requirements (IBC Code 15.18)

For certain products, the cargo pump room should be located on the deck level or cargo pumps should be located in the cargo tank. The Society may give special consideration to cargo pump rooms below deck.

1519. Overflow control (IBC Code 15.19)

1. The provisions of this Article are applicable where specific reference is made in column "o" in the table of **Sec 17,** and are in addition to the requirements for gauging devices.

2. In the event of a power failure on any system essential for safe loading, an alarm should be given to the operators concerned.

3. Loading operations should be terminated at once in the event of any system essential for safe loading becoming inoperative.

4. Level alarms should be capable of being tested prior to loading.

5. The high-level alarm system required under **Par 6** should be independent of the overflow control system required by **Par 7** and should be independent of the equipment required by **1301.**

6. Cargo tanks should be fitted with a visual and audible high-level alarm which complies with **Pars 1** to **5** and which indicates when the liquid level in the cargo tank approaches the normal full condition.

7. A tank overflow control system required by this Article should:

(1) come into operation when the normal tank loading procedures fail to stop the tank liquid level exceeding the normal full condition;
(2) give a visual and audible tank overflow alarm to the ship's operator; and
(3) provide an agreed signal for sequential shutdown of onshore pumps or valves or both and of the ship's valves. The signal, as well as the pump and valve shutdown, may be dependent on operator's intervention. The use of shipboard automatic closing valves should be permitted only when specific approval has been obtained from the Society and the port Administrations concerned.

8. The loading rate (LR) of the tank should not exceed:

$$LR = \frac{3{,}600\,U}{t} \quad (\mathrm{m^3/h})$$

where

U = ullage volume ($\mathrm{m^3}$) at operating signal level;

t = time (s) needed from the initiating signal to fully stopping the cargo flow into the tank, being the sum of times needed for each step in sequential operations such as operator's responses to signals, stopping pumps and closing valves; and should also take into account the pipeline system design pressure.

1520. Alkyl(C_7–C_9) nitrates, all isomers (IBC Code 15.20)

1. The carriage temperature of the cargo should be maintained below 100°C to prevent the occurrence of a self-sustaining, exothermic decomposition reaction.

2. The cargo may not be carried in independent pressure vessels permanently affixed to the vessel's deck unless:

(1) the tanks are sufficiently insulated from fire; and

(2) the vessel has a water deluge system for the tanks such that the cargo temperature is maintained below 100°C and the temperature rise in the tanks does not exceed 1.5°C/hour for a fire of 650°C (1200°F).

1521. Temperature sensors (IBC Code 15.21)

Temperature sensors should be used to monitor the cargo pump temperature to detect overheating due to pump failures.

Section 16 Operational Requirements

1601. Maximum allowable quantity of cargo per tank (IBC Code 16.1)

1. The quantity of a cargo required to be carried in a type 1 ship should not exceed 1,250 m^3 in any one tank.

2. The quantity of a cargo required to be carried in a type 2 ship should not exceed 3,000 m^3 in any one tank.

3. Tanks carrying liquids at ambient temperatures should be so loaded as to avoid the tank becoming liquid-full during the voyage, having due regard to the highest temperature which the cargo may reach.

1602. Cargo information (IBC Code 16.2)

1. A copy of this Chapter, or national regulations incorporating the provisions of this Chapter, should be on board every ship covered by this Chapter.

2. Any cargo offered for bulk shipment shall be indicated in the shipping documents by the product name, under which it is listed in Sec 17 or 18 or the latest edition of MEPC.2/Circ. or under which it has been provisionally assessed. Where the cargo is a mixture, an analysis indicating the dangerous components contributing significantly to the total hazard of the product shall be provided, or a complete analysis if this is available. Such an analysis shall be certified by the manufacturer or by an independent expert acceptable to the Society.

3. Information should be on board, and available to all concerned, giving the necessary data for the safe carriage of the cargo. Such information should include a cargo stowage plan to be kept in an accessible place, indicating all cargo on board, including each dangerous chemical carried:

(1) a full description of the physical and chemical properties, including reactivity necessary for the safe containment of the cargo;
(2) action to be taken in the event of spills or leaks;
(3) countermeasures against accidental personal contact;
(4) fire-fighting procedures and fire-fighting media;
(5) procedures for cargo transfer, tank cleaning, gas-freeing and ballasting;
(6) for those cargoes required to be stabilized or inhibited in accordance with **1501., 1505. 1** (11) or **1513. 3,** the cargo should be refused if the certificate required by these paragraphs is not supplied.

4. If sufficient information necessary for the safe transportation of the cargo is not available, the cargo should be refused.

5. Cargoes which evolve highly toxic imperceptible vapours should not be transported unless perceptible additives are introduced into the cargo.

6. Where column "o" in the table of **Sec 17** refers to this paragraph, the cargo's viscosity at 20°C shall be specified on a shipping document and if the cargo's viscosity exceeds 50mPa·s at 20°C, the temperature at which the cargo has a viscosity of 50mPa·s shall be specified in the shipping document.

7. Where column "o" in the table of **Sec 17** refers to this paragraph, the cargo's melting point shall be indicated in the shipping document.

1603. Personnel training (IBC Code 16.3)

1. All personnel should be adequately trained in the use of protective equipment and have basic training in the procedures appropriate to their duties, necessary under emergency conditions.

2. Personnel involved in cargo operations should be adequately trained in handling procedures.

3. Officers shall be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo, based on the guidelines developed by IMO, and a sufficient number of them shall be instructed and trained in essential first aid for cargoes carried, based on the guidelines developed by the IMO. Refer to the Medical First Aid Guide for use in Accident involving Dangerous Goods (MFAG), which provides advice on the treatment of casualties in accordance with the symptoms exhibited as well as equipment and antidotes that may be appropriate for treating the casulity and to the relevant provisions of the STCW Code, part A and B.

1604. Opening of and entry into cargo tanks (IBC Code 16.4)

1. During handling and carriage of cargoes producing flammable or toxic vapours, or both, or when ballasting after the discharge of such cargo, or when loading or unloading cargo, cargo tank lids should always be kept closed. With any hazardous cargo, cargo tank lids, ullage and sighting ports and tank washing access covers should be open only when necessary.

2. Personnel should not enter cargo tanks, void spaces around such tanks, cargo handling spaces or other enclosed spaces unless:

(1) the compartment is free of toxic vapours and not deficient in oxygen; or
(2) personnel wear breathing apparatus and other necessary protective equipment, and the entire operation is under the close supervision of a responsible officer.

3. Personnel should not enter such spaces when the only hazard is of a purely flammable nature, except under the close supervision of a responsible officer.

1605. Stowage of cargo samples (IBC Code 16.5)

1. Samples which have to be kept on board should be stowed in a designated space situated in the cargo area or, exceptionally, elsewhere, subject to the approval of the Society.

2. The stowage space should be:

(1) cell-divided in order to avoid shifting of the bottles at sea;
(2) made of material fully resistant to the different liquids intended to be stowed; and
(3) equipped with adequate ventilation arrangements.

3. Samples which react with each other dangerously should not be stowed close to each other.

4. Samples should not be retained on board longer than necessary.

1606. Cargoes not to be exposed to excessive heat (IBC Code 16.6)

1. Where the possibility exists of a dangerous reaction of a cargo such as polymerization, decomposition, thermal instability or evolution of gas, resulting from local overheating of the cargo in either the tank or associated pipelines, such cargo should be loaded and carried adequately segregated from other products whose temperature is sufficiently high to initiate a reaction of such cargo (see **701. 5**(4)).

2. Heating coils in tanks carrying this product should be blanked off or secured by equivalent means.

3. Heat-sensitive products should not be carried in deck tanks which are not insulated.

4. In order to avoid elevated temperatures, this cargo should not be carried in deck tanks.

Section 17 Summary of Minimum Requirements

1. The list of the products applied to this Section shall refer to the summary of minimum requirements in chapter 17 of the IBC Code, as amended, which shall be in accordance with the guidances specified separatedly.
2. Mixtures of noxious liquid substances presenting pollution hazards only and which are provisionally assessed under regulation 6.3 of MARPOL Annex II, may be carried under the requirements of this Chapter applicable to the appropriate position of the entry in this Section for noxious liquids, not otherwise specified (n.o.s).

Section 18 List of Chemicals to which this Chapter does not apply

1. This Section applies to products, which have been reviewed for their safety and pollution hazards and determined not to present hazards to such an extent as to warrant application of the Code.

2. Although the products listed in this Section fall outside the scope of this Chapter, the attention of the Society is drawn to the fact that some safety precautions may be needed for their safe transportation. Accordingly, the Society should prescribe appropriate safety requirements.

3. Some liquid substances are identified as falling into pollution category Z and, therefore, subject to certain operational requirements of Annex II of MARPOL 73/78.

4. Liquid mixtures which are assessed or provisionally under regulation 6.3 of MARPOL Annex II as falling into pollution category Z or OS, and which do not present safety hazards, may be carried under the appropriate entry in this Section for "Noxious or Non-Noxious liquid Substances, not otherwise specified (n.o.s)".

5. The list of the products applied to this Section shall refer to the products in chapter 18 of the IBC Code as amended. The explanatory notes of the products are of the following.

(1) Product name : The product names shall be used in the shipping document for any cargo offered for bulk shipments. Any additional name may be included in brackets after the product name. In some cases, the product name are not identical with the names given in previous issues of the Code.

(2) Pollution category : The letter Z means the pollution category assigned to each product under Annex II of MARPOL 73/78. OS means the product was evaluated and found to fall outside the categories X, Y, or Z.

6. The list of products shall be in accordance with the guidances specified separatedly.

Section 19 Index of Products Carried in Bulk

The index of products shall be in accordance with the guidances specified separately.

Section 20 Transport of Liquid Chemical Wastes

2001. General (IBC Code 20.1)

1. Maritime transport of liquid chemical wastes could present a threat to human health and to the environment.

2. Liquid chemical wastes should, therefore, be transported in accordance with relevant international conventions and recommendations and, in particular, where it concerns maritime transport in bulk, with the requirements of this Chapter.

2002. Definitions (IBC Code 20.2)

For the purpose of this Section:

(1) "**Liquid chemical wastes**" are substances, solutions or mixtures, offered for shipment, containing or contaminated with one or more constituents which are subject to the requirements of this Chapter and for which no direct use is envisaged but which are carried for dumping, incineration or other methods of disposal other than at sea.

(2) "**Transboundary movement**" means maritime transport of wastes from an area under the national jurisdiction of one country to or through an area under the national jurisdiction of another country, or to or through an area not under the national jurisdiction of any country, provided at least two countries are concerned by the movement.

2003. Applicability (IBC Code 20.3)

1. The requirements of this Section are applicable to the transboundary movement of liquid chemical wastes in bulk by seagoing ships and should be considered in conjunction with all other requirements of this Chapter.

2. The requirements of this Section do not apply to:

(1) wastes derived from shipboard operations which are covered by the requirements of MARPOL 73/78;

(2) substances, solutions or mixtures containing or contaminated with radioactive materials which are subject to the applicable requirements for radioactive materials.

2004. Permitted shipments (IBC Code 20.4)

Transboundary movement of wastes is permitted to commence only when:

(1) notification has been sent by the competent authority of the country of origin, or by the generator or exporter through the channel of the competent authority of the country of origin, to the country of final destination; and

(2) the competent authority of the country of origin, having received the written consent of the country of final destination stating that the wastes will be safely incinerated or treated by other methods of disposal, has given authorization to the movement.

2005. Documentation (IBC Code 20.5)

In addition to the documentation specified in **1602.**, ships engaged in transboundary movement of liquid chemical wastes transported in bulk should carry on board a waste movement document issued by the competent authority of the country of origin.

2006. Classification of liquid chemical wastes (IBC Code 20.6)

For the purpose of the protection of the marine environment all liquid chemical wastes transported in bulk should be treated as Category A noxious liquid substances, irrespective of the actual evaluated category.

2007. Carriage and handling of liquid chemical wastes (IBC Code 20.7)

Liquid chemical wastes are to be carried in ships and cargo tanks in accordance with the minimum requirements for liquid chemical wastes specified in **Sec 17**, unless there are clear grounds indicating that the hazards of the wastes would warrant:

(1) carriage in accordance with the ship type 1 requirements; or

(2) any additional requirements of this Chapter applicable to the substance or, in case of a mixture, its constituent presenting the predominant hazard.

Section 21 Criteria for assigning carriage requirements for products subject to the IBC Code

This Criteria is to be in accordance with the guidances specified separately.⫝

KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

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Part 7
Ships of Special Service

GA-07B-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 7 "SHIPS OF SPECIAL SERVICE(CH 5, 6)"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date 1 July 2011

CHAPTER 5 SHIPS CARRYING LIQUEFIED GASES IN BULK

Section 15 Filling Limits for Cargo Tanks

- 1501. 1 has been amended.

CHAPTER 6 SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

Section 11 Fire Protection and Fire Extinction

- 1101. has been deleted.

Section 14 Personnel Protection

- 1402. 2 (5) has been newly added.

CONTENTS

CHAPTER 5 SHIPS CARRYING LIQUEFIED GASES IN BULK

Section 1 General

101. Application

In application to 101. of the Rules, requirements for ships not having the international certificate of fitness for the carriage of liquefied gases in bulk shall be complied with Annex 7A-1 of this guidance.

106. Definitions

1. Cargo area

Cargo area extended by the requirements in **303. 1** (2) of the Rules is, for example, as shown in **Fig 7.5.1** of the Guidance.

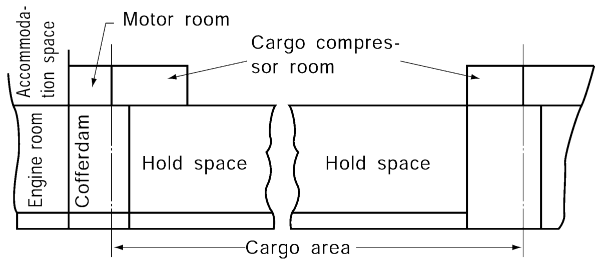


Fig. 7.5.1

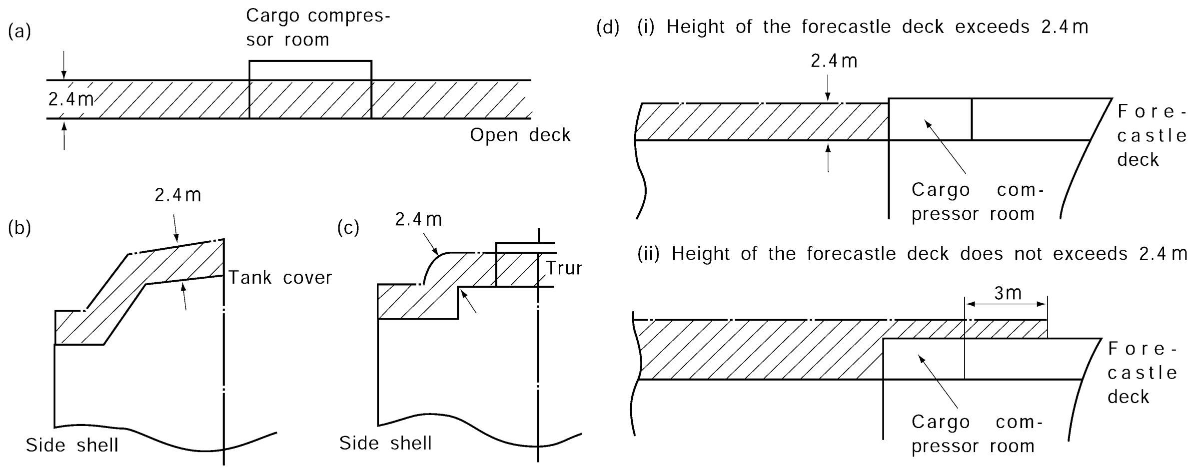
2. Gas-dangerous space

(1) The "approved manner to ensure that its atmosphere is at all times maintained in a gas-safe condition" referred to in **106. 17** (1) of the Rules means to ensure that there are no openings which are directly led to the compartments specified in **106. 17** (2) through (12) of the Rules, or to protect by air locks specified in **306.** of the Rules.

(2) The "3 m of any cargo tank outlet, gas or vapour outlet, cargo pipe flange or cargo valve or of entrances and ventilation openings to cargo pump rooms and cargo compressor rooms" referred to in **106. 17** (7) of the Rules is to be measured as a sphere above outlets and openings, and as a cylinder below.

(3) The "area on the open deck up to a height of 2.4 m above the weather deck" referred to in **106. 17** (8) of the Rules is, for example, as shown in (a) through (d) of **Fig 7.5.2** of the Guidance.

(4) The "direct opening into" referred to in **106. 17** (12) of the Rules includes those openings such as hatches normally used for access which are closed by doors, covers, etc. Bolted plates for removal of machinery need not be regarded as direct openings where another means for access are provided.



Note:
A space in the cargo compressor room is to consider the gas-dangerous space in accordance with the requirements in **106. 17**(6) of the Rules.

Fig 7.5.2

3. Hold space

"Hold spaces" in the requirements in **106. 19** of the Rules includes the peripheral compartments of cargo tanks in the case of integral tanks. (See **Fig 7.5.3** of the Guidance)

4. Independent

The "provisions available for the potential connection to other systems" referred to in **106. 20** of the Rules include the blank flanges.

5. Interbarrier space

"Inter-barrier space" referred to in **106. 22** of the Rules means the peripheral compartments of the cargo tanks in the case of integral tanks. (See **Fig 7.5.3** of the Guidance)

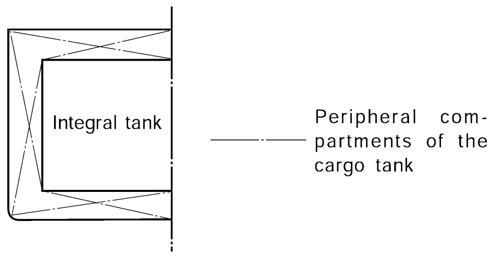


Fig 7.5.3

Section 2 Ship Survival Capability and Location of Cargo Tanks

202. Freeboard and intact stability

1. Solid ballast

In applying the requirements in **202. 4** of the Rules, the solid ballast is to comply with the following requirements.

(1) In case where solid ballast is arranged under unavoidable reasons to ensure stability of the ship, the distance between such solid ballast and the cargo tank is to be not less than 760 mm at any point.

(2) The solid ballast is to be of concrete blocks and similar materials which can be fitted securely to the hull structure of the ship. No solid ballast consisting of scrap iron in bulk, etc. is accepted.

2. Stability information

The items relating to the survival capability of the ship to be entered in the stability information specified in **202. 5** of the Rules are to include, at least, the following (1) through (5) :

(1) Data relating to loading and distribution of cargo and ballast necessary to ensure compliance with damage survival requirements.

(2) Data relating to the ship's survival capabilities.

(3) Plan showing the damage control procedures (describing the locations of fittings necessary for the damage control such as closing appliances and valves, and list of instructions for their controls)

(4) Data relating to the effects of free surface or liquid heeling moments of cargo tanks at all stages of filling.

(5) Example calculations and standard blank forms to facilitate calculations (which are useful for verifying compliance with the survival requirements in an intact condition of the ship).

203. Shipside discharges below the freeboard deck

1. In applying the requirements in **203. 1** of the Rules, the following requirements (1) to (3) are to be complied with :

(1) The scupper pipes within the superstructure are to be in accordance with the requirements in **Pt 5, Ch 6, 302. 1** of the Guidance.

(2) The inboard side open ends of scupper pipes are to be in accordance with the requirements in **Pt 5, Ch 6, 302. 2** (1) (A) of the Guidance.

(3) The direct overboard discharge pipes of top side tanks are to be in accordance with the requirements in **Pt 5, Ch 6, 302. 2** (1) (B) of the Guidance.

2. The requirements of **203. 1** of the Rules don't apply to the overboard discharge pipes from the superstructure and deckhouse located on or above the second deck on freeboard deck.

204. Conditions of loading

To ensure the compliance with the survival requirements in **209.** of the Rules for "all anticipated conditions of loading and variations in draught and trim" specified in **204.** of the Rules at least one or combination of the following (1) to (3) are to be taken for the draught up to the summer water load line :

(1) Carry out damage stability calculations for all anticipated conditions of loading.

(2) Provide manual or calculating machine capable of carrying out the required damage stability calculations. When calculating machine is provided, suitable means of redundancy is to be provided for possible failure of the machine.

(3) Provide diagrams permitting to verify compliance with the survival requirements on the basis of the data in intact condition of the ship(e.g. KG values).

205. Damage assumptions

1. Other damages

For the purpose of the requirements in **205. 2** (2) of the Rules, the transverse bulkheads assumed to remain intact in the requirements in **208. 1** (4) to (6) of the Rules may also be assumed that they remain free from local damages.

206. Location of cargo tanks

1. For the purpose of the requirements in **206. 1** of the Rules, cargo tanks are to be arranged where distances to the primary barrier are to be satisfied with the Rule requirements in case the distances between cargo tanks are fixed.

2. For the purpose of the requirements in **206. 3** of the Rules, the suction wells are not to be installed less than 760 mm from the shell plating.

207. Flooding assumptions

1. General

(1) Conditions that are anticipated to cause more severe results are to be selected of all anticipated conditions of loading, and consideration is to be given to the following (A) through (H) in making calculation according to **207. 1** of the Rules.
   (A) Tanks in way of the assumed damage filled with liquid at increments of about 25 % between empty and the maximum weight of liquid, or liquids, intended to be carried in the particular tanks under consideration.
   (B) The distribution of liquids in the adjacent tanks concerned which will give the most severe result, taking trim into account.
   (C) A number of draughts over the operating range, up to and including the tropical freeboard mark. The fresh water free boards need not be considered.
   (D) The effect of damage involving the machinery space and adjacent tanks containing liquids over a number of draughts as in (C) above.
   (E) The ship in either the departure or the arrival condition, whichever will give the most severe result.
   (F) The ship without trim and a sufficient number of trims covering the operating range, in order to permit interpolation.
   (G) Where the assumed damage causes the ship to trim by the stern, condition having the largest allowable trim by the stern, consistent with operational requirements.
   (H) Where the assumed damage causes the ship to trim by the bow, condition having the largest allowable trim by the bow, consistent with operational requirements.

(2) The free surface effects of intact cargo tanks in the damage stability calculation are to be computed for the actual angle of heel caused by assumed damage and for each angle of heel within the stability limit.

(3) In calculating the effect of free surface of consumable liquids, it is to be assumed that, for each type of liquid, at least one transverse pair or a single centre line tank has maximum free surface, and the tank or combination of tanks to be taken into account are to be those where the effect of free surfaces is the greatest ; in each tank the centre of gravity of the contents is to be taken at the centre of volume of the tank. The remaining tanks are to be assumed either completely empty or completely filled, and the distribution of consumable liquids among these tanks is to be such as to obtain the greatest possible height above the keel for the centre of gravity.

(4) In calculating free surface effects given in the preceding (3), the requirements are to be complied with preceding (2).

2. Permeability

For the purpose of the requirements in **207. 2** of the Rules, the Society may approve a lesser permeability in consideration of volume of the insulations etc. provided within the compartment.

3. Damage of transverse bulkhead

In applying the requirements for damage of transverse bulkhead specified in **207. 4** of the Rules, the extent of damage when the transverse bulkhead is stepped or recessed, are for example, as shown in **Fig 7.5.4** of the Guidance.

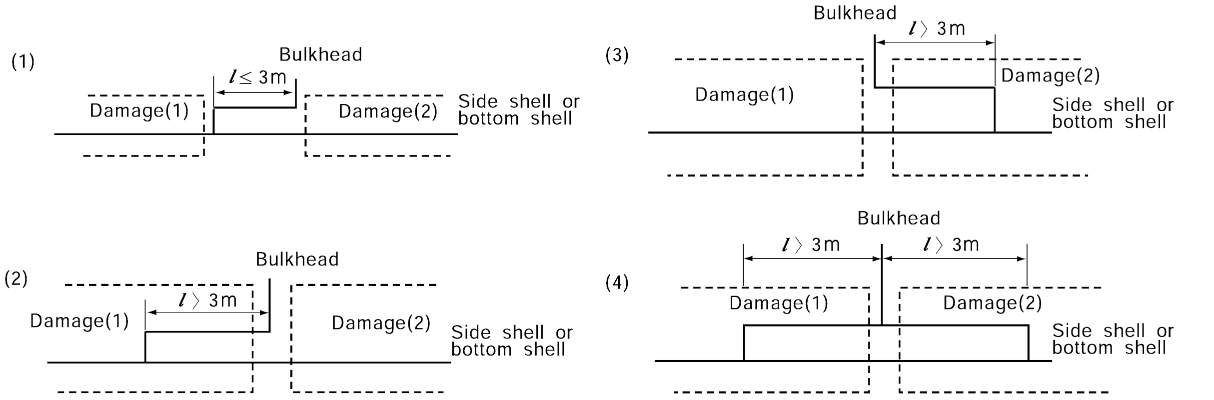


Fig 7.5.4

4. Equalization arrangements

(1) The equalization arrangements specified in **207. 6** of the Rules are to be made operable from a readily accessible place in the damaged condition before using the equalization arrangement.

(2) The righting arm curve of the ship without using the equalization arrangement referred to in the preceding (1) is to be determined in accordance with the requirements in **207. 3** of the Rules, but calculation in this case is to be made assuming that the cross-levelling pipe is closed or this equalization arrangement is not effectively functioning.

(3) The cross sectional area of the cross-levelling pipe used for the equalization arrangement referred to in the preceding (1) is to satisfy the value obtained from the following equation :

$$A \geq 7.5 \frac{V}{\sqrt{H}} \quad (\mathrm{cm}^2)$$

where:

A : cross sectional area of cross-levelling pipe (cm^2)

V : estimated flooding volume in flooded compartment (cm^3)

H : height from the draught line before flooding to the centre line of pipe (m)

(4) "ducts of large cross-sectional area" referred to in **207. 6** of the Rules are to satisfy both of the following equations :

$$A \geq 150 \frac{V}{\sqrt{H}} \quad (\mathrm{cm}^2), \qquad A \geq 2Sh \quad (\mathrm{cm}^2)$$

where:

V : value obtained by the preceding (3)

H : height obtained by the preceding (3) to the centre of duct

S : frame distance (cm). However, in case of longitudinal framing system, S may be obtained from the following equation but not to be less than 61 cm :

$$S = 45 + 0.2 L_f \quad (\mathrm{cm})$$

h : B/15 (cm)

5. Progressive flooding

The "arrangements should be such that progressive flooding cannot thereby extend" referred to in the requirements in **207. 7** of the Rules may be such as a stop valve operable from the exposed deck and accommodation space, etc. provided outside the extent of damage. In this case, any part of operating systems is to effectively function for assumed damage.

6. Buoyancy of superstructure

(1) For the purpose of **207. 8** of the Rules, the longitudinal extent of damage to superstructures above a machinery space located aft is to be the same as the longitudinal extent of the side damage to the machinery space specified **208. 1** of the Rules. (See **Fig 7.5.5** of the Guidance)

(2) The sliding watertight doors specified in **207. 8** (2) of the Rules are to be remotely operable from a readily accessible place in case of damage. Further, the openings of weathertight accepted within the minimum range of residual stability are to be capable of being securely closed at final equilibrium.

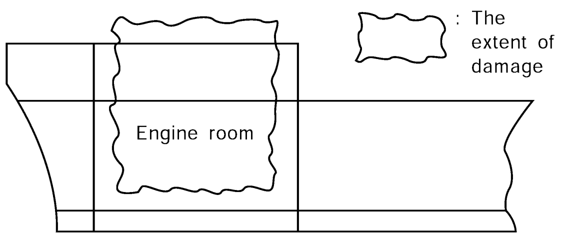


Fig. 7.5.5

208. Standard of damage

1. General

(1) For the purpose of the standard of damage specified in **208. 1** of the Rules, damage assumed to have sustained within 0.3 L_f or there about from the stern are to be in accordance with the following requirements (A) and (B) :

(A) For bottom damage for 0.3 L_f from the forward perpendicular and above (according to **205. 1** (2) of the Rules), such damage may not be considered beyond the point of 0.3 L_f from the forward perpendicular.

(B) For cases of bottom damage which is applied to damage sustained in areas after the point of 0.3 L_f from the forward perpendicular (according to **205. 1** (2) of the Rules), such damage is to be considered up to the point corresponding to 0.3 L_f - 5.0 m from the forward perpendicular.

(2) For a type 3G ship less than 125 m in length(L_f) specified in **208. 1** (6) of the Rules, the ability to survive the flooding of machinery space is to be in accordance with the following (A) and (B):

(A) The ability to survive the flooding of machinery space is to be in accordance with the requirements **209. 1** (1) and (2) of the Rules.

(B) Where L_f is 70 m or more and less than 125 m, the areas under the curve at least within 20° range beyond the position of equilibrium are to be 0.0175 m · rad or more at final equilibrium after flooding.

(C) Where L_f is less than 70 m, the areas under curve are to be 0.0088 m · rad or more.

(3) In case the bulkhead in machinery space is watertight structure at the flooding of machinery space referred to in the preceding (2), around machinery space areas of superstructures located aft may be considered the spare buoyancy. In this case the doors located at bulkhead of machinery space are to be sliding watertight doors remotely operated from superstructure deck.

2. Standard of damage for small ships

Small ships specified in **208. 2** of the Rules are ships less than 70 m of L_f. Special dispensations except type 1G ships may be in accordance with the following (1) through (4) :

(1) The extent of damage and the standard of damage are to be complied with the requirements **205.** and **208. 1** of the Rules respectively.

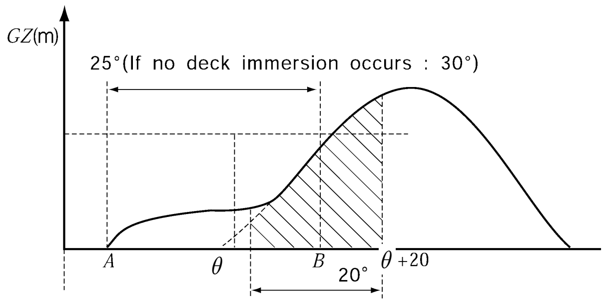
(2) It is to be in accordance with the requirements **209. 1** (1) and (2) of the Rules.
(3) The areas under the righting lever curve within 20° range beyond the position of equilibrium are to be 0.0175 m · rad or more at final equilibrium after flooding.
(4) The maximum values of residual righting lever is not limited.

209. Survival requirements

1. Survival requirements

(1) For the purpose of the requirements of **209. 1** (1) of the Rules, openings specified in the following (A) and (B) may be regarded as watertight flash deck openings.
 (A) Openings protected by tank covers with strength equivalent to deck plating.
 (B) Openings for cargo containment systems on the weather decks sealed with effectively packing of non-combustible material complied with the requirements in **Pt 8, Ch 1, 103.** (1) of the Rules or equivalent and of sufficient strength.
 (C) Sounding pipe with closing head
(2) For the purpose of **209. 2** (1) of the Rules, openings capable of being closed weathertight whose immersion are accepted within the required range of residual stability are to be closed securely at final equilibrium after flooding. However, the requirement may not apply to float type air pipes with automatic closing systems in water.

2. For the purpose of **209. 2** (1) of the Rules, the righting lever curve may be considered to satisfy the requirements within the range of residual stability between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs) further through 20° from any arbitrary angle of heel within the residual stability range. (See **Fig 7.5.6** of the Guidance)



θ : any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs).

Fig 7.5.6

Section 3 Ship Arrangements

301. Segregation of the cargo area

1. Segregation of the hold space

(1) "Forward of machinery spaces of category A" referred to in **301. 1** of the Rules means to be located forward of the forward bulkhead (including the stepped or recessed portions) in machinery spaces of category A. (See **Fig 7.5.7** of the Guidance)

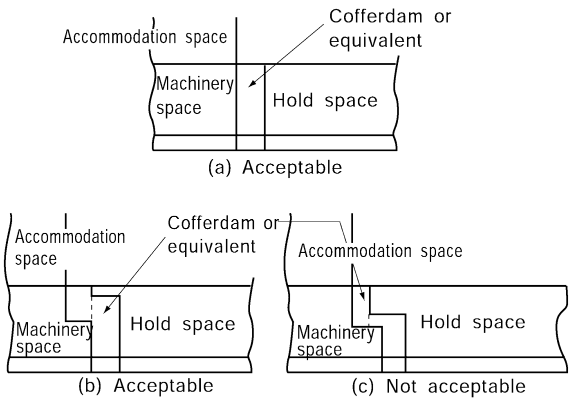


Fig. 7.5.7

(2) Where machinery spaces of category A are located forward of hold spaces, which "deemed necessary by the Society for the safety or navigation of the ship" specified in the requirements in **301.1** of the Rules, the following requirements (A) and (B) are to be complied with. Further, the Society may give additional requirements when deemed necessary. :

(A) The requirements for fire protection and fire extinguishing for the machinery spaces of category A specified in **Pt 8** of the Rules are to be complied with.

(B) The requirements for periodically unmanned machinery spaces specified in **Pt 6, Ch 2** of the Rules and **Pt 8, Ch 2** of the Guidance are to be complied with.

(3) Hold spaces are neither to be located forward of the collision bulkhead nor aftward of the aft peak bulkhead.

2. Segregation of the hold space in case of a cargo containment system not requiring secondary barrier

(1) "If there is no source of ignition or fire hazard" referred to in the requirements in **301. 2** of the Rules means those compartments such as ballast tanks, fresh water tanks, cofferdams, fuel oil tanks, cargo service spaces where there is no source of ignition and is not normally entered by persons, cargo pump rooms and cargo compressor rooms, etc.

(2) The packing used for bolted watertight manholes fitted on the boundaries of ballast tanks, cofferdams, fuel oil tanks from among the compartments referred to the preceding (1) may not be of non-combustible material.

3. Segregation of the hold space in case of a cargo containment system requiring secondary barrier

"If there is no source of ignition or fire hazard" referred to in the requirements in **301. 3** of the Rules means the compartments specified in **301. 2** (1) above.

4. Segregation of cargo piping

(1) For the purpose of the requirements in **301. 5** (1) of the Rules, combinations of a screw-down check valve and a check valve or of a spectacle flange and a stop valve are to be provided at the inter-connections of cargo or cargo vapour lines and inert gas lines necessary for the operation. (See **Fig 7.5.8** of the Guidance)

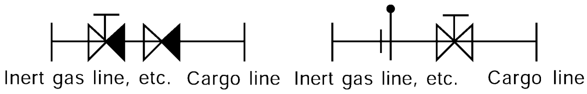


Fig. 7.5.8

(2) The screw-down check valve specified in the preceding (1) may be replaced with a combination of check valve and stop valve. Further, the spectacle flange may be replaced with a spool piece.

(3) "Vertical trunk-way" referred to in the requirements in **301. 5** (3) of the Rules is to comply with the following requirements (A) through (G) :

(A) The access opening in the vertical trunk-way is to comply with the requirements in **305. 3** of the Rules.

(B) The bilge discharge system in the vertical trunk-way is to comply with the requirements in **307. 1** (2) and **2** of the Rules.

(C) Pressure relief system complying with the requirements in **802. 2** of the Rules is to be provided.

(D) Inerting system complying with the requirements in **902. 2** of the Rules is to be provided.

(E) The electrical installations within the vertical trunk-way are to comply with the requirements in **1002. 3** (1) of the Rules.

(F) Ventilation system complying with the requirements in **1202.** of the Rules is to be provided.

(G) Gas detecting system complying with the requirements in **1306. 7** of the Rules is to be provided.

5. Emergency cargo jettisoning piping system

For the purpose of the requirements in **301. 6** of the Rules, the emergency cargo jettisoning piping system is to comply with the requirements in **308. 3** and **7** of the Rules. The Society may give additional requirements according to details of arrangement.

6. Openings for cargo containment system

"Arrangements for sealing the weather decks in way of openings for cargo containments systems" referred to in **301. 7** of the Rules means the arrangements complying with the requirements in **Pt 4, Ch 2, 102.** and 103. of the Rules.

302. Accommodation, service and machinery spaces and control stations

1. Segregation of hold spaces requiring a secondary barrier

"To be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead" referred to in **302. 1** of the Rules means that boundaries of the compartment are so arranged as not to make linear contact or point contact with hold spaces. (See **Fig 7.5.9** of the Guidance)

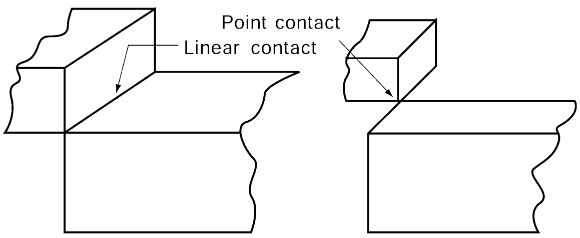


Fig. 7.5.9

2. Location of air intakes and openings in to accommodation spaces, etc.

Compliance with the requirements in **302. 4, 308. 4, 802. 10** and **1201. 6** of the Rules would also ensure compliance with the requirement in **302. 2** of the Rules. Air outlets are subject to the same requirements as air inlets and air intakes.

3. Arrangements of entrances, air inlets and openings

(1) Windows and side-scuttles "so designed that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured" referred to in **302. 4** of the Rules means those fitted with packing and clamping devices. These window and side scuttles are subject to hose tests or other suitable tests acceptable to the Society to verify their gas-tightness.
(2) In case where clear view screens are provided in wheelhouse within the restricted area specified in **302. 4** of the Rules, additional clamping devices are to be provided to the clear view screen or alternative arrangement of closing the window to make it gastight when the screen is not in rotating motion is to be made.
(3) The requirements in **302. 4** of the Rules may not apply to ships dedicated to the carriage of cargo which require neither F nor T in column f of **Table in Ch 5, Sec 19** of the Rules.

4. Closing devices of air intakes and openings

(1) For the purpose of the requirements in **302. 6** of the Rules, closing devices for air intakes and openings are to have suitable gas-tightness where steel made fire protection flaps without gaskets are not accepted.
(2) For the purpose of the requirements in **302. 6** of the Rules, the closing devices in ships intended to carry toxic products which require T in column f of the Table in **Ch 5, Sec 19** of the Rules, the following requirements (A) through (D) are to be complied with :
(A) The requirements in the preceding (1) are to be complied with.
(B) The compartments required to have closing means operable from inside are to be as follows :
(a) radio rooms and navigating rooms
(b) mess rooms and galleys
(c) cabins, lavatories, hospitals, etc.
(C) Internal closing required in (B) above is not required for such compartments not normally manned as listed below.
(a) deck store rooms
(b) forecastle store rooms
(c) engine room casings and steering gear compartments
(d) workshops
(e) cargo control rooms located within the cargo area
(D) When internal closing is required, this is to include both ventilation intakes and outlets.

303. Cargo pump rooms and cargo compressor rooms

1. Location

(1) For the purpose of the requirements in **303. 1** of the Rules, where cargo pump rooms and compressor rooms are permitted to be fitted at the after end of the after-most hold space or at the forward, the arrangements are, for example, as shown in **Fig 7.5.10** of the Guidance.

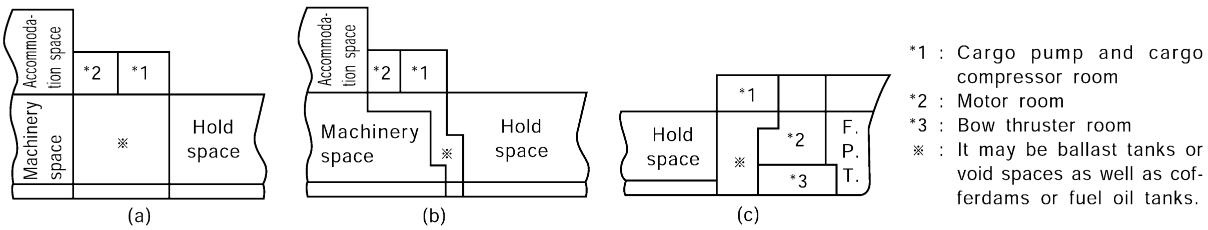


Fig. 7.5.10

(2) For the purpose of the requirements in **303. 1** (1) of the Rules, the arrangement that cargo pump rooms and cargo compressor rooms are located below the exposed deck is not accepted.
(3) The compartments within the cargo area extended according to the requirements in **303. 1** (2) of the Rules may not be regarded as gas-dangerous space as far as the following requirements (A) and (B) are complied with (See **Fig 7.5.11** of the Guidance). However, consideration is to be given to the requirements in **303. 1** (3) of the Rules.

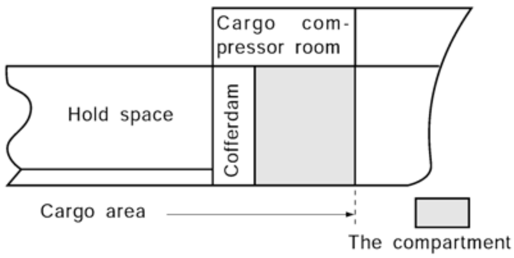


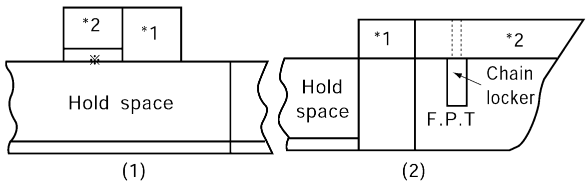
Fig. 7.5.11

(A) The access holes and air vents to the compartment are to have no openings to gas-dangerous space.
(B) The compartment is not to fall under any compartments specified in **106. 17** (1) and (2) of the Rules.

(4) The requirements in **303. 1** (3) of the Rules are also to apply to cases where cargo area is not extended according to the requirements in **303. 1** (2) of the Rules.

2. Gastight seal of shaft

(1) Shaft seals such as those manually feeding grease periodically are not considered as the "other means of ensuring the permanence of the gas seal" referred to in **303. 2** of the Rules.
(2) The shaft seals required in **303. 2** of the Rules are to be provided outside cargo pump rooms and cargo compressor rooms.
(3) The arrangement of motor rooms housing electric motors driving cargo pumps and cargo compressors referred to in **303. 2** of the Rules is to be as, for example, shown in **Fig 7.5.12** (1) of the Guidance. If the arrangement can not be complied with the above requirement in case of such as a small ship, it may be as, for example, shown in **Fig 7.5.12** (2) of the Guidance, where the openings of compartments such as chain lockers considered as the source of ignition are provided in the motor rooms, however, the openings are to be closed by steel watertight covers fitted with warning signs stating that "The openings are to be always kept closed. If opened, the motor room is to be sufficiently ventilated."
(4) The motor rooms referred to in the preceding (3) are to be arranged in gas-safe spaces.



*1 : Cargo pump and cargo compressor room
*2 : Motor room
※ : Cofferdam it is to be needed for the hold space having secondary barrier.

Fig. 7.5.12

3. Access and discharge of drainage

Drain plugs provided on the casing walls of the compartment for draining onto the exposed deck may be accepted, as the "Suitable arrangements...... to deal with drainage" referred to in **303. 3** of the Rules.

304. Cargo control rooms

1. Location

The boundaries where "A-60" class insulation is required according to the requirements in **304. 1** (2) of the Rules are to be as, for example, shown in **Fig 7.5.13** of the Guidance. The ceilings and floors of the cargo control room, asterisked in the drawing, are also to be applied with "A-60" class insulation.

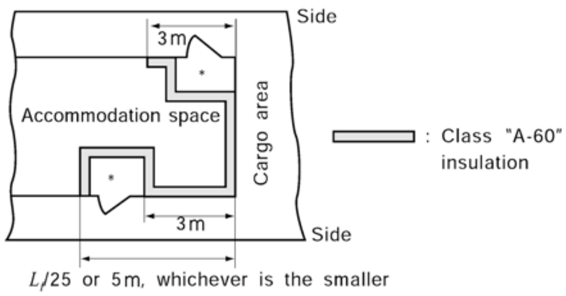


Fig 7.5.13

2. Source of ignition

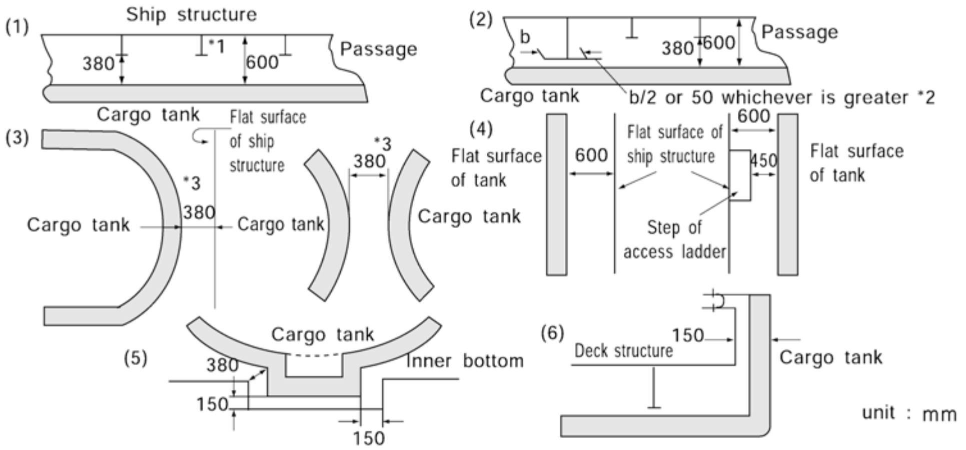
For the purpose of the requirements in **304. 3** of the Rules, the electrical installations in the cargo control room are to comply with the requirements in **1002.** of the Rules depending on the location of the room. The cargo control room is to be provided with mechanical ventilation complying with the requirements in **1201.** of the Rules.

305. Access to spaces in the cargo area

1. The minimum clearance for inspection required in the requirement of **305. 1** and **2** of the Rules are to be as shown in **Fig 7.5.14** of the Guidance.

2. Access for inspection of insulation

According to the requirements in **305. 2** of the Rules, neither visual inspection may be required on one side of the insulation in hold spaces of membrane tanks and semi-membrane tanks nor apply the requirements in **305. 3** of the Rules.



(Note)
1. *1 : This distance between the surface to be inspected and the surface to which structural elements are fitted may b at least 450*mm* in case of a curved tank surface (e.g. in case of type C independent tank).
2. *2 : Where the Surveyor does not require to pass between the surface to be inspected and any part of the structure.
3. *3 : Where the Surveyor does not require to pass between that curved surface and another surface, a smaller distanc than 380*mm* may be accepted taking into account the curved surface.
4. If necessary for inspection, fixed or portable staging is to be installed. This staging is not to impair the distances required in (1) to (4) of the picture.
5. If fixed or portable ventilation ducting has to be fitted in compliance with **1202.** of the Rules, such ducting is not to impair the distances required above (1) to (4) of the picture.

Fig 7.5.14 Cargo Tank Clearances for Inspection

3. The details of minimum opening size required in **305. 3** (1) (B) and (C) of the Rules are to be as shown in **Fig 7.5.15** of the Guidance.

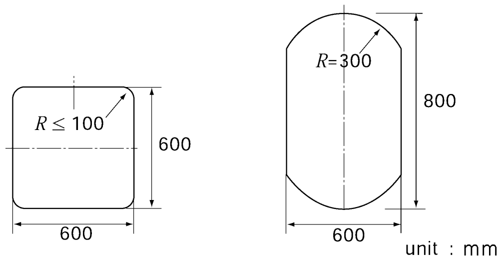


Fig 7.5.15 Minimum Opening Size

4. Access to spaces in the hold spaces, etc.

(1) In applying the requirements in **305. 3** (1) (B) of the Rules, type C independent tanks may have the access holes from exposed spaces with a diameter not less than 600 mm.

(2) In case where those tanks can not be provided with the access holes specified in the preceding (1) due to strength reasons in ships with L_f not more than 70 m, they may be replaced with circular holes with a diameter not less than 500 mm or oval holes with equivalent open area. However, they are to be sufficient to allow entry by a personnel wearing protective clothing and to allow unconscious personnel to be removed from the space.

(3) In case where direct or indirect access from open weather deck without access to gas-safe space, the requirements of **305. 3** (1) (B) and (C) of the Rules may not apply to spaces separated from hold spaces described in **106. 17** (4) (B) of the Rules.

(4) Access hole from weather deck specified in the preceding (3) may be opened at gas-dangerous space. In this case, it is to be applied the requirements for gas-dangerous space except the requirements of **305. 3** (1) (B) and (C) of the Rules.

(5) In applying the requirements in **305. 3** (3) of the Rules, access hole from the weather deck is to comply with the requirements in the preceding (4).

5. Access to gas-safe spaces

"Open weather deck" referred to in the requirements of **305. 4** of the Rules means the exposed part of the uppermost continuous deck within the cargo area.

306. Air-locks

1. Location of gastight doors

For the purpose of the requirements in **306. 1** of the Rules, the steel doors for air-lock are to be verified for their gas-tightness by hose tests or other means considered appropriate by the Society, as necessary.

2. Maintenance of overpressure in the protected space

For the purpose of the requirements in **306. 4** of the Rules, maintenance of overpressure in spaces protected by air-locks is to be by the differential pressure sensing devices provided within the compartment, but alternatively, either of the following method (1) or (2) may be employed :

(1) The following means are considered acceptable alternatives to differential pressure sensing devices in spaces having a ventilation rate not less than 30 air changes per hour :
(A) monitoring of current or power in the electrical supply to the ventilation motors ; or
(B) air low sensors in the ventilation ducts.

(2) In spaces where the ventilation rate is less than 30 air changes per hour and where one of the means specified in the preceding (1) is fitted, in addition, the arrangements are to be made to de-energize electrical equipment which is not of the certified safe type, if more than one air-lock door is moved from the closed position.

3. Ventilation

(1) For the purpose of the requirements in **306. 5** of the Rules, the ventilating fans for air-lock space and their air intakes are to be provided in the gas-safe space. However, in this case, the ventilating fans may not comply with the requirements in **1201.** of the Rules. Protection screens of not more than 13 mm×13 mm square mesh are to be fitted in outside openings of ventilation ducts.

(2) For the purpose of the requirements in **306. 5** of the Rules, verification of maintenance of pressure in spaces protected by air-locks is to be by, for example, monitoring of current in electrical supply to the ventilation motors, air flow sensors in the ventilation ducts or differential pressure sensing devices. The standard ventilation rate in the air-lock space is 8 air changes per hour.

307. Bilge, ballast and fuel oil arrangements

1. Drainage arrangements of hold spaces

(1) For the purpose of the requirements in **307. 1** (1) of the Rules, the drainage arrangements of hold spaces are to be of bilge pumps and bilge pipings provided with in the cargo area complying with the requirements in **Pt 5, Ch 6, Sec 4** of the Rules, or to be of bilge suction system by eductors. In the case of bilge eductors, those capacity and arrangement are to comply with the requirements in **Pt 5, Ch 6** of the Guidance and the total capacity of the eductor is not to be less than 40 m^3/hr.
(2) Where eductors are provided in accordance with the preceding (1), root valves are to be provided in driving water lines at the aft end of the cargo area, and the branch lines of the driving water line are to be fitted with screw-down check valves.
(3) For the purpose of the requirements in **307. 1** (1) of the Rules, the means to detect gas leakage in hold spaces, when the hold spaces are not inerted, may be commonly used for sounding pipes specified in **Pt 5, Ch 6, 203.** of the Rules. In case where the sounding pipes are provided together with gas leakage detecter, an automatic closing head is to be fitted at the each of upper end of the sounding pipes. When hold spaces are inerted, the requirements in (4) are to be complied with.
(4) For the purpose of the requirements in **307. 1** (2) of the Rules, the drainage arrangements of hold spaces are to comply with the requirements in the preceding (1) and (2). The means of detecting gas leakage in hold spaces is to be of the level alarm system of closed type complying with the requirements in **1302. 2** (3) of the Rules.
(5) Cofferdam and void spaces are also to comply with this Article.

2. Drainage system of interbarrier spaces

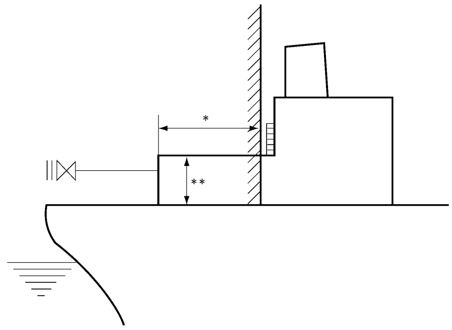
For the purpose of the requirements in **307. 2** of the Rules, the drainage arrangements for dealing with any leakage into the hold or insulation spaces are to comply with the following requirements (1) through (4) :

(1) Even in the case of a partial secondary barrier which is designed on condition that the total volume of leaked cargo would evaporate, the drainage arrangements are to be provided.
(2) In case where a complete secondary barrier is provided and estimation of leakage of liquid cargo is not carried out, the capacity of the drainage arrangements is to comply with the requirements in **Pt 5, Ch 6, Sec 4** of the Rules.
(3) The drainage arrangements to deal with the leaked cargo may commonly serve as those required in **307. 1** (2) of the Rules.
(4) The piping system of the drainage arrangements of leaked cargo is to comply with the requirements in **Sec 5** of the Rules. The water-driven eductor is not accepted as such arrangement.

308. Bow or stern loading and unloading arrangements

1. Arrangements of air inlets and openings

For the purpose of the requirements in **308. 4** of the Rules, the arrangements of air intakes and openings to accommodation spaces are, for example, not to be provided within the shadowed range in **Fig 7.5.16** of the Guidance.



* : $0.04L_f$ or 3m, whichever is the greater, but need not exceed 5m.

** : To be of the standard height of superstructure prescribed in the 1966 International Load Line Convention or more.

Fig 7.5.16

Section 4 Cargo Containment

402. Definitions

1. Integral tanks

In case where the design vapour pressure is made higher than 0.025 MPa in accordance with the requirements in **402. 1** (2) of the Rules, special consideration is to be given to stress concentration for the welding and detailed construction of cargo tanks.

2. Membrane tanks

In case where the design vapour pressure is made higher than 0.025 MPa in accordance with the provision to the requirements in **402. 2** (2) of the Rules, this vapour pressure is to be taken into account when model test specified in **404. 2** (2) of the Rules is conducted. In this case, special consideration is to be given to stress concentration for the welding and construction details of the adjacent hull structure.

3. "Recognized standards" of the requirements in **402. 4** (2) of the Rules means normally the requirements in **Pt 3, Ch 15** of the Rules.

4. In applying the requirements of **402. 4** (4) of the Rules, if the carriage of products (it is only applicable to products having a relative density exceeding 1.0) not covered by the requirements in **Pt 7, Ch 5** of the Rules is intended, the following requirements (1) and (2) are to be complied with :

(1) The double amplitude of the primary membrane stress $\triangle\sigma_m$ created by the maximum dynamic pressure differential $\triangle P$ is not to exceed the allowable double amplitude of the dynamic membrane stress $\triangle\sigma_A$ as specified in **402. 4** (4) of the Rules, ie: $\triangle\sigma_m \leq \triangle\sigma_A$.

(2) The dynamic pressure differential $\triangle P$ is to be calculated as follows:

$$\triangle P = P(a_{\beta 1}Z_{\beta 1} - a_{\beta 2}Z_{\beta 2})/1.02 \times 10^5 \quad \text{(MPa)}$$

where P, a_β, Z_β are as defined in **403. 2** (2) of the Rules, see also **Fig 7.5.17** of the Guidance. $a_{\beta 1}$ and $Z_{\beta 1}$ are the a_β- and Z_β- values giving the maximum liquid pressure hgdmax as defined in **403. 2** of the Rules. $a_{\beta 2}$ and $Z_{\beta 2}$ are the ab and Z_β values giving the minimum liquid pressure hgdmin.

In order to evaluate the maximum pressure differential $\triangle P$, pressure differentials is to be evaluated over the full range of the acceleration ellipse as shown in **Fig 7.5.17** of the Guidance.

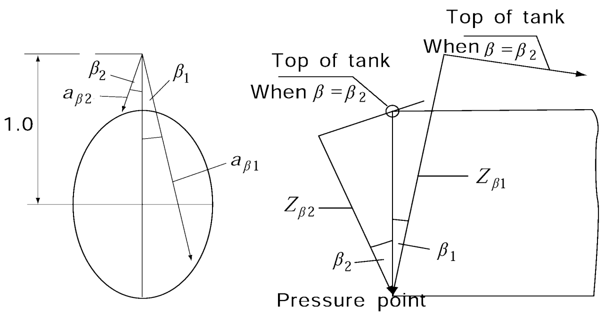


Fig 7.5.17 Acceleration Ellipse and Evaluation of Pressure Differentials

5. Design vapour pressure

For the purpose of the requirements in **402. 6** (2) of the Rules, when a design vapour pressure either higher or lower than 45°C is employed, the ambient temperature is to be of the highest atmospheric temperature of the sea area which is the permanent trade area of the ship obtained from the weather data covering a long period.

6. Design temperature

"Provision to the satisfaction of the Society" referred to in the requirements in **402. 7** of the Rules means the cargo temperature/pressure control systems and temperature indication system complying with the requirements in **Sec 7** and **Sec 13** of the Rules.

403. Design loads

1. General

(1) For the purpose of the requirements in **403. 1** (2) of the Rules, in the case of type B and C independent tanks, their stress levels under the pressure tests are to be confirmed that they are within the stress range specified in the **410. 10** (2) and (3) of the Rules.
(2) The cargo tanks other than those indicated in the preceding (1) are to be verified in strength undergoing the enough analysis required for each tank type in considering the internal pressure distribution at the time of the pressure test. However, when the detailed analysis is carried out, the preceding (1) may apply.
(3) For the purpose of the requirements in **403. 1** (4) of the Rules, the added mass due to hull damage or flooding may not be considered.

2. Internal pressure

(1) As the "Equivalent calculation procedures" referred to in the requirements in **403. 2** (1) of the Rules, the following (A) to (B) may be based upon :
(A) In the case of square tanks, the water head at arbitrary point j on the tank plate is to be obtained from the following equations :

$$h_j = h_{j \cdot st} + h_{j \cdot dyn} \quad \text{(MPa)}$$

$$h_{j \cdot st} = \frac{P_0 + \rho \cdot z_j}{1.02 \times 10^5} \quad \text{(MPa)}$$

$$h_{j \cdot dyn} = \frac{\rho \sqrt{(x_j \cdot a_x)^2 + (y_j \cdot a_y)^2 + (z_j \cdot a_z)^2}}{1.02 \times 10^5} \quad \text{(MPa)}$$

P_0 and ρ : as specified in **403. 2** of the Rules.
a_x, a_y and a_z : as specified in **Fig 7.5.18** of the Guidance and in **403. 2** of the Rules.
x_j, y_j and z_j (m) : as specified in **Fig 7.5.18** of the Guidance.

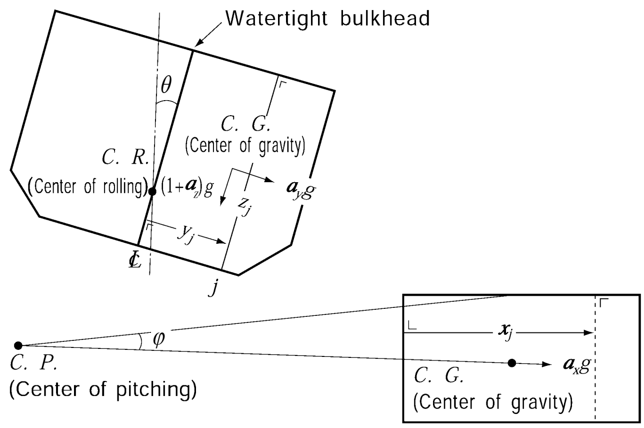


Fig. 7.5.18

(B) In the case of spherical tanks, pressure $P(\phi, \theta)$, at arbitrary point on the tank plate is to be obtained from the following equations :
(a) $P(\phi,\theta) = P(\phi,\theta)_{st} + P(\phi,\theta)_{dyn}$ ·· (MPa)

$$P(\phi,\theta)_{st} = P_0 + \rho \cdot R \cdot (1-\cos\theta)/(1.02\times10^5) \quad \text{(MPa)}$$

$$P(\phi,\theta)_{dyn} = \sqrt{P_1^2+P_2^2+P_3^2} \quad \text{(MPa)}$$

$$P_1 = \rho \cdot R(\sqrt{1+a_x^2} - a_x \cdot \sin\phi \cdot \cos\theta - 1)/(1.02\times10^5) \quad \text{(MPa)}$$

$$P_2 = \rho \cdot R(\sqrt{1+a_y^2} - a_y \cdot \sin\phi \cdot \cos\theta - 1)/(1.02\times10^5) \quad \text{(MPa)}$$

$$P_3 = \rho \cdot R \cdot a_z(1-\cos\theta)/(1.02\times10^5) \quad \text{(MPa)}$$

where ;

P_0, ρ, a_x, a_y and a_z : as specified in the preceding (A)

R : inner radius of sphere (m)

ϕ, θ : as specified in **Fig 7.5.19** of the Guidance.

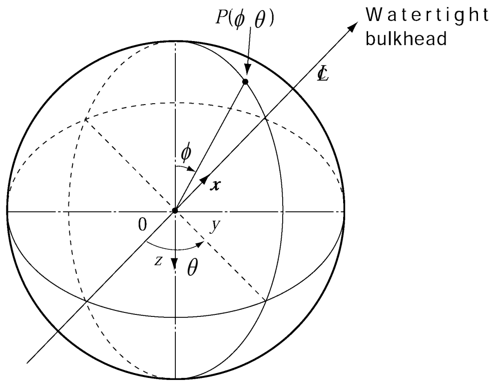


Fig. 7.5.19

(b) Notwithstanding the value specified in the preceding (a), the value of P is not to be less than the following value :

$$P(\phi,\theta)_{\min} = P_0 + \rho \cdot R(1+a_z) \cdot (1-\cos\phi)/(1.02\times10^5) \quad \text{(MPa)}$$

where;

P_0, ρ, R and a_z : as specified in the preceding (A).

(C) In the case of cylindrical tank arranged horizontally along the longitudinal direction of the ship, pressure $P(x_j, \phi)$ at an arbitrary point on the tank plate is to be obtained from the following equation :

(a) $P(x_j,\phi)_{st} = P_0 + \rho R(1-\cos\phi)/(1.02\times10^5)\ (1.02\times10^5)$ .... (MPa)

$$P(x_j,\phi)_{dyn} = \sqrt{P_1^2+P_2^2+P_3^2} \quad \text{(MPa)}$$

$$P_1 = \rho \cdot x_j \cdot a_x/(1.02\times10^7) \quad \text{(MPa)}$$

$$P_2 = \rho \cdot R(\sqrt{1+a_y^2} - a_y\sin\phi - 1)/(1.02\times10^5) \quad \text{(MPa)}$$

$$P_3 = \rho \cdot R \cdot a_z(1-\cos\phi)/(1.02\times10^5) \quad \text{(MPa)}$$

$$P(x_j,\phi)_{\min} = P_0 + \rho \cdot R(1+a_z)(1-\cos\phi)/(1.02\times10^5) \quad \text{(MPa)}$$

where;

P_0, ρ, a_x, a_y and a_z : as specified in the preceding (B)

R : inner radius of cylinder (m)

ϕ, x_j : as specified in **Fig 7.5.20** of the Guidance.

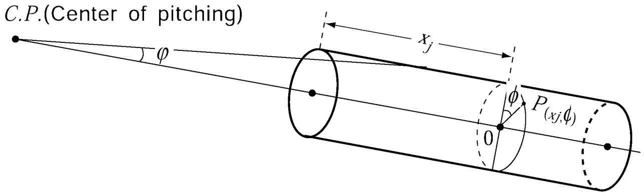


Fig. 7.5.20

(b) Notwithstanding the value specified in the preceding (a), the value of P is not to be less than the following value :

$$P(x_j, \phi)_{\min} = P_0 + \rho \cdot R(1+a_z)(1-\cos\phi)/(1.02\times 10^5) \cdots \text{ (MPa)}$$

(2) For the purpose of the requirements in **403. 4** (3) of the Rules, the stress due to fatigue load may be generally determined by using the cumulative probability curve as shown in **Fig 7.5.21.**

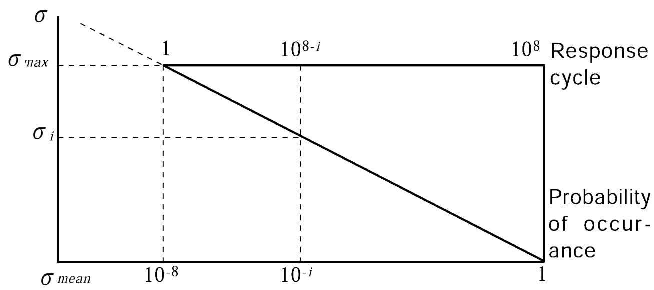


Fig. 7.5.21

(3) When the fatigue strength analysis specified in the requirements in **404. 5** of the Rules is carried out using the frequency distribution of cyclic stress shown in the preceding (2), the number of representative stress(σ_i) is to be eight, and σ_i and its number of repetition n_i may be obtained from the following equation :

$$\sigma_i = \frac{17-2 \cdot i}{16}\sigma_{\max}$$
$$n_i = 0.9\times 10^i$$

where :

i = 1, 2, ..., 8

σ_{max} : stress induced by the predicted maximum dynamic load (half amplitude)

(4) For the purpose of **403. 4** (4) of the Rules, the fatigue load used in the calculation of propagation speed of fatigue cracks is, as a rule, to be the predicted maximum load value that can occur at the most severe period in the trade area specified. In case where analysis is made by using the load frequency distribution given in **Fig 7.5.4** of the Rules, the number of representative stress(σ_i) is to be set at five and si and its number of repetition n_i may be obtained from the following equations :

$$\sigma_i = \frac{5.5-i}{5.3}\sigma_{max}$$
$$n_i = 1.8\times 10^i$$

where :

i = 1, 2, . . ., 5

σ_{max} : stress created by the predicted maximum load

(5) The "ships for restricted service" referred to in **403. 4** (5) of the Rules means those ships with notations "Coasting Service" or "Smooth Water Service" affixed. In this case, the dynamic load may be determined by the results of calculation of ship motions carried out on the basis of the data on sea and weather conditions at the navigating area which are considered appropriately by the Society.

3. Sloshing loads

(1) For the purpose of the requirements in **403. 5** of the Rules, sloshing loads are to be determined in such a way that assessments are made by model experiment for each type of cargo tanks. For cargo tanks where partial filling is intended, data concerning the resonant period of the hull and natural period of the liquids are to be available on board the ship for avoiding the danger of resonance.

(2) Notwithstanding the requirements in the preceding (1), in the type C independent tank in ships with L_f not exceeding 90 m, consideration for structural strength of cargo tanks due to sloshing loads may not be necessary. For tanks partial filling is intended, however, sufficient consideration is to be taken for the installation of equipment in cargo tanks such as cargo piping and cargo pump, against impact loads due to sloshing.

4. Thermal loads

(1) For the purpose of the requirements in **403. 6** (1) of the Rules, arrangements for cooling down are to be provided so as not to cause excessive stress on the tank structures. Further, where cargo with temperature lower than 0°C but not lower than -55°C is carried, such installations for cooling down are also to be provided.

(2) The arrangements shown in the preceding (1) are to be such that safety in cooling down using the arrangements has been proved by records of cargo tanks of similar design or cooling down operation is performed at a rate not exceeding the safe temperature reduction curve which has been proved by thermal stress analysis.

(3) The installations shown in the preceding (1) are to be also capable of performing cooling down at time when excessive thermal loads may be anticipated due to splashing of the residual cargo liquid in ballast passage of the ship under heavy weather as well as at time of cargo loading.

(4) For the purpose of the requirements in **403. 6** (2) of the Rules, no thermal stress analysis may be required for cargo tanks with design temperature of -10°C or upward, in general. In cargo tanks with design temperature at -55°C or below, the structural strength is to be verified through thermal stress analysis by taking into account the vertical temperature distribution at time of cooling down and partial cargo loading, and when necessary, the temperature distribution in the direction of the plate thickness of plating of full loaded tanks.

(5) For tanks other than those specified in the preceding (4), the Society may request thermal stress analysis of the cargo tank by taking into account the constraining condition of the cargo tank by tank supporting structure in case where the tank supporting system is special, and thermal analysis in consideration of the effect of materials with different coefficients of thermal expansion in case where such materials are used.

(6) In the cases referred to in the preceding (4) and (5) where the type of tank supporting system is special, the Society may request thermal analysis on the tank supporting structure itself.

404. Structural analysis

1. Membrane tanks

(1) For the purpose of the requirements in **404. 2** (1) of the Rules, in the assessments of plastic deformations and fatigue of the membrane and thermal insulation materials, all static and dynamic stresses and thermal stress specified in **403.** of the Rules are to be taken into account.

(2) In the assessments referred to in the preceding (1), verification is to be made through fatigue tests on a model combining the elements of the tank, secondary barrier, insulation structure and tank supporting structure considering the dimensional effects on real tank and the effects of dispersions in materials and fabrication accuracy as an integral part of the test specified in **404. 2** (2) of the Rules.

(3) Tests specified in the requirements in **404. 2** (2) of the Rules, are to be conducted on a model in combination of the primary barrier, insulation structure and secondary barrier. Test object and testing procedure are to be determined for each type of tank in each case.

(4) The assessments of collapse of the membrane referred to in the requirements of **404. 2** (4) of the Rules are to be made in accordance with the following requirements (A) to (C) :

(A) For overpressure and negative pressure in the interbarrier space, collapse test is to be conducted on a prototype model of the membrane to verify its ultimate strength.

(B) For sloshing loads, impact load experiment is to be carried out on a prototype model of the membrane to verify its strength when the Society considers necessary.

(C) For vibrations, the natural frequency of the membrane is to be determined whereby it is to be verified that the membrane does not undergo resonance with the vibrations excited by propeller and main engine.

(5) For the purpose of the requirements in **404. 2** (5) of the Rules, the hull structure adjacent to membrane tanks is to comply with the requirements in **Pt 3, Ch 15** of the Rules and, in addition, the stress in the hull structure is to be restricted in consideration of the structural strength of membrane tanks, if necessary. The allowable stresses of the membrane, membrane supporting structures and insulation materials are to be determined in each case according to the mechanical properties of materials, records of construction, product specifications and levels of product quality control practice.

2. Semi-membrane tanks

(1) For the purpose of the requirements in **404. 3** of the Rules, stress analysis is to be carried out on the structural members of cargo tanks in consideration of the loads specified in the requirements in **403.** of the Rules. In this case, the requirements in **405. 1** (4) of the Rules apply correspondingly to the allowable stress.

(2) For stress analysis referred to in the preceding (1), the Society may request model test to verify the accuracy in such stress analysis or stress measurements at time of pressure test of cargo tanks when the Society deems necessary.

3. Type A independent tanks

(1) For the purpose of the requirements in **404. 4** (1) of the Rules, the corrosion allowance may be reduced or may not be required in accordance with the requirements in **405. 2** of the Rules. In structures where the membrane or axial force due to internal pressure can not be neglected, the calculation equation specified in **Pt 3, Ch 15** of the Rules may be used after suitable modification.

(2) In case where no corrosion allowance specified in **405. 2** of the Rules is required in accordance with the preceding (1), stiffeners may have section modulus more than 1/1.2 of one required in **Pt 3, Ch 15, Sec 2** of the Rules.

(3) For the purpose of the requirements in **404. 4** (2) of the Rules, the following (A) to (C) are to be considered for loads and ship deflections.

(A) Ship deflections due to longitudinal bending moment in waves and longitudinal still water bending moment.

(B) Ship deflections due to horizontal bending moment in waves and twisting moment, when necessary due to type of supporting structures.

(C) Internal pressure specified in **403. 2** of the Rules.

4. Type B independent tanks

In applying the requirements in **404. 5** of the Rules, the following requirements (1) through (10) are to be complied with :

(1) The cargo tank structure is to be analyzed by three dimensional frame structural analysis method or finite element method. The model for the analysis is to include concerned hull structures and support construction considering ship deflections and local deflections of hull due to vertical, horizontal and twisting moments.

(2) The strength members of cargo tanks are to be computed in details by the finite element method. In case where compatible results can be obtained, however, the frame structural analysis method may be used in replacement therewith.

(3) In the preceding (1) and (2), dynamic loads necessary for the calculation of interactions between the hull and cargo tanks specified in **404. 5** (2) of the Rules are, as a rule, to be determined by long-term distribution in accordance with the requirements in **403. 4** and **404. 5** (3) of the

Rules where the most probable largest load in terms of the probability of occurrence as deemed appropriate by the Society is to be used. The dynamic stress(σ_{dyn}) due to such loads are to be evaluated for their phase difference according to the requirements in **405. 1** (9) of the Rules, and the total stress including dynamic stress is to be the sum of such dynamic stress and static stress(σ_{st}). However, the load within cargo tanks may be considered as the internal pressure specified in the requirements in **403. 2** (2) of the Rules by using the value of long-term distribution of acceleration computed by direct calculation according to the requirements in **403. 4** and **404. 5** (3) of the Rules.

(4) The scantlings of cargo tank plates and stiffeners fitted to tank plates are to the satisfaction of the Society in consideration of the stress distribution and the mode of stress.

(5) In case where bulkheads are provided in cargo tanks, the scantlings of bulkhead plates and stiffeners fitted to the bulkhead plates are to the satisfaction of the Society.

(6) The strength members in cargo tanks are to be subjected to fatigue strength analysis for both the base metal and welded joints of high stress regions and stress concentration regions. S-N curves are to be plotted by experiment by the taking into account the following (A) through (F) :

(A) Shape and size of test specimen
(B) Stress concentration and notch sensitivity
(C) Mode of stress
(D) Mean stress
(E) Welding conditions
(F) Ambient temperature

In the experiment, the number of test specimen is to be determined statistically and S-N curves are to be plotted against non-destruction probability P = 50 %.

(7) Relative to the design standards for the secondary barrier, the crack propagation analysis specified in the requirements in **404. 5** (1) of the Rules is to be carried out to verify that the assumed initial cracks would not reach the critical crack length in a period. The rate of cargo leakage is to be computed on the basis of the crack length obtained by this analysis.

(8) It is to be verified that the cargo tank plates and associated structural members have sufficient strength against compressive buckling, tripping buckling of stiffeners, shearing buckling, and bending buckling of tripping brackets.

(9) The cargo tank plates and stiffeners are to have such scantlings as not to be caused harmful effects by resonance with the vibrations of exciting sources. The natural frequencies of the cargo tanks and stiffeners used in the above assessment are to be the minimum values in a state in contact with cargo liquid.

(10) The accuracy in stress analysis is to be verified by model tank test or pressure measurements taken at time of pressure tests on a real ship in accordance with the requirements in **410. 13** of the Rules.

5. Type C independent tanks

(1) For the purpose of the requirements in **404. 6** of the Rules, for the scantlings, shapes and reinforcements of openings of cargo tanks against internal pressure in cargo tanks, the requirements for Class 1 pressure vessels in **Pt 5, Ch 5** of the Rules apply.

(2) The "standard acceptable to the Society" referred to in the requirements in **404. 6** (2) of the Rules means such standards as KS, ASME, etc. P_4 among design external pressure P_0 is to be the value computed by applying the requirements in **Pt 3, Ch 10, Sec 2, Ch 16, Sec 2** and **Ch 17, Sec 2** of the Rules corresponding to the location of the tanks.

405. Allowable stresses and corrosion allowances

1. Allowable stresses

(1) The "classical analysis procedures" referred to in the requirements in **405. 1** (3) of the Rules means the beam theory where the type of stress to be assessed is the combined stress of bending stress and axial stress.

(2) For the purpose of the requirements in **405. 1** (3) of the Rules, the allowable stress for the equivalent stress σc when detailed stress calculations are made on primary members is to be as given in **Table 7.5.1** of the Guidance.

Table 7.5.1 Allowable Stresses for the Primary Equivalent Stress

Ferrite steels	Austenitic steels	Aluminium alloys
0.79 R_e	0.84 R_e	0.79 R_e
0.53 R_m	0.42 R_m	0.42 R_m
(Note) For each member, the smaller of the above values is to be used with R_e and R_m as specified in **405. 1** (7) of the Rules		

(3) For the purpose of the requirements in **405. 1** (5) of the Rules, the allowable stress for the primary stress of the prismatic Type B independent tanks is to be in accordance with the requirements in **405. 1** (4) of the Rules.

(4) For the purpose of the requirements in **405. 1** (7) of the Rules, the values of R_e and R_m when the strength of welds is less than that of the parent metal as in the case of 9 % nickel steel are to be of the required values of mechanical properties of the weld metal. For welded joints of aluminium alloys R5083-O and R5083/5183 and 9 % nickel steel, the values of R_e and R_m may be modified in consideration of the increase in the yield stress and tensile stress at low temperature after taking into account the welding procedure employed.

(5) Permissible stresses in way of supports of type C independent tanks made of carbon manganese steel.

(A) For the purpose of the requirements in **405. 1** of the Rules, the following criterion for the allowable stresses in way of supports of type C independent tanks made of carbon manganese steel may be used:

$$\sigma_e = \sqrt{(\sigma_n + \sigma_b)^2 + 3\tau^2} \leq \sigma_a$$

where:

σ_e : equivalent stress($\mathrm{N/mm^2}$)

σ_n : nominal stress in the circumferential direction of the stiffening ring ($\mathrm{N/mm^2}$)

σ_b : bending stress in the circumferential direction of the stiffening ring ($\mathrm{N/mm^2}$)

τ : shear stress in the stiffening ring ($\mathrm{N/mm^2}$)

σ_a : allowable stress ($\mathrm{N/mm^2}$), to be taken as the smaller of the values:

0.57 R_m or 0.85 R_e

R_m and R_e as defined in **405. 1** (7) of the Rules

Equivalent stress values Re is to be calculated over the full extent of the stiffening ring by a procedure acceptable to this Society, for a sufficient number of load cases as defined in **406. 2** and **3** of the Rules.

(B) The following assumptions are to be made for the stiffening rings:

(a) The stiffening ring is to be considered as a circumferential beam formed by web, face plate, if any, and associated shell plating.
The effective width of the associated plating should be taken as:

(i) For cylindrical shells:
an effective width (mm) not greater than 0.78 $\sqrt{rt}$ on each side of the web.
A double plate, if any, may be included within that distance.
where:
r = mean radius of the cylindrical shell (mm)
t = shell thickness (mm)

(ii) For longitudinal bulkheads (in the case of lobe tanks):
the effective width (mm) is to be determined according to established standards.
A value of 20 tb on each side of the web may be taken as a guidance value.
where:
t_b = bulkhead thickness (mm)

(b) The stiffening ring is to be loaded with circumferential forces, on each side of the ring, due to the shear stress, determined by the bi-dimensional shear flow theory from the shear force of the tank.

(C) The following factors are to be taken into account:

(a) Elasticity of support material (intermediate layer of wood or similar material)

(b) Change in contact surface between tank and support, and of the relevant reactions, due to:

- thermal shrinkage of tank
- elastic deformations of tank and support material

The final distribution of the reaction forces at the supports is not to show any tensile forces.

(D) The buckling strength of the stiffening rings is to be examined.

2. Corrosion allowances

(1) The corrosion allowance "where there is no environmental control around the cargo tank, such as inerting" referred to in the requirements in **405. 2** (1) of the Rules, in the case of steel, is to be 1 mm. Except for tanks carrying cargoes containing considerable amounts of impurities or corrosive substances such as chlorine and sulfur dioxide, no corrosion allowance may be required for aluminum alloys and stainless steel.

(2) For the purpose of the requirements in **405. 2** (2) of the Rules, no corrosion allowance may be required for the internal surface of pressure vessels including the Type C independent tank except for the case where corrosive substances are to be loaded. For the exterior surface where there is no environmental control around the cargo tank such as inerting or where there is no protection by suitable insulation materials having the approved vapour barrier, the corrosion allowance for steel is to be the smaller of 1 mm or 1/6 of the required thickness excluding the corrosion allowance.

(3) In case where no corrosion allowance is considered for cargo tanks protected by insulation according to the requirements in **405. 2** (2) of the Rules, the gastightness of the vapour barrier of insulation structure is to have been verified. This gastightness is to be verified in the test of insulation specified in the requirements in **409. 7** of the Rules.

406. Supports

1. General

In spaces between the refrigerated tanks and supports, suitable insulation materials are to be provided so that hull structure might not be cooled excessively through the supporting structures according to the requirement of **408. 1** of the Rules.

2. Provision against the rotational effect

(1) The analysis of supporting structures against the load conditions specified in **406. 2** and **3** of the Rules is to be done while giving considerations to the following conditions (A) and (B) :

(A) A condition where static load by the weight of cargo tank containing the cargo at a static heel angle of 30° and the static sea water pressure without dynamic pressure due to waves is imposed.

(B) A condition where load by the weight of cargo tank containing the cargo with the acceleration caused by ship motions specified in the requirements in **406. 3** of the Rules and the dynamic seawater pressure due to waves are imposed. Such dynamic sea water pressure due to waves may be determined by the requirements in **Pt 7, Ch 3, 103.** of the Rules.

(2) The results of analysis for the conditions indicated in the preceding (1) are not to exceed the allowable stress determined in consideration of the requirements in **405. 1** of the Rules depending on type of cargo tanks. Further, sufficient safety factor against the critical buckling stress is to be considered.

407. Secondary barrier

1. Hull structure acting as a secondary barrier

(1) For the purpose of requirements in **407. 2** (2) of the Rules, thermal stress analysis is to be carried out for the calculation condition in case of cargo leakage specified in the requirements in **409. 1** of the Rules.
(2) The combined stress of the maximum membrane stress or the maximum bending stress obtained in the analysis of the preceding (1) and the static stress created by the static load specified in the requirements in **403.** of the Rules is not to exceed 90 % of the yield stress of the material.
(3) In the ship designed under the same design temperature and loading conditions of similar ships where it is verified that the thermal stress is sufficiently small, the Society may accept omission of the analysis referred to in the preceding (1).

2. Tank type and secondary barrier

The conditions for approving partial secondary barrier for the semi-membrane tanks specified in Note 2 of **Table 7.5.2** of the Rules are to be in accordance with the following (1) through (6) :

(1) Detailed stress analysis is to be carried out. Wave loads as the design load are to be assumed in details according to the requirements in **403. 4** of the Rules. The results of stress analysis are to be verified for the accuracy by measuring the stresses at time of pressure tests on a real ship or model test.
(2) The results of stress analysis under the requirements in the preceding (1) are not to exceed the allowable stress specified in the requirements in **405. 1** (4) of the Rules.
(3) The requirements in **404. 4** (6), (7) and (9) of the Guidance are to be complied with.
(4) Cargo tanks are to be subjected to buckling analysis depending on their structural type whereby it is to be verified that they have sufficient strength against buckling.
(5) Repair procedures for cargo tanks are to be established. On the fatigue strength and crack propagation analysis in case such repair procedures have been applied, assessments are to be carried out by applying the requirements in **404. 4** (6) and (7) of the Guidance correspondingly.
(6) The hull structure adjacent to cargo tanks is to be subjected to strength analysis compatible with the case of cargo tanks. In addition to carrying out detailed stress analysis by the method of which accuracy has been verified by stress measurements, etc., it is to be verified that the strength is sufficient through the fatigue strength analysis and crack propagation analysis done by applying the requirements in **404. 5** of the Rules correspondingly.

3. Standards of secondary barrier

(1) For the purpose of the requirements in **407. 4** of the Rule, the secondary barriers of nonmetal material are to conform to the following requirements (A) to (C) :
  (A) Compatibility with the cargo is to have been verified, and to have necessary mechanical properties at the cargo temperature under the atmospheric pressure.
  (B) A model test may be required to prove that the secondary barrier has effective performance when the Society deems it necessary.
  (C) For welded joints, welding procedure tests and production test are to be conducted. The test plans for the above are to have been approved by the Society beforehand.
(2) For the purpose of the requirements in **407. 4** (1) of the Rules, no special analysis of the complete secondary barrier for verifying that "it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days" may be carried out except for cases where the Society deems it specially necessary.

4. Extent of secondary barrier

(1) For the purpose of the requirements in **407. 5** of the Rules, the extent of the secondary barrier is, at least, to cover the surface of leaked liquid cargo corresponding to a static heel angle of 30°.
(2) The "surface of leaked liquid cargo" referred to in the preceding (1) means a surface of fully leakage of fully loaded cargo for the complete secondary barrier, and of liquid cargo determined in accordance with the requirements in **407. 6** of the Rules for the partial secondary barriers.
(3) For spaces outside the extent of the secondary barriers specified in the preceding (1), the hull structures are to be protected against splashes of leaked cargo by the spray shields specified in the requirements in **407. 6** (2) of the Rules, or the extent of the secondary barrier is to be suitably extended.

5. Partial secondary barrier

(1) For the purpose of the requirements in **407. 6** of the Rules, the protection of the inner bottom plating at the lower part of cargo tanks is to conform to the following requirements (A) and (B) :

(A) According to the requirements in **407. 2** of the Rules, the inner bottom plating is to act as the secondary barrier.

(B) In case where a drip tray is provided as a secondary barrier for example as shown in **Fig 7.5.22** of the Guidance with consideration so as not to allow the leaked liquid cargo to overflow from the secondary barrier, no protection may be required. However, where no such consideration is taken, the inner bottom plating is to be protected by insulation materials.

(2) The spray shield specified in the requirements in **407. 6** (2) of the Rules is to have been verified by test that it has satisfactory performance to act as the shield.

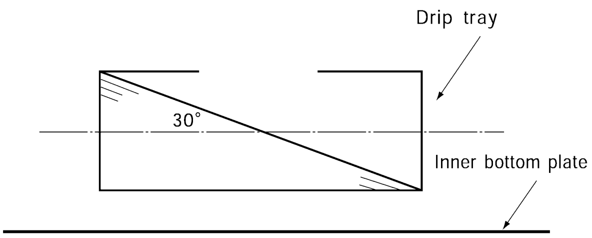


Fig. 7.5.22 Drip Tray to Protect the Inner Bottom Plate

6. Periodical survey of secondary barrier

(1) For the purpose of the requirements in **407. 7** of the Rules, the test procedure where visual inspection of the secondary barrier is not possible is to be in accordance with the following requirements (A) to (C) :

(A) The inspection method of the secondary barrier and its criteria relating to the performance to act as the secondary barrier are to be verified for their effectiveness through model test.

(B) The secondary barrier is to be verified by model test for the required performance. This model test is to be capable of verifying that the secondary barrier can maintain the necessary performance throughout the life of the ship.

(C) When sufficient data to prove the effectiveness and reliability relative to the preceding (A) and (B) are submitted to the satisfaction of the Society, this model test may be omitted.

408. Insulation

1. Protection of hull structure for low temperature products

For the purpose of the requirements in **408. 1, 2** and **3** of the Rules, the calculation conditions in computing the temperature of hull structures are to be in accordance with the following (A) through (D) :

(A) The loading condition of the ship for the calculation is to be full loaded condition.

(B) At the upright cargo leakage is to be considered for the calculation in accordance with the following (a) through (d). However, no leakage may be considered for integral tanks and type C independent tanks.

(a) It is to be assumed that the failure of all cargo tanks located between transverse watertight bulkheads are caused. However, in case where the cross section of the ship is divided into more than one compartments by longitudinal bulkheads of the ship, it is to be assumed that the failure of all cargo tanks within each such compartment is caused.

(b) It is to be assumed that the locations of the failure of the cargo tank cover all conceivable ones.

(c) It is to be assumed that only the liquid cargo leaks out where the cargo tank, supports and hull remain intact without involving any deflections or fracture.

(d) For cargo tanks where the complete secondary barrier is required according to the requirements in **407. 3** of the Rules, it is to be assumed that the leakage of liquid cargo occurs instantaneously and the levels of residual liquid cargo in damaged cargo tank and the leaked liquid level in the hold space reach the same level instantaneously.

(C) The boundary conditions of the calculation mode1 are to be in accordance with the following requirements (a) through (k) :

(a) The temperature of the compartment adjacent to hold spaces is to be determined by heat transmission calculation. The atmosphere of the compartment which is adjacent to the compartment contiguous to hold space may be taken as a still air at 0°C. In the case of machinery space, it may be assumed as a still air at 5°C.

(b) It is to be assumed that there is no radiation of sun beam.

(c) The atmospheric air and sea water are to be assumed as still atmospheric air at 5°C and still sea water at 0°C respectively.

(d) The structures in hold space such as insulation materials and supports are to be assumed that they do not absorb liquid cargo.

(e) In compartments where gases exist other than in hold spaces, it is to be assumed that they are in natural convection.

(f) It is to be assumed that the gas and liquid within the same compartment are at the same temperature.

(g) At time of damage to the cargo tank, the gaseous phase in the cargo tank and that in hold spaces are to be assumed to have a pressure equals to the atmospheric pressure.

(h) It is to be assumed that there is no transfer of gases within the insulation materials.

(i) It is to be assumed that there is no influence of moisture.

(j) The temperature of the secondary barrier in a state of leakage is to be assumed to be the same as the cargo temperature at the atmospheric pressure, whereas the temperature of the intact cargo tank is the design temperature. The ship is to be assumed to stay upright.

(k) It is to be assumed that there is no influence of paints.

(D) The calculation conditions in heat transmission calculation are to be in accordance with the following requirements (a) through (i) :

(a) Temperature distribution and heat transmission are to be dealt with as the phenomena in a steady state. No transient condition may be considered.

(b) Sea water is to be assumed to have a density of 1,025 kg/m^3 and a coagulation point of 2.5°C with physical properties compatible with those of fresh water for other items.

(c) The liquid cargo is to be assumed to have uniform temperature distribution.

(d) The heat transfer coefficients at various boundaries can be computed by using the numeral values given in **Table 7.5.2** of the Guidance, but calculation may be carried out by using empirical equations given in the heat transfer engineering data which has been made public. In this case, heat transfer due to radiation is also to be taken into account.

Table 7.5.2 The Heat Transfer Coefficient at Various Boundaries

Boundaries	Heat transfer coefficients (W/m^2·°C)
Still gas ← → Hull or liquid	5.8
Still sea water ← → Hull	116.3
Cargo vapour ← → Hull contacted to air	11.6

(e) The substance for which temperature distribution is investigated is to be assumed to be of homogeneous one without directivity.

(f) Frames may be dealt with as fins.

(g) In case where hold spaces located forward and afterward the hold space under study are in the same conditions, they may be treated as a two dimensional problem.

(h) The cooling effect by the latent heat of evaporation of the liquid cargo may not be taken into account.

(i) The temperature of structural members is to be represented by the temperature at their half thickness, and for individual members, the following requirements (i) through (iv) are to be complied with :

(i) The temperature of those frames fitted to plates is to be assumed to be the same as the temperature of the plates, but when the temperature distribution of the frame in the direction of depth is known, the area mean of the temperature distribution may be taken.

(ii) The temperature of web frames supporting frames or plates is to be the temperature at their half depth for webs, and the temperature of face plates for these.
(iii) The temperature of members connecting the inner shell and outer shell, e.g., brackets and girders is to be of the mean of the temperature of the inner shell and that of the outer shell.
(iv) The temperature of brackets is to be the temperature at their centroid.

409. Materials

1. Hull material not forming secondary barrier

(1) For the purpose of the requirements in **409. 4** of the Rules, brackets, panel breakers on such as girders, tripping brackets and docking brackets provided to prevent buckling of structural members may be excluded from the application of the requirements.
(2) Notwithstanding the requirements in the preceding (1), for longitudinal strength members and stiffeners in deep tanks and watertight bulkheads among those shown above the requirements apply.

2. Insulation materials

(1) For the purpose of the requirements in **409. 5** of the Rules, insulation materials of independent tanks and integral tanks are to be free from generating harmful defects that degrade the insulation performance even under such conditions of service that can actually take place in insulation structure including forced deflection and thermal expansion and contraction.
(2) The performance referred to in the preceding (1) is to be verified in the insulation procedure test specified in 5 below as necessary.

3. Protection of insulation

For the purpose of the requirements in **409. 6** of the Rules, insulation materials are to be protected in accordance with the following requirements (1) to (3) :

(1) For insulation materials installed in hold spaces and tank covers, no fire protections and protections for mechanical damage may be provided except for cases where such are specially necessary. However, these insulation materials are to be applied with coating or subjected to surface treatment with aluminium foil, etc.
(2) Insulation materials provided at exposed areas are to be protected by galvanized iron sheets or to be of the non-combustible insulation materials specified in the requirements in **Pt 8, Ch 1, 104.** (1) of the Rules applied with moisture-resistant coating. In case where the Society deems necessary, provision of steel covering may be requested as a protection against mechanical damage.
(3) The coating materials to be applied on the surface of insulation materials are to comply with the requirements in **Pt 8, Ch 1, 308. 2** of the Rules or equivalent.

4. Properties of insulation materials

(1) For the purpose of the requirements in **409. 7** of the Rules, the properties of insulation materials are, in general, to be verified by the tests given in **Table 7.5.3** of the Guidance.
(2) In addition to complying with the requirements in the preceding (1), property verification test may be requested by the Society depending on the insulation system.
(3) If the material, which has been approved according to the Guidance given by the Society, satisfies the performance requirements and such performance is considered to serve the purpose, the tests referred to in the preceding (1) may be omitted.
(4) For insulation materials to which the requirements in the preceding (1) to (3) do not apply, the following requirements (A) and (B) are to be complied with :
 (A) For insulation materials used for supports of independent tanks, the requirements given in the column of membrane tank and semi-membrane tank in **Table 7.5.3** of the Guidance apply.
 (B) For insulation materials provided in cargo tanks to which no provision of insulation is required according to the requirements in **408.** of the Rules, data on the necessary properties of those specified in **409. 7** (1) of the Rules depending on the insulation system is to be submitted to the Society.
(5) The test method for the properties specified in **409. 7** (1) of the Rules is to be **Table 7.5.4** of the Guidance or to the satisfaction of the Society.

5. Quality control of insulation materials

"The satisfaction of the Society" referred to in the requirements in **409. 8** of the Rules means as shown in the following (1) and (2):

(1) The insulation materials are to be approved in accordance with the Guidance. In the above, tests and inspection are to be conducted according to the procedures on the manufacture, storage, handling and product quality control established by the manufacturer.

(2) The inspection for insulation work is to include the following items of tests and inspections (A) to (C):

(A) Insulation procedure test
For insulation system and insulation procedure without previous records, tests are to be conducted in accordance with the test plan approved by the Society. The test may be conducted at the manufacturer of insulation materials or shipyard as necessary.

(B) Insulation production test
In accordance with the test plan approved by the Society in advance, tests are to be conducted to verify the work control, working environment control and product quality control during insulation procedure.

(C) Completion inspection
After the insulation work is completed, inspection is to be conducted for dimensions, shape, appearance, etc. in accordance with the procedures already approved by the Society, and in addition, the insulation performance is also to be verified in the test specified in **410. 14** of the Rules.

Table 7.5.3 Properties of Insulation Material for Cargo Tank Types

No.	Ensuring items		Integral tank	Membrane/ semi-membrane tank[3)]	Type A/B independent tank	Type C independent tank	Internal insulation tank[4)]	Note
1	Compatibility with the cargo			○[1)]	○[1)]		○	
2	Solubility in the cargo			○[1)]	○[1)]		○	
3	Absorption of the cargo		□	○[1)]	○[1)]		○	
4	Shrinkage			○[1)]	○[1)]	○	○	
5	Aging		□	○	○[1)]	□	○	
6	Closed cell content		△	△	△	△	△	applied only to closed cell material
7	Density		○	○	○	○	○	
8	Mechanical properties	Bending strength	○	○	○	○	○	
		Compress. strength		○			○	
		Tensile strength	○	○	○	○	○	
		Shearing strength	○	○	○[2)]	○[2)]	○	
9	Thermal expansion		□	○			○	
10	Abrasion			○	△[1)]		○	
11	Cohesion		□	△		□	△	applied to cohered material
12	Thermal conductibility		○	○	○	○	○	
13	Resistance to vabration		△	△	△[1)]		△	refer to **409. 9** of the Rules
14	Resistance to fire and flame spread		○	○	○	○	○	

Remarks
○ : Items to be verified through verification test for properties.
△ : Items to be verified through verification test where deemed necessary depending on the insulation material.
□ : Items for which preparation of data on the properties is desirable.

Notes :
1) Necessary when the insulation material acts as spray shield specified in the requirements in **407. 6** (2) of the Rules. In other cases, data on the properties is to be prepared.
2) Not generally required for cargo tanks where the design temperature exceeds -10°C.
3) It is necessary to verify the fatigue strength characteristics in accordance with the requirements in **402. 2** and **404. 3** of the Rules.
4) It is necessary to verify the fatigue strength characteristics in accordance with the requirements in **404. 7** and **409. 7** (2) of the Rule.

Table 7.5.4 Test Items for Insulation Materials

Test items	Test methods
1. Compatibility with the cargo	Tensile, compress., shearing, bending test after dipping in the cargo
2. Solubility in the cargo	Changes in thesize and weight of test specimen before and after dipping in the cargo
3. Absorption of the cargo	Comparison of weight of test specimen or test of water absorbing properties before and after dipping in the cargo
4. Shrinkage	ASTM D2126
5. Aging	ASTM D756 (Comparison of thermal conductivity before and after aging)
6. Closed cell content	ASTM D2856
7. Density	ASTM D1622
8. Mechanical properties	Bending (ASTM C203, D790) Compress.(ASTM D1621) Tensile (ASTM D1623) Shearing (ASTM C273)
9. Thermal expansion	ASTM D696
10. Abrasion	-
11. Cohesion	-
12. Thermal conductibility	KS L9016, ASTM C518
13. Resistance to vibration	-
14. Resistance to fire and flame spread	DIN4102

410. Construction and testing

1. Independent tanks

(1) For the purpose of the requirements in **410. 1** (1) of the Rules, the fillet weld of the full penetration type approved for joints between cargo tank plates and dome are, at least, to conform to the following requirements (A) or (B) depending on cargo tank type :

(A) In the case of Type A independent tank, non-destructive testing procedure is to be established.

(B) In the case of Type B and Type C independent tank, records of production are to be kept and fatigue strength is to be ensured by fatigue strength analysis and non- destructive testing procedures established for the proposed construction.

(2) The "dome-to-shell connections" referred to in the requirements in **410. 1** (1) of the Rules are applicable to tanks with MARVS is 0.07 MPa or below, and the connections mean ordinary cargo pipes or other penetrations of equivalent size sufficiently small when compared with the size of dome.

(3) In welding of the penetrations referred to in the preceding (2) full penetration type welding may not be required, but are to have proper grooves. In this case, all the weld lines for penetrations of pipes with outside diameter exceeding 100 mm, and the partial weld lines for those with outside diameter of 100mm or below, are to be subjected to non-destructive test as appropriate.

(4) The "specifically approved by the Society" referred to in the requirements in **410. 1** (2) (A) of the Rules means the case of tanks where MARVS is 1.0 MPa or below and the design temperature is higher than -10°C satisfying both of the following requirements (A) and (B). However, this is to be limited to areas where non-destructive test is possible.

(A) Pressure vessels where removal of backing strip is operationally difficult and which are not used in an atmosphere liable to generating stress corrosion cracks.

(B) There is no excessive stress concentration.

(5) As a case "specially approved by the Society" referred to in the requirements in **410. 1** (2) (b)

of the Rules, full penetration welding may not be required for small nozzle diameters for use in measurement, inspection or similar other application being fitted to the cargo tank with MARVS of not more than 1.0 MPa and the design temperature is not less than -10°C. In this case, welding is to comply with the requirements in KS B 6231.

2. Membrane tanks

(1) For the purpose of the requirements in **410. 3** of the Rules, quality assurance procedure, welding control, design details, quality control of materials, construction method, inspection and standards of production testing of components for membrane tanks are to be developed during the prototype test specified in **404. 2** of the Rules or another prototype test separately conducted for development of production procedure, and their effectiveness is to be verified. The relevant data is to be noted in the construction procedure manual for cargo tanks including the insulation construction of membrane tanks.
(2) The construction procedure manual referred to in the preceding (1) is to be approved by the Society after being verified through prototype test.

3. Integral tanks

For the purpose of the requirements in **410. 6** of the Rules, the hydraulic test of integral tanks is to conform to the requirements in **Pt 3, Ch 1, 209.** of the Rules. However, for tanks whose design MARVS exceeds 0.025 *MPa* or specific gravity of the cargo exceeds 0.6, the test may be such as to conform to the requirements specified in **410. 10** (1) of the Rules correspondingly.

4. Hull structure adjacent to membrane or semi-membrane tanks

(1) The "hydrostatically or hydropneumatically tested in accordance with recognized standards" referred to in the requirements in **410. 7** of the Rules means the hydraulic test according to the requirements in **Pt 3, Ch 1, 209.** of the Rules. In this case, hydraulic pressure may be applied from hull structures such as ballast tanks and cofferdams.
(2) The leakage test for the "other hold structure supporting the membrane" referred to in the requirements in **410. 7** of the Rules is to be in accordance with the testing procedure applicable to general hull structures as specified in **Pt 3, Ch 1, 209.** of the Rules.

5. Type C independent tanks

(1) For the purpose of the requirements in **410. 9** (1) of the Rules, the allowable dimensional deviations for the manufacture and fabrication are to conform to the requirements in **Pt 5, Ch 5, 402. 5** of the Rules, and in addition to the requirements in KS B 6231.
(2) For the purpose of the requirements in **410. 9** (2) (B) of the Rules, the ultrasonic testing is to be conducted in the following cases (A) and (B) :
  (A) In case where defect detection by radiographic testing fails and ultrasonic testing is considered additionally necessary.
  (B) In case where ultrasonic testing is considered necessary for the quality control of essential structural members.
(3) For the purpose of the requirements in **410. 9** (2) of the Rules, testing procedure and acceptance criteria for the non-destructive tests are to be in accordance with the requirements in **603. 6** (1) of the Guidance.

6. Hydrostatic or hydropneumatic test for independent tank

(1) For the purpose of the requirements in **410. 10** (1) and (2) of the Rules, the hydrostatic or hydropneumatic test of cargo tanks is to be conducted by simulating the actual load conditions (static load + dynamic load) in accordance with the following requirements (A) and (B) :
  (A) Test of cargo tanks
  Hydrostatic-hydropneumatic test is to simulate the static pressure of cargo, acceleration by ship motions and internal pressure including the vapour pressure by water head and pneumatic pressure. (See **Fig 7.5.23, 7.5.24** and **7.5.25** of the Guidance)
  (B) Load test of supporting structures
  Hydraulic test is to simulate the cargo weight and the load created by the acceleration due to ship motions solely by the weight of water. (See **Fig 7.5.26** of the Guidance)
(2) All tests specified in the preceding (1) (A) and (B) may be conducted individually.

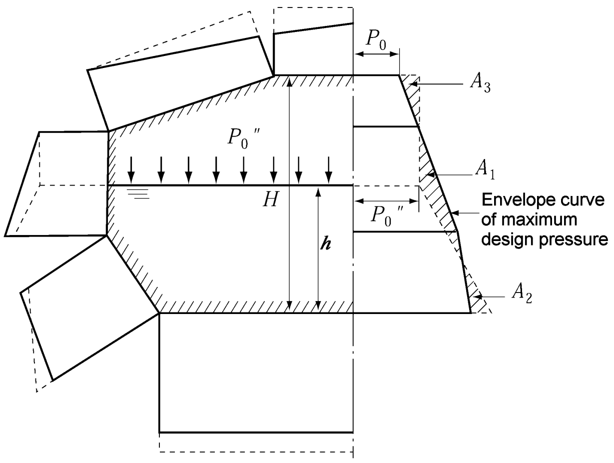


Fig 7.5.23 Simulating the Internal Pressure Distribution of Rectangular Tank

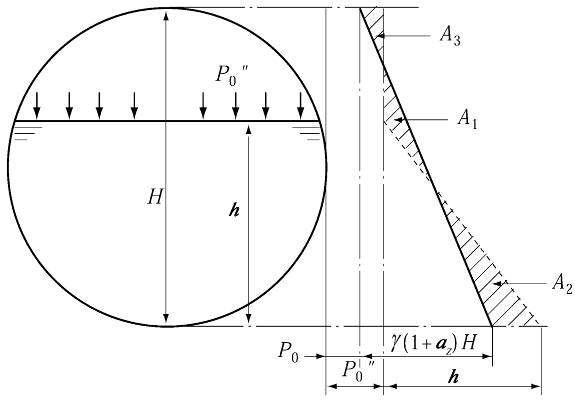


Fig 7.5.24 Simulating the Internal Pressure Distribution of Spherical Tank

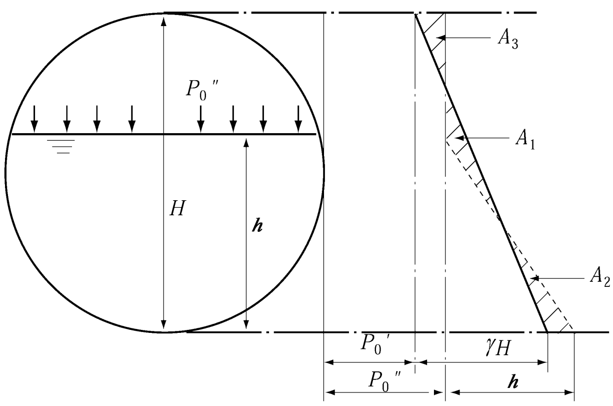


Fig 7.5.25 Simulating the Internal Pressure Distribution at Pressure Discharge

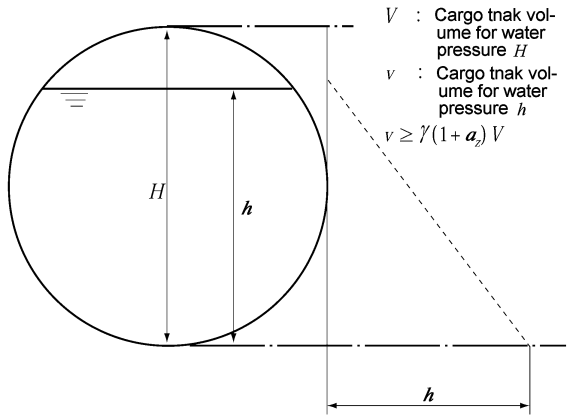


Fig 7.5.26 Simulating the Loading Condition of Support Structure

* Explanatory notes on symbols in **Fig 7.5.23** to **7.5.26** of the Guidance

------	: maximum loading condition which is predicted to actually encounter
···	: pressure testing condition simulating as far as practicable (P_0'' and h are to be chosen so that $P_0'' > P_0$ or $P_0'' > P_0'$ and $A_2 + A_3 > A_1$ as far as practicable)
H	: depth of tank
h	: water head
γ	: specific gravity of cargo
a_z	: maximum vertical acceleration (non-dimensional)
P_0	: design vapour pressure at ordinary passage
P_0'	: design vapour pressure during pressurized unloading in port
P_0''	: air pressure

(3) In the case of the cargo tank of supports which can be regarded as those of the same type manufactured at the same manufacturing plant, implementation of the second and subsequent tests of cargo tanks and supports specified in the preceding (1) (B) may be omitted when deemed acceptable by the Society.

(4) The "pressure vessels other than simple cylindrical and spherical pressure vessels" referred to in the requirements in **410. 10** (3) (A) of the Rules means those cylindrical or spherical pressure vessels with supporting structures of well proved records. In tanks of special shape having supporting structures likely to cause excessive bending stress or bicylindrical shape tanks, the stress

levels are to be verified by strain measurement through prototype test.

(5) "Where necessary" referred to in the requirements in **410. 10** (3) (D) of the Rules means a case in which the shipbuilding berth or hull structure can not withstand the hydrostatic load when cargo tanks are filled with water to the tank top level and another case in which a large load exceeding the design load is imposed on the structural members of the tank or adjacent structures by conducting the hydrostatic test.

(6) For the purpose of the requirements in **410. 10** (3) (F) of the Rules, the leakage test is to be of the airtightness test conducted at a pressure of MARVS or more of the pressure vessel.

7. Tightness test for cargo tanks

For the purpose of the requirements in **410. 11** of the Rules, in case where leakage of cargo tanks can not be inspected in the hydraulic test or hydrostatic-hydropneumatic test according to the requirements in **410. 10** of the Rules, the tightness test of cargo tanks is to be conducted separately. This test is to be of the airtightness test conducted at a pressure of MARVS or more of the cargo tank.

8. Stress measurements instrumentation of type B independent tanks

For the purpose of the requirements in **410. 13** of the Rules, in case where stress measurements of the cargo tank previously built which can be regarded as the tank of the same design manufactured at the same shipyard had resulted in good agreement with design stress levels, provision of instrumentation of independent tanks stress levels for tanks subsequently built may be omitted.

9. Gas-trial and cargo full loading test (related to 505. 4 of the Rules)

(1) In accordance with the requirements in **410. 14** and **505. 4** of the Rules the following tests (A) and (B) are to be conducted in the attendance of the Surveyor to verify the performance of the cargo containment installations and cargo handling equipment :

(A) Gas-trial

On items given in **Table 7.5.5** of the Guidance, tests are to be conducted to verify the performance of the cargo containment system cargo handling equipment and instrumentation using a suitable quantity of the cargo after the completion of all the construction work. However, for cargo tanks with a design temperature of 0°C or more, omission of this test may be accepted if substitution is made by the operating test with the substituting medium to verify the requirements given in **Table 7.5.5** of the Guidance except for the case where the tank is of the first cargo tank manufactured by the manufacturer of cargo tanks.

(B) Cargo full loading test

On items given in **Table 7.5.6** of the Guidance, tests are to be conducted after completion of all the construction work to verify that the cargo containment installations, cargo handling equipment and instrumentation satisfy the design conditions under the fully loaded condition of cargo. However, for this test, the attendance of the Surveyor may be omitted for ships whose cargo containment and cargo transfer installations can be regarded as of the same specification of those which have previously been built and tested at the same shipyard.

(2) The kinds of real liquid cargo and gas used in the gas-trial and cargo full loading test specified in the preceding (1) are to be such that reproduction of the most severe conditions of those design conditions of the cargo containment system, the transfer installations, the reliquefaction system, etc. and consideration is to be given to the following requirements (A) and (B) :

(A) The verification relative to design temperatures is to be made by reproducing the condition that the cargo on the basis of which design temperature has been determined is cooled down as close to the design temperature as practicable.

(B) For design conditions basing on the corrosivity or extreme toxicity, omission of verification through the use of these cargoes in gas-trial may be accepted in case where experimental data and information to prove the compliance of the construction and equipment including structural materials have been submitted to the Society.

(3) The quantities of the real cargo and vapour used in the gas-trial and cargo full loading test referred to in the preceding (1) are to be sufficient to conducting the tests specified in (1) above.

(4) The cargo full loading test to capacity specified in the preceding (1)(B) may be conducted simultaneously with the gas-trial indicated in the preceding (1)(A).

(5) The survey items "at loading operation" specified in **Table 7.5.6** of the Guidance in the preceding (1)(B) may be substituted by the test items which were carried out during on board test and gas trial, and the survey items on "Condition of cargo tanks and other cargo containment

systems after full loading" may be confirmed when the inspection for "discharging operation" is carried out.

Table 7.5.5 Test Items at the Gas Trial

Test item	◎ : Attendance of the Surveyor ○ : Submittion of the record	Inspection equipme	Survey item
1. Drying test	○	· Inert gas generator	· Dew point · Change of dryness in cargo tanks and hold spaces
2. Inerting test	○	· Inert gas generator	· Operation of the inert gas generator · Measuring of atmosphere in cargo tanks
3. Inert gas purge test using cargo vapour	○	· Cargo vapourizer · Compressor	· Change of O_2/temperature of cargo vapour in cargo tanks · Quantity of cargo vapour (or liquid) supply · Capacity of the vapourizer · Capacity of the compressor
4. Cool-down test	◎/○	· Spray pump · Compressor · Cargo piping · Temperature indicators forcargo tank · Spray piping	· Temperature curve of cargo tanks[1)] · Inspection of hold spaces/condition of insulation of tanks (after cool-down) · Cooling condition of spray piping·Cooling condition of cargo piping · Capacity of spray pump · Cargo consumption · Capacity of compressor (property of return gas) · Temperature/pressure in cargo tank · Shrinkage of cargo tank[2)]
5. Loading test of cargo liquid	◎/○	· Compressor · Cargo piping related for loading · level gauge/temperature indicator	· Temperature/pressure level in cargo tanks · Temperature/pressure in hold spaces · Temperature/pressure of cargo liquid/gas at manifolds · Service condition of cargo piping
6. Operation test of cargo pump	◎/○	· All cargo pumps	· Discharge pressure/current of cargo pumps · Liquid level/pressure in cargo tanks · Stripping
7. Operation test of pressure/temperature control system	◎/○	· Depend on the type of controls	· Depend on the type of controls

Notes :
1) The Society may approve omission in consideration of the quality control status and manufacturing records of insulation materials.
2) To be verified only in case of independent tanks.

Table 7.5.6 Survey Items of Full Load Test

	Survey items
1. At loading operation	· Continuous loading rate · Actual operation of level, temperature, pressure indicator, etc. · Actual operation of alarm system[1)] · Actual operation of overflow control system[1)]
2. Condition of cargo tanks and other cargo containment systems after full loading	· Cargo tanks and supports · Hull adjacent to cargo tanks (cold spot) · Insulation capacity of cargo tanks and supports · Atmosphere in hold spaces
3. During voyage	· Insulation capacity of cargo tanks and supports · Cold spot on the construction adjacent to cargo tanks · Capacity of pressure/temperature indicator
4. At discharging operation	· Discharging rate · Other operation of discharging · Submitting/survey of related records without attendance for **3** above.
Note : 1) In case where implementation is difficult, the verification of operation may be made by suitable other method.	

10. Cold spot inspection

(1) The cold spot inspection of cargo tanks specified in **410. 16** of the Rules is to be carried out during the cargo full loading test to capacity specified in **410. 9** (1) for the membrane tank, semi-membrane tank, internal insulation tank, and when necessary, independent tank.

(2) The cold spot inspection of cargo tanks specified in the preceding (1) may be confirmed when the inspection for discharging operation is carried out.

11 Examination before and after the first loaded voyage (Only if the LNG Vessels)

In accordance with the requirements in 410. 14 & 16 of the Rules, it is preferred that Gas Trial and Cargo Loading Tests are finished at the shipyard, but either or both of these may be postponed until after entering into a voyage and the survey requirements are as follows

(1) First Loading (Considered to be full loading) :

(A) Priority to be given to latter stages of loading (approximately last 6 hours).

(B) Review cargo logs and alarm reports.

(C) Witness satisfactory operation of the following:

- Gas detection system.
- Cargo control and monitoring systems such as level gauging equipment, temperature sensors, pressure gauges, cargo pumps and compressors, proper control of cargo heat exchangers, if operating, etc.
- Nitrogen generating plant or inert gas generator, if operating.
- Nitrogen pressure control system for insulation, interbarrier, and annular spaces, as applicable.
- Cofferdam heating system, if in operation.
- Reliquefaction plant, if fitted.
- Equipment fitted for the burning of cargo vapors such as boilers, engines, gas combustion units, etc., if operating.

(D) Examination of on-deck cargo piping systems including expansion and supporting arrangements.

(E) Witness topping off process for cargo tanks including high level alarms activated during normal loading.

(F) Advise master to carry out cold spot examination of the hull and external insulation during transit voyage to unloading port.

(2) First Unloading :

(A) Priority to be given to the commencement of unloading (approximately first 4 - 6 hours).

(B) Witness emergency shutdown system testing prior to commencement of unloading.
(C) Review cargo logs and alarm reports.
(D) Witness satisfactory operation of the following:
- Gas detection system.
- Cargo control and monitoring systems such as level gauging equipment, temperature sensors, pressure gauges, cargo pumps and compressors, proper control of cargo heat exchangers, if operating, etc.
- Nitrogen generating plant or inert gas generator, if operating.
- Nitrogen pressure control system for insulation, interbarrier, and annular spaces, as applicable.
- On membrane vessels, verify that the readings of the cofferdam and inner hull temperature sensors are not below the allowable temperature for the selected grade of steel. Review previous readings.
- Cofferdam heating system, if in operation.
- Reliquefaction plant and review of records from previous voyage.
- Equipment fitted for the burning of cargo vapors such as boilers, engines, gas combustion units, etc., if operating.

(E) Examination of on-deck cargo piping systems including expansion and supporting arrangements.
(F) Obtain written statement from the Master that the cold spot examination was carried out during the transit voyage found satisfactory. Where possible, the surveyor should examine selected spaces.

12. Inspection of Secondary Barrier

With respect to the requirement of **410. 12**, it is to be verified that secondary barriers keep a specific level of tightness required in the system design in accordance with an appropriated procedures. For cargo containment system with glued secondary barriers, a tightness test are to be carried out in accordance with approved system designers' procedure before and after initial cool down and related values obtained in the test are to be recorded for the use as reference for periodical surveys. If significant differences in the results before and after cool down for each tank or between tanks or if other anomalies are observed, an investigation is to be carried out and additional testing such as differential pressure, thermographic or acoustic emissions testing is to be carried out as necessary. For containment systems with welded metallic secondary barriers, a tightness test after initial cool down is not required.

411. Stress relieving for type C independent tanks

1. Stress relieving by post-weld heat treatment

For the purpose of the requirements in **411. 1** of the Rules, the stress relieving is to be in accordance with the following requirements (1) to (3) :

(1) The post-weld heat treatment is to comply with the requirements in **Pt 5, Ch 5, 403.** of the Rules.
(2) For 9 % nickel steel, 5 % nickel steel and aluminium alloy 5083-O, post-weld heat treatment may, in general, be omitted.
(3) For cargo tanks made of carbon steel and carbon manganese steel with the design temperature of -10°C or more, the requirements in **Pt 5, Ch 5, 403.** of the Rules may be based upon except for cargo tanks anticipated to carry chlorine, ammonia and toxic cargoes.

Section 5 Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems

501. General

1. Process pressure vessels

(1) For the purpose of the requirements in **501. 2** of the Rules, "process pressure vessels" means the pressure vessels used for cargo operation, cooling, processing of boil-off gases and temporarily containing the cargo inside where heat exchangers are included. They, however, do not include those pressure vessels for refrigerant without containing cargo and parts of cargo pumps, compressors and valves subjected to internal pressure.

(2) Of those process pressure vessels referred to in the preceding (1), for the process pressure vessels that are not used for cargo storage, only the requirements in **404. 6** (1) and (2), **405. 1** (6) and **2, 409. 3, 410. 1, 2, 9, 10** (3), **11** and **18** and **411. 1** of the Rules apply.

502. Cargo and process piping

1. General

(1) For the purpose of the requirements in **502. 1** (1) of the Rules, "product and process piping" means the piping used for cargo operation, cooling, heating, processing and disposing of boil-off gases having a possibility of coming to contact with the cargo. The refrigerant piping which does not directly come to contact with the cargo is not included.

(2) For product and process piping referred to in the preceding (1), in addition to the requirements in **502.** to **505.** of the Rules and, the requirements **Pt 5, Ch 6** of the Rules apply where considered as necessary by the Society.

(3) For the purpose of the requirements in **502. 1** (3) of the Rules, for piping with design temperature lower than 5°C, the following requirements (A) to (C) are to be complied with to protect the hull structure.

(A) The branches of the piping are to be insulated for thermally separating them from the hull structure. However, in case where the materials of hull structures comply with the requirements given in **Table 7.5.7** of the Rules against the temperature obtained by heat transmission calculation in consideration of the design temperature of the piping, these requirements may be dispensed with.

(B) As a means of protection for hull structures against cargo leakage from the piping, drain pans or equivalent manufactured from the materials specified in **Table 7.5.5** and **Table 7.5.6** of the Guidance having sufficient capacity are to be arranged according to the design temperature of the piping at all locations where liquid leakage is likely.

(C) Drain pans or equivalent indicated in the preceding (B) are to be provided below all flange joints of liquid piping with design temperature not exceeding 55°C located outside the cargo tanks. However, in case where the arrangement is made in such a way that the hull structures do not reach dangerous temperature even in case of leakage from flanges, these requirements may be dispensed with.

(4) The materials of drain pans referred to in the preceding (3) (B) and (C) may be made such that they comply with the requirements of Korean Industrial Standards or recognized standards and are suitable for the design temperature of the piping system.

(5) For the purpose of the requirements in **502. 1** (4) of the Rules, the electrical bonding is to conform to the requirements of **Pt 6, Ch 1, 104.** of the Rules. In case where the gasketed flange joint are used, the flange bolts only are not considered as an earthing, and the connections and earthing are to be provided with earthing conductors. Also, in case where electrical bondings are necessary for cargo tanks and secondary barriers, such bondings are to be provided at readily accessible places.

(6) The "suitable means" referred to in the requirements in **502. 1** (5) of the Rules means the residual liquid discharging piping led to cargo tank, liquid cargo line or other drain tank.

(7) "All pipelines or components which may be isolated in a liquid full condition" referred to in the requirements in **502. 1** (6) of the Rules means, for example, those pipelines given in the following (A) and (B) :

(A) Pipeline between two adjacent stop valves.

(B) Pipeline between stop valve and compressor or pump likely to be liquid full. However, where the relief valve mounted on the compressor or pump is in effective condition, this requirement may be dispensed with.

(8) For the pipeline indicated in the preceding (7), a relief valve is to be provided irrespective of its design pressure. This relief valve is to be of approved one in accordance with the special requirements given by the Society.

(9) The "means to detect and dispose of any liquid cargo which may flow into the vent system" referred to in the requirements in **502. 1** (7) of the Rules means the fol1owing (A) and (B) (See **Fig 7.5.27** of the Guidance) :

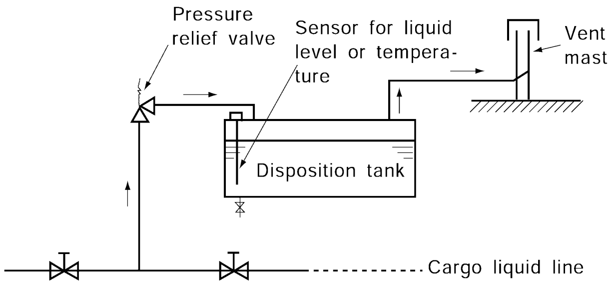


Fig 7.5.27 Example Means to Detect and Dispose of Any Liquid Cargo Which may Flow into the Vent System

(A) As a means to dispose of the liquid cargo, a tank with a capacity larger than those determined in the following (a) to (c) is to be provided. The material of the disposition tank is to be of equivalent to the liquid cargo piping or higher grade, and in the case of pressurized cargo tanks, consideration is to be given to the temperature drop due to expansion and evaporation.

(a) By assuming possible state of liquid full condition that may actually take place, the quantity of liquid cargo to be covered is to be determined.

(b) Due to heat input from the fire, the quantity of expansion for the quantity of liquid indicated in (a) above to rise from the initial temperature (normally, the minimum design temperature of the pipeline) to the temperature of vapour saturation at the set pressure of the relief valve is to be obtained and on the basis of which the quantity of the liquid to the disposition tank is to be determined.

(c) By giving consideration to the back pressure of the vent pipeline, the liquid phase quantity in the disposition tank of the inflow quantity obtained in the preceding (b) is to be computed to obtain the capacity.

(B) As a means for detecting liquid cargo, a high level alarm sensor or low temperature alarm sensor in case of low temperature cargo tanks, and a high level alarm sensor in case of pressure cargo tanks, are to be provided in the disposition tank and to issue alarm when the sensor functions.

2. Scantlings based on internal pressure

For the purpose of the requirements in **502. 2** of the Rules, the following requirements are to be complied with :

(1) The joint efficiency of electric-resistance welded pipes where non-destructive testing for full length of weld lines is not conducted is to be 0.85.

(2) For methane, propane, butane, butadiene and propylene cargoes, the corrosion allowance is to be 0.3 mm for carbon-manganese steel and 0 mm for stainless steel and aluminium alloys. Where effective corrosion control are taken for the interior of carbon-manganese steel pipes, the corrosion allowance may be 0.15 mm.

(3) In addition to the preceding (2), for carbon-manganese steel pipes arranged on open deck without any effective external corrosion control means, 1.2 mm is to be added to the required corrosion allowance.

(4) The negative manufacturing dimensional deviation in pipe thickness is, except for expressly provided otherwise, to be in accordance with the requirements in **Pt 2, Ch 1, 401. 7, 402. 7** and **404. 7** of the Rules.

3. Design pressure

(1) For the purpose of the requirements in **502. 3** (2) of the Rules, where design vapour temperature higher or lower than 45°C is employed, the requirements in **402. 6** (1) of the Rules apply.

(2) The "relief valve on a pipeline system" referred to in the requirements in **502. 3** (2) (F) of the Rules means the one which is approved in accordance with the special requirements given by the Society.

4. Permissible stress

(1) The "minimum wall thickness to be in accordance with recognized standards" referred to in the requirements in **502. 4** (2) of the Rules means the value corresponding to Schedule 40 of KS SPPS for carbon-manganese steel, and the value corresponding to Schedule 10 *S* for stainless steel. However, for steel pipes provided with effective corrosion control or those not arranged under corrosive environment, the value may be reduced to the extent acceptable to the Society with a limitation of 1 mm. Further, the value for pipes in cargo tanks and pipes having open ends may also be reduced to the extent acceptable to the Society.

(2) The cases where increase in pipe size is required according to the requirements in **502. 4** (3) of the Rules are the cases in which such becomes necessary on the basis of the results of stress analysis specified in the requirements in **502. 5** of the Rules, and in which suitable supports and means to absorb structural expansion and contraction can not be arranged due to convenience of on-deck piping, etc.

(3) As a presumption for the condition indicated in the preceding (2), the supports for piping are to be so arranged as to prevent exertion of the own weight of the pipe on valves or other fittings and to prevent generation of excessive vibration.

(4) For the purpose of the requirements in **502. 4** (4) of the Rules, fittings are to comply with the following requirements (A) and (B) :

(A) Valves, flanges and other fittings are to comply with the requirements of KS, ANSI or equivalent for their type and size, and the requirements in **Pt 5, Ch 6, 104.** of the Rules for flanges.

(B) The design pressure of bellows type expansion joints to be used in vapour piping may be taken 0.2 MPa for those provided on pipelines with open ends, and 0.5 MPa for those provided on other pipelines.

5. Stress analysis

(1) For the purpose of the requirements in **502. 5** of the Rules, the calculation conditions and allowable stress in the stress analysis are to be in accordance with the following requirements (A) through (E) as standard :

(A) As temperature condition, a state uniformly cooled down to the design temperature is to be considered. As the reference temperature (thermal stress = 0), 15°C is to be regarded as standard.

(B) Loading conditions are to be in accordance with the following requirements (a) through (d) :

(a) As internal pressure, the design pressure specified in the requirements in **502. 3** of the Rules is to be considered.

(b) The own weight of pipelines, when can not be neglected, is to be considered including its acceleration.

(c) As forced displacement, the forced strains corresponding to allowable sagging moment and hogging moment for the hull are to be considered.

(d) As thermal load, one which can be determined according to the condition indicated in the preceding (A) is to be considered.

(C) Support conditions are to be as deemed appropriate by the Society depending on the construction, arrangement and materials of the pipe supports.

(D) Allowable stresses are to be as deemed appropriate by the Society depending on the calculation method and materials of pipelines.

(E) Insulation materials are to be considered to give no contribution at all to the strength of the pipeline.

(2) According to the requirements in **502. 5** of the Rules, stress analysis may be required for pipings with the design temperature higher than -110°C where the following (A) to (C) are relevant :

(A) Where suitable supports or means to absorb structural expansion and contraction can not be arranged due to convenience of on-deck piping arrangement.
(B) Where new supporting method or new means to absorb expansion and contraction are used.
(C) Other cases where the Society deems necessary.

6. Materials

(1) For the purpose of the requirements in **502. 6** (1) of the Rules, the materials of pipings, valves and fittings are to comply with the relevant requirements in **Sec 6** of the Rules, and at the same time, to conform to the relevant requirements in **Pt 2, Ch 1** of the Rules. However, for materials used in pipings as specified in the following (A) through (D), those conforming to KS or other standards as deemed appropriate by the Society may be used where they comply with the requirements in Sec 6 of the Rules considering the temperature.
(A) Pipes, valves and pipe fittings used for cargo piping and process piping with the design pressure not exceeding 1.0 MPa and design temperature of 0°C or more.
(B) Valves and pipe fittings used for cargo piping and process piping with the design pressure not exceeding 3.0 MPa and design temperature of 0°C or more and nominal diameter less than 100 A.
(C) Pipes, valves and pipe fittings used for accessory piping or instrumentation piping with diameter not exceeding 25 mm irrespective of the design pressure and design temperature.
(2) Notwithstanding the requirements in the preceding (1), the piping having open ends not coming to contact with the liquid cargo led from the pressure relieving valves of cargo tanks and cargo piping or process piping with the design temperature of -55°C or higher may not be made of the steel for low temperature services specified in **Table 7.5.6** of the Rules. Further, its material may be such as to comply with KS or other standards as deemed appropriate by the Society.
(3) For the purpose of the requirements in **502. 6** (2) of the Rules, the insulation applied on the short pipes with a melting point lower than 925°C fitted to the cargo tank, except for the minimum range of area necessary for inspection and maintenance of pipe flanges, is to be protected according to the requirements specified in **409. 3** (2) of the Guidance. Further, the insulation materials for cargo piping and other piping are to conform to the requirements in **409. 4** (4) (B) of the Guidance.

503. Tests of piping components and pumps prior to installation on board

1. Requirements of type tests

(1) For the purpose of the requirements in **503. 1** (1) of the Rules, those valves which are relevant to the following (A) or (B) are to be approved in accordance with the requirements in the Guidance.
(A) All valves used for the cargo and process piping with the design temperature lower than -55°C.
(B) Those valves used for accessory piping or instrumentation piping of the design temperature lower than -55°C with an outside diameter exceeding 25 mm and normally come to contact with the cargo.
(2) For the purpose of the requirements in **503. 1** (2) of the Rules, all bellows type expansion joints provided on all cargo piping including the cargo liquid/vapour piping provided both inside and outside the tanks, and vent piping with open ends are to be of the approved ones in accordance with the special requirements given by the Society.

504. Piping fabrication and joining details

1. Application

According to the requirements in **504. 1** of the Rules, the requirements specified in **504. 2** to 6 of the Rules may be modified in accordance with the following (1) and (3) :
(1) For pipes provided inside the cargo tanks with open end excluding pump discharging pipings, the following requirements (A) to (C) apply :
(A) Butt welded joints with backing strips, sleeve joints and screw joints may be used in all cases.
(B) Slip-on and socket welded joints may be used in all cases.
(C) Non-destructive testing for butt welded joints may be omitted.

(2) For pipes with open ends provided outside the cargo tanks are to conform to the requirements specified in the preceding (1) (A) and (B), and in addition, the non-destructive testing for butt welded joints may be reduced to 10% sampling.

2. Connection of pipes without flanges

The "screwed couplings" referred to in the requirements in **504. 2** (3) of the Rules are to conform to the requirements of KS B 0222 or equivalent.

3. Flange connection

For the purpose of the requirements in **504. 3** (2) of the Rules, type and size of flange connections are to comply with the **Pt 5, Ch 6, Fig 5.6.1** of the Rules for the welded neck, slip-on and socket welded type as following requirements (1) to (3) :

The others except welding connection are to comply with the requirements of KS, ANSI or other standards as deemed appropriate by the Society for their type and size.

(1) Welded neck type : Type A in **Pt 5, Ch 6, Fig 5.6.1** of the Rules
(2) Slip-on welded type : Type B1 in **Pt 5, Ch 6, Fig 5.6.1** of the Rules
(3) Socket welded type : Type B2, B3 in **Pt 5, Ch 6, Fig 5.6.1** of the Rules

4. Welding, post-weld heat treatment and non-destructive testing

(1) For the purpose of the requirements in **504. 6** (2) of the Rules, the post-weld heat treatment of pipes with thickness less than 10 mm may be omitted except for those required in the requirements in **Pt 5, Ch 6, 105. 5** of the Rules.
(2) For the purpose of the requirements in **504. 6** (3) of the Rules, the radiographic testing method and the judgement for acceptance are to conform to the requirements in **Pt 5, Ch 6, 1204.** of the Rules.
(3) The "other non-destructive tests" referred to in **504. 6** (3) (B) of the Rules means the ultrasonic testing, and depending on use of pipes, magnetic particle testing or liquid penetrant testing, and the testing procedures are to conform to the requirements in KS D 0250, KS D 0213, KS B 0816.

505. Testing of piping on board

1. Application

For the purpose of the requirements in **505. 1** of the Rules, for pipes within the cargo tank and pipes with open ends, the hydraulic test and leak test specified in the requirements in **505. 2** and **3** of the Rules may be omitted. However, the hydraulic test specified in the requirements in **505. 2** of the Rules is to be conducted for pipes without open ends and discharging pipes provided inside the cargo tanks.

2. Leak test

For the purpose of the requirements in **505. 3** of the Rules, the leak test of pipelines is to be conducted at a pressure of 90 % of the design pressure of the pipings, The test pressure may be modified, when test is conducted with a liquid of high leak detecting ability.

3. Test under operating condition

For the purpose of the requirements in **505. 4** of the Rules, the test is to be conducted according to the requirements in **410. 9** of the Guidance.

506. Cargo system valve requirements

1. Stop valves fitted to the cargo tank

(1) For the purpose of the requirements in **506. 1** (1) and (2) of the Rules, no expansion joints are to be provided between the cargo tank and stop valves fitted to the cargo tank. "To be capable of local manual operation and provide full closure" referred to in the requirements means that the stop valve is fitted with manual operated closing means.
(2) For the purpose of the requirements in **506. 1** (2) of the Rules, the duplicated provisions of manual stop valve and emergency shutdown valve may be made in such a way as shown in

Fig 7.5.28 of the Guidance.

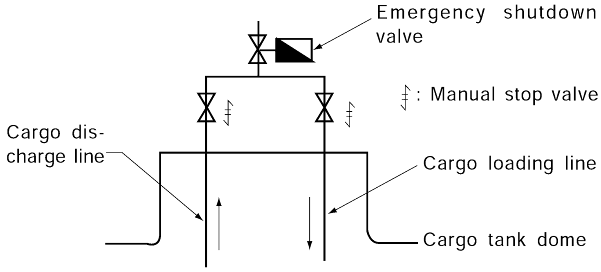


Fig. 7.5.28 Duplicate Provisions of Stop Valve and Emergency Shutdown Valve

2. Cargo hose connection

(1) The "connections not used in transfer operations" referred to in the requirements in **506. 3** of the Rules means those not used for cargo operation, for example, hose connection used for gas free operation. In this case, stop valve and blind flange are to be provided at the connection.
(2) For the purpose of the requirements in **506. 3** of the Rules, the connection between the cargo hose connection and shore line is to be electrically bonded.

3. Emergency shutdown valves

The emergency shutdown valves specified in **506. 4** of the Rules are to be in accordance with the following requirements (1) to (5) :

(1) In case where there is no cargo control room and no remote control of cargo operation is carried out, one of the remote control locations of the emergency shutdown valves is to be in the wheelhouse.
(2) The "fail-closed type" referred to in the requirement of the Rules is, for example, one of given in the following (A) and (B) :
  (A) The type in which the hydraulic or pneumatic pressure is solely used in valve opening motion, and the valve closing motion including the case of fail-closure is effected by spring or weight.
  (B) Where valve diameter is so large that both opening and closing motions of the valve are hydraulically or pneumatically effected, the operating oil or air in the fail-closure operation is to be supplied from a specially provided accumulator and the system setup is to comply with the following requirements (a) to (c) :
    (a) The valve operating cylinder may be used for both ordinary motion and fail-closure motion, but the hydraulic or pneumatic line from the special accumulator for fail-closure operation to the valve operating cylinder is not to serve commonly with those for ordinary valve operation. Further, no stop valve is to be provided on the hydraulic or pneumatic line for fail-closure.
    (b) The capacity of a special accumulator for fail-closure operation is to be sufficient to operate, at least, twice all the emergency shutdown valves. However, when a special accumulator is connected to the emergency shutdown valves of the same type provided on both sides of the ship, it may be made in such a way that the emergency shutdown valves on one side is operated twice.
    (c) Alarm is to be given in the event of loss of hydraulic or pneumatic pressure for ordinary valve motion and activation of fail-closure operation.
(3) To "be capable of local manual closing operation" referred to in the requirements of the Rules means the one which can be directly manually closed, and in addition those shutdown by manual release of hydraulic pressure or pneumatic pressure or shutdown by manual pump.
(4) To "fully close under all service conditions within 30 s of actuation" referred to in the requirements of the Rules means that the emergency shutdown valve assumes the completely closed within 30 s from the issuance of closing signals of the valve. This provision may not apply to the manual emergency shutdown valves given in the preceding (3).
(5) No stop valve is to be provided on the hydraulic or pneumatic line for closing the emergency shutdown valve.

507. Ship's cargo hoses

1. General

For the purpose of the requirements in **507.** of the Rules, the cargo hoses carried by the ship are to be one of given in the following (1) to (3) :

(1) Accepted ones by either preliminary survey in accordance with Ship Safety Act or inspection in accordance with the requirements of type approval
(2) Accepted ones by an inspection organization recognized by the Society
(3) Approved ones in accordance with the requirements of the Guidance

508. Cargo transfer methods

1. Cargo transfer installations

(1) For the purpose of the requirements in **508. 1** of the Rules, when the cargo transfer methods are of the submerged pumps or by deep well pumps, standby cargo pump or the cargo transfer installations according to the requirements in **508. 2** of the Rules are to be provided.
(2) The standby cargo pump referred to in the preceding (1) may be such as to conform to the following requirements :
  (A) Where two sets or more cargo pumps are provided in one cargo tank, the provision of standby cargo pump may be omitted even when both of them are normally subjected to simultaneous operation. Where cargo tank of such a construction that it is separated by a bulkhead and connecting holes or bulkhead valve with remote control are not provided, each such tank separated by the bulkhead is to be regarded as one cargo tank.
  (B) The stripping pump may be regarded as a standby cargo pump.
  (C) The eductor may be regarded as a standby cargo pump. In this case, however, care is to be taken so that even when cargoes of different kinds are carried simultaneously, the driving fluid is available at all times.
(3) The cargo pumps specified in the requirements in **508. 1** of the Rules are to be approved in accordance with the requirements of the Guidance.

2. Cargo transfer by gas pressurization

(1) The "gas pressurization" referred to in the requirements in **508. 2** of the Rules means, for example, to pressurize the cargo tank with cargo vapour pressurized by cargo compressor or cargo heater.
(2) The compressor referred to in the preceding (1) is to be approved in accordance with the Guidance.

Section 6 Materials of Construction

601. General

1. Mechanical properties

For the purpose of the requirements in **601. 5** of the Rules, the required values of tensile strength, yield stress and elongation of a material are to be in accordance with the requirements in **Pt 2, Ch 1** of the Rules applicable to the material.

2. Alternative materials

When the design temperature of a material falls under the higher temperature range than the specified one for the material in **Table 7.5.5** and **Table 7.5.6** of the Rules, the impact test temperature given in **Table 7.5.3** to **Table 7.5.6** of the Rules correspondingly to the design temperature may be used instead of the impact test temperature depending on the material. For example, in the case of 2.25 % nickel steel pipes used at the design temperature of -45°C, the impact test temperature may be -50°C, while in the case of 3.5 % nickel steel plates used at the design temperature of -61°C, the impact test temperature may be -70°C.

3. Properties after post-weld heat treatment

For the purpose of the requirements in **601. 8** of the Rules, when post-weld heat treatment is carried out, the properties of the base material are to be in accordance with the requirements given in **Table 7.5.3** to **Table 7.5.6** of the Rules in the heat treated condition or equivalent condition whether such post-weld heat treatment is regarded in **411.** or **504. 6** (2) of the Rules or not. The welds properties at welding procedure qualification tests and production weld tests specified in the requirements in **603.** of the Rules are to satisfy the requirements in **603. 4** and **6** of the Rules in the heat treated condition.

602. Material requirements

(1) For the purpose of the requirements in **Table 7.5.3** of the Rules, the following requirements are to be complied with :
   (A) The use of the longitudinally or spirally welded pipes given in the Note (1) of the Table is to be in accordance with the relevant requirements in **Pt 2, Ch 1, Sec 4** of the Rules.
   (B) Fittings of type C independent tanks and process pressure vessels with the design pressure not exceeding 3.0MPa and design temperature of 0°C or more and nominal diameter less than 100A given in Note (1) may comply with the requirements of KS or other standards as deemed appropriate by the Society.
   (C) The controlled rolling as a substitution for normalizing given in Note (2) may be of the temperature controlled rolling or Thermo-Mechanical Controlled Processing (TMCP). Also, the controlled rolling as a substitution for tempering and quenching may be of TMCP.
(2) The controlled rolling as a substitution for normalizing or tempering and quenching given in Note (4) of **Table 7.5.4** of the Rules may be of TMCP.
(3) For the purpose of the requirements in **Table 7.5.5** of the Rules, the following requirements are to be complied with :
   (A) For the purpose of the requirements in Note (2) of the Table, aluminium alloy of 5083, austenitic stainless steel, 36 % nickel steel and 9 % nickel steel may be used at the design temperature up to 196°C.
   (B) For the purpose of the requirements in Note (4) of the Table, the chemical composition limit of a material, if the material specified in **Pt 2** of the Rules, is to be in accordance with the relevant requirements in **Pt 2, Ch 1** of the Rules.
   (C) For the purpose of the requirements in Note (7) of the Table, the omission of the impact test given in Note (7) of the Table may generally be accepted for the austenitic steel of the type referred to in the Table.
(4) For the purpose of the requirements in **Table 7.5.6** of the Rules, the following requirements are to be complied with :
   (A) The use of vertically or spirally welded pipes given in Note (1) of the Table is to be in accordance with the requirements in the preceding (1) (A).
   (B) The requirements for forgings and castings given in Note (2) of the Table are to be in ac-

cordance with the relevant requirements in **Pt 2, Ch 1** of the Rules if specified.
(C) For the design temperature given in Note (3) of the Table lower than -165°C, the provision in the preceding (3) (A) are to apply.
(D) The chemical composition limit given in Note (5) of the Table is to be in accordance with the requirements in the preceding (3) (B).
(E) The omission of the impact test given in Note (8) of this Table are to be in accordance with the requirements in the preceding (3) (C).

603. Welding and non-destructive testing

1. General

(1) The requirements in **603.** of the Rules apply to independent tanks, semi-membrane tanks, process pressure vessels, integral tanks and piping. The requirements on membrane tanks, are to the satisfaction of the Society depending on the structural type of the tank.
(2) For the purpose of the requirements in **603. 6** of the Rules, the following requirements (A) and (B) are to be complied with.
(A) The impact test may generally be omitted for austenitic stainless steels of types given in **Table 7.5.5** and **Table 7.5.6** of the Rules.
(B) The impact test may generally be omitted for aluminum alloys of 5083 and welding material of 5183.

2. Welding procedure qualification tests of cargo tanks and process pressure vessels

For the purpose of the requirements in **603. 3** (2) of the Rules the following requirements are to be complied with :

(1) Longitudinal bend tests which are required in lieu of transverse bend tests in the case where the base material and weld metal have different strength level specified in **603. 3** (2) (B) of the Rules, such as 9 % nickel steel, are to be in accordance with the requirements in **Pt 2, Ch 2, 402.** of the Rules.
(2) For the purpose of the requirements in **603. 3** (2) (D) of the Rules, for type C independent tanks and process pressure vessels, macroscopic and microscopic examinations and hardness tests are to be carried out according to the requirements of the Rules. For other independent tanks, integral tank and semi-membrane tanks, macroscopic examinations are to be carried out according to the requirements in **Pt 2, Ch 2, Sec 4** of the Rules.

3. Test requirements

(1) For the purpose of the requirements in **603. 4** of the Rules, the welding procedure qualification test are also to comply with the relevant requirements in **Pt 2, Ch 2, Sec 4.** and **Pt 5, Ch 5, Sec 4** of the Rules.
(2) For the purpose of the requirements in **603. 4** (1) of the Rules, the transverse tensile strength of weld metal which has lower tensile strength than that of the parent metal, e.g. in the case of 9 % nickel steel, is to comply with the requirements in **Pt 2, Ch 2, 402. 5** of the Rules.
(3) For the purpose of the requirements in **603. 4** (2) of the Rules, bend tests are also to comply with the requirements in **Pt 2, Ch 2, 402. 6** of the Rules. In case where the base metal is of RLP9 specified in **Pt 2, Ch 1** of the Rules, bend tests may be omitted.
(4) For the purpose of the requirements in **603. 4** (3) of the Rules, the test temperature of impact tests may be determined in accordance with the requirements in **601. 2** of the Guidance.

4. Welding procedure qualification tests for piping

For the purpose of the requirements in **603. 5** of the Rules, welding procedure qualification tests for pipes are also to be in accordance with the relevant requirements in **Pt 2, Ch 1** and **Pt 2, Ch 2, Sec 4** of the Rules.

5. Production weld tests

(1) For the purpose of the requirements in **603. 6** of the Rules, production weld tests are also to be in accordance with the relevant requirements in **Pt 2, Ch 2, Sec 3** of the Rules and **Pt 5, Ch 5, 405.** of the Rules.
(2) For the purpose of the requirements in **603. 6** (1) of the Rules, the number of test specimens for production weld tests of secondary barriers may be reduced to the extent as deemed appropriate by the Society considering the experience of same welding procedures in past, workman-

ship and quality control. In general, intervals of production weld tests for secondary barriers may be approximately 200 mm of butt weld joints and the tests are to be representative of each welding position.

(3) For the purpose of the requirements in **603. 6** (4) of the Rules, number of test specimens for the production weld tests for integral tanks may be reduced to the same level as in the case of secondary barrier given in the preceding (2). Production weld tests for membrane tanks are left to the discretion of the Society depending on the construction system of the tank.

6. Non-destructive testing

(1) For the purpose of the requirements in **603. 7** (1) of the Rules, the following requirements are to be complied with.

(A) For the non-destructive tests specified in the requirements in **603. 7** (1) (B) of the Rules for the remaining welds of tank plates of type A and B independent tanks and semi-membrane tanks other than butt welds, fillet welds of highly stressed parts of main structural members of cargo tanks are to be examined magnetic particle or dye penetrant tests given in the following (B). Butt welds of highly stressed parts of main structural members such as face plates of girders are to be subjected to radiographic test given in the following (B).

(B) The following requirements (a) through (d) are to apply as the testing procedures and acceptance criteria for the non-destructive tests referred to in the requirements in **603. 7** (1) (C) of the Rules :

(a) For radiographic tests, the test may be in accordance with the requirements in KS B 0845, ISO 2437, ISO 2504 and ISO/R1027 where the acceptance criteria are to be KS Grade 2 or higher. In the case of KS Grade 3, acceptance is left to the discretion of the Society in consideration of the importancy of the structural members and nature of defects, etc.

(b) For ultrasonic tests, the requirements in KS D 0250 apply correspondingly.

(c) For magnetic particle test, the requirements in KS D 0213 apply correspondingly.

(d) For dye penetrant tests, the requirements in KS B 0816 apply correspondingly.

(C) Where ultrasonic tests are performed as a substitution for radio-graphic tests according to the requirements in **603. 7** (1) (C) of the Rules, at least 10 % of the whole testing objects are to be subjected to radiographic tests.

(2) For the purpose of the requirements in **603. 7** (3) of the Rules, the welding inspection procedures and acceptance criteria for integral tanks are to comply with the requirements in **603. 7** (1) (A) of the Rules correspondingly. The procedures and criteria for membrane tanks are to be to the satisfaction of the Society, depending on the structural type of the tanks.

(3) For the purpose of the requirements in **603. 7** (6) of the Rules, the radio-graphic tests of secondary barriers where the hull structure acts as the secondary barrier are to be performed for the double bottom tank top platings and bulkhead platings in accordance with the requirements for shell platings of ordinary ships specified in **Pt 2, Ch 2, 309.** of the Rules.

Section 7 Cargo Pressure/Temperature Control

701. General

1. Means of control

The "system allowing the product to warm up and increase in pressure" referred to in the requirements in **701. 1** (3) of the Rules means the pressurized cargo tanks which are, in general, accepted for ships with limited area of service. The ambient design temperature and period of voyage as the design conditions of the system are to be to the satisfaction of the Society in consideration of the sea and weather conditions of the service area, and where necessary, possible extension of voyage for sheltering from heavy weather.

2. Design requirement of the systems

(1) For the purpose of the requirements in **701. 2** of the Rules, the cooling system is to comply with the following requirements (A) to (C) :
- (A) For the refrigerating plant, the following requirements (a) and (b) are to be complied with :
  - (a) In the case of indirect system, the relevant requirements in **Pt 9, Ch 1** of the Rules are to be complied with.
  - (b) In the case of the direct system, the following requirements (i) through (vii) are to be complied with :
    - (i) The construction of compressors is to be such that causes only a small amount of gas leakage and without sparks.
    - (ii) A relief valve or overpressure preventing device is to be provided on the discharge from the compressor. However, when overpressure is unlikely, this requirement may be dispensed with. The vent pipe of the relief valve of the compressor is to be led to the vent system specified in the requirements in **802. 9** of the Rules.
    - (iii) A pressure gauge is to be provided on the discharge side of the compressor.
    - (iv) Means to avoid the entry of cargo liquid into the compressor are to be provided.
    - (v) The requirements in **Pt 9, Ch 1, 401.** and **404. 1** of the Rules apply correspondingly.
    - (vi) The temperature of the cooling sea water used in the calculation of capacity of the refrigeration plant is to be the ambient sea water temperature specified in **701. 2** of the Rules.
    - (vii) The compressors and heat exchangers are to be approved in accordance with the requirements of the Guidance.
- (B) For pressure vessels and pipings, the requirements in **501. 2** and **502.** of the Rules and **501. 1** and **502. 1** (1) of the Guidance are to be complied with.
- (C) For pressure relief valves, level gauges and other fittings, the relevant requirements in **Secs 5, 8** and **13** of the Rules apply correspondingly as necessary.

(2) The increments/decrements of design ambient temperature specified in the requirements in **701. 2** of the Rules are to be in accordance with **402. 3** of the Guidance.

(3) The maximum temperature of steam and heating media within the cargo area is to be adjusted to take into account the temperature class of the cargoes.

3. Design requirement for dangerous cargoes

The "certain highly dangerous cargoes specified in **Sec 17**" referred to in **701. 3** of the Rules means the cargoes to which **1703. 2** of the Rules applies as required in column h in Table of **Sec 19** of the Rules.

702. Refrigeration systems

1. Stand-by unit and heat exchanger

For the purpose of the requirements in **702. 1** of the Rules, the stand-by unit of the refrigeration system and stand-by heat exchangers are to comply with the following requirements :

(1) The stand-by refrigeration system referred to in the requirements of the Rules does not include heat exchanger.

(2) Where the whole necessary capacity is shared by multiple sets of units, the capacity of the stand-by unit may be made in such a way that it compensates the capacity of one unit having

the largest capacity among others.

(3) Where the refrigeration plants are all driven by electric motors, electrical supply to the motors is to be fed from two or more generators.

(4) The piping of the stand-by heat exchangers may, for example, be made as given in **Fig 7.5.29** of the Guidance. In this case, the total capacity of the heat exchangers including stand-by unit is to be 125 % or more of the maximum requirement.

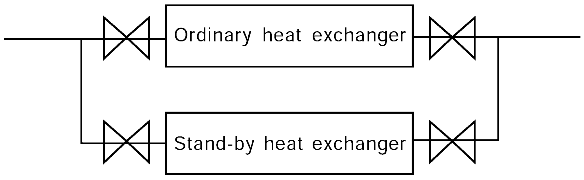


Fig. 7.5.29 The Example Piping of the Stand-by Heat Exchanger

2. Requirement for carrying simultaneously cargoes or chemical reaction

The "cargoes which may react chemically in a dangerous manner" referred to in **702. 2** (1) of the Rules means those cargoes in combination as given in **Table 7.5.7** of the Guidance. For other cargoes not given in this Table, except for those given in the notes of the Table, decision is to be taken in each case upon investigating the physical properties.

Table 7.5.7 Cargoes Which may React Chemically in a Dangerous Manner

Group No.	Groups	Product name								
6	Ammonia	Ammonia, anhydrous	6							
7	Aliphatic amines	Dimenthylamine Monoethylamine		7						
16	Alkylene oxides	Propylene oxide	*H*	*H*	16					
19	Aldehydes	Acetaldehyde	*H*	*H*		19				
30	Olefines	Butadiene Ethylene Propylene Butylene Methyl acetylene -propadiene alxtures					30			
31	Paraffins	Butane Ethane Methane (LNG) Propane						31		
35	Vinyl halides	Vinyl chloride							35	
36	Halogenated hydrocarbons	Ethyl chloride Methyl bromide Methyl chloride								36

Notes:
1. [H] in Table denotes possibility of dangerous reaction whereas blank column signifies no possibility of such reaction.
2. In general, chlorine and ethylene oxide are to be individually refrigerated or not carried together with other cargo.
3. Nitrogen has no danger of reacting with other cargo.

3. Cooling water

(1) "Any other essential service" referred to in the requirements in **702. 3** of the Rules means water supply to equipment necessary for propulsion, discharge of bilges, ballasting/deballasting and fire services specified in **Pt 5, Ch 1, 102. 1** of the Guidance. The service for the water spray system specified in the requirements in **1103.** of the Rules is to be included therein.

(2) In case where the stand-by cooling pump is used for service common to that given in the preceding (1), the capacity of this pump is not to be less than the total capacity of the maximum cooling requirement and the necessary capacity for the particular service.

4. Type of refrigeration system

The "certain cargoes specified in **Sec 17**" referred to in the requirements in **702. 4** (1) and (3) of the Rules means those cargoes to which the application of the provisions of **1704. 1** of the Rules is required in column h in Table of **Sec 19** of the Rules.

5. Heat Exchange

For the purpose of the requirements in **702. 5** of the Rules, the compressors for the refrigerant and other equipment that directly handle the refrigerant are, as a rule, to be installed within the cargo area. However, in case where proper means of detecting the leakage of the cargo into the refrigerant and shutting-off the inflow of the leaked cargo to the spaces outside the cargo area after the detection of leakage is established depending on the possibility of cargo leakage into the refrigerant pipes within the heat exchangers, this requirement may be dispensed with.

Section 8 Cargo Tank Vent System

801. General

For the purpose of the requirements in **801.** of the Rules, the pressure relief system of hold spaces is to be in accordance with the following requirements :

(1) In hold spaces not regarded as the interbarrier space and in case where environmental control within the space is required in accordance with the provisions in **902.** and **903.** of the Rules, one or more pressure relief systems of sufficient capacity are to be provided. The set pressure of those pressure relief systems is to be so set as not to exceed the design pressure of the cargo containment system and hull construction under the condition of dry air sealing, inerting or voyaging. The location of the vent discharge outlet to which the exhaust from the pressure relief systems is to be in accordance with the requirements in **Pt 5, Ch 6, 201. 5** of the Rules, and in addition, consideration is to be given so as not to cause the inert gas to accumulate on deck.

(2) The pressure relief system of hold spaces regarded as the interbarrier space or part thereof is to conform to the requirements in **802. 2** of the Guidance.

(3) The evaluation of the adequacy of type C independent tank vent system is to be in accordance with requirements in IMO Res. A. 829(19).

802. Pressure relief systems

1. Pressure relief system for interbarrier spaces

(1) The "pressure relief devices to the satisfaction of the Society" referred to in the requirements in **802. 2** of the Rules means pressure relief valves, rupture discs or equivalent. Two or more of them in combination are to be provided in each space to be covered.

(2) When only pressure relief valves are provided as the pressure relief devices given in the preceding (1), the following requirements (A) and (B) are to be complied with :

(A) In case where the cargo tank is of the type A independent tank, semi-membrane tank provided with complete secondary barrier, membrane tank or integral tank, the following requirements (a) and (b) are to be complied with :

(a) The capacity of the pressure relief system is to be sufficient to relieve the greater of the maximum supply capacity of the inerting system and dry air supply system or the estimated volume of cargo evaporation in an event of failure of the cargo tank.

(b) Pressure relief valves are to be in accordance with the requirements in **802. 3** of the Guidance.

(B) In case where the cargo tank is of the type B independent tank or semi-membrane tank provided with partial secondary barrier, the following requirements (a) and (b) are to be complied with :

(a) The capacity of pressure relief device is to be in accordance with the preceding (A) (a).

(b) Pressure relief valves may not be such as being approved in accordance with the requirements in **802. 3** of the Guidance. However, they are to be equivalent to those complying with the requirements for PV valves in **Pt 7, Ch 1, 1004. 1** of the Guidance.

(3) When, as a pressure relief device referred to in the preceding (1), pressure relief valve and rupture disc are provided in combination, they are to conform to the following requirements (A) to (C) for the cargo tank types indicated in the preceding (2) (A) :

(A) The capacity of the pressure relief valve is to be sufficient to relieve the maximum supply capacity of the inerting system.

(B) Pressure relief valves are to be in accordance with the requirements in the preceding (2) (B) (b).

(C) The capacity of rupture disc is to be sufficient to relieve the volume of cargo evaporation in an event of failure of the cargo tank, and the construction is to be as deemed appropriate by the Society.

(4) The relieving capacity of pressure relief devices for interbarrier spaces is to be determined as followings :

(A) The combined relieving capacity of the pressure relief devices for interbarrier spaces surrounding type A independent cargo tanks where the insulation is fitted to the cargo tanks may be determined by the following formula :

$$Q_{sa} = 3.4 A_c \frac{\rho}{\rho_v} \sqrt{h} \quad (\mathrm{m^3/s})$$

where:

Q_{sa} : minimum required discharge rate of air at standard conditions of 273K and 0.1013 MPa

A_c : design crack opening area ($\mathrm{m^2}$), $\pi\delta\, l/4$

δ : maximum crack opening width (m), 0.2 t

t : thickness of tank bottom plating (m)

l : design crack length equal to the diagonal of the largest plate panel of the tank bottom (m), see **Fig 7.5.30** of the Guidance

h : maximum liquid height above tank bottom plus 10·MARVS (m)

ρ : density of product liquid phase at the set pressure of the interbarrier space relief device ($\mathrm{kg/m^3}$)

ρ_v : density of product vapour phase at the set pressure of the interbarrier space relief device and a temperature of 273 K ($\mathrm{kg/m^3}$)

(B) The relieving capacity of pressure relief devices of interbarrier spaces surrounding type B independent cargo tanks may be determined on the basis of the preceding (A). However, the leakage rate is to be determined in accordance with **407. 6** (1) of the Rules.

(C) The relieving capacity of pressure relief devices of interbarrier spaces of membrane and semi-membrane tanks is to be evaluated on the basis of specific membrane or semi-membrane tank design.

(D) The relieving capacity of pressure relief devices of interbarrier spaces adjacent to integral type cargo tanks may, if applicable, be determined as for type A independent cargo tanks.

(E) Interbarrier space pressure relief devices in the scope of this paragraph are emergency devices for protecting the hull structure from being unduly overstressed in case of a pressure rise in the interbarrier space due to primary barrier failure. Therefore, such devices need not comply with the requirements in **802. 9** and **802. 10** of the Rules.

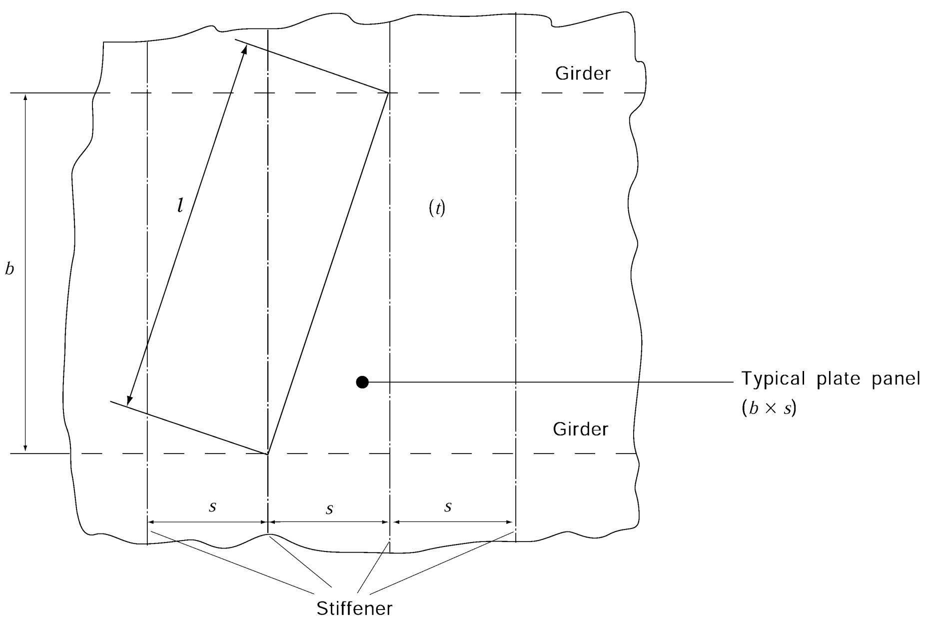


Fig. 7.5.30 The Example Size of Tank Bottom Plate

2. Arrangement of pressure relief valves

For the purpose of the requirements in **802. 4** of the Rules, for the cargo tank with the design temperature lower than 0°C, it is to be verified through temperature distribution calculation, etc. that the valve would not freeze or it is provided with anti-freezing construction. In ships where the requirements in **Pt 3, Ch 20** of the Rules apply or ships regularly navigate through the sea of cold zone, the pressure relief valves are to have satisfactory proved function under freezing condition or to be provided with heating system to prevent functional inability due to freezing.

3. Capacity of pressure relief valves

For the purpose of the requirements in **802. 5** of the Rules, pressure relief valves to be provided in cargo tanks, cargo piping and interbarrier spaces, as necessary, are to be approved in accordance with the Guidance for Approval of Manufacturing Process and Type Approval, etc.

4. Changing of set pressure of relief valves

The means as "necessary for isolating the valves not in use from the cargo tank" referred to in **802. 6** of the Rules means, for example, the arrangement as shown in **Fig 7.5.31** of the Guidance.

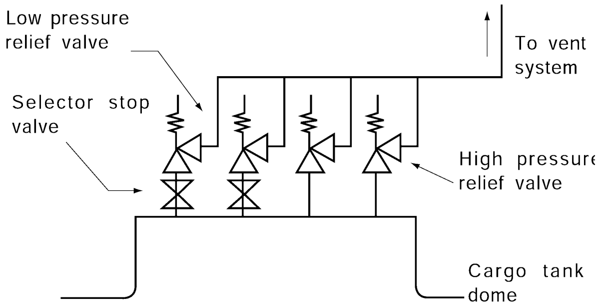


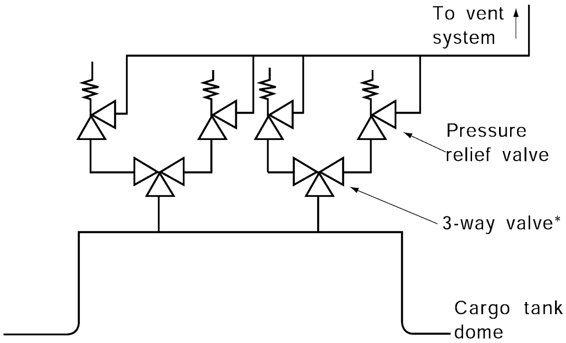
Fig. 7.5.31

5. Stop valves between tanks and pressure relief valves

(1) For the purpose of the requirements in **802. 8** of the Rules, no stop valve is to be provided in the vent piping on the downstream of the pressure relief valve.

(2) The "suitable arrangements" referred to in the requirements in **802. 8** (1) of the Rules means, for example, the arrangement as shown in **Fig 7.5.31** of the Guidance, the arrangement through transfer of the 3-way valve as shown in **Fig 7.5.32** of the Guidance or by stop valve of inter-locking type.

(3) The "suitably maintained spare valve" referred to in the requirements in **802. 8** (3) of the Rules means, for example, valves of the same type and capacity of valve ① and valve ② in the arrangement as shown in **Fig 7.5.33** of the Guidance. In this case, if valve ① and valve ② are of the completely same type and capacity, only one set of such spare may be accepted.



* : 3-way valve in which the direction of opening is indicated where means are provided to prevent any intermediate valve position

Fig. 7.5.32

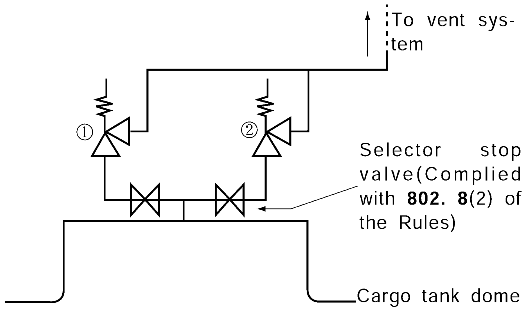


Fig. 7.5.33

6. Venting system

(1) To "be so constructed that the discharge of gas will be directed upwards and so arranged as to minimize the possibility of water or snow entering the vent system" referred to in the requirements in **802. 9** of the Rules means for example, as shown in **Fig 7.5.34** of the Guidance.
(2) For the purpose of the requirements in **802. 9** of the Rules, the height of the vent discharge outlet is to be measured from the exposed deck at the place where the vent mast is provided.

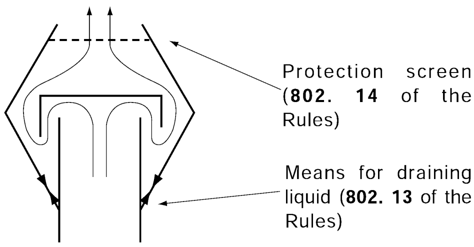


Fig. 7.5.34 Example of Construction of Vent Discharge Outlet

7. Arrangement of vent exits

For the purpose of the requirements in **802. 10** of the Rules, the distance to the vent discharge outlet is to be measured horizontally.

8. Arrangement of all other cargo vent exits

For the purpose of the requirements in **802. 11** of the Rules, the arrangements of other vent discharge outlet are to be in accordance with following requirements (1) to (3) :

(1) Vent discharge outlets from the gas fuel piping specified in **1603. 6** of the Rules are to be in accordance with the requirements in **802. 9** and **10** of the Rules.
(2) Vent discharge outlets shown in the following (A) and (B) are to be arranged at a horizontal distance not less than 10 m from the nearest air intakes, discharge outlets or opening to accommodation spaces, service spaces and control stations, or other gas-safe spaces.
   (A) Vent discharge outlet of the discharge gas from gas detecting system specified in the requirements in **1306. 5** (2) of the Rules.
   (B) Discharge outlet specified in the requirements in **1603. 5** of the Rules
(3) Vent discharge outlets from pressure relief valves or rupture discs of interbarrier spaces are to be installed in gas dangerous zones.

9. Pressure relief system for carrying incompatible cargoes simultaneously

The "separate pressure relief system" referred to in the requirements in **802. 12** of the Rules means the independent vent system including an independently provided pressure relief valve. In this case, no specific requirement is provided on the distance between vent discharge outlets.

10. Means for draining of vent piping system

For the purpose of the requirements in **802. 13** of the Rules, drain plugs or drain cocks are to be provided at places, such as vent post bottoms and bend parts of vent pipes, where drains are likely to accumulate.

11. Protection screens on vent outlets

The "protection screens" referred to in the requirements in **802. 14** of the Rules means wire gauze of 13 mm × 13 mm mesh or below with suitable strength against falling objects.

12. The "special guidelines" referred to in **802. 18** of the Rules means **Annex 7A-2.**

803. Additional pressure relieving system for liquid level control

1. Requirement of additional pressure relieving systems

The words "to prevent the tank from becoming liquid full" contained in **803. 1** of the Rules have the meaning that at no time during the loading, transport or unloading of the cargo including fire conditions will the tank be more than 98 % liquid full, except as permitted by the requirements in **1501. 3** of the Rules.

804. Vacuum protection systems

1. Fitting of vacuum protection systems

(1) For the purpose of the requirements in **804. 2** (1) of the Rules, the means to stop all suction of the cargo liquid or cargo vapour may be by shutting off valves or stopping the equipment provided that they are automatically operated.
(2) For the purpose of the requirements in **804. 2** (2) of the Rules, the vacuum relief valve is to conform to the requirements in **802. 5** of the Rules and to be approved in accordance with the Guidance. However, means as specified in the requirements in **804. 2** (1) or (3) of the Rules are to be provided, and where vacuum relief valve adjusted to function at a pressure lower than such means is provided as an additional device, the requirements may be dispensed with for this vacuum relief valve as an additional means.

2. Requirement of vacuum protection systems

For the purpose of the requirements in **804. 3** of the Rules, vacuum relief valves are to be in accordance with the following requirements (1) and (2) :

(1) Only for cases where vacuum relief valves adjusted to a set pressure lower than the operating pressure of the device specified in the requirements in **804. 2** (1) or (3) of the Rules, are provided for additional means of the devices, it may be accepted to admit the air to be introduced into the tank even in case of flammable cargoes except for the cases specified in the relevant requirements in **Sec 17** of the Rules.
(2) The air suction opening for the vacuum relief valve as an additional device indicated in the preceding (1) may be made in such a way that the requirements in **802. 9** and **10** of the Rules do not apply. However, the requirements in **Pt 5, Ch 6, 201. 5** of the Rules are to be complied with, and the construction of the suction opening is, for example, to be as shown in **Fig 7.5.34** of the Guidance.

805. Size of valves

1. Size of valves

For the purpose of the requirements in **805. 2** of the Rules, the fire exposure factor is to be in accordance with the following requirements (1) through (4) :

(1) The insulation materials used at exposed spaces when F = 0.5 are to conform to the requirements in **409. 3** (2) of the Guidance.
(2) In the case of integral tanks, F = 0.1.
(3) The fire exposure factor of the tank which partially protrudes beyond the tank cover having the

fire integrity equivalent to the deck and deck structure is to be of such a value as obtained by proportional distribution of cargo tank surface areas above and below the deck or tank cover.

(4) In case where hold spaces filled with dry air is accepted for semi-membrane tanks provided with partial secondary barriers in accordance with the requirements in **902. 2** (2) of the Rules, F = 0.2.

Section 9 Environmental Control

901. Environmental control within cargo tanks and cargo piping systems

1. Gas-free and purge systems of cargo tanks

For the purpose of the requirements in **901. 1** of the Rules, the design and arrangement of gas-freeing and purging piping systems of cargo tanks are to be in accordance with the following requirements (1) and (2) :

(1) For installation of piping and fixing of pipe fittings in cargo tanks, sufficient consideration is to be taken for possible transient temperature differential.
(2) The effectiveness of replacement of cargo tank atmosphere is to be verified at time of gas trial given in **410. 9** of the Guidance.

2. Monitoring of purging and gas-freeing

For the purpose of the requirements in **901. 2** of the Rules, the arrangement of gas sampling points in cargo tanks is to be determined according to the cargo properties, cargo tank construction and capacity and the abilities of gas-freeing and purging systems, and where appropriate, the adequacy of the arrangement of gas sampling points is to be verified by the performance test. The locations of gas sampling points are, as standard, to be at the upper, middle and lower space of the cargo tank.

3. Inerting of cargo tanks

For the purpose of the requirements in **901. 3** of the Rules, for cargo tanks carrying petroleum products, etc. the requirements in this Chapter apply, and in addition, the requirements specified in **Pt 8, Ch 1, 401. 2** of the Rules are to be complied with.

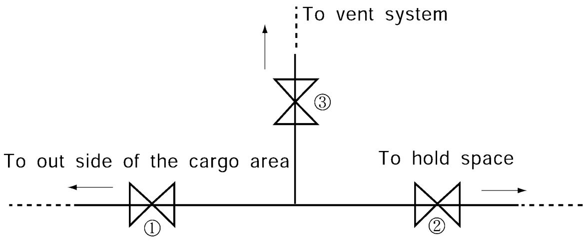
902. Environmental control within the hold spaces (cargo containment systems other than type C independent tanks)

1. Environmental control, requiring full secondary barriers

(1) For the purpose of the requirements in **902. 1** of the Rules, even in cases where full secondary barrier is not required according to the requirements in **407. 3** of the Rules, if flammable gases are carried in type A independent tank, integral tank, membrane tank and semi-membrane tank, the requirements in **902. 1** of the Rules apply correspondingly.
(2) The "suitable dry inert gas" referred to in the requirements in **902. 1** of the Rules means the inert gas of which dew point is controlled in accordance with **904. 1** (4) of the Guidance. Further, the "normal consumption for at least 30 days" referred to in the requirements in **902. 1** of the Rules is to be given consideration for the effects of atmospheric pressure and temperature variations during the passage and additional consumption by gas detection, etc.

2. Environmental control, requiring partial secondary barriers

(1) For the purpose of the requirements in **902. 2** of the Rules, even in cases where the provision of partial secondary barriers is not required according to the requirements in **407. 3** of the Rules, when flammable gases are carried by type B independent tank, the requirements in **902. 2** of the Rules apply.
(2) The "suitable dry inert gas" and the "normal consumption for at least 30 days" referred to in the requirements in **902. 2** (1) of the Rules are to be as specified in 1 (2) above.
(3) In cases where dry air is introduced into the interbarrier spaces and hold spaces, at least the following requirements (A) to (C) are to be complied with :
    (A) Dew point of dry air is to be controlled according to **904. 1** (4) of the Guidance.
    (B) On the supply piping of dry air, one stop valve is to be provided at the inlet into the space which is filled with dry air, and two non-return valves are to be provided within the cargo area side near the forward or aft end of the cargo area. However, one of the two non-return valves may be substituted by 3-in one set as **Fig 7.5.35** of the Guidance.



1) When dry air is being supplied, stop valves ① and ② are to be opened, and stop valves ③ is to be closed.
2) When dry air supply is stopped, stop valve ③ is to be opened, and stop valves ① and ② are to be closed.

Fig. 7.5.35

(C) Instrumentation is to be provided in accordance with the following requirements (a) to (c) :
  (a) At the outlet of the dry air supply system, pressure gauge and thermometer are to be provided.
  (b) One or more dew point meters as deemed appropriate by the Society are to be provided. However, in case where only one dew point meter is provided, a spare cell unit is to be provided.
  (c) At the outlet of the dry air supply system, interbarrier spaces and hold spaces, connections for dew point meter are to be provided.

3. Environmental control for non-flammable gases

(1) The "suitable dry air or inert atmosphere" referred to in the requirements in **902. 3** of the Rules means a state in which spaces are filled with the air with controlled dew point or inert gas according to the requirements in **904. 1** (4) of the Guidance. This inert gas system may not conform to the requirements in 904. and 905. of the Rules, but is to be provided with a storage system or generating system capable of making up a consumption for at least 30 days.
(2) In case where dry air is introduced according to the preceding (1), the requirements in **902. 2** (3) of the Guidance are to be complied with.

4. Environmental control for doble hull and double bottom spaces

Ventilation, inerting and gas measurements for double hull and double bottom spaces are to comply with the requirements in **Ch 1, 1009.** to **1011.** of the Rules.

903. Environmental control of spaces surrounding type C independent tanks

1. Environmental control of spaces surrounding type C independent tanks

For the purpose of the requirements in **903.** of the Rules, the environmental control of the compartment is to be in accordance with **902. 3** (1) and (2) of the Guidance.

904. Inerting

1. Properties of inert-gas and its supply

For the purpose of the requirements in **904. 1** of the Rules, the following requirements (1) through (4) are to be complied with :

(1) For the inert gas supply piping, evaporator and heater, if necessary, are to be provided so that the compartment supplied with inert gas can be maintained at proper temperature and pressure and further, thermometer and pressure gauges are to be provided for monitoring.
(2) Where the inert gas is stored in inert gas bottles, the following requirements (A) through (D) are to be complied with :
  (A) The inert gas bottles and piping are to be dealt with according to the following requirements (a) to (c) :
    (a) The material of the piping may be according to the requirements of the standard as deemed appropriate by the Society.
    (b) The gas bottle may be according to the requirements of the National Standards notwith-

standing the requirements in **Pt 5, Ch 5, Sec 3** of the Rules.
(c) The hydraulic tests for pipes, valves and pipe fittings may be omitted.
(B) The location of installation of the bottles is to be as given in the following (a) and (b) :
(a) The inert gas bottles are, as a rule, to be located in the storage room within the cargo area.
(b) The storage room of inert gas bottles is to be well ventilated so as not to allow leaked gas accumulate the room and be capable of being accessed from the exposed deck.
(C) The inert gas bottles are to be so arranged to be safe against ship motions and vibrations, and are to be stored upright as far as practicable.
(D) The piping system, after assembly of board, is to be subjected to airtightness test at a pressure 1.25 times the maximum working pressure or more, and free flow test at a suitable pressure.

(3) Where the permanent storage tank installed on deck is used as the inert gas storage container, the requirements for the design, tests and inspection of the tank and the piping are to be in accordance with the relevant requirements specified for process pressure vessels and piping systems in **Sec 4** and **Sec 5** of the Rules. However, consideration may be given as appropriate depending on their service conditions.
(4) The dew point of dry inert gas is, in general, not exceed the minimum design temperature of the exposed surface of the insulation material of the cargo tank into the hold space and hul1 structural members of the space being inerted in normal condition.

2. Storage of inert gas at low temperature

For the purpose of the requirements in **904. 3** of the Rules, the thermal isolation between the hull structure and the storage tank, and where necessary, the inert gas supply piping is to be in accordance with **502. 1** (3) of the Guidance.

3. Prevention of the back flow of cargo vapour

For the purpose of the requirements in **904. 4** of the Rules, the arrangement to prevent the back flow of cargo vapour from entering the inert gas system is to be in accordance with **301. 4** (1) of the Guidance. (See **Fig 7.5.36** of the Guidance)

4. Isolation of spaces being inerted

(1) For the purpose of the requirements in **904. 5** of the Rules, the isolation of the spaces being inerted such as cargo tanks, cargo piping system, process pressure vessels and their piping system from the inert gas system are to be in accordance with the preceding **Par 3.**
(2) The isolation of the spaces being isolated other than those indicated in the preceding (1) is to be in accordance with the following requirements (A) and (B) :
(A) The isolation of the interbarrier spaces, hold spaces where the cargo vapour does not exist in normal condition and the outer side of double wall gas fuel piping specified in the requirements in **1603. 1** (1) of the Rules may be by a stop valve.
(B) The isolation of the compartments where cargo vapours are likely to exist in normal condition is to be by the combination of screw-down check valve, stop valve, automatic or control valve, and non-return valve. (See **Fig 7.5.36** of the Guidance)

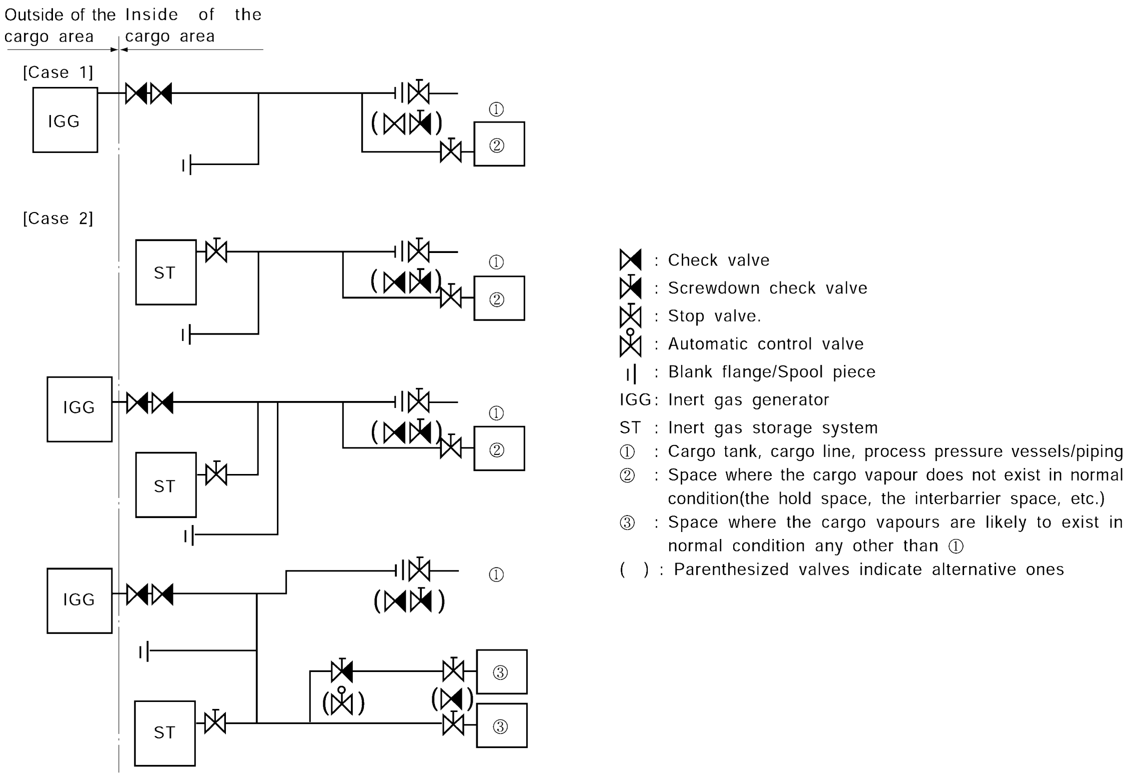


Fig. 7.5.36

905. Inert gas production on board

1. Inert gas production equipment

(1) For the purpose of the requirements in **905. 1** of the Rules, the combustion type inerting systems are to be in accordance with the relevant requirements of **Pt 8, Annex 8-5** of the Guidance and the following requirements (A) to (C).

(A) Inerting gas production equipment is to be provided with sufficient amount of suitable fuel oil.

(B) Where two sets or more inerting gas production equipments are provided, the stop valve is to be installed on the supply outlets of each equipment.

(C) Where the volumetric blower is provided in inerting gas production equipment, the pressure relief valves are to be installed on discharge outlets of blowers to prevent generating the over pressure.

(2) In addition to the preceding (1), nitrogen generating system is to be complied with the relevant requirements in **Pt 8, Annex 8-5** of the Guidance.

(3) The components of inerting gas production equipment given in the preceding (1) and (2) are to be approved by the Society.

Section 10 Electrical Installations

1001. General

1. Certified safe type equipment

(1) The words "satisfaction of the Society" referred to in **1001. 5** of the Rules mean the explosion protected electrical equipment required by **Pt 6, Ch 1, Sec 9** of the Rules and having the performance classified by Gases and Vapours Group and Temperature Class according to **Table 7.5.8** of the Guidance by the type of vapour or equivalent.

(2) The words "approved one as the certified safe type" mean that type tested as the explosion-protected electrical equipment in accordance with the requirements in **Pt 6, Ch 1, 109. 3** and **4** of the Rules and/or equipment recognized that there is no fear of serving as a source of ignition structurally.

Table 7.5.8 Gases and Vapours Groups and Temperature Class

Product name	UN number	Gases and vapours groups	Temperature class
Acetic aldehyde	1089	II A	T4
Ammonia, anhydrous	1005	II A	T1
Butadiene	1010	II B	T2
Butane	1011	II A	T2
Butane－propane mixtures	1011/1978	II A	T2
Butylenes	1012	※	※
Chlorine	1017	－	－
Diethyl ether	1155	II B	T4
Dimethylamine	1032	II A	T2
Ethane	1961	II A	T1
Ethyl chloride	1037	II A	T1
Ethylene	1038	II B	T2
Ethylene oxide	1040	II B	T2
Ethylene oxide－propylene oxide mixtures with ethylene oxide content of not more than 30 % by weight	2983	※	※
Isoprene	1218	II B	T3
Isopropylamine	1221	II A	T2
Methane (LNG)	1972	II A	T1
Methyl acetylene-propadiene mixtrues	1060	※	※
Methyl bromide	1062	※	※
Methyl chloride	1063	II A	T1
Monoethylamine	1036	II A	T2
Nitrogen	2040	－	－
Propane	1978	II A	T1
Propylene	1077	II A	T2
Propylene oxide	1280	II B	T2
Refrigerant gases (see notes)	－	－	－
Sulphur dioxide	1079	－	－
Vinyl chloride	1086	II A	T3
Vinyl ethyl ether	1302	II B	T3
Vinylidene chloride	1303	II A	T2

Notes:
1. Temperature classes and gases and vapours groups are as defined in IEC 60079.
2. 「―」 indicates that the product is non-flammable, and * is to be to satisfaction of the Societ

Section 11 Fire Protection and Fire Extinction

1101. Fire safety requirements

1. Exclusion of ignition source

For the purpose of the requirements in **1101. 2** of the Rules, in the gas-dangerous zones or areas specified in the requirements in **106. 17** of the Rules, for ships carrying flammable substances, electrical equipment, windlasses, openings of chain lockers which are regarded as sources of ignition are not to be provided except for those approved under the relevant requirements in **Sec 10** of the Rules.

1102. Fire water main equipment

1. Fire pump and fire main

For the purpose of the requirements in **1102. 1** of the Rules, the minimum pressure at fire hydrant of the fire main is to be not less than 0.5 MPa gauge irrespective whether the fire pump and water main as used as part of water spray system or not.

2. Nozzles

For the purpose of the requirements in **1102. 4** of the Rules, all nozzles provided for fire-fighting are to be in accordance with the relevant requirements of **Pt 8, Ch 3** of the Rules.

3. Remote control

In case of applying the requirements in **1102. 5** of the Rules, at least one of fire pumps is to be capable of starting by remote control, and all valves provided between the fire pump and fire main are to be capable of being opened by remote control from the navigation bridge or other control stations outside the cargo area.

1103. Water spray system

1. Area to be covered

(1) For the purpose of the requirements in **1103. 1** (1) of the Rules, the area to be covered at the exposed tank dome is to include the areas where stop valves for cargo tanks and emergency shutdown valves specified in the requirements in **506. 1** of the Rules are fitted.
(2) For the purpose of the requirements **1103. 1** (3) of the Rules, the area of the manifold is to include the areas where emergency shutdown valves specified in the requirements in **506. 3** of the Rules are fitted. Further, the "control valve" referred to in the requirements in **1103. 1** (3) of the Rules is to include stop valves for the transfer of cargo line to and from vapour line.
(3) The "high fire risk items" referred to in the requirements in **1103. 1** (4) of the Rules are not to include the hydraulic machinery and electric motors. Further, the "boundaries .... all facing the cargo area" referred to in the requirements in **1103. 1** (4) of the Rules are not to include the ceiling of the compartment to be covered.

2. Arrangement and capacity

For the purpose of the requirements in **1103. 2** of the Rules, the following requirements (1) to (2) are to be complied with :

(1) The nozzles for protecting vertical surfaces are to be arranged per every two tiers for the end walls of the accommodation spaces, as standard.
(2) The intermediate valves fitted with the fire main are to be provided at the connections between the branch line and spray main for example, as shown in **Fig 7.5.37** of the Guidance.

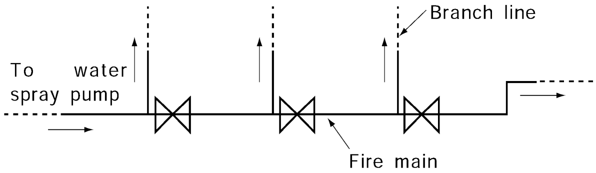


Fig. 7.5.37

3. Use for other services

For the purpose of the requirements in **1103. 4** of the Rules, the ballast pump and bilge pump may be used commonly for the water spray system.

1104. Dry chemical powder fire-extinguishing systems

1. General

The "satisfactory to the Society" referred to in the requirements in **1104. 1** of the Rules means that the requirements in **507. 1** of the Guidance are complied with.

2. Component of the systems

For the purpose of the requirements in **1104. 2** of the Rules, dry chemical powder fire-extinguishing systems are to conform to the requirements in **1104. 2** to **6** of the Rules, and in addition they are to be approved in accordance with the Guidance.

3. Monitors and hand hose lines

For the purpose of the requirements in **1104. 3** of the Rules, the manifold areas may be protected by only one monitor provided that it can be so fixed to protect the manifold area used for cargo operation even if there are manifolds on both sides of the ship.

4. Capacity of dry chemical powder

For the purpose of the requirements in **1104. 6** of the Rules, when the areas to be covered are located higher than the installed positions of monitors and manual hose reels, the Society may request increase in the capacity of these monitors and manual hose reels depending on their arrangement.

1105. Cargo compressor and pump rooms

1. Fixed fire-extinguishing installation for cargo compressor and pump rooms

For the purpose of the requirements in **1105. 1** of the Rules, the fixed gas fire-extinguishing systems for cargo compressor and pump rooms are to be in accordance with the requirements following (1) through (6). Independent inert gas system is to be provided, if the fire-extinguishing medium is not compatible with inerting.

(1) The fixed gas fire-extinguishing system is to conform to the relevant requirements in **Pt 8, Ch 3** of the Rules correspondingly.
(2) In the case of carbon dioxide or halogenated hydro-carbon fire-extinguishing systems, the requirements in **Ch 6, 1102. 1** of the Rules are to be complied with.
(3) In the case of the nitrogen gas fire-extinguishing system, the volume of nitrogen gas is to be not less than that multiply following values by total volume of the relevant spaces and also to be in accordance with national requirements.

$$\frac{21 - O_2}{21} \times 1.2$$

where :

O_2 : limit volume of carbon (Vol%)

(4) The storage containers and pipings for nitrogen gas fire-extinguishing system are to be such that nitrogen gas equal to 85 % of the volume of preceding (3) can be discharged into the space within 2 minutes.

(5) The boundaries of cargo compressor and pump rooms in relation to the requirements in **1105.** of the Rules is to remain in a state corresponding to "A-0" class fire integrity including doors, etc. of the boundaries. Packing provided for doors is, as a rule, to be of non-combustible material defined in the relevant requirements in **Pt 8, Ch 1** of the Rules. However, in case where special consideration is taken for structural details in way of openings, materials and quantity of the packing, the packing need not be of non-combustible one.

(6) Notwithstanding the requirements in the preceding (5), when steel blind covers are provided for the windows fitted on the boundary of the compartment and the exposed area, these windows may not be "A-0" class. Further, at the boundary to electric motor room, no windows are to be provided unless they correspond to "A-0" class.

Section 12 Mechanical Ventilation in the Cargo Area

1201. Spaces required to be entered during normal cargo handling operations

1. Ventilation exhaust ducts from gas-dangerous spaces

For the purpose of the requirements in **1201. 6** of the Rules, the construction of ventilation exhaust ducts is, for example, to be as shown in **Fig 7.5.38** of the Guidance.

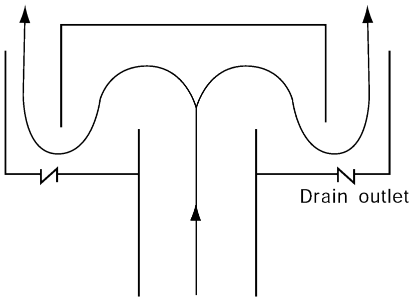


Fig. 7.5.38

2. Arrangement of ventilation intakes

For the purpose of the requirements in **1201. 7** of the Rules, ventilation intakes are, at least, to be located in the gas-safe areas.

3. Construction of ventilation fans

For the purpose of the requirements in **1201. 9** of the Rules, the following requirements (1) and (2) are to be complied with :

(1) Ventilation fans are to be approved in accordance with the Guidance.
(2) The ventilation fans for motor rooms where electric motors to drive cargo compressors and cargo pumps are installed are to conform to the requirements in **1201. 9** of the Rules, and in addition, to the following requirements (A) and (B) :
   (A) To have a ventilation capacity of not less then 30 air changes of the total volume of the motor room per hour.
   (B) Electric motors driving ventilation fans are to conform to the relevant requirements in **Ch 5, Sec 10** of the Rules depending on the location of motors, and in addition, to the requirements for exterior-mounted type specified in **Pt 8, Ch 1, 312. 2** of the Guidance when motors are installed in exposed spaces.

4. Spare parts

"Spare parts" means one spare impeller for each type of fan.

5. Protection screens of ventilation duct openings

The Protection screens are to be in accordance with **802. 11** of the Guidance.

1202. Spaces not normally entered

1. Ventilation of hold spaces

(1) Natural ventilation alone is not acceptable.

Section 13 Instrumentation (Gauging, Gas Detection)

1301. General

1. Centralization of controls equipments and indicators

For the purpose of the requirements in **1301. 3** of the Rules, in case where control equipment and indicators are unable to be centralized in the cargo control room or other suitable places, they are to be provided in the wheelhouse.

2. Calibration and test of measuring instruments

For the purpose of the requirements in **1301. 4** of the Rules, tests and inspections of measuring instruments are to be in accordance with the following requirements (1) to (3) :

(1) Tests and inspections of measuring instruments during manufacture of each are to conform to the following requirements (A) to (C) :
  (A) Gas detection equipment are to be in accordance with the requirements in the Guidance.
  (B) Level gauges are to be in accordance with the requirements in the Guidance for Approval of Manufacturing Process and Type Approval, Etc.
  (C) Pressure gauges and temperature indicating devices are to be in accordance with the requirements of the standards recognized by the Society or are to be manufactured under effective quality control system and to be ensured for their reliability.

(2) After installation on board the ship, the instrument is to be subjected to operation test to verify that it has the specified performance. This test is not necessarily conducted with the actual cargo, but for gas detection equipment, suitable test gases are to be used in the test.

(3) For retests and testing procedures of instrumentation after installation on board the ship, at least the following items are to be noted in the Operation Manual specified in the requirements in **1801. 1** of the Rules :
  (A) Check method and testing procedure before use
  (B) Check method and testing procedure during use
  (C) Periodical check method and intervals specified by the manufacturer
  (D) Service life of equipment (excluding those permanent system components)
  (E) Periodical inspection procedure specified in the requirements in **Pt 1, Ch 2, 204.** (4) of the Rules
  (F) Other precautions

1302. Level indicators for cargo tanks

1. General

For the purpose of the requirements **1302. 1** of the Rules, the following requirements (1) and (2) are to be complied with :

(1) The performance and construction of level gauges are to be approved according to the Guidance for Approval of Manufacturing Process and Type Approval, Etc.

(2) The effectiveness and number of units of level gauges are to be in accordance with the following requirements (A) and (B) :
  (A) Where only one level gauge is fitted, it is to be arranged so that any necessary maintenance can be carried out while the cargo tank is in service.
  (B) For example, in case where gauging of levels is limited at high level and low level, such level is considered effective on condition that cargo is loaded within such range.

2. Type of level indicators

For the purpose of the requirements in **1302. 2** of the Rules, in case where the prospective cargoes are plural and the type of level gauges required in column g in Table of **Sec 19** of the Rules is also plural where two or more level gauges are provided for each requirement (in the case shown in **1** (2) (A) above, may be one), they may be multiplicate. However, for the type of level gauge for less severe requirements, warning sign stating that the level gauge is not to be used for other cargoes than the specified cargoes is to be posted.

3. Sighting ports

For the purpose of the requirements in **1302. 3** of the Rules, the construction and liquid-tight and gas-tight performance of the sighting ports are to be equivalent to the tank top plating and suitable protection steel covers are to be provided. For the purpose of the requirements in **1302. 1** of the Rules, the sighting ports are not to be regarded as level gauges required.

4. Tubular glass gauge

Tubular glass gauges are to conform to the requirements in **1302. 4** of the Rules, and in addition, to the requirements in **Pt 5, Ch 5, 129.** of the Rules.

1303. Overflow control

1. General

For the purpose of the requirements in **1303. 1** of the Rules, the following requirements are to be complied with :

(1) High level alarm systems are to be in accordance with **Pt 7, Ch 1, 1004. 5** of the Guidance.
(2) The sensor for automatic closing of the loading valve for overflow control may be combined with those of level gauges required in **1302. 1** of the Rules.

2. Omission of automatic shutoff

The "maximum possible pressure during the loading operation" referred to in the requirements in **1303. 2** (2) of the Rules is to be considered as the maximum pressure generated by the discharge pressure of shore-based transfer pump and cargo vapour pressure.

3. Level alarms with electrical circuits

To "be capable of being tested prior to loading" referred to in the requirements in **1303. 3** of the Rules means to be capable of verifying by test (for example, by buzzer test) that all alarm circuits are in normal working condition when verification through actual operation is impossible. However, a special attention is to be paid to those that can not be always monitored the breaking down of the circuit.

1304. Pressure gauges

1. Pressure gauges and alarms of cargo tanks

(1) The low pressure alarm provided on the navigation bridge under the requirements in **1304. 1** of the Rules, when the provision of vacuum relief valve is required by the provision in **804. 2** of the Rules, is to be capable of issuing alarm at a suitable differential pressure between inside and outside of cargo tank, which is lower than the maximum design external pressure of the cargo tank.
(2) The alarm system specified in the requirements in **1304. 1** of the Rules is to issue visible and audible alarms.

1305. Temperature indicating devices

1. General

The "lowest temperature for which the cargo tank has been approved by the Society" referred to in the requirements in **1305. 1** of the Rules means the lowest design temperature indicated together with the classification characters in the Register Book.

2. Temperature indicating devices of hull structure when a cargo is carried at a temperature lower than −55°C

The word, "where applicable" referred to in the requirements in **1305. 2** of the Rules means the case where provision is made for heating the structural hull members as specified in the requirements in **408. 4** of the Rules. At four points, at least, on double bottom tank top platings, the temperature sensors are to be provided.

3. Temperature indicating devices of cargo tanks when a cargo is carried at a temperature lower than −55°C

For the purpose of the requirements in **1305. 3** of the Rules, the temperature indicating devices for cases of carrying the cargo at a temperature lower than -55°C are to be in accordance with the following requirements :

(1) In order to verify the cooling down or loading procedures according to the requirements in **403. 4** (1) of the Guidance, temperature indicating devices required in the provisions in **1305. 3** (1) of the Rules are to be provided.

(2) The temperature sensors provided for verifying the cooling down procedure specified in the requirements in **1305. 3** (2) of the Rules are to be arranged under considering the arrangement of spray nozzles and construction of cargo containment system. For the other cargo tanks which can be regarded as having the same construction and arrangements as the cargo tanks provided with above sensors, the temperature indicating devices specified in the requirements in preceding (1) and **1305. 1** of the Rules may only be provided.

1306. Gas detection requirements

1. General

The "equipment acceptable to the Society" referred to in the requirements in **1306. 1** of the Rules may be followed as given in **507. 1** (1) to (3) of the Guidance.

2. Positions of fixed sampling heads

For the purpose of the requirements in **1306. 2** of the Rules, the positions of fixed sampling heads are to be arranged where cargo vapours are liable to accumulate by taking into account the geometrical configurations of the compartment to be covered, construction and arrangement of the space within the compartment. In this case, the sampling heads are, as a rule, to be provided at least at two locations for each such compartment.

3. Location of gas detection equipment

The "safe location" referred to in the requirements in **1306. 5** (2) of the Rules means the location specified in **802. 8** (2) of the Guidance when the sampled gas is of the dangerous ones. In case where the sampled gas is not dangerous, it may be returned to the place of sampling.

4. Gas detection equipment for toxic products

For the purpose of the requirements in **1306. 9** of the Rules, the use of portable gas detecting equipment is to be in accordance with the following requirements :

(1) At least two sets of portable gas detecting equipments are to be provided on board.

(2) In the case of the cargo expressed in "$F+T$" in column f in Table of **Sec 19** of the Rules, the fixed type flammable gas detecting device specified in the requirements in **1306. 11** of the Rules is to be provided additionally.

(3) In case where the equipments are composed of consumables such as detecting tubes, suitable spare parts such as detecting tubes are to be provided on board in addition to the equipments specified in the preceding (1) by taking into account the shipboard work and the frequency of carriage of the cargo. In the case of the detecting tube type, detecting tubes are to be provided for each kind of loadings cargos as above requirement, but two suction pumps for each type of the portable detection equipments may be enough.

5. Gas detection for cargo containment systems other than independent tanks

For the purpose of the requirements in **1306. 11** of the Rules, the gas detection equipment for hold spaces and interbarrier spaces of cargo tanks other than independent tanks are to be in accordance with the following requirements :

(1) In the case of integral tanks, the requirements in **1306. 11** of the Rules do not apply. However, the requirements in **1306. 7** (5) of the Rules apply to the hold space of this cargo containment system.

(2) The available measuring range of gas detector is to be ordinarily made under the graduation where the lower explosive limit is taken as 100% but the range may be changeable to measure gas concentration between 0 % and 100 % in volumetric percent if necessary.

6. Gas detection for toxic gases

For the purpose of the requirements in **1306. 12** of the Rules, the gas sampling pipes of hold spaces and inter-barrier spaces dealing with toxic gas in case of portable gas detection equipment are to have openings at the upper part or lower part of the compartment in consideration of the cargo vapour density and automatic closing pipe heads are to be fitted at their top ends. In case where the sounding pipes specified in the requirements in **Pt 5, Ch 6, 203.** of the Rules can be used for the purpose in consideration of the cargo vapour density and the set pressure of the relief valve of the compartment, they may be used commonly therewith.

7. Instruments for measurement of oxygen levels

The "suitable instrument for the measurement of oxygen levels" referred to in the requirements in **1306. 14** of the Rules means the one as given in **507. 1** of the Guidance in a corresponding manner.

Section 15 Filling Limits for Cargo Tanks

1501. General

1. Filling limit higher than 98 %

For the purpose of the requirements in **1501. 3** of the Rules, the loading limits are to be in accordance with the following requirements :

(1) The "filling limit (FL)" means the maximum liquid volume in a cargo tank relative to the accepted tank volume when the liquid cargo has reached the reference temperature specified in the requirements in **1501. 4** of the Rules. In this case, the total volume of the cargo tank may include the volume of tank dome provided that either of the following conditions is satisfied :

(A) In applying the requirements in **403. 2** (2) of the Rules, consideration is given to the tank dome for determining Z_β.

(B) Tank dome is to be in accordance with **403. 2** (2) of the Guidance.

(2) In case where the following conditions (A) and (B) are satisfied, the filling limit may be a value exceeding 98% within the limit not exceeding 99.5 % :

(A) The maximum allowable filling limit results from the following formula :

$$\frac{V_{FL}}{V} \times 100 \ (\%)$$

where

V_{FL} : cargo tank volume to liquid level corresponding to the filling limit (m^3)

V : accepted total tank volume (m^3)

(B) Under conditions specified in **802. 17** of the Rules, the suction funnels of the pressure relief valves are to remain well above the sloped liquid level for the expanded volume determined by following formula :

$$V_{FL} \times \frac{100 + \alpha_t}{100} \ (\mathrm{m}^3)$$

where:

α_t : the value as given by the following formula :

$$\alpha_t = \sqrt{\alpha_1^2 + \alpha_2^2 + \alpha_3^2} \ (\%)$$

α_1 : relative increase in liquid volume due to the tolerance of level gauges as given by the following formula : $\alpha_1 = \frac{dV}{dh}\left(\frac{h \times \Delta Z}{V}\right) \ (\%)$

where:

dV/dh : variation of tank volume per metre filling height at the filling height h $(\mathrm{m}^3/\mathrm{m})$

h : filling height (m) at the filling limit FL to be investigated (FL > 98 %)

$\triangle Z$: maximum total tolerance of level gauges (%)

V : as specified in the preceding (A)

α_2 : relative increase in liquid volume due to the tolerance of temperature gauges as given by the following formula :

$$\alpha_2 = 100 \times \left\{ 1 - \left(\frac{T_C - T_L - \Delta T}{T_C - T_L} \right)^{0.26} \right\} (\%)$$

where:

T_C : critical temperature of the product (K)

T_L : highest loading temperature of the product (K)

$\triangle T$: maximum tolerance of temperature gauges (K)

α_3 : relative increase in liquid volume due to the difference between loading temperature and the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves taking into account the accuracy of the cargo tank calibration as given by the following formula :

$$\alpha_3 = \left(\frac{\rho_L}{\rho_R} - 1 \right) \times \Delta a \quad (\%)$$

where:

ρ_L and ρ_R : cargo densities as defined in **1501. 2** of the Rules

$\triangle a$: accuracy of cargo tank calibration (%)

2. Reference temperature

The "cargo tank becoming liquid full" referred to in the requirements in **1501. 4** (2) of the Rules is to be construed as given in **803. 1** of the Guidance in a corresponding manner.

Section 16 Use of Cargo as Fuel

1605. Special requirements for main boilers

1. The "on the pipe of each gas burner a manually operated shut-off valve should be fitted" referred to the requirements in **1605. 4** of the Rules is to be in accordance with **Fig 7.5.39** of the Guidance.

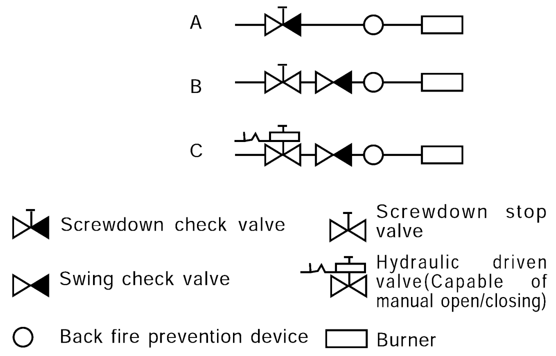


Fig. 7.5.39 Example for Arrangement of Manually Operated Shutoff Valve

Section 17 Special Requirements

1720. Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide (content of not more than 30 % by weight)

1. Valves, flanges and fittings

For the purpose of the requirements in **1720. 3** (3) of the Rules, the materials for insulation and packing with neoprene, natural rubber, asbestos and binders used with asbestos are not to be used. The materials containing oxides of magnesium, also are not to be used.

2. Padding of nitrogen gas

For the purpose of the requirements in **1720. 15** of the Rules, the nitrogen gas generator of membrane type capable of ensuring a purity not less than 99% in volume may be used.

Section 18 Operating Requirements

1801. Cargo information

1. General

In the cargo information specified in the requirements in **1801. 1** of the Rules, at least, the following items (1) through (11) are to be included, and the detailed contents are to be guided by the requirements in **Ch 18** of the IGC Codes with the contents as specified in **Sec 18** of the Rules. These detailed contents may be covered under separate booklets, but in such a case, it is to be expressly shown in the specific operation manual that reference is to be made to separate booklet.

(1) Cargo information
  (A) A full description of the physical and chemical properties necessary for the safe containment of the cargo
  (B) Action to be taken in the event of spills or leaks
  (C) Counter-measures against accidental personal contact
  (D) Fire-fighting procedures and fire-fighting media
  (E) Procedures for cargo transfer, gas-freeing, ballasting, deballasting, environmental control within the hold spaces and interbarrier spaces, tank cleaning and changing cargoes
  (F) Special equipment needed for the safe handling of the particular cargo
  (G) Minimum allowable inner hull steel temperatures
  (H) Emergency procedures
  (I) Action to be taken for inhibition
(2) Cargo stowage information
  (A) Hull strength and strength of cargo containment system
  (B) Stability (intact and damage)
(3) Personal training
  (A) Emergency measures
  (B) Assignment of work duty (cargo handling, fire-fighting, etc.)
  (C) Use of protective clothings and first-aiding
(4) Access to gas-dangerous spaces
  (A) Entering after gas-free or entering wearing protective clothings under the supervision of the duty officer
  (B) Exclusion of source of ignition
  (C) Special measures in the case of internal insulation tanks
(5) Carriage of low temperature cargoes
  (A) Use of heating arrangement
  (B) Procedures of cooling down
(6) Handling of protective equipment and their storage areas
(7) Cargo transfer system and control
  (A) Tests and inspection of control
  (B) Tests and inspection of alarms and emergency shutdown system
(8) Cargo transfer operation
  (A) Discussion between ship personnel and the persons responsible at the shore facility at time of cargo discharge
  (B) Emergency procedures
  (C) Cargo stowage plan
(9) Cargo handling operation
(10) Information on national rules and regulations
(11) The provisions in each Chapter of the IGC Code prescribing the working restrictions which are also specified in the following requirements of **Ch 5** of the Rules :
  106. 32, 308. 1 (1), **308. 3** (3), **308. 4, 308. 5, 410. 14, 701. 1** (5), **802. 5, 802. 7, 901. 3, 902., 904. 2, 1201. 10, 1202., 1301. 4, 1303. 1, 1306. 6, 1306. 9, 1402. 4, 1402. 5, 1402. 6, 1501., 1502., 1603., 1704. 2, 1704. 3, 1706., 1707., 1708., 1710., 1711., 1712., 1713., 1714., 1715., 1716., 1717., 1718. and 1720.**

Section 19 Summary of Minimum Requirements

The requirements for the construction and equipment of the ship when the cargo recognized to have equivalent danger of the liquefied gas or other cargo indicated in **Sec 19** of the Rules is carried are to be determined according to the physical properties (vapour pressure, liquid density, latent heat of evaporation, etc.) of the cargo as far as the basic design of the construction and equipment are concerned unless otherwise required by the Administration. Further, each item of the minimum requirements and special requirements of **Sec 19** of the Rules are to be determined individually. ⚓

CHAPTER 6 SHIPS CARRYING DANGEROUS CHEMICALS IN BULK

Section 1 General

101. General

1. Application

(1) Where the products specified in Table of **Sec 17** of the Rules are added to the cargo carried in bulk to maintain the properties of the cargo, the requirements in **Ch 6** of the Rules may not apply to such additive cargoes. However, in consideration of the properties and quantity of such additive cargoes, additional requirements for tank vent system, electrical installations, instrumentation, safety equipment, etc. may be applied.

(2) Where the mixed products not reacting with each other such as polymer, etc. are carried, all requirements for the product separated each other are to apply.

106. Definitions

1. Definitions

(1) For the purpose of **Ch 6** of the Rules and the Guidance, the term "adjacent" means all cases of facial contact, linear contact and point contact unless otherwise specified.

(2) The term "cargo area" referred to in **106. 5** of the Rules excludes the fuel oil tanks adjacent to the cargo tanks or slop tanks of the arrangement as given in **Fig 7.6.1** of the Guidance. However, the requirements specified in **Ch 6, 304.** of the Rules apply.

(3) The piping system "separated" from each other as referred to in **106. 24** of the Rules mean either of the following :

(A) Piping system completely independent from each other.

(B) The piping system that come through with the tank carrying other cargo, but can be separated by the means as exemplified in [Acceptable] in **Fig 7.6.2** of the Guidance when cargoes likely to cause dangerous reaction with each other are carried may be regarded as those completely independent from each other. In case where separation can be achieved by this method, operational precautions are to be noted in the Operation Manual.

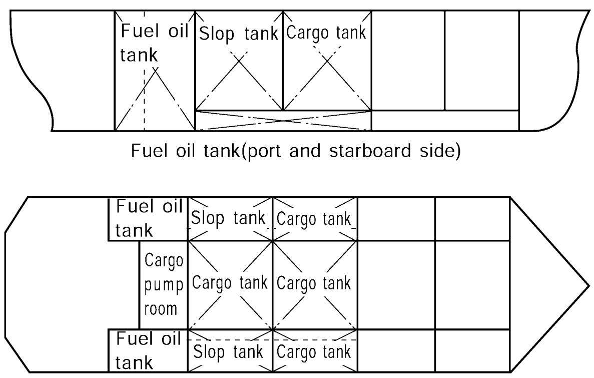


Fig. 7.6.1

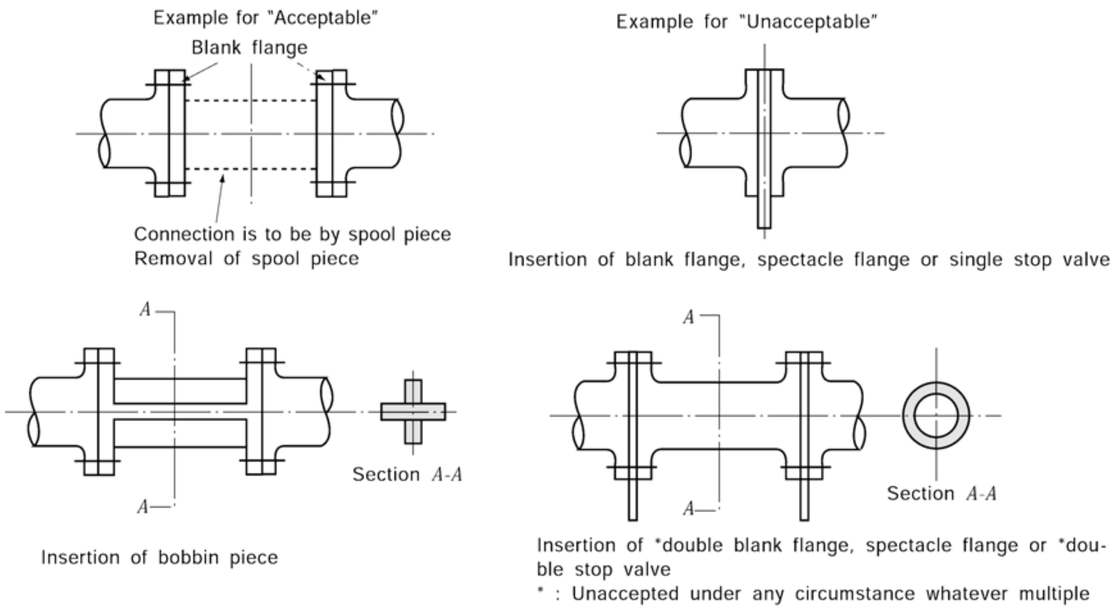

Example for "Acceptable"
Blank flange
Connection is to be by spool piece
Removal of spool piece
Example for "Unacceptable"
Insertion of blank flange, spectacle flange or single stop valve
A
A
Section A-A
Insertion of bobbin piece
A
A
Section A-A
Insertion of *double blank flange, spectacle flange or *double stop valve
* : Unaccepted under any circumstance whatever multiple

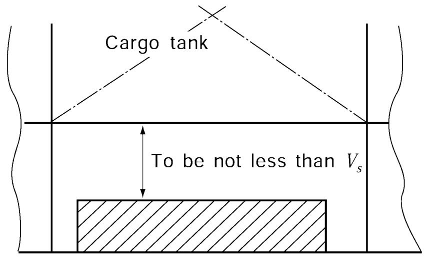
Fig. 7.6.2

Section 2 Ship Survival Capability and Location of Cargo Tanks

202. Freeboard and intact stability

1. Solid ballast

Where the requirements for the initial stability are not satisfied, use of solid ballast may be approved. When solid ballast is provided directly below the tank, the distance between the top of solid ballast and cargo tank bottom is to be not less than the vertical extent of damage(V_s) as given **Fig 7.6.3** of the Guidance.



Shaded section : Solid ballast
V_s: Vertical extent of damage given in **205.** of the Rules

Fig. 7.6.3

203. Shipside discharges below the freeboard deck

1. For the purpose of the requirements in **203. 1** of the Rules, the following requirements (1) and (2) are to be complied with.

(1) The scupper pipes within the superstructure are to be in accordance with the requirements in **Pt 5, Ch 6, 302. 1** of the Guidance.

(2) The inboard open ends of scupper pipes are to be in accordance with the requirements in **Pt 5, Ch 6, 302. 2** (1) (A) of the Guidance.

2. The requirements of **203. 1** of the Rules do not apply to the overboard discharges led through the shell from the superstructure and deckhouse located on or above the second deck on freeboard deck.

3. The scupper pipe in hazardous area is not to pass through the safety area or engine room.

205. Damage assumption

1. Assumed maximum extent of damage

For the purpose of the standard of damage specified in **205. 1** (2) of the Rules, damage assumed to have sustained within 0.3 L_f from the forward perpendicular of the ship are to be in accordance with the following requirements (1) and (2) :

(1) For bottom damage for 0.3 L_f from the forward perpendicular and forward (according to **205. 1** (2) of the Rules), such damage may not be considered beyond the point of 0.3 L_f from the forward perpendicular.

(2) For cases of bottom damage which is applied to damage sustained in areas after the point of 0.3 L_f from the forward perpendicular (according to **205. 1** (2) of the Rules), such damage is to be considered up to the point corresponding to 0.3 L_f - 5.0 m from the forward perpendicular.

206. Location of cargo tanks

1. Location of cargo tanks

Notwithstanding the requirements for the location of cargo tanks in **206.** of the Rules, cargo pump room bilges or tank washings may be thrown into any cargo tanks.

2. Suction well installed in cargo tanks

It is desirable that the area of suction well is not larger than the area necessary for the installation of cargo pumps, suction pipes, valves, heating coils, etc. added with the area necessary for sufficient suction, cleaning and maintenance.

207. Flooding assumptions

1. Equalization arrangements

The "cross-levelling pipes" specified in **207. 6** of the Rules are to comply with the following requirements :

(1) Use of this equalization arrangement is to be accepted only for obtaining the GZ area of 0.0175 m.rad for the righting lever of 0.1 m and the range between the state of equilibrium and 20°. Without the use of this equalization arrangement, the requirements for heel angle and positive stability range are to be satisfied. (See **Fig 7.6.4** of the Guidance)

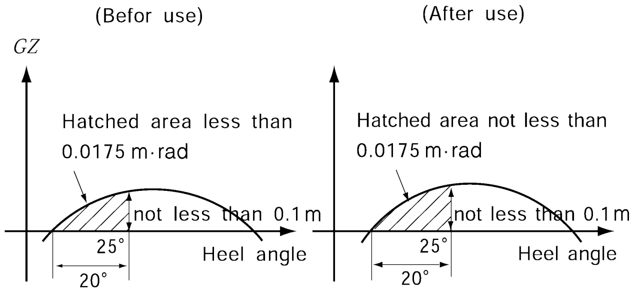


Fig 7.6.4

(2) When righting lever curves before use of this equalization arrangements are determined, the following assumptions are to be made :
   (A) The cargo or consumable liquid in the damaged space has completely spilled out.
   (B) The damaged space is filled with sea water to the water level outside the ship.
   (C) The cross-levelling pipes are closed.

(3) The time required for horizontal adjustment is to be not more than 15 minutes.

(4) The cross sectional area A of piping used for horizontal adjustment is to be as follows :

$$A \geq 7.5\,V/\sqrt{H} \quad (\mathrm{cm}^2)$$

where:

V : Quantity of water expected to enter the flooded space (m^3)

H : Height from the draught line before flooding to the centre line of the pipe (m)

(5) It is not desirable to connect spaces on both sides of the ship with a large diameter duct to ensure the same rate of flooding as this aggravates the heeling moment of the ship in turning motion.

2. Buoyancy of superstructure

(1) In the case of the side damage where the machinery space is regarded as one-space flooding in **207. 8** of the Rules, damage extent applicable to spaces other than the machinery space is applied to poop. With this reason, therefore, the space within poop surrounding the machinery space and enveloped by watertight bulkheads can not be treated as a reserve buoyancy unless watertight bulkheads are arranged as given in **Fig 7.6.5** of the Guidance. However, in case where such treatment is accepted under the special requirements for small ships in accordance with **208. 2** of the Rules as a special relaxation by the Society, the above requirements may not be applied. Where the engine room bulkhead is knuckled, the space between the foremost end and the aftermost end is to be taken as the damaged space of the superstructure as given in **Fig 7.6.6** of the Guidance.

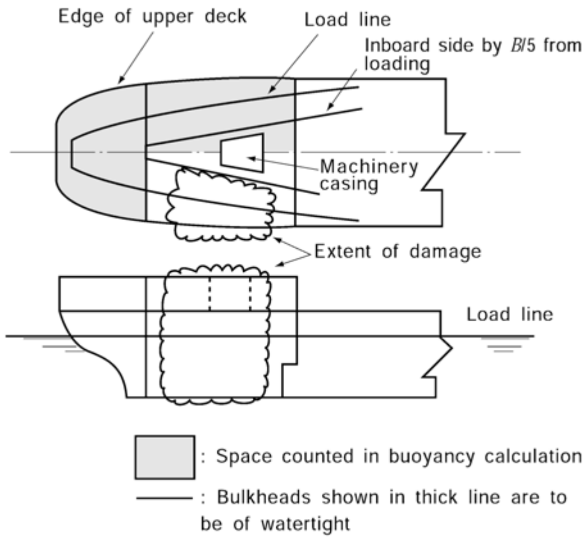


Fig 7.6.5

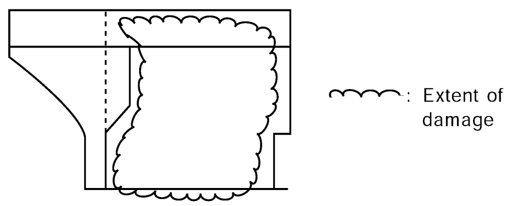


Fig 7.6.6

(2) In **207. 8** (2) of the Rules, the remotely operated sliding watertight doors are to be capable of being controlled from a safe and readily accessible place. Weathertight openings submerge in water under the minimum range of residual stability are to be capable of closing securely in a state of equilibrium.

208. Standard of damage

1. Assumed extent of damage

(1) In **208. 1** (3) and (5) of the Rules, the treatment of the stairway cases located forward or aft end bulkheads of the machinery space is to be in accordance with **Fig 7.6.7** of the Guidance.

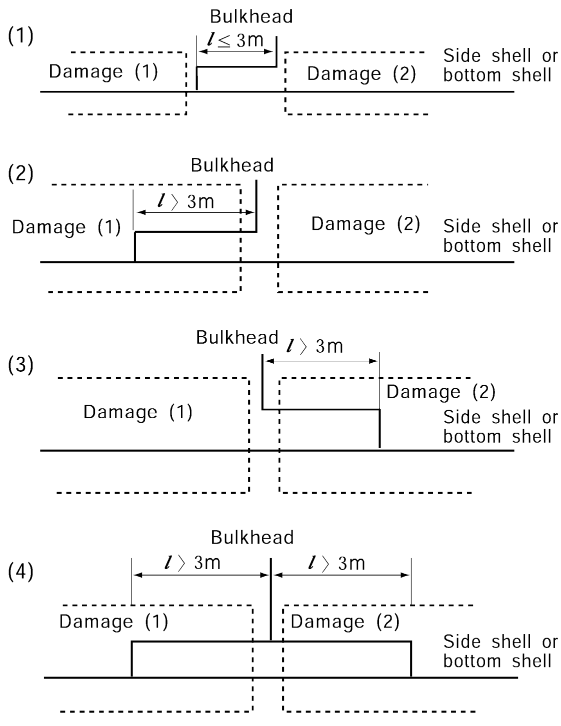


Fig 7.6.7

(2) In **208. 1** (6) of the Rules, the expression "should be considered by the Society" means that the survival requirements specified in 209. of the Rules under a condition of flooding only in the machinery space are satisfied, or the following requirements are satisfied (See **Fig 7.6.8** of the Guidance) :

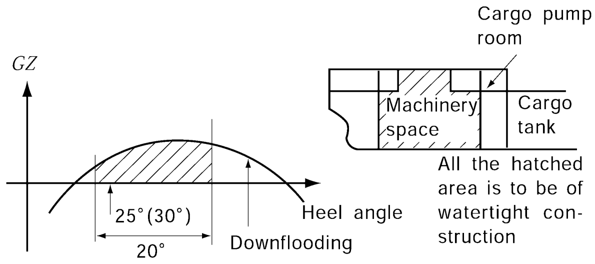


Fig. 7.6.8

(A) The area with positive sign of the righting lever curve within the range from an arbitrary point between the final state of equilibrium after flooding and 25° (or 30° when the deck side line is not submerged) to 20° is to be :
(a) $70\,m \leq L_f < 125\,\mathrm{m}$: 0.0175 m·rad or more.
(b) $L_f < 70\,\mathrm{m}$: 0.0088 m · rad or more
(B) The position of down flooding is to be in accordance with **209. 3** (1) of the Rules.
(C) The angle of heel is to be in accordance with **209. 2** (2) of the Rules. Where the machinery casing is of the watertight construction, the space in poop surrounding the machinery space may be treated as a reserve buoyancy. When a door is provided, it is to be of the watertight sliding door remotely operated from the poop deck.

2. Alternative measures

The "special dispensations" in **208. 2** of the Rules are to be in accordance with the following. (See **Fig 7.6.9** of the Guidance)

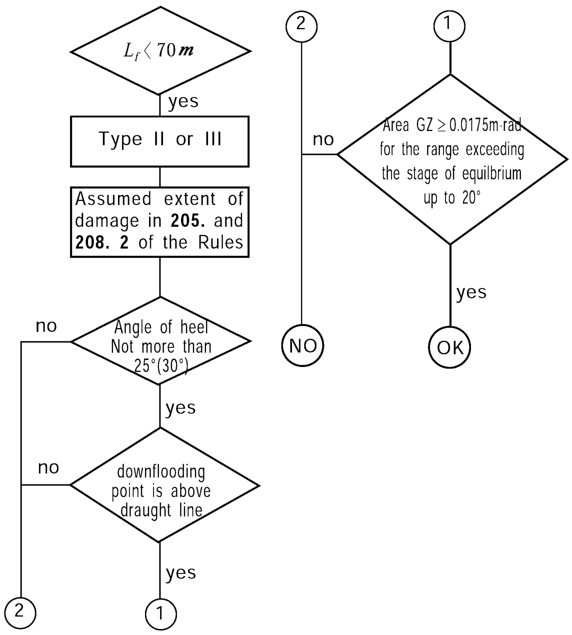


Fig. 7.6.9

(1) No dispensations are to be accepted for Type I ships.
(2) Small ships mean as those whose $L_f < 70\,\mathrm{m}$.
(3) Except for the case of flooding of machinery space of Type III ships(**208. 1** (6) of the Rules), it is to be in accordance with the following :
(A) Assumed extent of damage is to be in accordance with **205., 208. 1** (3) and (6) of the

Rules.

(B) Down flooding point and angle of heel are to be in accordance with **209. 2** and **3** of the Rules.

(C) The area with positive sign of the righting lever curve within the range from an arbitrary point between the final stage of equilibrium after flooding and 25° (or 30° when the deck side line is not submerged) to 20° is to be 0.0175 m.rad or more.

(D) The maximum value of GZ is not specified.

209. Survival requirements

1. Stability criteria at any stage of flooding

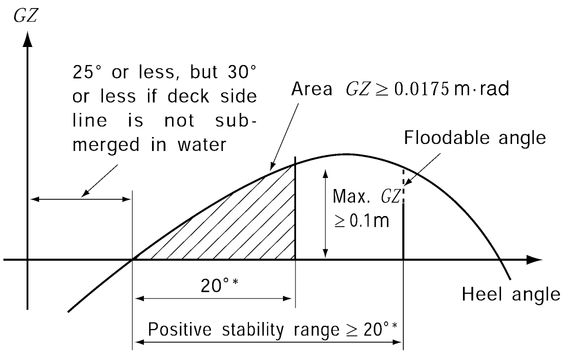
The words "to the satisfaction of the Society" in **209. 2** (3) of the Rules mean as follows :

In ordinary cases, the final stage of flooding is considered most severe, but the most severe condition may be encountered during intermediate stages of flooding involving replacement of sea water in the damaged space. In this connection, stability during such intermediate stages of flooding are to be considered when specifically requested by the Society.

2. Stability criteria at final equilibrium after flooding

(1) In **209. 3** of the Rules, floodable weathertight openings within the minimum stability range (20°) are to be capable of being securely closed at the final stage of equilibrium after flooding. Where safe access thereto is impracticable due to submersion of deck or large angle of heel, such weathertight openings may not be accepted. However, air pipes of float type, etc. having self-closing mechanism in case of submersion in water may be accepted.

(2) The survival requirements at the final stage of equilibrium after flooding are to be in accordance with **Fig 7.6.10** of the Guidance.



Note * : The initial point of calculation of the stability range at an angle of heel of 20° may be taken arbitrarily at any intermediate point between the angle of heel at the final stage of equilibrium and the maximum angle of heel.

Fig 7.6.10

Section 3 Ship Arrangements

301. Cargo segregation

1. Segregation of tank containing cargo or residues of cargo

For cargo tanks and slop tanks, neither linear contacts nor point contacts with accommodation spaces, service spaces, machinery space, etc. are to be accepted. Further, no segregation of spaces in contact by means of slanting plates is to be accepted.

2. Segregation of cargoes which react with other cargoes

Where cargoes which react with other cargoes in a hazardous manner are loaded simultaneously, the ship arrangement as given in **Fig 7.6.11** of the Guidance is not to be accepted. Only in the requirements for segregation of cargoes which react with each other, the linear contacts and point contacts as given in **Fig 7.6.12** of the Guidance may be accepted. Where the cargo pipes are of common pipes, they are not to pass through cargo tanks carrying cargoes which react with each other in a hazardous manner except for the cases where pipe arrangement is provided a tunnel or made as given in **Fig 7.6.13** of the Guidance.

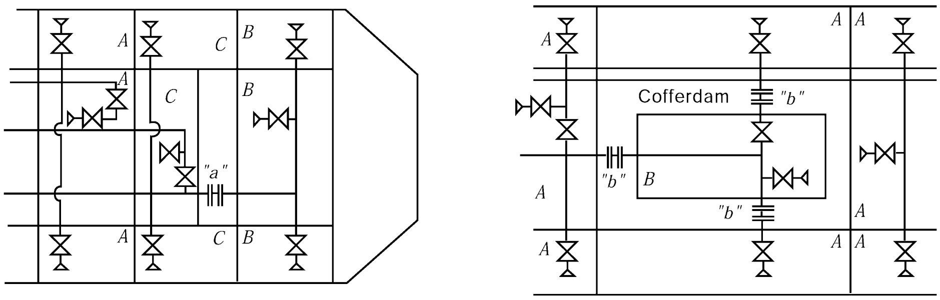
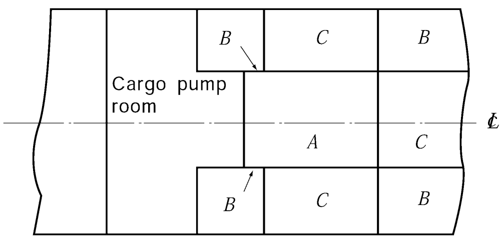
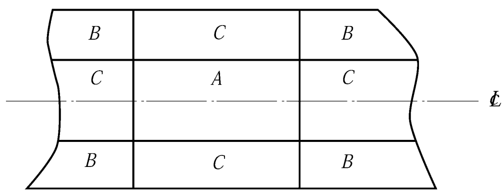


Fig. 7.6.13



A and *B* react with each other in a hazardous manner. (Arrowhead of *B* indicates facial contacts.)
A and *C*, and *B* and *C* do not react with each other in a hazardous manner.

Fig. 7.6.11



A and *B* react with each other in a hazardous manner.
A and *C*, and *B* and *C* do not react with each other in a hazardous manner.

Fig. 7.6.12

Notes :
1. "a" and "b" are to be separated within cofferdam or void spaces in the method specified in 301.5 of the Rules. No separation in thanks is to be accepted.
2. A and B are cargoes which react with each other in a hazardous manner.
3. A and C, and B and C are safe cargoes which do not react with each other in a hazardous manner. In this case, however, cargo operation of cargo B by connecting the spool pieces of "a" and "b: after discharging cargo A is unacceptable, and therefore provisions of independent cargo pumps may be required for cargo operation on tanks segregated under the method given above.

3. Cargo piping

Cargo piping is not to pass through the spaces specified in **301. 3** of the Rules and, in addition, spaces such as fuel oil tanks, fresh water tanks and control stations.

302. Accommodation, service and machinery spaces and control stations

1. Arrangements

When segregated by a gastight deck and well ventilated, such a space is not electrically hazardous space, and in this case, arrangement of accommodation spaces, service spaces or control stations above fuel oil tanks adjacent to cargo tanks in the poop as given in Fig **7.6.14** of the Guidance may be accepted. Paint lockers, regardless of their use, should not be located above the cargo area.

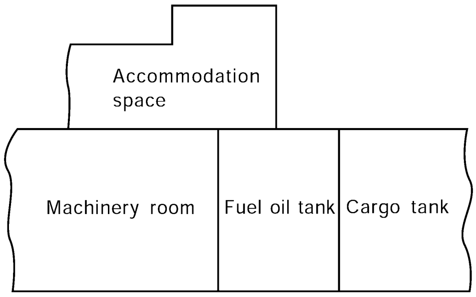


Fig 7.6.14

2. Location of air intakes and openings

The locations of air intakes and openings are to comply with the requirements in **302. 3, 307. 4, 803. 2, 1201. 5** and **1512.** of the Rules.

3. Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations

(1) For exhaust air outlets of the mechanical ventilation system of accommodation, service and machinery spaces and exhaust air outlets specified in **302. 2, 307. 4, 803. 3** and **1512. 1** of the Rules the requirements in this Chapter also apply.

(2) Spaces where doors can be provided are to be restricted to lockers containing cargo gears and safety equipment, cargo control room and decontamination shower room. As given in **Fig 7.6.15** of the Guidance, these spaces are not provided with passageways led to accommodation spaces and service spaces and control station, and the casings, floors and ceilings adjacent to the accommodation spaces are to be insulated to "A-60" standard.

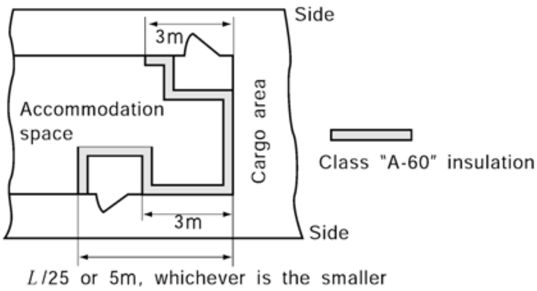


Fig 7.6.15

(3) The gastight wheelhouse doors and windows are to be fitted with packing and dog bolts. These windows, doors and clear view screens are to be hose-tested at a pressure of 0.2MPa. To ensure gastightness of the clear view screen, an additional window fitted with dog bolts or other means of gastight capable of tightening the window pane when the screen is not rotating are to be provided.

(4) For ships carrying dangerous chemicals in bulk, irrespective of the kind of cargo, coaming is to be provided at the forward end of the deckhouse to prevent the ingress of the cargo overflown on the deck into the deckhouse including the accommodation and service spaces and control stations as given in **Fig 7.6.16** of the Guidance. The height of coaming is to be 300 mm from the deck, 50 mm above the upper edge of the sheer strake or 50 mm above the upper face of the deck longitudinals, whichever is the greatest.

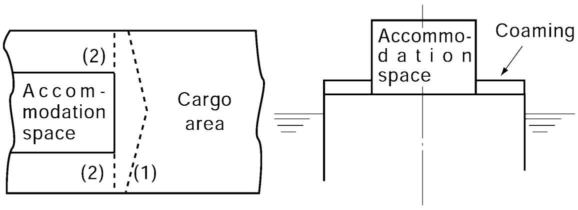


Fig. 7.6.16

303. Cargo pump rooms

1. Arrangement of cargo pump rooms

Where cargo pump rooms are normally manned, or in case where cargo pump rooms are specially large, an additional escape trunk is to be provided. In this case, it is desirable that two escape routes led to the weather deck are available.

2. Permanent arrangement for hoisting an injured person

The permanent arrangement for hoisting an injured person from cargo pump room is to be in accordance with the following requirements :

(1) To be capable of being one-man-operated from the weather deck.
(2) To be capable of lifting an injured person up to the place on the weather deck.
(3) To be capable of lifting a weight of not less than 255 kg.

3. Access ladders

The angle of normal access ladders provided in cargo pump room to a horizontal plane is to be not more than 60°.

4. Means for discharging cargoes and bilges

(1) For pumps and valves dealing with cargoes likely to cause corrosions of structural members or contamination with other bilges within the cargo pump room due to leakage of corrosive cargoes, interactive cargoes or water prohibitive cargoes, proper bilge processing systems are to be provided according to degree of hazard. For instance, as the bilge processing systems for pumps dealing with interactive cargoes, provisions of independent bilge processing systems may be considered. In case where interactive cargoes are handled in the same cargo pump room, simultaneous cargo operations are to be avoided whereby the next cargo operation is to be carried out after complete bilge processing for the first cargo.
(2) Slop tanks specified in **303. 5** of the Rules are to comply with the following requirements (A) through (D) :
(A) In case of using the tank both as cargo tank and slop tank, the same requirements applicable to cargo tanks apply.
(B) Where no cargo is carried and only bilges or tank washings are contained, no requirements for ship type (only concerning the cargo tank arrangement) apply, notwithstanding kind of cargoes contained in bilges or tank washings. However, for the minimum requirements other than ship type, the following (a), (b) and (c) are to be complied with :
(a) For ventilation system, electrical installation and instrumentation, the severest of the requirements applicable to the cargoes contained in the slops is to apply.
(b) For tank environmental control and its special requirements, all the requirements for all cargoes contained in the slops are to be satisfied.
(c) For tank type, the requirements for the cargo contained in the slops are to be satisfied.
(C) For tank washings of tanks that carried the dangerous cargoes subjected to **1512.** of the Rules, slop tanks containing bilges of the cargo pump room used for the cargo operation of these cargoes and pipes serving them, the requirements of **1512.** of the Rules apply without exceptions.
(D) In case where two or more cargoes which react in a hazardous manner are carried, the tank washings and bilges containing these cargoes are not to be contained in the same slop tank. Therefore, slop tanks equal in number to that of cargoes which react in a hazardous

manner carried at the same time are to be provided. In this case, when cargo tanks are used as slop tanks, these cargo tanks are to be provided with the pumps and pipelines to serve as the slop tanks.

(E) For ships carried the oil subjected to MARPOL 73/78 Annex 1, the capacity of slop tanks is to be complied with MARPOL 73/78 Annex 1.

5. Cargo pump discharge pressure gauges

"Cargo pumps" specified in **303. 6** of the Rules are the cargo pumps, tank cleaning pumps, bilge pumps, etc. used for handling cargoes and liquids containing cargoes in general.

6. Gas tightness of shafting passing through bulkhead or deck

The shaft seals of a type for periodical feeding of grease are not acceptable. Only continuous gas-tight sealing type is acceptable. These shaft seals are to be provided outside the cargo pump room. (See **Fig 7.6.17** of the Guidance)

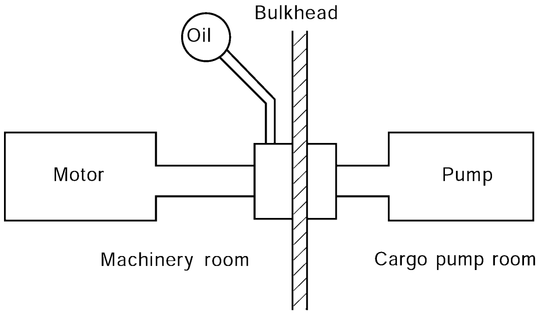


Fig. 7.6.17

304. Access to spaces in the cargo are

1. General

(1) Spaces having direct openings to hold spaces containing independent tanks are to be to the requirements in **304.** of the Rules irrespective of the definition of the cargo area. Fuel oil tanks which have face contacts, linear contacts or point contacts with cargo tanks and those arranged directly below cargo pump room are not included in the cargo area, but subject to the following requirements.

(A) Fuel oil tank adjacent to cargo tank or in linear or point contact therewith. (See **Fig 7.6.18** of the Guidance) Access holes are to be to the requirements in this Paragraph, and access is to be from the cargo area.

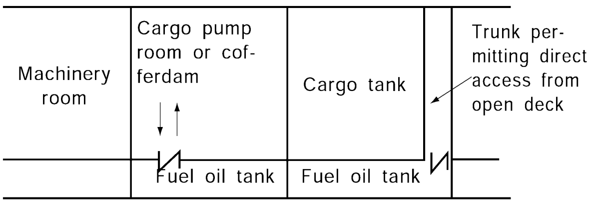


Fig. 7.6.18

(B) Fuel oil tank directly below cargo pump room. (See **Fig 7.6.19** of the Guidance) Access holes are to be to the requirements in this Paragraph, and in consideration of possible cargo leakage, access is to be from the cargo area.

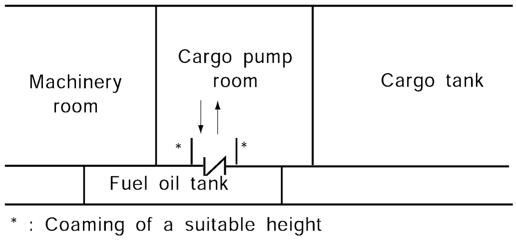


Fig. 7.6.19

(C) For fuel oil tanks given in **Fig 7.6.20,** the requirements in this Paragraph do not apply. Access from the cargo area is desirable.

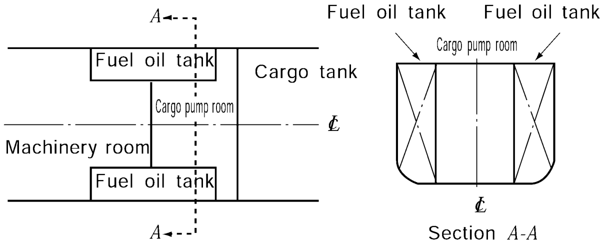


Fig. 7.6.20

(2) For access openings of double bottom, etc., the following requirements are to be complied with : Two access routes are, as a rule, necessary for double bottom or similar other spaces as given in (1) to (3) of **Fig 7.6.21** of the Guidance. The arrangement as given in (4) of **Fig 7.6.21** of the Guidance is not to be accepted. On condition that easy access is provided and an unconscious injured person can be rescued, only one access route may be accepted for a relatively small space. On duct keel, access openings are to be provided at both ends, and an opening led to weather deck is to be provided at intervals not exceeding 60 m.

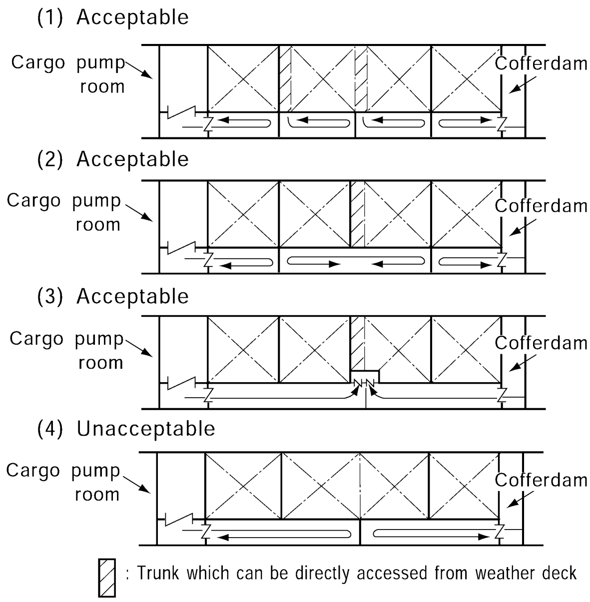


Fig. 7.6.21

(3) Access openings to independent cargo tanks are to be in accordance with the following requirements :
Independent cargo tanks are to be provided with trunks or domes protruding beyond the weather

deck as given in **Fig 7.6.22** of the Guidance and cargo tank hatches are to be provided on the top of these trunks or domes. No opening of any construction is to be provided on the cargo tank wall below the weather deck.

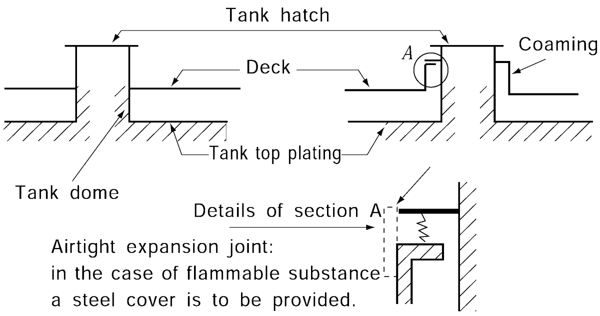


Fig. 7.6.22

2. Minimum clear opening for access through horizontal openings

The minimum opening dimensions are to be 600 mm × 600 mm with rounded corners.

3. Minimum clear opening for access through vertical openings and arrangements of vertical openings

Access openings are to comply with the following requirements:

(1) Opening of 600 mm × 800 mm is to be so oriented that the major axis is taken in the vertical direction. However, where the major axis is difficult to be taken in the vertical direction under the structural reason, horizontal direction may be taken.

(2) At access openings and in the vicinity, no pipes or equipment that interfere with the assurance of access route are to be arranged.

4. Relaxation of opening dimension

Opening dimensions may be as given in **Table 7.6.1** of the Guidance provided that person wearing safety equipment has access to openings and an injured person is easily rescued from the bottom of spaces.

Table 7.6.1 Relaxation of Opening Dimension

Spaces	Minimum dimension (mm)
Cargo Tanks	600×600
Void Spaces, W.B.T	H : 500×500, V : 500×650
F.O.T	H : 450×450, V : 400×500

305. Bilge and ballast arrangements

1. General

(1) The discharge arrangements of permanent ballast tanks adjacent to cargo tanks may be such that ballast pumps in the machinery space are used as given as **Fig 7.6.23** of the Guidance and ballast or bilges are discharged overboard through the eductor in the cargo pump room. In this case, check valve is to be provided between the ballast pump and eductor and spool piece is to be provided on the weather deck within the cargo area.

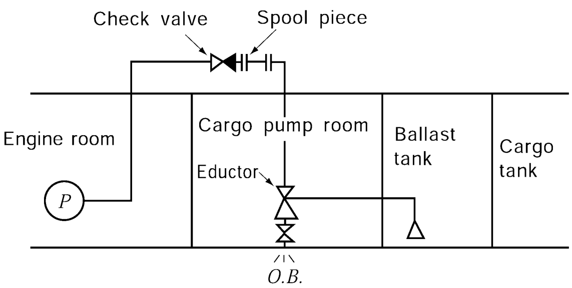
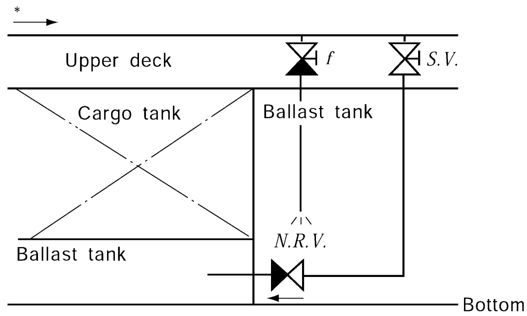


Fig. 7.6.23

(2) The words "ensure filling from tank deck level and check valves are fitted" referred to in **305. 1** of the Rules mean that exclusively used for filling from the weather deck but can not be used for discharging fitted with stop valves on the weather deck or stop valves operable from the weather deck and additionally check valves are provided as given in **Fig 7.6.24** of the Guidance. Further, sufficient consideration is to be taken so as not to cause non-compliance with the damage stability requirements due to damage to pipelines or spillage of dangerous ballast or cargo into other compartments.



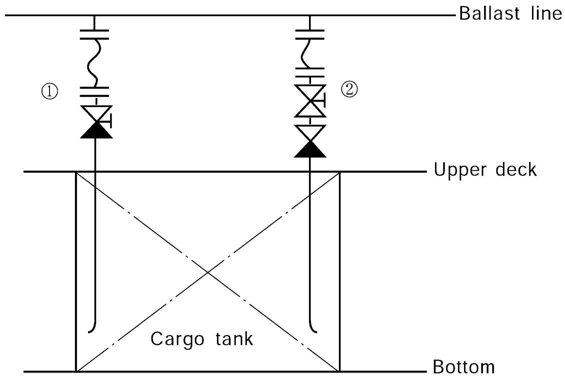
* : A line to ensure filling only from the pump in machinery room
N.R.V. : Non-return valve (Check valve)
S.V. : Stop valve
f : Stop valve + check valve or screw-down check valve

Fig. 7.6.24

(3) Pipelines of ballast tanks adjacent to cargo tanks and not adjacent to cargo tanks are to be basically independent.

2. Filling of ballast in cargo tanks

(1) The case referred to in **305. 2** of the Rules as "the filling line has no permanent connection to cargo tanks or piping and that check valves are fitted" is to be as given in **Fig 7.6.25** of the Guidance. In this case, filling is to be limited to that from the open deck, where spool pieces or hoses and stop valves or check valves are required.
(2) When filling is made from the open deck according to the preceding (1), the piping arrangement in cargo tanks is to be such that the filling pipe is extended as close to the bottom as practicable to minimize generation of static electricity.



① Hose (spool piece) + screw-down check valve
② Hose (spool piece) + stop valve + check valve

Fig 7.6.25

3. Bilge pumping arrangements for the cargo area

Pipes dealing with cargo or cargo residues passing through void spaces, double bottom and ballast tank spaces are to be treated within the bilge cargo spaces of the compartments even when they are segregated from tanks containing cargo or cargo residues by double bulkheads.

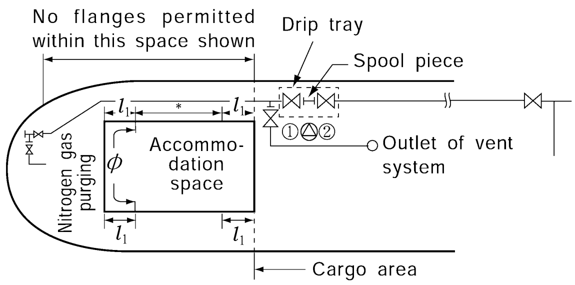
306. Pump and pipeline identification

"Marking" referred to in **306.** of the Rules is to be made by peel-resisting tapes or paint coat to clearly identify respective pipes.

307. Bow or stern loading and unloading arrangements

1. General

The bow or stern loading and unloading arrangements are to be given in **Fig 7.6.26** of the Guidance, as a standard.



l_1 : $L/25$ or 3m, whichever is the greater, but need not exceed 5m.
* : Where inlets, air intakes, openings, etc. are permitted to be provided.
ϕ : Where inlets, air intakes, openings, etc. are not permitted to be provided.
Valve ① : The stop valve required in **307. 3** (1) of the Rules.
Valve ② : The stop valve necessary for fitting/removal of the spool piece.
⚠ : Spray shield is to provided for valves and spool piece. (portable one may be accepted.)

Fig 7.6.26

2. Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations

All openings such as entrances, to accommodation, service and machinery spaces and control stations, air inlets, rope hatches, openings to machinery casing, openings in escape routes, etc. are to be arranged in areas outside the shaded sections given in **Fig 7.6.27** of the Guidance. The standard height of superstructure is to be as given in **Table 7.6.2** of the Guidance.

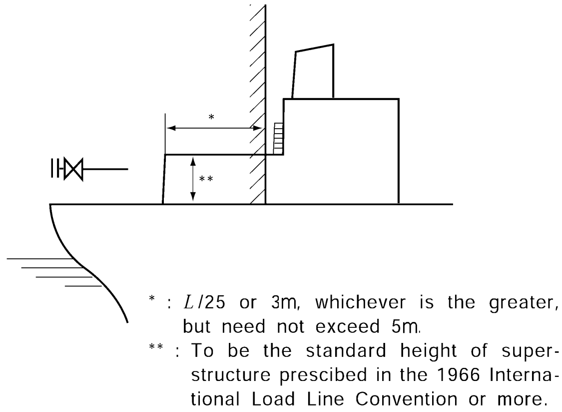


Fig 7.6.27

Table 7.6.2 The Standard Height (m)

L (m)	Low Poop	Other poop
Not more than 30	0.90	1.80
75	1.20	1.80
Not less than 125	1.80	2.30

3. Escape route

The "escape route" referred to in **307. 6** of the Rules means the escape route from machinery space.

4. Continuous coamings

The "continuous coamings of suitable height" referred to in **307. 7** of the Rules are the coamings provided on the cargo handling machinery and gear with a height above deck of 150 mm or 50 mm above the upper edge of the sheer strake as given **Fig 7.6.28** of the Guidance, whichever is the greater, and are to be arranged in direction of breadth of ships continuously.

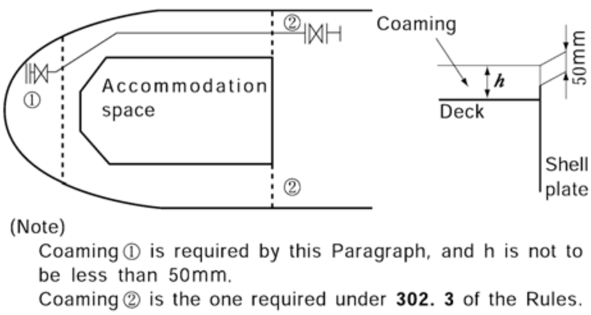


Fig 7.6.28

5. Fire-extinguishing arrangements

One each monitor for foam fire-extinguishing system and portable foam applicator unit required in the cargo area are to be provided. The hydrant connected with the portable foam applicator unit is to be arranged within the range effective for discharging the fire-extinguishing medium and the portable foam applicator unit is to be stowed in a space ready for immediate use.

Section 5 Cargo Transfer

501. Piping scantlings

1. Design standard for piping

(1) In **501. 6** (1) of the Rules, the minimum thickness of stainless steel pipes is, in general, to be in accordance with the following requirements :
· Cargo pipes passing through ballast tanks : Schedule 40 S
However, the minimum thickness is to satisfy the requirements for thickness of pipes subjected to internal pressure specified in **501. 1** of the Rules.

(2) The protection for cases "Where necessary for mechanical strength" referred to in **501. 6** (2) of the Rules is to be provided as follows :
(A) No protection is required for steel pipes used for ordinary applications.
(B) Where aluminium pipes, stainless steel pipes of which thickness is reduced according to their tensile strength, etc. considered vulnerable to impact loads are used, suitable protection is to be provided.
(C) It is desirable that manifolds are to be made of steel.
(D) Pipes passing through bulkheads or decks, those arranged an elevated space above upper deck, those subjected to load of the loading arms at the manifold may be required to have increased thickness.

(3) In "Flanges, valves and other fittings" referred to in **501. 6** (3) of the Rules, the use of stop valves and expansion joints is to be in accordance with the following requirements :
(A) To comply with the requirements in **Pt 5, Ch 6** of the Rules (for both Class I and Class II pipes).
(B) Since use of expansion joints is not allowed for the cargo pipes within tanks containing the cargo for which special means for the maintenance of product quality are required, expansion of the pipes is to be absorbed by U-bends, etc.
(C) The materials of valves, seals, etc. are not to be of the ones of which use is prohibited.

502. Piping fabrication and joining details

1. Joint of cargo piping

Cargo pipes are to be joined by welded joints except for the flange joints for shut-off valves and expansion joints, spool pieces and equivalent fittings approved in **502. 2** of the Rules and flange joints necessary for painting, lining, assembly, inspection or maintenance. Further, movable anti-acid shields to guard against spray are to be provided at flange welding of cargo pipes above the deck referred to in **1511.** of the Rules.

2. Direct connection of pipes without flanges

Where Class I pipes or Class II pipes are required under **504.** of the Rules for butt-welded joints in **502. 3** (1) of the Rules, the requirements in **Pt 5, Ch 6** of the Rules are to be complied with. The butt welding procedure for cargo pipes (including liquid cargo and vapour cargo) where use of Class III pipes are permitted is to be the same as in Class II pipes. However, nondestructive testing may not be carried out.

3. Expansion joints

The "bellows" referred to in **502. 4** (1) of the Rules are not to be used for cargoes having corrosive or polymerizing nature unless consideration is taken for the cargo drains trapped in the corrugated parts of the joints.

503. Flange connections

1. Standards for flanges

The "standard approved by the Society" referred to in **503. 2** of the Rules means the requirements in **Pt 5, Ch 6, 104.** of the Rules.

504. Tests requirements for piping

1. Application

The classification standard and test requirements for cargo piping are to be in accordance with **Tables 7.6.3** and **7.6.4** of the Guidance.

Table 7.6.3

Ship type	Classification of applicable cargo (See **Table 7.6.4** of the Guidance)	Remark
Type 1	Class I pipes	Irrespective of the design pressure and temperature, the requirements in the left-hand column apply, as a standard. For compatibility between cargo and cargo piping materials, separate investigation is to be made.
Type 2	Class II pipes	
Type 3	Class III pipes	

Notes :
(1) Cargo piping means the piping to transfer liquid cargo and vapour cargo.
(2) Cargo piping for slop tanks arranged in accordance with the requirements of ship type 3 is to be classified into Class III irrespective of the ship type requirements for cargo contained in slop tanks.
(3) Cargo piping passing through the tanks cargo with higher ship type requirements is to comply with the requirements of the piping specified for such cargo.

Table 7.6.4. Test Requirements for Piping

<table>
<tr><th rowspan="2"></th><th rowspan="2">Materials of pipe</th><th rowspan="2">Materials of valves, cocks and pipe fittings</th><th colspan="3">Shop tests for pipe fabrication</th><th rowspan="2">Shop tests for valves and pipe fittings</th><th rowspan="2">Shipboard tests for piping</th></tr>
<tr><th>Welding procedure qualification tests</th><th>Non-destructive tests</th><th>Hydraulic tests</th></tr>
<tr><td>Class I</td><td rowspan="2">Materials complying, as a rule, with the requirements in Pt 2, Ch 1 of the Rules.</td><td rowspan="2">Materials complying, as a rule, with the requirements in Pt 2, Ch 1 of the Rules. However, materials complying with the requirements of KS or equivalent may be accepted at the discretion of the Society.</td><td rowspan="2">To be carried out on piping of Class I or Class II where the following ① to ③ are relevant :
①Joinings between pipes, pipes and valves, and pipes and fittings are made welding for the first time.
② When new welding method is employed.
③ When base material, type of welding materials or type of joints is changed.</td><td>①Radiographic testing for the entire length of butt-welded joints of pipes with nominal diameter exceeding 65A.
②Radiographic testing for the sampled buttwelded joints of pipes with nominal diameter not more than 65A.
③In place of radiographic testings, suitable other non-destructive testing may be accepted.
④ Magneticparticle testing or suitable other for fillet weld of pipes.</td><td rowspan="3">①All pipes of Class Ⅰ, Class Ⅱ and Class Ⅲ, steam pipes, feed pipes, compressed air pipes, fuel oil pipes of which design pressure exceeds 0.35 MPa are to be subjected to hydraulic tests with fittings attached after fabrication at a test pressure 1.5 times the design pressure.
② The test pressure for hydraulic test for pipes with design temperature exceeding 300°C is to be specified separately.
③The hydraulic test for welded joints between pipes or pipes and valves of piping arranged onboard the ship is to be specified separately.</td><td rowspan="2">Valves and fittings of piping of Class I or Class II are subject to hydraulic test at a pressure of 1.5 times the design pressure.</td><td rowspan="3">① All pipes are subject to leak test in their service condition.
② All pipes are to be subjected to preliminary test together with the equipment they serve.
③ Fuel oil pipes and tank heating pipes are to be subjected to leak test at a pressure of 1.5 times the design pressure. However, the test pressure is to be at least 0.4MPa or more.
④ The piping of the refrigerating instal lation is to be sub-jected to the requirements specified in Pt 5, Ch 6, 1205. (4) of the Rules.
⑤ All cargo pipes are to be subjected to the hydraulic test at a pressure of 1.5 times the design pressure.</td></tr>
<tr><td>Class II</td><td>①Radiographic testing or suitable other testing for buttwelded pipes with nominal diameter exceeding 80A.
②Magnetic particle testing or suitable other testing for fillet weld of pipes.</td></tr>
<tr><td>Class III</td><td>Materials complying with the requirements of KS or equivalent</td><td>Materials complying with the requirements of KS or equivalent</td><td></td><td></td><td></td></tr>
</table>

505. Piping arrangement

1. Cargo piping under deck

(1) "the stop valve operable from the weather deck" referred to in **505. 2** of the Rules is to be located in the vicinity of each open end within each tank.

(2) "As an exception ..." specified in **505. 2** of the Rules following is applicable only to the cargo piping arranged in one cargo tank or slop tank adjacent to the cargo pump room as given in the shaded section of **Fig 7.6.29** of the Guidance. In this case, an additional stop valve is to be provided between the bulkhead valve and cargo pump.

(3) The word "leakage" referred to in **505. 2** (1) of the Rules includes the leakage through packing.

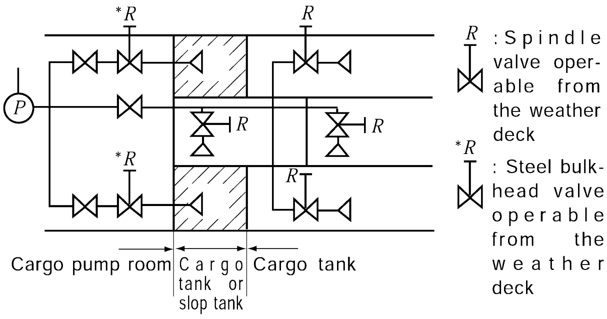


Fig. 7.6.29

506. Cargo transfer control systems

1. General

(1) The "one stop valve capable of being manually operated on each tank filling and discharge line, located near the tank penetration" referred to in **506. 1** (1) of the Rules, for cargo pipes provided in cargo tanks as given in **Fig 7.6.30** of the Guidance may be omitted if there are stop valve specified in **505. 2** of the Rules (stop valve located near the open end and operable from the weather deck) and bulkhead valve provided in the cargo pump room specified in **505. 3** of the Rules.

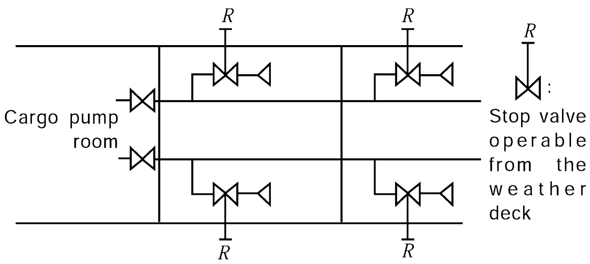


Fig. 7.6.30

(2) Stop valve is not required at the deck penetration of the discharge piping of deep well pump or submerged pump provided independently in each tank, but a stop valve is to be provided near at each penetration of weather deck as given in **Fig 7.6.31** of the Guidance for the direct cargo filling line(piping capable of filling cargo without being led through the cargo pump).

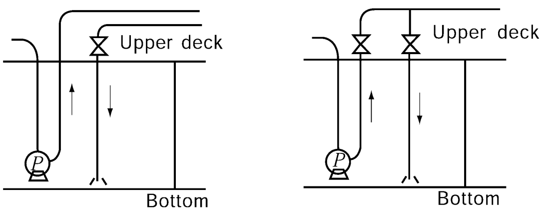


Fig. 7.6.31

(3) When the "direct cargo filling line" specified in the preceding (2) is provided, the open end of such direct cargo filling line for highly flammable and/or toxic chemicals is to be extended to not more than 10 cm above the tank top or sump surface or the filling pipe radius, whichever is the greater.
(4) The "one stop valve" referred to in **506. 1** (2) of the Rules is also required for the hose connection used for the transfer of cargo vapour.
(5) In addition to the preceding (4), a stop valve is required for the hose connection to the shore vapour circulation. When the stop valve is of the portable type for fitting as necessary, stop valves equal to or greater, in number, than the maximum number of tanks scheduled for simultaneous loading of the cargo requiring shore circulation are to be provided at shore for the ship. The restriction to the number of loaded cargo tanks according to the number of these stop valves is to be noted in the Operation Manual of the ship carrying dangerous chemicals in bulk.
(6) It is desirable that the "remote shut-down devices" referred to in **506. 1** (3) of the Rules can be centrally controlled from a place manned at all times during the cargo operation (e.g. cargo control station).

507. Ship's cargo hoses

1. General

(1) The "hoses" referred to in **507. 1** of the Rules are to comply with the following requirements :
  (A) When come in contact with the cargo, hoses are not to be mechanically damaged or caused extreme degrading in their function.
  (B) The materials of cargo hoses are not to give hazardous effects on the cargo.
(2) In the preceding (1), if cargo hoses are integral with the emergency cargo pump or they are submerged in the tank connected to the pump, the requirements in the preceding (1) are to be considered for both the inside and outside surfaces of hoses.

Section 7 Cargo Temperature Control

701. General

1. General

The "cargo heating or cooling system" referred to in **701. 1** of the Rules is to comply with the following requirements :

(1) For possible failure of any component or the whole system serving as a source of heating in ships carrying the cargo requiring heating and to which the requirements in this Chapter apply, means are to be provided so as not to disable cargo heating, cargo operation or not to endanger the safety of the ship.

(2) For the refrigerating installations and insulation materials of ships carrying the cargo requiring cooling to which the requirements in this Chapter apply, the requirements in **Ch 5, Sec 4** to **Sec 7** of the Rules and those specified in **Pt 9, Ch 1** of the Rules for Refrigerating Installations apply correspondingly. Particular attention is to be paid to the cargo since propylene oxide for the refrigerating installation of which detailed requirements are specified.

(3) Cargo requiring heating means the dangerous chemicals with a melting point not less than 15°, as a standard, but if deemed necessary by the Society, heating means for cargo may be required according to the service area and operation condition of the ship. In this case, the temperature measuring equipment specified in **701. 5** of the Rules is to be of the fixed type.

(4) The maximum temperature of steam and heating media within the cargo area is to be adjusted to take into account the temperature class of the cargoes.

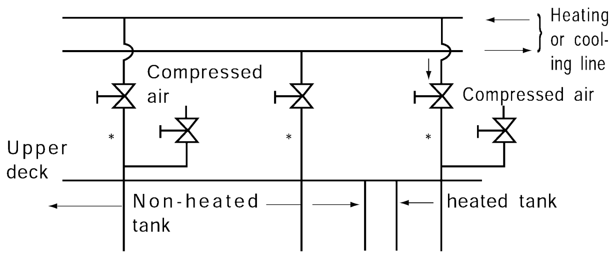
2. Control valves of cargo temperature control system

The "valves to isolate the system for each tank and to allow manual regulation of flow" referred to in **701. 3** of the Rules means the valves provided between the main vapour line and each tank and are capable of regulating flow rate. This also applies to the case of the refrigerating installations. In **Table 7.6.1** of the Rules where carriage of the water prohibiting cargoes to which the requirements of **1516. 2** of the Rules apply is intended, spool pieces are to be provided in addition to these valves.

3. Maintenance of pressure in cargo temperature control system lines

As the provision for the maintenance of the pressure specified in **701. 4** of the Rules, compressed air may be supplied from the deck general service air line fed from the air reservoirs and air compressors in the machinery space to the heating (cooling) piping.

When it is solely planned to carry the heated (cooled) cargo in all tanks, compressed air may be fed from the compressed air main, but if it is intended to carry the heated (cooled) cargo in part of tanks with the rest of tanks used for the carriage of non-heated (non-cooled) cargo, compressed air is to be supplied from the connection on the tank side of the stop valve of the compressed air branch line as given in **Fig 7.6.32** of the Guidance. In case where carriage of the cargo not requiring heating (or cooling) but requiring to inert the tanks and cofferdams adjacent thereto, no air is to be sealed in the line but inert gas is to be filled in. Consideration is to be given so as not to cause dangerous mutual reaction between the sealing medium and the cargo. Where other means are employed for the maintenance of line pressure, the same requirements apply.



* For the heating (cooling) lines led to tanks where water prohibiting cargoes are carried, spool pieces are to be provided on the tank side of the stop valve.
Where the cargo causing harmful reaction with the thermal medium is carried, the heating (cooling) lines are to be emptied, dried and gases are to be filled before cargo loading.

Fig. 7.6.32

4. Means for measuring the cargo temperature

"When overheating or overcooling could result in a dangerous condition" referred to in **701. 5** (4) of the Rules means such a case where the adjacent cargo tanks or fuel oil tanks are heated or cooled to the extent that they suffer from thermal effects. In this case, the temperature sensing ends are to be provided at least at two locations on the liquid surface and bottom of the tank.

5. Circuit operated with heating or cooling medium

(1) The cargoes falling under the requirements in **701. 6** of the Rules are to be those to which application of the requirements of either **1512., 1512. 1** or **1512. 3** specified in **Table 7.6.1** of the Rules is required, but they also apply to the cargo with a notation of "*T*" in vapour detection of the Table.

(2) "where the medium is sampled to check for the presence of cargo" referred to in **701. 6** (3) of the Rules is to be of the detection tank fitted with a detection cock as given in **Fig 7.6.33** of the Guidance, as a standard. Although provision of a oil observation tank in the machinery space is required for ordinary tankers according to the requirements in **Pt 7, Ch 1, 1002. 9** of the Rules, in the case of carriers carrying dangerous chemicals in bulk, provision in the machinery space is not permitted and such means is to be provided on the weather deck within the cargo area without exception. Means of detection is to be by an effective toxic gas-detecting tube or suitable testing agent. The suitable testing agent is to have been procured from the manufacturer.

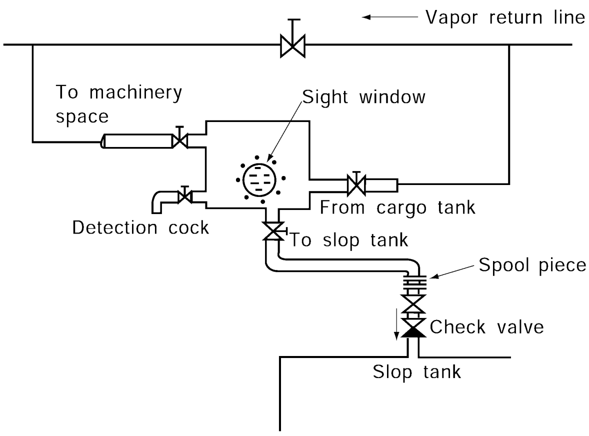


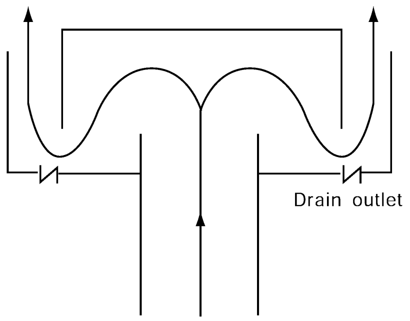
Fig. 7.6.33

Section 8 Cargo Tank Venting and Gas-freeing Arrangements

802. Cargo tank venting

1. Venting systems

(1) "Tank venting systems are to be arranged to prevent entrance of water into the cargo tanks and at the same time, vent outlet are to direct the vapour discharge upwards in the form of unimpeded jets" referred to in **802. 1** of the Rules mean the outlet as given in **Fig 7.6.34** of the Guidance.



Drain outlet is to be sized so small that no bulk of vapour leaks out.

Fig. 7.6.34

2. Provision for drainage of vent lines

The "cargo vent lines are to be self-draining back to the cargo tanks" referred to in **802. 2** of the Rules is to be so arranged that drains of the vent lines will flow into cargo tanks by natural gravitation by heels and trims of the ship. In case where such piping arrangement is impracticable, drain cocks are to be fitted at the location of PV valves and other places where drains tend to accumulate. For drain cocks which are capable of returning drains to the slop tanks when large volume of drains are accumulated, hose connections are to be provided.

3. Provision to protect liquefied head exceeding design head

(1) When the "provision made to ensure that the liquid head in any tank does not exceed the design head of the tank" referred to in **802. 3** of the Rules is designed, the following items are to be considered :
(A) loading and unloading rate
(B) filling of ballast and discharge rate
(C) gas evolution
(D) pressure loss considered resistance coefficient
(E) pressure loss in ventilation system
(F) operating pressure(suction/discharge setting pressure) where high velocity venting valves or relief valves are used
(G) density of equilibrium of the vapour/air mixture
(H) air supply rate by fixed type ventilation system

(2) Except for the case specified in **1519.** of the Rules, no independency is required among liquid level gauges, high liquid level alarm system and overflow control system. The high level alarm system or overflow control system required in **1519.** of the Rules may be used for the prevention of cargo tank overpressure. When the cargo having a larger specific gravity than the design specific gravity is carried in partial loading, the cargo tank is to be provided with the measuring systems required in 1301. of the Rules, and additionally, high liquid level alarm system capable of being set at arbitrary levels is to be provided for the protection of the cargo tank.

(3) The system fitted with valves and flanges for connecting cargo hoses at hatches on the top of cargo tank for preventing cargo tank overpressure as given in **Fig 7.6.35** of the Guidance may be accepted only when either of the following (A) or (B) is relevant :

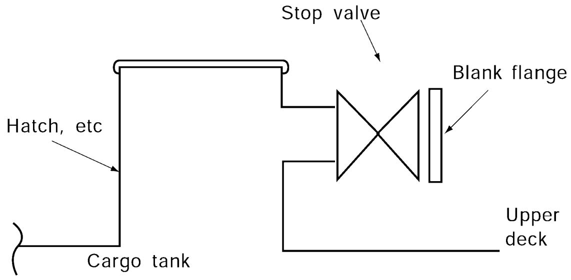


Fig. 7.6.35

(A) Cargo loading is carried out only at ports fully equipped with circulating systems
(B) Where method of cargo transfer to other cargo tanks has been established. In this case, however, cargo loading may be restricted under the requirements for mutual reaction with each other.
In either case of (A) or (B), much difficulty is involved in observing the operational restrictions and hence it is desirable to install the high level alarm or overflow control system specified in **1519.** of the Rules. For tanks carrying the cargo with a flash point of not more than 60°C, provision of the high level alarm system or overflow control system conforming to **Pt 7, Ch 1, 1004. 7** of the Rules is required where spill valves are not to be used. (Spill valves are not deemed equivalent.)

4. Design parameter of venting systems

(1) The size of vent system specified in **802. 4** of the Rules is to be given consideration so that the back pressure produced during the cargo operation at the maximum design loading rate does not exceed either of the following allowable pressures :
(A) Where no special consideration is taken for the strength of tank, the tank design pressure 2.45 m (head)
(B) Where cargo tank is suitably strengthened and the tank has been tested in the presence of the Surveyor of the Society, such tank test head.
(2) The parameters specified in **802. 4** of the Rules are to be considered in sizing of a tank venting system. In a cargo with a boiling point not more than 45°C having a high vapour pressure, the factor exceeding 1.25 may be required in connection to the gas evolution during loading specified in **802. 4** of the Rules.
(3) During the cargo loading/unloading, venting may be carried out through a by-pass line provided for the PV valve or high-speed discharge system. In this case, the height of atmospheric discharge opening of the by-pass line is to comply with the requirements for the height of the discharge outlet of the venting system specified in **803. 3** (1)and **1512. 1** (1) and (2) of the Rules. However, any venting arrangement to discharge the vapour directly by opening the high-speed discharge system is not accepted.

5. High level alarms and overflow control systems specified in the **Ch 6 802. 3** of the Rules are to be type approved by this Society.

803. Types of tank venting systems

1. Open tank venting system

The term "with due regard to cargo segregation" referred to in **803. 1** of the Rules means the design that restricts the ingress of the cargo of a cargo tank into other cargo tanks through vent lines even at times of heavy weather as given in **Fig 7.6.36** of the Guidance. In consideration of possible degrading of product quality due to coming to contact with different dangerous chemicals or their vapours, however, it is desirable that even the open type vent system be of independent design as far as practicable.

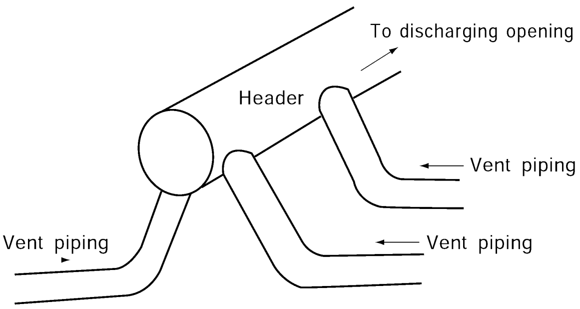
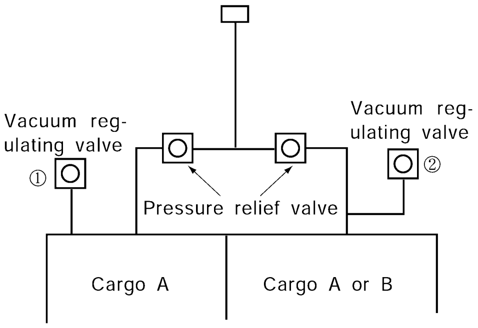


Fig. 7.6.36

2. Controlled tank venting system

(1) The words "such individual vents on the pressure side only may be combined into a common header or headers, with due regard to cargo segregation" referred to in **803. 2** of the Rules mean as follows :

(A) In case where the controlled venting systems of the cargo tanks carrying the cargoes different from each other or the same cargoes are led to a common pipe header, the pressure relief valves and vacuum regulating valves are to be separate from each other, and any other arrangement than that given in **Fig 7.6.37** of the Guidance is unacceptable. This requirement does not apply to tanks where cargoes which react in a dangerous manner are carried.



(Vacuum regulating valve is to be of the arrangement either ① or ②)

Fig. 7.6.37

(B) When PV valves whose pressure side and vacuum side are led to the common pipe for the vent system of the cargo tank intended to carry cargoes different from each other or the same cargos are used, any arrangement other than the venting system independent for each tank is unacceptable. Accordingly, both the arrangements given as (a) and (b) of **Fig 7.6.38** of the Guidance are unacceptable.

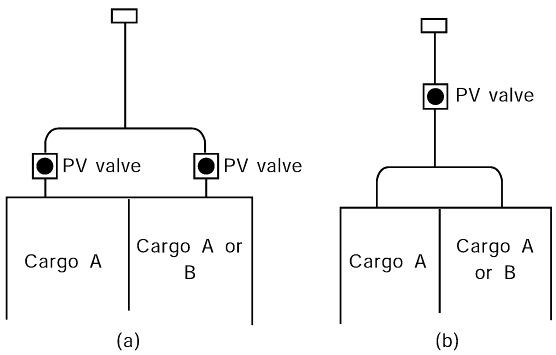


Fig. 7.6.38

(2) The measurement of the height of vent outlet "not less than 6 m above the weather deck" referred to in **803. 4** (1) of the Rules is to be taken as given in **Fig 7.6.39** of the Guidance. As for the height of the opening of the vacuum regulating valve, it is to be not less than 760 mm above the freeboard deck for the cargo to which application of **1516. 1** of the Rules is not required.

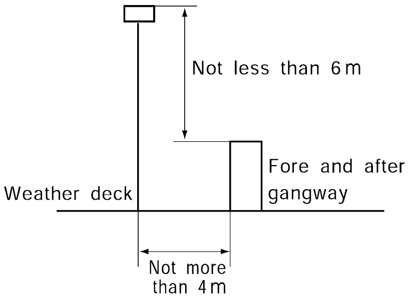


Fig 7.6.39

(3) As the countermeasures against the "freezing of cargo vapour or by icing up in adverse weather conditions" referred to in **803. 7** (3) of the Rules, ships operated in cold zone are to be provided with heating systems, etc. for the prevention thereof. In ships not provided with special heating systems, proper maintenance and inspection work procedures are to have been established.

(4) PV valves referred to **803. 2** of the Rules are to be type approved by the Society. The pressure setting, installation, tests and marking of the PV valves are to comply with the requirements of **Pt 8, Ch 3, 505. 1** of the Guidance.

(5) Devices to prevent the passage of flame(including high velocity valves) referred to **803. 5** and **6** are be type approved by the Society. The design, arrangement, inspection and etc., are to comply with the requirements of **Pt 8, Ch 2, 104. 11** of the Guidance.

805. Cargo tank gas-freeing

1. The method and instruction of cargo tank gas-freeing are to be described on the Cargo Operation Manual in detail.

2. Openings for gas-freeing are to be arranged at places as far as at least the distance specified in **803.** or **1512.** of the Rules from all openings or air intakes of accommodation or service spaces.

Section 9 Environmental Control

901. General

1. Inerting or padding of cargo tanks

(1) The inert gas supply system for ensuring "sufficient inert gas available on the ship to compensate for normal losses during transportation" referred to in **901. 3** (1) of the Rules is to be as follows :

(A) The nitrogen gas generating system that separates nitrogen from the air may be used in combination of the inert gas contained in a pressure vessel as a make-up system at sea.

(B) The required quantity of inert gas to be carried onboard the ship is to be determined for each ship in consideration of the construction and equipment of the ship, but it, as a rule, is to be not less than 5 % of the total volume of cargo spaces to be inerted or expected loss during 30 day voyage, whichever is greater.

(2) Where inerting gas is generated on board by oil-fired inert gas generators according to **901. 3** (1) of the Rules, followings are to comply with. In the case of systems using inert gas from other source, special consideration is to be required.

(A) Inert gas systems are to comply with IMO Res. A.567(14) "Regulation for inert gas systems on chemical tankers". In this resolution, Administration means this Society.

(B) A water seal of inert gas piping device on deck may be replaced by venting valve between two sets of shut-off valve, and following conditions are to be complied with :

(a) Valve is to be operated automatically. Open and close signal is to be obtained directly from the inflow of inert gas or the differential pressure.

(b) The alarm device for valve malfunction is to be installed. For example, the operating situation for blower stop and open of supply valve is to be condition of alarm operation.

(C) In addition to IMO Res A.567(14), following requirements are to be complied with.

(a) Drawings and data to be submitted are to comply with **Pt 8, Ch 1** of the Guidance.

(b) Automatic combustion control capable of producing suitable inert gas under all service conditions is to be fitted to the inert gas generators.

(c) Where two sets of inert gas blowers are provided, total capacity is to be provided equally at two sets, and each blower's capacity is to be 1/3 of total capacity and over.

(d) Materials used in inert gas systems are to be suitable for their intended purpose. In particular those parts or scrubbers, blowers, non-return devices, scrubber effluent and other drain pipes which may be subjected to corrosive action of the gases and/or liquids are to be either constructed of corrosion resistant material or lined with rubber, glass fiber epoxy resin or other equivalent coating material.

(e) The compartment provided with oil burning type inert gas generators is to be fire protection structure such as machinery space of category A.

(f) All devices installed on board are to be satisfied by the Surveyor on the test according to the working condition.

(3) The "means to be provided for monitoring" referred to in **901. 3** (4) of the Rules are to be as follows :

(A) Continuous monitoring system

(a) Continuous monitoring by fixed oxygen content meter, or

(b) Combined use of continuous pressure measurement of tank atmosphere and portable oxygen content meter.

(B) In the case of the cargo where the "closed type" is required for measurement instruments and inerted method is applied, the measurements by a portable oxygen content meter are to be taken at such measuring line from which no cargo is leaked onto the deck during and after the measurements, and means are provided to lead the exhaust gas to the cargo vent lines. In the case of the cargo where the "restricted type" is required, means are to be provided so that the opening for measurement are automatically closed.

2. Environmental control for double hull spaces, etc.

Ventilation, inerting and gas measurement for double hull and double bottom spaces are to comply with **Ch 1, 1009.** to **1011.** of the Rules.

Section 10 Electrical Installations

1001. General

1. Electrical equipment installed in the flammable atmosphere

(1) The words "to the satisfaction of the Society" referred to in **1001. 5** of the Rules are to be in accordance with the following (A) or (B) :

(A) Those complying with the requirements in **Pt 6, Ch 1, Sec 9** of the Rules, and having apparatus groups and temperature classes given in column i in table of **Sec 17** of the Rules according to the type of gas.

(B) Explosion-protected electrical equipment in **Pt 6, Ch 1, Sec 9** of the Rules and having type approval by the Society.

(C) Those approved as having no structural hazard to serve as a source of ignition.

1002. Bonding

1. Bonding

In application to 1002. of the Rules, the electrical bonding is to conform to the requirements of **Pt 6, Ch 1, 104.** of the Rules. In case where the gasketed flange joint are used, the flange bolts only are not considered as an earthing, and the connections and earthing are to be provided with earthing conductors.

Section 11 Fire Protection and Fire Extinction

1102. Cargo pump rooms

1. Fire-extinguishing system for the ships dedicated to the service of a restricted number of cargoes

The term "an appropriate fire-extinguishing system approved by the Society" referred to in **1102. 2** of the Rules means fixed carbon dioxide fire extinguishing system. The fire extinguishing system for ships carrying only the restricted number of cargoes as defined "No-nil requirements" in column j in table of **Sec 17** of the Rules is left to the discretion of the Society.

1103. Cargo area

1. Type of foam concentrate

(1) The "regular protein foam" referred to in **1103. 2** of the Rules means the foam without either any agents or anti-frozen agents added to be leveled the liquid point not higher than 0°C.
(2) Where plural fire extinguishing agents including foam are defined effective in column l in table of **Sec 17** of the Rules, foam fire extinguishing system is to be provided.

2. Arrangements for providing foam

For the purpose of the requirements in **1103. 3** of the Rules, the arrangements for providing foam are to be as follows :

(1) For the deck area of cargo tanks, reference is to be made to **Fig 7.6.40** of the Guidance.
(2) In supplying foams to inside the cargo tanks, access hatches, etc. may be used.

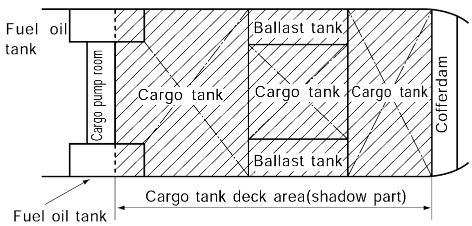


Fig. 7.6.40

3. Rate of supply of foam solution

For the purpose of the requirements in **1103. 5** (3) of the Rules, the minimum capacity of the monitor for ships less than 4,000tons deadweight is to be 1,000 l per minute and the rate of spray may be set at 10 $l/m^2/min$.

4. Specification of monitor and foam applicator

For the purpose of the requirements in **1103. 7** of the Rules, for the monitor and foam applicator for ships less than 4,000 tons deadweight, the requirements in preceding 3 are to apply correspondingly.

5. Requirements of fire main

For the purpose of the requirements in **1103. 12** of the Rules, the fire main is to be capable of discharging at least two lines of water jet on deck, accommodation space, control rooms and machinery space during the fire-fighting operation by foam.

6. Alternative provisions installed in ships dedicated to the carriage of a restricted number of cargoes

The fire extinguishing systems for ships carrying the cargoes defined "No-nil requirements" in column l in table of **Sec 17** of the Rules are left to the discretion of the Society.

7. Portable fire-extinguishing equipment

As portable fire-extinguishing equipment, two fire extinguishers with a capacity of 9 l to 13.5 l using the fire-extinguishing agents suitable for the type of cargo carried are to be provided at each manifold. These fire extinguishers are to be stored at suitable places except for the time of cargo operation.

8. Exclusion of sources of ignition

For the purpose of the requirements in **1103. 15** of the Rules, the windlasses and chain lockers are to be regarded as sources of ignition and are not to be provided in the dangerous compartments given in **1002.** of the Rules. The relevant requirements in **Pt 8, Ch 2** of the Rules are also to be complied with.

1104. Special requirements

1. Special requirements

(1) For ships dedicated to exclusive carriage of one type of cargo relating to the fire-extinguishing installation given in column l in table of **Sec 17** of the Rules, either one of the alternative fire-extinguishing equipment specified therein may be selected and provided notwithstanding the requirements in column l. Further, the fire-extinguishing arrangements in ships carrying only the cargo defined "NF" in column i and "No-nil requirements"in column l in table of **Sec 17** of the Rules are to be such that any places on deck within the cargo area can be covered by water spray from at least two lines of fire nozzles discharged from separate fire hydrants.

(2) The capacity of fire-extinguishing agent of dry chemical fire extinguishers is to be the greater or more of the following capacities :

(A) The capacity required in **Ch 5, 1104. 6** of the Rules.

(B) 1.5 kg/m^2 of the total deck area of the cargo tanks which are expected to carry simultaneously the cargo for which the fire-extinguishing equipment is required. For other requirements for installations, the requirements in **Ch 5, 1104.** of the Rules apply correspondingly.

(3) The "C-water spray" required in column l in table of **Sec 17** of the Rules as the fire-extinguishing equipment of "ammonium solution of 28 % or less" may be replaced with the water spray from the fixed deck foam system.

Section 12 Mechanical Ventilation in the Cargo Area

1201. Spaces normally entered during cargo handling operations

1. Ventilation prior to entering the compartment

For the purpose of the requirements in **1201. 2** of the Rules, the ventilating period before the entrance of person in the compartments is to be 15 minutes as standard.

2. Type of ventilation systems

For the purpose of the requirements in **1201. 4** of the Rules, the ventilation ducts in cargo pump room are to be provided at the upper part of cargo pump room, and in addition, to be arranged in compliance with the requirements in **Pt 7, Ch 1, 105.** of the Rules. Further, the suction openings are to be arranged as far apart as practicable from each other, for instance on a diagonal line of cargo pump room, in consideration of the vapour density of the cargo and air intaking efficiency.

3. Arrangement of ventilation intakes

For the purpose of the requirements in **1201. 6** of the Rules, the ventilation intakes are to be so arranged as to minimize the possibility of recycling hazardous vapours.

4. Arrangement of ventilation ducts

For the purpose of the requirements in **1201. 7** of the Rules, in view of the difficulties involved in the maintenance when protection against the approved type of cargo to be carried is required, the location of ventilation ducts on the bulkhead bounding the cargo pump room and machinery room as given in **Fig 7.6.41** of the Guidance is not allowed.

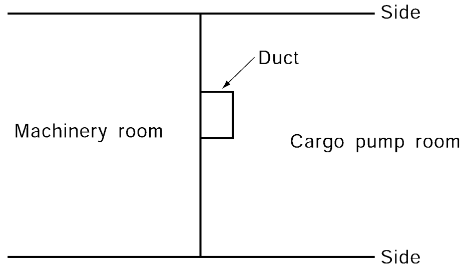


Fig. 7.6.41

5. Requirements of electric motors driving fans

In application of **1201. 8** of the Rules, the ventilation fan "of non-sparking construction" is to be comply with the requirements specified in **Ch 1, 1006. 2** of the Guidance.

6. Spare parts for fan

For the purpose of the requirements in **1201. 9** of the Rules, one spare impeller is to be provided for each type of fan.

7. Protection screens fitted in the opening of ventilation ducts

For the purpose of the requirements in **1201. 10** of the Rules, the protection screens may be of wire gauze of 13 mm × 13 mm mesh. However, the wire gauze is to have suitable strength against the falling impact of foreign objects.

1202. Pump rooms and other enclosed spaces normally entered

1. In application to 1202 of the Rules, the following requirements are to be complied with :

(1) The requirements in **1202.** of the Rules apply irrespective whether the control system of the pumps and valves in the pump room is provided outside the pump room or not.

(2) The pump room and other enclosed spaces normally entered are to have 20 air changes per hour and, in addition, the requirements in **1201.** of the Rules are to be complied with. In enclosed spaces normally entered, the special lockers and storage rooms specified in **1401. 2** of

the Rules and suitable clearly marked locker specified in **1402. 5** of the Rules which are readily accessible for persons are to be included. However, for the enclosed small spaces where the maximum travel distance to the door is 5 m or less, it is difficult to install the fixed ventilation system, portable ventilation system may be permitted.

(3) The ballast pump room where no cargo piping whatever penetrates therethrough or where cargo pipings without having flange joints and valves penetrate therethrough is to be dealt with in accordance with the following requirements :

(A) The exhaust outlet of the mechanical ventilation fans of the ballast pump room may not undergo the restriction to its location specified in **1201. 5** of the Rules.

(B) The exhaust inlet and outlet of the mechanical ventilation fans serving the ballast pump room is to be provided with a protective wire gauge of 13 mm × 13 mm mesh.

(C) For the exhaust ventilation fans of the ballast pump room, spare parts as required for the ventilation fans of cargo pump room are to be provided for each type.

(D) The fire hydrants are to be provided as the fire-extinguishing arrangement of the ballast pump room, but no fixed gas fire-extinguishing system is required.

1203. Spaces not normally entered

1. Spaces not normally entered

The ventilation system provided in spaces not normally entered is not allowed to be the natural ventilation alone. Where a fan is provided in the permanent duct, eight air changes per hour, and where no permanent duct is provided, sixteen air changes per hour are to be provided.

Section 13 Instrumentation

1301. General

1. Types of gauging devices

(1) The openings for the restricted device and closed device of the types of gauging devices referred to in **1301. 1** of the Rules are to comply with the following requirements:

(A) Restricted device :

The inside diameter of the opening is to be not more than 200 mm for both sounding pipe and ullage hatch and to be provided with self-closing type pipe head fitting. For cargo tank sounding/ullage measuring, the device is to be of the gas seal valve capable of being fitted with a measuring device of the construction restricting a massive leakage of cargo vapour. Glazed peeping window is to be provided separately as necessary.

(B) Closed device :

The closed construction is to be of all welded construction, as a rule, but flange construction for periodic inspection which is normally not open may be accepted as the closed device.

(2) In types referred to in **1301. 1** (1), (2) and (3) of the Rules, the closed type may serve commonly with open type and restricted type, and the restricted type, with open type respectively. Namely, the degree of safety is the highest in the closed type followed by the restricted type and then open type, thus it descends in the order of description. In the cargo tank where loading of the cargo required to be provided with the closed devices is expected, restricted devices may be provided in addition to closed devices. In more specific terms, in case where carriage is made of the cargo for which the use of closed devices is required, only the closed devices are to be used, but when carriage is made of the cargo in this tank for which the use of restricted devices is required, either of the closed devices and/or restricted devices may be used. However, for tanks where use of either the closed devised or restricted devices is required, open devices are not to be provided from the safety point of view.

(3) Where peeping windows are provided as a means of gauging device, their construction, liquid and gas sealing performance are to be equivalent to that of tank top, and are to be fitted with protective covers of sufficient strength.

(4) The fitting of a gauging device on the bulkhead of tank with a flange is not allowed under any circumstances. Namely, the gauging device is to be housed in a recessed pipe as shown in **Fig 7.6.42** of the Guidance.

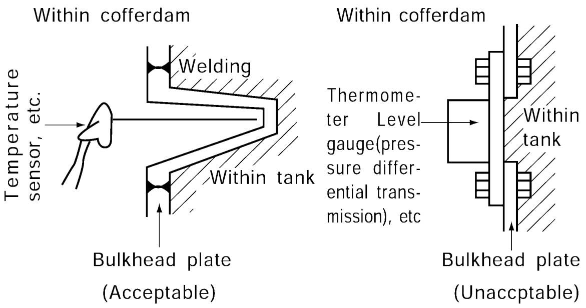


Fig. 7.6.42

(5) The performance and construction of liquid level indicator are to have been approved in accordance with the Guidance for the Approval of Manufacturing Process and Type Approval, Etc.

(6) The tests (pressure, temperature, etc.) and inspection for other gauging devices are to be comply with the following requirements (A) and (B). However, the performance test does not necessarily require a test using the real cargo if as the effect of the device can be verified.

(A) Testing procedure at time of manufacture

Performance tests are to be conducted using the real cargo according to the test plan prepared by the manufacturer. However, in the case of devices which are of the same type previously approved, the performance test using the real cargo may be omitted on approval by the Society. In the case of fixed type device, tests and inspection are to be arranged in accordance with the shipboard test plan approved by the Society.

(B) Reinspection and retesting procedures onboard.

For the gauging devices and equipment fitted onboard the ship, the data specifying the following items (the data are to have been approved by the Society) are to be placed onboard the ship.

(a) Check procedure before use (including the testing procedure)
(b) Check procedure during use (including the testing procedure)
(c) The periodical check procedure established by the manufacturer and service frequency
(d) Service life
(e) Tests and inspection procedures at periodical inspection
(f) Other precautions

1302. Vapour detection

1. Requirements for some products which are not available with toxic vapour detection

In case where a suitable vapour detection instrument for a specific cargo is not available, approval from the Society is to be obtained. However, it is desirable that fixed type vapour detection instruments are installed as far as such are available. At least against carbon disulfide and chlorsulfonic acid, fixed type vapour detection instruments are to be provided.

Section 14 Personnel Protection

1401. Protective equipment

1. Requirements for work clothes and protective equipment

Work clothes and protective equipment specified in the requirements in **1401. 1** of the Rules are to be capable of protecting the entire body of the wearer against cargo splashes in all directions, and the number of sets necessary for those working on deck and in cargo pump room are to be provided. Where one type of work clothes or protective equipment is not sufficient for all prospective types of cargo of the ship, necessary number of sets for respective types of cargo is to be provided.

2. Lockers for work clothes and protective equipment

The protective equipment used for once or more to handle the cargo to which the requirements in **Ch 6** of the Rules apply are, as a rule, to be stored in the lockers provided within the cargo area. One set of these is to be stored in the locker near the cargo pump room at all times. The construction of the special locker for the storage of protective equipment provided in the cargo area is to comply with the requirement in **Pt 3, Ch 17** of the Rules. When this can not be complied with under unavoidable reasons, protective equipment may be stored in the store room or locker having no openings to accommodation space and service space and located outside the cargo area as shown in **Fig 7.6.43** of the Guidance. This requirement does not apply to brand new protective equipment, unused equipment, or equipment which has not been used since undergoing a thorough cleaning process.

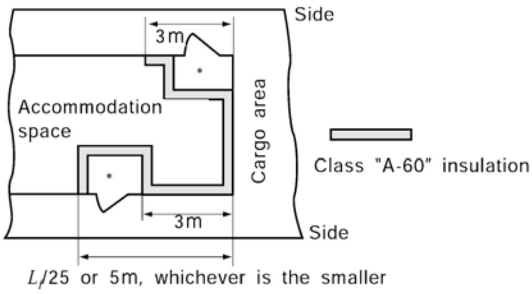


Fig 7.6.43

* : When the storage place of protective equipment is provided within the accommodation space or service space, such is only allowed at areas with openings as specified in **302. 3** of the Rules. In this case, it is desirable to provide showers, etc. within the room. the location of the store room of cargo specimens referred to in **1605. 4** of the Rules is to be dealt with in the same manner as above.

1402. Safety equipment

1. The number of safety equipment is to be determined after carefully studying the arrangement and scheme of shipboard working persons.

2. The safety equipment specified in **1402. 2** of the Rules is to comply with the following requirements :

(1) The term "perform work for at least 20 min." means a capacity in terms of the free air volume at atmospheric pressure is 800 litres or more.
(2) Work clothes and protective equipment of excellent acid-resisting, alkali-resisting and anti-toxic features against the types of prospective cargo are to be used. No duplicated use of work clothes and protective equipment with those required under **1401. 1** of the Rules, in number, is permitted.
(3) The length of the fire-resisting life line is to be 30 m or more so that it can be used also for signalling between the person who enters the enclosed compartment and the other person outside the compartment.
(4) The explosion-proof light is to be capable of lighting for a period not less than 3 hours.

(5) The suits for toxic cargoes are to be fitted with integral gloves and boots.

3. The air compressor referred to in **1402. 3** (2) of the Rules is to be capable of charging the air bottles placed onboard to their maximum working pressure.

4. The additional requirements for the cargo pump room of ships carrying cargo for which no effective vapour detection instruments are provided are to be as given in the following (1) and (2) :

(1) The additional air bottles for the work in the cargo pump room of ships carrying toxic cargo without being provided with effective vapour toxicity detection instruments are to be provided in addition to the number of spare air bottles specified in **1402. 3** of the Rules.

(2) The capacity of the equivalent air bottle in replacement with the low pressure air piping as an additional air breathing apparatus is to be not less than 4,800 litres under the atmospheric pressure.

1403. Emergency equipment

In application to **1403. 2** of the Rules, reference is made to the Medical First Aid Guide for use in Accidents Involving Dangerous Goods (MFAG), which provides advice on the treatment of casualities in accordance with the symptoms exhibited as well as equipment and antidotes that may be appropriate for treating the casualty.

Section 15 Special Requirements

1502. Ammonium nitrate solution, 93 % or less

1. Temperature of the heat exchanging medium in the tank heating system

For the requirements in **1502. 4** of the Rules, the temperature alarm is to be of visible and audible alarm. The detecting temperature is to be the mean temperature within the tank, but the heating system is to be so arranged to avoid uneven heating.

2. Fixed installation for ammonia gas injection system

For the requirements in **1502. 6** of the Rules, where ammonia gas is injected into cargo, the cargo is to be circulated during the injection being made.

3. Type of cargo pump

The sealing system of centrifugal pump is to be of the stuffing box provided with lantern rings as shown in **Fig 7.6.44** of the Guidance and the pressurized fresh water is to be injected into the stuffing box from lantern rings.

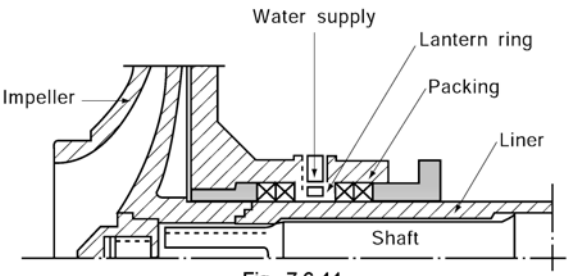


Fig. 7.6.44

1503. Carbon disulphide

1. Opening for emergency sounding

The opening for emergency sounding is to be provided with sluice valve and cock fitted with automatic closing devices. Further, warning signs banning their use other than in emergency cases are to be fitted.

1505. Hydrogen peroxide solutions

1. Fixed water spray system

When the rate and estimated size of the spill referred to in **1505. 1** (10) (B) of the Rules are calculated, the piping and hoses are to be considered to have undergone total loss.

1508. Propylene oxide and mixtures of ethylene oxide/propylene oxide with an ethylene oxide content of not more than 30 % by weight

1. Conditions of carriage

The nitrogen gas produced by the membrane type nitrogen gas generator capable of ensuring a purity of 99 % or more by volume may be used as the nitrogen gas to be sealed.

1510. Sulphur, molten

1. Cargo temperature control system

For the requirements in **1510. 6** of the Rules, the cargo temperature control system may employ manual temperature control trip, etc. provided that the cargo tanks are equipped with cargo temperature indicators and high/low temperature alarms. In this case, tank temperatures are to be so monitored and controlled as not to allow them to exceed 155°C at any points of measurement. In case where the heating medium does not exceed 155°C, the requirements here may be reduced to the temperature indicator only.

2. The double pipes or effective devices are to be provided so that cargo pipe or ventilation pipe is not to be solidified.

1511. Acids

1. Anti-corrosive treatment

For the purpose of the requirements in **1511. 2** of the Rules, the use of lining or corrosion-resistant materials is to be applied also to the boundary walls of cargo pump room (the bottom and boundaries to a height of 1 m from the bottom). Where the effectiveness of lining or corrosion-resistant materials is not verified, the boundary walls are to be used corrosion-resistant materials.

2. Means of guard against the danger of cargo being sprayed and leakage

For the purpose of the requirements in **1511. 4** of the Rules, the shields to guard against the danger of cargo being sprayed and leakage are to be of acid-resistant materials.

3. Segregation of cargo from oil fuel tanks

For the purpose of the requirements in **1511. 6** of the Rules, in segregating cargo tanks carrying cargoes or cargo residues from oil fuel tanks, none of facial contacts, linear contacts and point contacts are accepted.

4. Apparatus for detection of leakage of cargo

For the purpose of the requirements in **1511. 7** of the Rules, the apparatus for detection of leakage of cargo is to be of the pH meter and hydrogen detector. These apparatuses may be of portable ones. Further, alternative means such as litmus papers may also be used.

5. Material of bilge pumping and drainage arrangements in cargo pump room

For the purpose of the requirements in **1511. 8** of the Rules, underneath the cargo pumps and associated flange joints, drain pans are to be provided and the collected drains are to be led to bilge wells through the drain lines. These drain lines are to be formed by corrosion-resistant materials or to be applied with effective coatings. Where the bottom of the cargo pump room and its casing walls to a height of 1m from the bottom are made corrosion-resistant, the requirements may be dispensed with.

1512. Toxic products

1. The tank venting systems referred to in **1512. 2** of the Rules are to be provided with the stop valve on return line to shore installation.

1513. Cargoes protected by additives

In application to **1513. 5** of the Rules, For equivalency arrangements for the carriage of styrene monomer, see MSC/Circ.879 and MSC/Circ.879/Corr.1.

1514. Cargoes with a vapour pressure greater than 0.1013 MPa absolute at 37.8°C

1. For the purpose of the requirements in **1514. 4** of the Rules, the tank venting systems are to be provided with the stop valve on return line to shore installation.

1516. Cargo contamination

1. No contamination of cargo with alkali or acidic materials

In segregating the cargo tanks carrying cargo to which the requirements in **1516.** of the Rules apply and the cargo tanks carrying cargo of either alkalinity or acidity, none of facial contacts, linear contacts and point contacts are accepted. Further, segregation of cargo pipes and tank venting systems is required.

2. No contamination with water

(1) The "permanent ballast or water tanks unless the tanks are empty or dry" referred to in **1516. 2** (3) of the Rules means that the tank casings, frames, etc. are free from attachments of water droplets or from moistened condition. In the cargo tanks adjacent to permanent ballast or water tanks not maintained in dry condition, no cargo to which the requirements in **1516. 2** of the Rules apply is to be carried. In this case, none of linear contacts and point contacts are accepted. However, the cross welding such as **Fig 7.6.45** may be accepted.

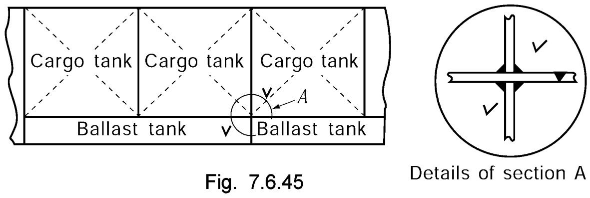


Fig. 7.6.45

(2) Where cargo that reacts dangerously with water is carried in the cargo tank adjacent to ballast tanks, the ballast tank is to be fitted with detachable spool pieces (at outside the tank, e.g. pump room, etc.), the said detachable spool pieces are to be removed after discharging the ballast, and then the open ends are to be blanked off. In this case, the ballast tanks are to be made in dry condition and, at the same time, it is to be ensured that there is no possibility of introducing ballast water thereto by erroneous operation. With permanent ballast tanks not in dry condition or cargo tanks adjacent to water tanks, the carriage of cargo to which the requirements in **1516. 2** of the Rules apply is not allowed. In this case, both linear contacts and point contacts may be not accepted. However, the cross welding such as **Fig 7.6.48** may be accepted. However, the linear contacts and point contacts divided into the cross welding such as **Fig 7.6.48** may be accepted

(3) Where cargo that reacts dangerously with water is heated, the thermal oil installations or the other indirect heating installations are to be provided.

1517. Increased ventilation requirements

1. Increased ventilation requirements

The "work areas or other similar spaces" referred to in **1517.** of the Rules are the service spaces, cargo control rooms and other similar spaces but not include cargo manifolds where cargo operation is carried out.

1518. Special cargo pump room requirements

Under any circumstances, no cargo pump room is arranged directly below open deck. Namely, for tanks carrying the cargo to which the requirements in **1518.** of the Rules apply, either submerged type cargo pump is to be provided therein or cargo pump room is to be provided on open deck.

1519. Overflow control

1. Test of level alarm

In the test of alarms carried out prior to loading, their functions are to be capable of being tested by actual operation of level gauges. When verification by actual operation is impracticable, suitable means to verify that the alarm circuits in normal condition as shown in **Fig 7.6.46** of the Guidance is to be provided.

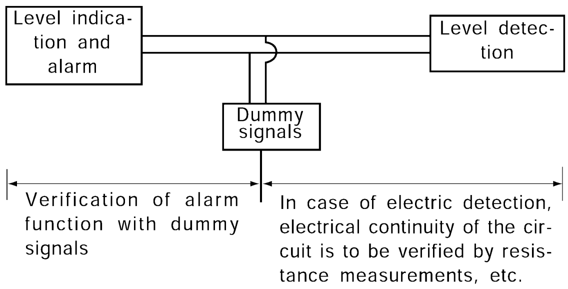


Fig. 7.6.46

2. Independence of high level alarm

For cargoes required to have high level alarm system and overflow control system in the requirements, the provisions of closed type instruments are required in many cases. For such tanks, the following detecting ends are required :

(A) Level gauging devices (**1301.** of the Rules)
(B) High level alarm (**1519. 6** of the Rules)
(C) Overflow controls (**1519. 7** of the Rules)

The above detecting ends (A), (B) and (C) are to be separate from each other. However, only for pipes to which the detecting ends of (B) and (C) (limit switch, float, electric device, etc.) are fitted, they may serve commonly. The electric, pneumatic or hydraulic circuits required for the detecting ends of (A), (B) and (C) are to be independent so that defect in one circuit may not cause functional disability in other circuits. In case where process units are provided on bridge, etc. for the purpose of visual display, the electric circuits concerned are to be independent at least up to the point of display. Power is to be supplied from distribution box.

3. Installation of high level alarm

When modular units are provided in the control room or on bridge as high level alarms specified in **1519. 6** of the Rules, level indicators and visible alarms independent from those (A), (B) and (C) given in the preceding 2 are to be provided. Visible and audible alarms are to be provided also in the cargo areas. Visible alarms are to be provided at such locations readily recognizable also from shore side. In case where no control room is provided, audible and visible alarms are to be provided in the cargo control room. Except for entering the cargo tanks which have thoroughly been washed clean, the testing device for detecting ends is to be provided outside the tank. Simulation test of electric circuit or self-monitoring circuit may be accepted.

Section 16 Operational Requirements

1601. Maximum allowable quantity of cargo per tank

The maximum allowable quantity of cargo specified in **1601.** of the Rules is to be determined in consideration of the thermal expansion of the cargo at temperature of 45°C Care is to be taken so as to ensure that the open ends of the venting system in the tank may not submerge in the cargo but in the gaseous phase under any trim condition of the ship at sea. Further, the maximum allowable quantity of cargo in cases where the tank temperature will possibly exceed 45°C being affected by tank heating is to be determined on the basis of such a temperature.

1604. Opening of and entry into cargo tanks

Covers of the cargo tank specified in **1604.** of the Rules, ullage hole covers and peeping hole covers or tank cleaning hatch covers are not to be opened except for cases where air is intaken in gas free operation, tank washing operation, gauging is taken of the tanks requiring the open devices and restricted devices and during gas detection and when samples are being taken.

1605. Stowage of cargo samples

When the stowage of cargo samples is made within the cargo area, such stowage compartment is to be only accessible directly from the exposed areas of the ship provided with exhaust type independent mechanical ventilating fan capable of ensuring twenty air changes or more per hour. Where it is difficult to install the permanent ventilation system due to the confined stowage compartment, portable ventilation system may be permitted. However, for the stowage small compartment where the maximum travel distance to the door is 5 m or less, it is difficult to install the fixed ventilation system, portable ventilation system may be permitted.

1606. Cargoes not to be exposed to excessive heat

In case where the tank carrying the cargo which is not to be exposed to excessive heat is subjected to tank heating or where the tank is adjacent to other tanks (cargo tanks, oil fuel tanks, etc.) which are heated, fixed type thermometers and temperature alarms are to be provided.

Section 17 Summary of Minimum Requirements

In application to **1** of the Rules, "The Guidance specified separatedly" means the Annex 7B-1 of this Guidance.

Section 18 List of products to which the Code does not apply

In application to **6** of the Rules, "The Guidance specified separatedly" means the Annex 7B-2 of this Guidance.

Section 19 Index of Products Carried in Bulk

"The Guidance specified separately" means the Annex 7B-3 of this Guidance.

Section 21
Criteria for assigning carriage requirements for products subject to the IBC Code

"The Guidance specified separatedly" means the Annex 7B-4 of the Guidance.

Annex 7A-1 Requirements for Ships not having the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk

Section 1 General

101. Application

1. The construction, equipment and survey of ships intended to be classified as liquefied gas carriers not having the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk are to be in compliance with the requirements in this Annex. "Liquefied gas carrier" in this Annex means a ship designed to contain and carry liquid dangerous cargoes in bulk having a vapour pressure (the pressure is expressed in gauge, and the same is to apply hereinafter) of 2 kg/cm^2 or above at a temperature of 38°C. However, the tests prescribed in **104. 2** (10) of Annex may be omitted by carrying out at the time of initial cargo handling of the ship.

2. General items not specified in this Annex, are to conform to the requirements specified in the relevant Parts of the Rules.

3. As for construction and equipment as well as surveys of liquefied gas carriers intended to carry cargoes having different properties from the liquefied petroleum gas, special consideration is to be paid according to the properties of the cargoes.

4. Loading facilities of liquefied gas carriers which are different from those specified in this Annex may be accepted by the Society, provided that those facilities are deemed equivalent to those required in this Annex.

5. The requirements of **Sec 2** in this Annex apply to pressurized liquefied petroleum gas carrier and the requirements of **Sec 3** apply to low temperature liquefied petroleum gas carriers. Ships, however, which are intended to transport liquefied petroleum gas at temperature below -50°C, are to be at the discretion of the Society.

102. Definitions

The definition of each nomenclature in this Annex is as follows :

1. The "pressurized liquefied petroleum gas carriers" mean the ships intended to contain and transport of the liquefied petroleum gas with the vapour pressure of 0.2 MPa or above at 38°C in storage tanks permanently attached to hull structure at atmospheric temperature and under pressurized condition.

2. The "low temperature liquefied petroleum gas carriers" mean the ships intended to contain and transport liquefied petroleum gas with vapour pressure of 0.2 MPa or above at 38°C, in fixed, independent from hulls and self-supporting type tanks thermally insulated from outside, at or near the atmospheric pressure under refrigerated condition.

3. For the pressurized liquefied petroleum gas carriers, tanks include storage tanks and auxiliary tanks. Storage tank is a storage tank specified in preceding **1** and auxiliary tank is a tank to provide forced pressure head to cargo pumps.

For the low temperature liquefied petroleum gas carriers, tanks are the tanks specified in preceding **2** in which liquefied petroleum gas is loaded.

4. Tank hold is a compartment in which storage tanks of preceding **1** and tanks of preceding **2** are installed.

5. Liquid is liquid phase of liquefied petroleum gas.

6. Gas is gaseous phase of liquefied petroleum gas.

7. Dangerous space is the space where inflammable or explosive substances are placed and where those are stored or are liable to escape into. For ships prescribed in this Annex, at least, following compartments and areas are to be considered as dangerous spaces:

(1) Tank.
(2) Compartment adjoining the tank.
(3) Compartment containing cargo handling machinery and equipment, such as cargo pump room, compressor room, etc.
(4) Zone or semi-enclosed space on open deck, within at least 3 m from any tank outlet, gas/vapour outlet, liquid outlet or cargo pipe flange.
   (A) Openings, as specified above, are the following openings ;
      Tank outlet : Manhole, tank fittings
      Gas outlet : Entrances and ventilation openings of spaces specified in (3), (7) and (8) safety valves, shore connection
      Liquid outlet : Shore connection, overboard discharge pipe
   (B) Flange of cargo pipe is as follows ;
      Cargo pipe means liquid and gas pipe except overboard discharge pipe
      Slip-on and screw type are considered as flanged type.
(5) Zone enclosed by the following width, height and length, on the weather deck:
   (A) Full breadth of the ship ;
   (B) 2.4 m in height above the weather deck ;
   (C) Total length obtained by extending 3 m each in both fore and after directions, with length from leading edge of the foremost storage tank to the trailing edge of the rearmost storage tank.
   (D) In the case of small ships where part of the forecastle deck corresponds to the dangerous space under the requirements of preceding (C) and when electrical equipment other than explosion-protected ones are installed between the leading edge of the foremost storage tank and extension of 3 m in fore direction under an inevitable reason, the following requirements are to be complied with:
      (a) A steel gas barrier is to be provided on the forecastle deck.
      (b) The height of the steel gas barrier is to be 2.4 m or more above the upper deck with the full width of the forecastle deck where the steel gas barrier is installed.
      (c) The steel gas barrier is not to be provided with any opening.
      (d) Electrical equipment is to be at least of the totally enclosed water-proof type.
(6) Exposed area within 2.4 m from the outer surface of storage tank.(in case where the tank is covered by insulator or protective enclosure, the distance is to be measured from its external surface.)
(7) Enclosed or semi-enclosed space where cargo piping is installed.
(8) Compartment where cargo hoses are stored.
(9) Enclosed or semi-enclosed space directly above the dangerous spaces prescribed in (2) or (3) above, except space which is partitioned by gastight bulkheads and is suitably ventilated. "suitably ventilated" means the mechanical ventilation separated from those for compartments specified in preceding (2), (3), (7) and (8), and the air charge rate are not limited.
(10) Any enclosed or semi-enclosed space which has a direct opening to any one of dangerous spaces prescribed in (1) to (9) above.
   The following items are not regarded as the direct openings.
   (A) For windows, manholes, etc.,
      (a) Fixed type gastight portholes
      (b) Bolted, gastight or watertight openings which are not necessary to be opened while the ship is at sea.
   (B) For doors,
      (a) In access opening doors of the living quarters on the upper deck where double, metal self-closing doors are provided in addition to weather-tight doors. Provided, however, that sufficient face-to-face contact is obtained for the self-closing type doors by applying packing to the contact face or by other adequate means.
      (b) In case where double, metal self-closing doors are provided in addition to weather-tight doors for deck storeroom, etc., and the space between the double doors is provided with effective mechanical supply ventilation system.
         In case where double, metal self-closing doors are provided in addition to weather-tight doors, and the space between the double doors is provided with effective mechanic\l supply ventilating system which is interlocked with the non-explosion-protected electrical equipment within the compartment.
         The above (b) may a\so apply to the access opening doors specified in (a) above. The

term "semi-enclosed spaces" specified in (4), (7), (9) and (10) above means the spaces separated by decks and bulkheads where the condition of ventilation is significantly different from that of exposed part of ship.

8. Void space in tank holds is an empty space around tanks in tank holds.

9. Secondary barrier is a structure to hold leaked cargo for more than a fixed period so as not to lower the temperature of main hull structures below that specified in the design.

103. Plans and documents to be approved

Where the loading facilities of liquefied petroleum gas are installed on board, at least, following plans and documents are to be approved by this Society.

Pressurized liquefied petroleum gas carriers

1. Plans and documents to be submitted for approval are as follows:

(1) Specifications for manufacture of tanks including details of welding material and welding procedures.
(2) Overall assembly diagrams and details of tanks and pressure vessels including details of seats for attachment of accessories, nozzles, and also of inner fittings.
(3) Accessory layout on tanks and pressure vessels, detailed drawings of accessories including liquid level gauges, quick closing valves, excess flow valves, etc.
(4) Layout and installation diagrams of storage tanks and auxiliary tanks, details of an deck penetrations and its closing appliances, and details of working benches.
(5) Piping diagrams of liquefied petroleum gas and instrument.
(6) Bilge arrangement and ventilation systems in compartments provided with the loading facilities of liquefied petroleum gas.
(7) Arrangement of safety devices.
(8) Arrangement of sensors for gas detectors.
(9) Details of valves for special purpose, cargo handling hoses, expansion joints, filters, etc. for liquefied petroleum gas.
(10) Constructions of cargo pumps, gas compressors and their prime movers.
(11) Drawings showing dangerous spaces.
(12) Arrangement of earth connections for tanks, piping, equipment, etc.
(13) Electric wiring plans and a table of electrical equipment in dangerous spaces. In this case, the table of electrical equipment is to comply with **Pt 6, Ch 1, 102.** of the Guidance.
(14) Other plans and documents which deemed necessary by the Society.

2. Documents to be submitted for reference are as follows:

(1) Specifications for cargo spaces.
(2) Compositions and physical properties of cargoes including a diagram of saturated vapour pressure within the temperature range from -10°C to 45°C.
(3) Strength calculation sheets of tanks and tank supports and calculation sheets of relieving capacity of safety valves including back pressure calculation of vent pipes.
(4) Piping arrangement of liquefied petroleum gas.
(5) Calculation sheets of filling limits for cargo.
(6) Operation manual prescribed in **106.** of this Annex.

Low temperature liquefied petroleum gas carriers

1. Plans and documents to be submitted for approval are as follows:

(1) Plans given in (5), (6), (9) to (14) of those required for pressurized liquefied petroleum gas carriers.
(2) Manufacturing specifications of tanks (including details of welding procedures, test and inspection plan of welds and tanks, properties of insulation materials and their processing manual).

(3) Construction and details of tanks.
(4) Accessory arrangement on tanks including details of fittings inside the tanks, and details of fittings including level gauges and valves for special purpose.
(5) Details of tank foundations, tank securing devices, deck portions through which tanks penetrate, and closing devices.
(6) Layout and attachment details of heat insulating materials.
(7) Details of secondary barriers, where they are provided.
(8) Details of emergency pressure relief devices from void spaces in tank holds, and details of discharging devices for leaked liquid.
(9) Details of pressure adjusting devices, where void spaces in tank holds are filled by inert gases.
(10) Sectional assembly, details of nozzles, fitting arrangement and details of fittings for various pressure vessels.
(11) Kinds and specifications of materials used for liquefied petroleum gas piping system in connection with the design pressures and/or temperatures.
(12) Piping diagram of refrigerant for re-liquefying devices of vapourized gas.
(13) Arrangements of sensors for gas detectors, temperature indicators, pressure gauges, etc.
(14) Construction of principal parts of re-liquefying devices of vapourized gas in accordance with the requirements for refrigerating devices.

2. Documents to be submitted for reference are as follows :

(1) Documents given in (1), (3) to (6) those required for pressurized liquefied petroleum gas carriers.
(2) Composition and physical properties of cargo including a saturated vapour pressure diagram within the necessary temperature range.
(3) Calculation sheets of capacity of liquefying devices of vapourized gas.

104. Tests and Inspections

Various tests and inspections are to be in accordance with the following requirements as well as the requirements in the relevant Chapters.

1. Pressurized liquefied petroleum gas carriers

(1) Hydrostatic tests
Tanks and pressure vessels, pipes, valves and their fittings for cargo, as well as cargo handling hoses are to be hydrostatically tested at the pressures specified below and are to be satisfactory before installation in the ships.
(A) Tanks and pressure vessels : 1.5 times the design pressure.
(B) Pipes, valves and fittings as well as cargo handling hoses : 2 times the design pressure (or the maximum working pressure).
(C) Cargo compressors and pumps : 1.5 times its maximum working pressure for the pressure parts.
(D) Cargo pipings : In case the welding is carried out at site, tests are to be performed after finishing of welding.

(2) Airtight tests
(A) Tanks and pressure vessels, pipings, valves and their fittings for cargo, as well as cargo handling hoses are to be tested for airtightness at the design pressure (or the maximum working pressure) and are to be satisfactory before installation in the ships.
(B) Piping systems for cargo, after installation in ships, are to be tested for airtightness at a pressure of 90 % or more of the set pressures of relief valves for the piping system and are to be satisfactory.
(C) Cargo compressors and pumps are to be tested for airtightness at the maximum working pressure for their pressure parts.
(D) Cargo pipings are to be tested after finishing of welding, where the welding is carried out at site.

(3) Radiographic tests
Welded joints of piping system for cargo are to be radiographically tested in accordance with the instruction of the Surveyor and are to be satisfactory. For weld joints on the cargo piping, 10 % or more of the joints are to be radiographically tested and the joints tested are to be considered for materials, joint figure, welding position, welding control, experience, etc.

(4) Confirmation tests
Safety valves, relief valves, pressure gauges, thermometers, safety devices, gas detectors, remote control devices, etc. are to be examined of their performance before or after being fitted up.

2. Low temperature liquefied petroleum gas carriers

(1) Tests and surveys of secondary barriers
Where secondary barriers are provided, their effectiveness is to be confirmed by suitable methods at the time of construction. It is also desirable to design them so that effectiveness may be checked at periodical surveys after having been placed in service. In case where the effectiveness of the secondary barriers cannot be checked after having been placed in service, their reliability is to be confirmed by suitable methods at the time of construction.

(2) Welding procedure qualification tests
The welding procedures for use in tank welding are to be those which have been accepted by tests for the welding procedure qualification tests in accordance with the requirements in **Pt 2, Ch 2, Sec 4** of the Rules.

(3) Non-destructive inspections of weld joints
(A) All butt-welded joints of tank plates are to be radiographically examined. Where, however, approved by the Society in consideration of liquid temperature, defect detecting ability, etc., a part of the radiographic examination may be substituted by other types of non-destructive inspections. Even in this case, the radiographic examination is to be carried out for over 20 % of the total butt-welded length and near the intersections of weld lines.
(B) Welded joints for cargo piping are to be radiographically examined satisfactorily in accordance with the instruction of the Surveyor.

(4) Hydraulic tests of tanks
(A) At least one tank or more are to subject to the following tests after their fabrication and before applying heat insulations. Water is to be filled up to the top plate of the tank (excluding the dome, which will be excluded hereinafter) and tanks are to subject to pressure by either pneumatic or hydrostatic pressure corresponding to a water head of either 2.45 m above the tank top plate or up to 0.6 m above the top of hatch opening from the tank top plate, whichever is the greater. Confirmation is to be made that there is no leakage and/or no harmful deformation under such pressure. The remaining tanks may be tested by filling water up to 60 % of the tank depth then applying the pneumatic pressure specified above. However, as for at least one tank, the test pressure or equivalent test water head is to be raised to a pressure 1.2 times the set pressure of the safety valve for overpressure.
(B) Where the structure does not permit inspection of the outer surface of tank plate at the hydrostatic pressure test, any other suitable means to compensate the above is to be proposed for the approval by the Society.

(5) Tests of various pressure vessels
Each pressure vessels and its fittings are to be hydrostatically tested and airtight tested by applying the provisions in preceding 1 (1) and (2) and are to be satisfactory.

(6) Heat insulating materials
Where heat insulations are applied on the tanks, model tests are to be carried out in respect of the method of its application, and confirmation is to be made that the insulations will not come off or break under working condition.

(7) Tank fittings
(A) Safety valves for overpressure, vacuum relief valves and tank fittings not connected to piping are, prior to their installation, to be hydrostatically tested at a pressure of 0.2 MPa and airtight tested at a pressure not less than 0.1 MPa, and are to be satisfactory.
(B) Fittings other than those specified in (A) are, prior to their installation, to be hydrostatically and airtight tested satisfactorily in accordance with (8) (A) and (B) below.

(8) Pipes, valves, pipe fittings, etc. for cargo
(A) Pipes, valves and pipe fittings for cargo and cargo hoses are, prior to their installation in the ship, to be hydrostatically tested satisfactorily at a pressure 2 times the maximum working pressure of the piping system or at a pressure of 1.0 MPa, whichever is the greater.
(B) Pipes, valves, pipe fittings for cargo and cargo hoses are, prior to their installation in the ship, to be airtight tested satisfactorily at the maximum working pressures.
(C) Piping system for cargo is, after installed in the ship, to be airtight tested satisfactorily at a pressure 90 % or more of the set pressure of the relief valve for the piping system.

(9) Confirmation tests
The requirements in preceding **1** (4) are also to apply low temperature liquefied petroleum gas carriers.

(10) Operation tests
The low temperature liquefied petroleum gas carriers are to be confirmed that each of tanks and each of the facilities fulfill the respective conditions initially planned, upon completion of the entire building work and under the fully loaded design condition. In addition, cargo handling facilities are to be inspected under operation with actual cargo.

105. Marking

1. In case of pressurized liquefied petroleum gas carriers, the following particulars are to be marked on each storage tank in a place where easily visible after being installed:

Design pressure, maximum working temperature, capacity, hydrostatic test pressure, date of manufacture, manufacturer's name and manufacturing number.

In case of low temperature liquefied petroleum gas carriers, the following particulars are to be marked in the vicinity of tank dome at a place easily visible:

Tank number, capacity, set pressure of safety valve for overpressure, maximum density of cargo, minimum working temperature, date of manufacture, and manufacturer's name.

2. The maximum working pressure is to be marked on cargo hoses.

3. All pipes connected to tanks are to be marked distinctly either for liquid or gas vapour.

106. Operation manual

Shipbuilders are to supply operation manual to the ship owners outlining operations and maintenance of various facilities for cargo handling as well as safety measures.

Section 2 Pressurized Liquefied Petroleum Gas carriers

201. Arrangement and installation of tanks and compartments containing tanks

1. Arrangement of tanks

Tanks are not to be installed forward of the collision bulkhead nor afterward of the after peak bulkhead.

2. Tank spaces on weather decks

When tanks are either on weather decks or partly projecting out of weather decks, the tanks or protruded parts are to satisfy the following requirements:

(1) Not to interfere with the crew's traffic and working.
(2) To be kept sufficiently from living quarters, boats, embarkation places, fire hydrants and machinery or instruments liable to cause explosion of gas.

3. Distance between tanks and hull structure

(1) The distance between tanks and hull structure such as inner edge of side frames (excepting frames specially provided), inner edge of bulkhead members (excepting girders) and top of inner plating of double bottoms is not to be less than 380 mm for maintenance and inspection, unless otherwise approved by the Society.
(2) For ships of 60 m or more in length, the distance between tanks and side plating is not to be less than 610 mm. And, for ships of single bottom construction, the distance between tanks and bottom plating is not to be less than 610 mm.
(3) Where two or more tanks are installed, the distance between tanks is not to be less than 380 mm, unless specially approved by the Society.

4. Location of manholes

Manhole and accessories of tanks are to be provided above weather decks.

5. Tank supports

Tanks are to be supported securely on steel foundations arranged to avoid excessive concentration of load near the support.

6. Compartments for tank installation

Compartments for tank installation are to be watertight and not to contain any possible source for igniting liquefied petroleum gas (i.e. heat or spark sources, electric equipment, etc.). The spaces are not to have any air communication with other compartments containing such ignition sources.

7. Watertightness of weather deck

In case where tanks penetrate through weather decks, their watertightness is to be in compliance with the requirements specified in **Pt 4, Ch 2 of** the Rules.

8. Earthing

Each tank is to be electrically earthed effectively.

202. Tanks and pressure vessels

1. Application

Tanks and pressure vessels for cargo (hereinafter referred to as "pressure vessel") are to be of welded construction and are to be in compliance with the requirements for welded pressure vessels Class 1 specified in **Pt 5, Ch 5** of the Rules, except those specified in this Section.

2. Materials

The materials for tanks and pressure vessels are to have good weldability and notch toughness at low temperatures to which they may be exposed. The materials used are subject to the Society's approval in respect of design and fabrication procedure.

3. Minimum thickness of shell and end plates

The thickness of shell and end plates of tanks and pressure vessels is not to be less than 8 mm. However, in cases where tanks and pressure vessels are not used for storing liquid continuously nor exceed 900 mm in diameter, the thickness may be reduced to 6 mm.

4. Manholes

The tank is to be provided with a manhole of not less than 275 mm × 375 mm or of diameter not less than 375 mm on or close to tank top. Where access trunk is fitted up to any tank, the inside diameter of trunk is not to be less than 750 mm.

203. Pipes, valves, pipe fittings, pressure vessel fittings and tank accessories for cargo

1. Materials and workmanship

(1) Valves, flanges, pipe fittings, pressure vessel fittings and tank accessories are to be of construction suitable for liquefied petroleum gas transported, and are to be made of steel or other materials approved by the Society.
(2) Valve seats, packings, gaskets, etc. are to be of material which has suitable properties against the corrosion by the liquid. The materials for gaskets of manholes or flanges are to withstand temperature of 530°C without failure.
(3) Pipes subjected to liquid or gas pressure are to be seamless or electric-resistance welded steel pipes.
(4) The workmanship of piping specified in preceding (3) is to comply with the requirements for Class 1 piping specified in **Pt 5, Ch 6** of the Rules.

2. Maximum working pressure of cargo piping system

(1) The maximum working pressure of piping system is defined as that during ordinary service.

Where additional pressure is applied on the system by pump, compressor, etc., this maximum pressure is to be properly adjusted taking account of such additional pressure.

(2) Where the maximum working pressure of piping system is less than 1.0 MPa, the pipes and pipe fittings are to be so designed as to withstand a pressure not less than 1.0 MPa, except for those of vent lines specified in **Par. 12** below.

3. Pipe joints

(1) Pipe joints are to be butt weld or flanged coupling, and flanges are to be joined to pipes by welding.
(2) Pipe flanges are to be of 2.0MPa or above in nominal pressure stipulated by KS (Korean Industrial Standard) or equivalent thereto, except for those of vent lines specified in 12 below.
(3) Screw joints of KS B 0222, only with the dimensions of PT25 or under, may be used in places where they can be shut off from tanks, liquid pressure vessels and main pipes for cargo transfer, and furthermore where inspection can be made easily.

4. Expansion joints

Where expansion joints are used in piping subject to pressure of tank or pressure vessel, or delivery pressure of pumps or compressors, they are to be bent pipes made of seamless or electric- resistance welded steel pipes, or to be approved corrugated expansion joints or the equivalent.

5. Relief valves in pipe lines

Relief valves are to be fitted up on pipe lines which are filled with liquid and closed, and consequently where an excessive pressure may occur. Escaping gas from relief valves is to be led to a main discharge line of safety valves on storage tanks.

6. Pipe supports

Piping is to be provided with adequate supports to prevent its own weight being exerted on valves and their fittings as well as to prevent its excessive vibration.

7. Bonding and earthing

Each pipe line is to be electrically connected and to be earthed effectively.

8. Tank accessories and valves

(1) Each storage tank is to be provided with shut-off valves for filling and discharging liquid or gas, safety valves, level gauges, thermometer wells and a pressure gauge, all of which are to be installed above the weather deck, and suitable access means are also to be provided for facilitating the operation. Where tanks are installed under the weather deck, these access means are to be placed on a trunk or a dome positioned on the weather deck. All connections to tanks are to be protected against mechanical damage.
(2) Manually operated stop valves for all the connections other than for safety valves and level gauging devices are to be provided as close to tanks as practicable.
(3) For tanks whose content is discharged outward with the level gauge opening exceeding 1.4 mm in diameter, excess flow valves are to be provided.
(4) Thermometer wells are to be terminated in liquid spaces and connections to the tank wall is to be welded or flanged and gastight lids are to be provided.
(5) A pressure gauge is to be fitted up at the highest location of each tank or its vicinity.
(6) Where the inside diameter of the pressure gauge exceeds 1.4 mm, the connecting pipe is to be provided with an excess flow valve.
(7) The excess flow valve is to close automatically at the flow rate of gas or liquid specified by the maker. Piping including fittings and accessories protected by an excess flow valve, is to have a capacity greater than the rated flow of the excess valve. Excess flow valves may be provided with a bypass not exceeding 1 mm in diameter to equalize pressures.

9. Valves and accessories attached to pressure vessels

The requirements in preceding 8 are to be applied, as far as possible, to valves and accessories attached to pressure vessels.

10. Filling and discharge pipes of tanks

(1) Either of the following valves is to be provided for each filling pipe:
(A) One check valve and one excess flow valve.

(B) One duplicate check valve.
(C) Two check valves.

(2) Except pipes to which filling connections, safety valves and liquid level gauges are provided, all liquid or gas connections to tanks are to be provided with automatic excess flow valves or internal-type quick shut-off valves being always closed except during filling or discharging operation. Such valves are to be provided with emergency shut-off devices by remote control with fusible plugs to melt at temperatures below 104°C thereby closing the shut-off valves automatically in case of fire, in addition to general shut-off devices.

(3) Where filling and discharging are to be performed through single connection and a screw-type stop valve and a quick shut-off valve specified in preceding (2) are provided, non-return valves or excess flow valves may be dispensed with.

(4) Excess flow valves, internal-type quick shut-off valves or non-return valves are to be fitted on the interior or exterior walls of tanks. Where, however, these valves are fitted up on the exterior walls of tanks, care is to be taken so that any undue strain may not cause breakage between the tanks and the valves.

11. Safety valves

(1) Two or more safety valves are to be fitted on each tank, and are to be set to blow-off steam automatically at a pressure not exceeding the design pressure of each tank.
Safety valves are to be among the following and other types of safety valves are to be approved by the Society whenever they are used.

(A) High lift type
The valve lift is to be 1/15 and above, below 1/7 the inside diameter of valve seat. The required areas of steam passages at the chest inlet and outlet are not to be less than the same and 2 times the required valve seat area respectively.

(B) Full bore type
The valve seat is not to be less than 1.15 times the area at the throat.
The area of steam passage at the valve seat is not to be less than 1.05 times the area at the throat, when the valve is open. And the minimum steam passage area at the outlet is not to be less than 2 times the area at the valve seat when the valve is open.

(2) The total capacity of safety valves on each tank is to be sufficient to relieve the volume obtained from the following formula at a pressure not exceeding 1.2 times the approved working pressure. However, for tanks lagged with insulating material, the required quantity of discharge of safety valves may be reduced within the range down to $W_r/2$ depending on the degree of heat insulation effectiveness, where approved by the Society.

$$W_r = 1.56 \times \frac{A^{0.82}}{L_h} 10^5$$

where :

W_r : Required discharge quantity(kg/h)

A : The following value depending on the shape and dimensions of each tank:

$D_t \times (U + 0.3\,D_t)$-------for tanks of cylindrical form having dished or semi-elliptical heads.

$D_t \times U$ --------------- for tanks of cylindrical form having hemispherical heads.

D_t^2 ------------------ for spherical tanks.

D_t : Outside diameter of tanks(m)

U : Overall external length of tanks(m)

L_h : Latent heat for vaporization of cargo at 1.2 times the approved working pressure of tanks(kcal/kg)

The discharge quantity of safety valves is following formula.

$$W = KCA(10P+1)\sqrt{\frac{M}{ZT}}$$

where :

W : Discharge quantity(kg/h)

A : πDL (cm^2) for high lift type

$\frac{\pi}{4}D_t^2$ (cm^2) for full bore type

D : Diameter of disc seat hole (cm)

L : Valve lift (cm)

D_t : Diameter of discharge part (cm).

P : Pressure 1.2 times the limit pressure of tanks(MPa)

M : Atomic weight of fluid

T : Absolute temperature of fluid at P (K)

Z : Compression coefficient of fluid gas at P and T (in case of uncertainty : 1)

K : 0.65

$$C = 387\sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

k : Specific heat ratio of fluid at P and T (It may be value at normal condition)

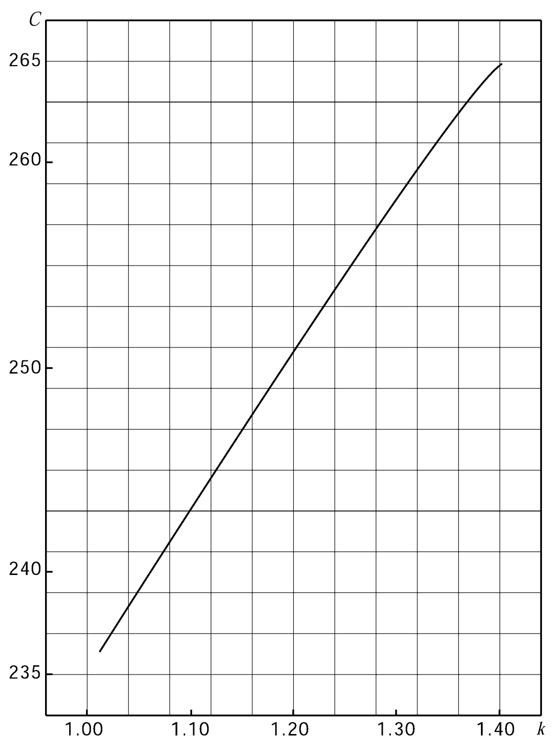


Fig. 1 Relationship between C and k

(3) Safety valves are to be attached to tanks near the highest part of vapour space so as to be able to discharge vapour gas during operation. No shut-off valve is to be fitted between the tanks and the safety valves, except where a set of interlocking type shut-off valves is so arranged that

when one of them is closed the others are automatically opened. In this case, total capacity of two or more safety valves opened are at all times to satisfy the requirements in preceding (2).

(4) One or more safety valves are to be fitted on each pressure vessel for liquid. The capacity and attachment of safety valves are generally to be in accordance with the requirements of preceding (1), (2) and (3) respectively.

12. Vent pipes for safety valves and relief valves

(1) Discharge from safety valves and relief valves is to be led to vent pipes.
(2) Stop valves are not to be fitted to vent pipes.
(3) Vent pipes are to be so designed as to prevent mechanical injury, intrusion of rain or snow and accumulation of drain.
(4) Vent pipes of safety valves on storage tanks are to be capable of discharging a quantity given in **Table 1** of this Annex according to the number of tanks connected to the vent pipe without interfering effective discharge from safety valves by excessive back pressure.

Table 1. Total Valve Discharge

Number of tanks	1 and 2	3	4	5	6 and more
Total valve discharge (%)	100	90	80	70	60

(5) Openings of vent pipes are to be located at a position of 4.5 m or more above the top of tank. Where a deckhouse is situated within horizontal distance of 15 m from the opening, openings are also to be located at a place 3 m higher above the top of deckhouse. At opening of each vent pipe, an effective frame arrester is to be provided.

13. Level gauges

(1) Level gauges of storage tanks are to be in compliance with the following requirements:
  (A) Level gauges are to be capable of indicating the highest level of liquid which will be loaded in the range from -7°C to 45°C.
  (B) Level gauges may be of any of the following types:
  Rotary tube type, slip tube type, fixed tube type, magnet type, automatic float type or similar types having equivalent effectiveness.
  (C) Level gauges of float type or magnet type are to be used in conjunction with tube type level gauges.
  (D) Where a level gauge is connected to a lead pipe fitted on the exterior of a tank, an automatic shut-off valve in case of failure of the lead pipe is to be fitted as close to the tank as practicable. Where, however, the lead pipe is of sufficiently robust construction, the automatic shut-off valve may be omitted.
  (E) A flat type sight glass may be equipped on an automatic float tape reading level gauge. In this case, the glass is to satisfy the requirements specified in (4) below and to be protected effectively by a metallic cover.
(2) Level gauges of intermediate tanks are to be in compliance with the requirements in preceding (1) (B) to (E). But, in case where a self-closing valve or an excess flow valve is equipped in conjunction with the manual stop valve at the connected part of the tank, flat glass type level gauges may be used.
(3) Flat glass type level gauges of pressure vessels are to be in compliance with the requirements in (2) above.
(4) The flat type sight glasses used in level gauges are to be made of heat treated high strength materials and the thickness is not to be less than 12.7 mm.
(5) Round type glass level gauges are not to be used in any case.

204. Cargo handling facilities

1. Application

The requirements in **204.** apply to cargo handling facilities with compressors and liquid pumps or compressors only. Where any other type of facilities than those mentioned above is intended to be provided, full particulars of the installation are to be submitted to be the Society for approval.

2. Location of cargo handling facilities

Cargo handling facilities are not to be located on the weather deck except in compartments in which piping and/or compressors are installed.

3. Cargo hoses

Cargo hoses are to be of suitable material to resist against chemical action of liquid and to be designed for a bursting pressure not less than 5 times the maximum working pressure to which they may be subjected.

4. Connection to shore pipe

(1) In the vicinity of connections between the shore pipes for cargo handling (for both liquid and gas) and the loading headers of ships, shut-off valves are to be provided, each of which can shut off each connection from shore pipes. Adequate shut-off valves are to be fitted on the connections so as to be able to release pressures in the pipes connected to the shore.
(2) The connections with shore pipes are to be arranged so that they may be electrically connected to each other.

5. Pumps and compressors

(1) Pumps and compressors are to be capable of transporting liquefied petroleum gas effectively and are to be so constructed as to minimize gas leakage as far as practicable and free from sparking.
(2) Pumps and compressors are not to be used for purposes other than cargo handling of liquefied petroleum gas.
(3) Where pumps or compressors are driven by engines located in an adjacent compartment, gastight glands are to be provided at portions where driving shafts pass through the bulkhead and alignment of shaft center is to be easily adjusted.
(4) Relief valves or other overpressure protection devices are to be provided on the delivery side of pumps or compressors, except where overpressure is not anticipated. Discharged liquid from the relief valve provided on a pump is to be led to the suction of the pump and the discharge from that provided on a compressor is to be led to the discharge pipe of safety valves on storage tanks, respectively.
(5) Pressure gauges are to be fitted on the delivery side of the pumps and compressors.
(6) Compressors are to be arranged so that no liquid may be sucked in. For this purpose, where an auxiliary tank is provided, suitable means are to be provided to stop the compressors automatically when the liquid level in the intermediate tank reaches the predetermined level.

6. Installation of pumps and compressors

Pumps and compressors are to be installed on the weather deck or in the compartments isolated from adjacent compartments by gastight bulkheads.

205. Ventilation, drainage, etc.

1. Ventilation system

(1) An independent mechanical ventilation system of exhaust type capable of changing the air at a rate of 20 times or more the compartment volume per hour is to be installed in each compartment in which pumps and/or compressors are installed and isolated from adjacent compartment by gastight bulkheads.
(2) An independent mechanical ventilation of supply type having the capacity specified in preceding (1) is to be provided in each compartment in which electric motors or electrical equipment are installed and petroleum gas is liable to intrude.
(3) An effective ventilation system is to be provided for tank holds.
(4) Outlet ends of exhaust pipes of compartments to the atmosphere which come under the provisions in preceding (1) and (2) are to be situated at a distance of 3 m or more from the entrances of companions, deckhouses or superstructures, except where compartments communicated to these entrances are safe spaces from danger of gas explosion.

2. Ventilation system of engine rooms and other compartments containing ignition sources

(1) The ventilation system of engine rooms and other compartments with possible ignition sources

in them is to be of air supply type. Openings of air inlet and outlet are to be placed as high as possible from tank top and possibly apart from ventilation openings of tanks, tank holds and compartments in which pumps and/or compressors are installed, and/or outlet ends of vent pipes from the safety valves.

(2) The ventilation openings of compartments, where the internal combustion engines, boilers or non-explosion-proof type electric equipment are installed, are to be so arranged as to prevent accidental introduction of gas through ventilation openings into the compartments, particularly in the event of failure of cargo handling equipment.

3. Bilge system

(1) The bilge system for the tank holds, pump rooms and compressor rooms for liquefied petroleum gas is to be independent from those of the other compartments.

(2) Not less than 2 sets of power pumps are to be provided in the compartments or on the deck for the purpose of drainage of the tank holds and the pump and/or compressor rooms. The capacity of each pump (Q) is not to be less than following formula. For ships less than 50 m in length, however, 2 sets of manual pumps may be substituted for one power pump.

$$Q = 0.575\, d^2 \ (\mathrm{m^3/h})$$

d : Inside diameter of the main bilge suction specified in preceding (4) (cm).

(3) Where ejectors or eductors are used instead of power pumps, their details are to be submitted to the Society for approval.

(4) The inside diameter of the main bilge suction pipe is to be as specified in **Pt 5, Ch 6, 404. 1** of the Rules.

(5) One of the power pumps specified in preceding (2) may be substituted by a suitable independent power pump in the engine room connected to an emergency suction pipe, which is provided in the tank and the inside diameter of which is not to be less than that of the main bilge suction pipe specified in preceding (4). In this case, the suction pipe is to be of independent bilge suction and a shut-off valve and a blank flange are to be provided in the engine room at the place where the pipe passes through the watertight bulkhead with a notice "For emergency use only" posted near the valve.

4. Cooling devices

Suitable cooling devices are to be provided on storage tanks to keep the liquid temperature in the tanks always below 45°C due to the rise of ambient temperature.

5. Prevention of discharging fire particle through exhaust pipe

Provisions are to be made to prevent discharging fire particles through exhaust pipes of boilers, internal combustion engines or cooking appliances.

6. Installation of equipment containing ignition sources

Any equipment containing ignition sources is not to be installed in the dangerous spaces specified in **102.** (7) of this Annex.

7. Gas detectors

An appropriate number of gas detector probes are to be arranged in tank holds, and a device which automatically detects gas concentration in the tank holds is to be installed.

206. Electrical installations

1. Application

Electrical installations are to be in compliance with the requirements in **206.** as well as the requirements in **Pt 6, Ch 1** of the Rules.

2. Power distribution system

The system of power distribution is to be one of the following types;

(1) Direct current with two insulated wires

(2) Single-phase two insulated wires
(3) Three-phase three insulated wires.
Earth indicating lamps or their alternative means and capacitors used for radio noise suppression may be earthed.

3. Switchboard, section board and power distribution board

Every outgoing circuit from switchboards, section boards or distribution boards is to be provided with a multi-pole circuit breaker or a multi-pole linked switch arranged to interrupt the circuit on each pole simultaneously.

4. Wiring in dangerous spaces

No cable is to be installed in the dangerous spaces specified in **102.** (7) of this Annex. Where it is inevitable to install cables in such spaces, the cables are to comply with the following requirements:

(1) Cables are of the type listed below.
Where corrosion may be anticipated, impervious sheath or equivalent protection is to be applied over steel armour for corrosion protection;
(A) Lead sheath armoured
(B) Impervious sheath armoured
(C) Mineral insulated metallic sheathed
(2) Cables installed is spaces which are always exposed to liquid or vapour of cargo are to be of a type which is not liable to be corroded by liquid or gas, nor to be damaged at the temperature and pressure encountered in any working condition.
(3) Cables are to be installed in the vicinity of the center line of the hull as far as practicable.
(4) Cables are to be installed sufficiently separated from decks, bulkheads, tanks and various pipes.
(5) Where cables pass through bulkheads which constitute the partitions between the dangerous space and the safety spaces or through decks, the sections are to be gastight.
(6) Cables installed in regular corridors or decks are to be properly protected from mechanical damages. Cables and their supports are to be attached so as to withstand expansion, contraction and other actions of the hull structure.
(7) Wiring between the electrical equipment in dangerous spaces and the switches or control devices thereof in safety zones are to have sealing boxes installed on the side of switches or control devices so as to maintain gastightness.
(8) Wiring and cables of intrinsically safe type circuit are to be of exclusive use, and they are to be installed separately from cables for general circuits.

5. Electrical installations in dangerous spaces

(1) No electrical installation is to be provided in the dangerous spaces specified in **102.** (7) of this Annex. Where it is inevitable to provide electrical installations in such spaces, they are to comply with the following requirements:
(A) In all dangerous spaces
Intrinsically safe type electrical equipment may be installed.
(B) In the dangerous spaces specified in **102.** (7) (A) of this Annex
Submerged type electric motors installed in tanks are to be of an explosion-proof type approved by the Society.
(C) In the dangerous spaces specified in **102.** (7) (B), (C) or (H) of this Annex
(a) Electrical sounding devices with enclosed covering may be installed. However, their cables are to be run in galvanized steel pipes of heavy gauge, and pipe joints are to be gastight.
(b) When cables for cathodic anti-corrosion devices from external power sources are installed through these compartments, for protection of the hull, they are to comply with the requirements in preceding (a).
(c) Explosion-proof lighting fittings considered suitable by the Society may be installed. However, the lighting fittings are to be arranged on at least two independent circuits, and are to be controlled by double-pole switches which are connected to locking devices of lighting fittings installed in safety zones outside the compartment. In addition, the lighting fittings and their corresponding double-pole switches are to be clearly labelled for identification.
(d) Where power supply cables to electrical equipment other than mentioned in preceding

(a), (b) and (c) are led through these spaces, their cables are to be kept to essential minimum, and the cables are to be run in galvanized steel pipes of heavy gauge which are maintained gastight. Cable expansion bends are not to be provided.

(D) In dangerous spaces specified in **102.** (7) (D), (G) or (I) of this Annex.
  (a) Explosion-proof electrical equipment considered suitable by the Society may be installed.
  (b) Cables may be installed through these spaces, however, as a rule, cable expansion bends are not to be provided.

(E) In dangerous spaces specified in **102.** (7) (E), (F) or (J) of this Annex.
The requirements in (D) may be applied. In addition, the cables may be provided with expansion and contraction portions.

(2) Where cargo pumps or compressors are driven by electric motors, the electric motors are to be installed in separate compartments which are partitioned by gastight bulkheads or decks from the compartments where pumps or compressors are installed. In case where it is difficult to comply with the above requirements, the documents are to be submitted in advance to the Society for approval.

(3) Where the separate compartments specified in preceding (2) conform to each of the requirements below, electrical equipment in those compartments may be of types other than explosion-proof type:
  (A) The construction, where the shafts pass through bulkheads or decks, is to comply with the requirements in **204. 5** (3) of this Annex.
  (B) Direct openings are not to be provided to the dangerous spaces specified in **102.** (7) of this Annex.
  (C) Air supply type mechanical ventilation devices, with adequate safety measures, are to be installed.

(4) Where the dangerous spaces are illuminated by lamps installed in safety zones through bulkheads or decks, one of the following requirements is to be satisfied :
  (A) To be illuminated from the safety zones through gastight glass windows fitted on bulkheads or decks. However, the gastight glass windows are not to reduce strength or watertightness of the bulkheads or decks to which the windows are fitted.
  (B) Explosion-proof bulkhead lighting fittings considered suitable by the Society are to be used. However, their fittings to bulkheads or decks are to be gastight, and the electric lamps are to be replaced from the safe side.

(5) It is recommended that the electrical equipment used for measuring, monitoring, controlling or communication are of intrinsically safe type.

6. Portable lighting appliances

Portable lighting appliances for use in dangerous spaces are to be of self-contained battery lamps of explosion-proof type or of explosion-proof type considered suitable by the Society.

Section 3 Low Temperature Liquefied Petroleum Gas carriers

301. Structural arrangements

1. Size of tanks

The inner length of tanks is to be 0.2 L or less. For ships less than 100m in L, the length of tanks is to be followings and over.

$$0.1L + 10 \ (\text{m})$$

2. Doble bottom

Unless specially approved by the Society, double bottoms are to be provided.

3. Cofferdams

Cofferdams are to be provided between the tank holds and the main engine rooms as well as the boiler rooms. The cofferdams may be concurrently used as tanks for storage of oil having a flashing point exceeding 60°C, ballast tanks, cargo pump rooms, etc. Further, in case where non-combustible insulations are applied on bulkheads between the tank holds and the main engine rooms as well as the boiler rooms, the above cofferdams may be omitted in accordance with the following requirements.

(1) This insulation in bulkheads is to be provided at the side of main engine rooms and of boiler rooms.

(2) For insulation materials, the fire test are to be carried out in accordance with the followings:

(A) Test specimen

The test specimen which is insulated on steel plate by the actual workmanship is to be complied with IMO Res. 754(18).

(B) Fire test

The specimen is to be exposed in a test furnace to the temperatures corresponding approximately to the Standard Time-Temperature Curve.

At the end of the first 5 minutes	576°C
At the end of the first 10 minutes	679°C
At the end of the first 15 minutes	738°C
At the end of the first 30 minutes	841°C
At the end of the first 60 minutes	945°C

(C) Criteria

The average surface temperature rise of steel plates is not to be more than 140°C, and the temperature rise recorded by any of the individual surface is not to be more than 180°C above its initial temperature at any of the individual surface during 1 hour test duration.

4. Arrangement of tanks

(1) Tanks are not to be provided forward of the collision bulkhead nor aftward of the after peak bulkhead.

(2) Hull structural members, tanks, insulations, etc. are to be arranged so that at least one surface of hull structure and each tank may be seen, and the distance between the hull structure and the tank, except where the Society specially approved as to be adequate for maintenance and inspection, is not to be less than 380 mm from the inner edge of side frames excluding special frames, the inner edge of bulkhead members excluding girders and the lower edge of deck members excluding girders, and is not to be less than 610 mm from the top of inner bottom plating. Further, the distance between the tank and the side plating is not to be less than 900 mm. The arrangement of tanks is to comply with **201** of this Annex.

5. Emergency facilities

(1) Emergency pressure relief devices are to be provided in the void spaces in tank holds. For leaked cargo, suitable discharging devices are to be provided.

(2) As a safeguard for the hull structure against major damage or failure of the tanks, devices are to be provided to throw away the cargo within a tank or tanks which have been damaged.

6. Gas detection, temperature detection, etc.

(1) Pressure relief valves are to be provided in the void spaces in tank holds so that pressures in void spaces may not rise above the predetermined pressure.

(2) To detect any leakage of cargo, a suitable number of probes for gas detectors are to be located in the void spaces in tank holds, and devices to automatically detect gas concentration are to be provided. They are to automatically indicate position and concentration of leaked gas at the location where they are placed for surveillance, either in voyage or during cargo handling. They are also to be set so that a warning signal may be issued when gas concentration exceeds at least 1/5 of the lower explosion limit value.

(3) The hull structures, which are liable to be cooled by leakage, etc. of cargo, are to be provided with temperature probes at suitable positions. They are to automatically indicate position and temperature of leaked gas at the locations where they are placed for surveillance, either in voyage or during cargo handling. They are also to be set so that a warning signal may be issued when temperature around probe becomes excessively low.

7. Watertightness of weather deck

The watertightness of weather decks around the domes of tanks is to comply with the requirements in **Pt 4, Ch 2** of the Rules.

8. Earthing

Each tank is to be electrically earthed effectively.

302. Hull Structures

1. Grades of steel in accordance with usage

(1) Where secondary barriers are provided:
Where secondary barriers are provided and layout are arranged so that hull structures may not be cooled excessively even in case of cargo leakage from tanks, the grades of steel used for hull structures are to be as specified in **Pt 3, Ch 1, 405.** and **406.** of the Rules.

(2) Where secondary barriers are not provided:

(A) At both atmospheric and sea water temperatures of 5°C and under normal conditions, the temperatures of the steel used for main hull structure are not to be equal to or lower than those listed below, depending on each grade.

RA steel	0°C
RB or RD steel	-10°C
RE steel	-20°C

(B) In case of leakage of cargo liquid from tanks, the temperatures of the steel used for main hull structure, at atmospheric and sea water temperatures of 5°C, are not to be equal to or lower than those listed below, depending on each grade.

RA steel	-10°C
RB or RD steel	-30°C
RE steel	-50°C

However, for steel plates more than 15 mm in thickness, and where their temperatures become below -35°C, steel for low temperature service specified in **Pt 2, Ch 1, 304.** of the Rules is to be used. When the temperatures of hull structure, the following condition is to be considered.

A. Ship condition
- A-1 Voyage with design load draft and design seagoing speed
- A-2 The hull is to be kept full load draft after damage outbreak, and trim and heeling are considered O condition.

B. Tank damage condition
- B-1 The damaged tank is to be one. However, in case watertight bulkheads are to be comparted in tank, one compartment may be considered.
- B-2 The damaged part is to be on the bottom. the plates of vertical, tops and etc. may not be considered.
- B-3 When the tank is damaged, it is considered that tank, support, equipment, hull, etc, are not deformed and not destruct regarding cargo as leakage and flowing out.
- B-4 It is happened in a twinkle that cargos leak and flow out, and the remained liquid level in the damaged tank and the liquid level in the empty spaces is to be equal immediately.

C. Boundary condition
- C-1 Damage is perceptible immediately.
- C-2 It is to be stationary vapour of +5°C in the compartments adjacent to vicinity empty spaces.
- C-3 The radiation of sunlight is to be ignored.
- C-4 Insulation material, supporting equipment and materials in the vicinity empty spaces are not to suck the cargo liquid except the materials for the discretion of the Society
- C-6 The phase of vapour in the vicinity empty spaces of damaged tank is that the evaporating gas is to rise at a uniform speed.
- C-7 The compartments filled with vapour other than the vicinity empty spaces of damaged tank are to be circulated naturally.

C-8 Vapour and liquid in the same compartment may be at the same temperature.
C-9 Vapour in the tank and phase of vapour in the vicinity empty spaces may be at the same pressure.
C-10 The gas movement in the insulating material may be ignored.
C-11 The humidity may be ignored.
C-12 The effect of paint may be ignored.

D. Calculation condition
D-1 The humidity distribution and the heat transfer are to be in normal condition. However, it is to be in abnormal condition instantaneously after damage break out.
D-2 Sea water is to be 1025 kg/m^3 of density, -2.5°C of freezing point, and others are marked with the property of fresh water.
D-3 The temperature of cargo is to be equal.
D-4 Heat transfer rate may be calculated by using the following values.

			Heat transfer rate ($kcal/m^2h℃$)
Atmosphere	↔	Hull	10
Outside sea water	↔	Hull	2000
Stationary vapour	↔	Hull or liquid	5
Stationary sea water	↔	Hull	100
Cargo liquid	↔	Hull adjacent to sea water	3000
Cargo liquid	↔	Hull adjacent to air	200

D-5 It may be considered that the temperature distribution on object without direction is not to equal generally.
D-6 Bone may be analyzed with fin.
D-7 It may be treated two dimensional problem.
D-8 The temperature of members is to be center temperature of the plate thickness, and the temperature of girder webs is to be average temperature of direction of web depth.

2. Hull structural members

Main structural members for hull referred to preceding **1.** (2) mean the members of **Table 2** of this Annex.

Table 2. Main Structural Members for Hull

Upper deck	Single hull	Deck, longitudinal beams, transverse beams, longitudinal & transverse girders
	Double hull (Topside tanks)	Inner shell plate, stiffeners, girders
Side	Single hull	Shell plates, transverse frame, side longitudinals, special frames
	Double hull	Longitudinal bulkhead plates, longitudinal bulkhead stiffeners and girders
Bilge hopper		Slopping plates, stiffeners, girders
Double bottom		Inner bottom plates, longitudinals, reverse frames of open floors
Transverse bulkhead		Bulkhead plates, stiffeners and girders
Others		Brackets (except tripping brackets)
(Note) Above girders are included girder plates and face. However, stiffeners on girder plates are not included.		

3. Material classes

In case the calculation for hull temperature is omitted, material classes for main structural members for hull are to be those specified in **Table 3.** of this Annex.

Table 3. Material Classes

Member			Steel grades
Upper deck	Single hull	Deck, longitudinal beams, transverse beams, longitudinal girders and brackets	*RB* or *RD*
	Double hull (Topside tanks)	Inner shell plates	*RB* or *RD*
Side	Single hull	All main structural member	*RE*
	Double hull	Longitudinal bulkhead plates Main structure member (except above)	*RE*, *RT*-35 in case of $t \geq 15$ *RB* or *RD*
Bilge hopper		Slopping plates Main structure member (except above)	*RE*, *RT*-35 in case of $t \geq 15$ *RB* or *RD*
Double bottom		Inner bottom plates Main structure member (except above)	*RE*, *RT*-35 in case of $t \geq 15$ *RB* or *RD*
Transverse bulkhead		Bulkhead plates Main structural member (except above)	*RE*, *RT*-35 in case of $t \geq 15$ *RB* or *RD*
Tank support material		Materials for integrated tank support Materials for unintegrated tank support	Equivalent of tank material *RB* or *RD*

(Note)
1. Main structural members mean members specified in **Table 2.**
2. The steel grades except main structural members specified in **Table 2** are to comply with **Pt 3, Ch 1, 405.** of the Rules.
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303. Tanks

1. Materials

The steel materials used in important parts of tanks are to be those specified in **Table 4** of this Annex or their equivalents.

Table 4 Kinds and Grades of Steel for Use in Tanks

Range of temperatures in service T (°C)	Thickness t (mm)		
	$t \leq 15$	$15 < t \leq 20$	$20 < t$
$-10 < T \leq 0$	*RB*	*RD*	*RE*
$-25 \leq T \leq -10$	*RE*, *RL* 24*A*		
$-35 \leq T < -25$	*RL* 24*A* or *RE* (for $t \leq 9$)		*RL* 24*B*, *RL* 33 or *RL* 37
$-50 \leq T < -35$	*RL* 24*B*, *RL* 33, *RL* 37		Material considered suitable by the Society.

2. Workmanship

(1) Tanks are to be shaped so that excessive stress concentration may be avoided, and any corners are to be smoothly rounded.
(2) The joining of tank plates are to be butt joints welded from both sides, except where specially approved by the Society.

3. Manholes

A manhole of each tank is to be provided above the weather deck, and its size is not to be less than 275 mm × 375 mm nor of diameter less than 375 mm.

4. Layout and scantlings of tank material

(1) The materials of which tanks are built are to be of sufficient strength in consideration of internal pressure of cargo, increased load due to inclination of tanks as well as dynamic loads due to ship motion, etc. However, the scantlings are to be in accordance with the following:

(A) The thickness of tank plates is not to be less than obtained from the following formula or 7 mm, whichever is the greater:

$$3.42S\sqrt{h}\times\sqrt{\frac{41}{\alpha}}+2.2\ \ (\mathrm{mm})$$

where

S : Spacing of stiffeners (m)

α : Specified minimum tensile strength of material used ($\mathrm{kg/mm^2}$)

h : Distance from the lower edge of tank plate to the top of hatch opening (m)

(B) The section modulus of stiffeners on tank plates is not to be less than obtained from the following formula:

$$CShl^2\frac{41}{\alpha}\ \ (\mathrm{cm^3})$$

where:

C and l : As specified in **Pt 3, Ch 15, 203.** of the Rules.

α and S : As specified in preceding (A)

h : Distance from the mid-point of l for vertical stiffeners, or from the mid-point of distance between the adjacent stiffeners for horizontal stiffeners, to the top of hatch opening (m)

(C) The depth, thickness of webs and face area of girders to support stiffeners on tank plates are not to be less than obtained from the following formulae respectively.

Depth of girder: 143 l (mm) or 2.5 a (mm), whichever is the greater.

Thickness of web : $0.01d_0 + 2.0$ (mm). However, in any case, the thickness of web is not to be less than obtained from the following formula:

$$0.0417C\frac{Shl}{d_1}\times\frac{41}{\alpha}+1.5\ \ (\mathrm{mm})$$

Face area : $71.3\frac{Shl}{d_0}\times\frac{41}{\alpha}-\frac{d_0t}{600}\ \ (\mathrm{cm^2})$

where

C, S, l and d_1 : As specified in **Pt 3, Ch 15, 204.** of the Rules.

d_0 : Depth of girders (mm)

a : Depth of slots for stiffeners (mm)

t : Thickness of webs of girders

α : As specified in preceding (A)

h : Distance from the mid-point of l for vertical girders, or from the mid-point of S for horizontal girders, to the top of hatch opening (m)

(2) Plates, stiffeners and girders of wash bulkheads provided in tanks are to be of sufficient strength in consideration of the size of tanks as well as of their opening ratio.

The scantlings of wash bulkheads are not to be less than obtained in accordance with **Pt 3, Ch 15** of the Rules by taking h_s obtained from the following formula instead of h. However, h_s is to be not less than 2.0.

$$h_s = \rho\left(0.176 - \frac{0.025}{100}L\right)(1-a)l_t$$

where

ρ : Specific gravity of cargo

L : Length of ship (m)

a : Opening rate of plates

l_t : Length of tanks (m)

304. Tank supports and fixings

1. Tank supports

Tank supports are to be made of suitable materials and are to be so constructed as to avoid any excessive load concentration on the hull structure as well as the tanks. They are also to be capable of coping with expansion or contraction due to change in tank temperature and are also to be of sufficient strength in consideration of the tank weight as well as the forces due to ship motion by rolling, pitching, etc.

2. Stopper of movement

Means of preventing movement of the tanks is to be provided so that the tanks may not move due to ship motion. This means of preventing the movement is to be capable of coping with expansion or contraction due to change in tank temperature and are also to be of sufficient strength in consideration of the forces due to ship motion by rolling, pitching, etc.

3. Prevention means of tank floating

Tanks are to be provided with devices to prevent floating of tanks, when void spaces in tank holds are flooded due to maritime disaster or other causes, thereby causing considerable damage to the hull structure by the floating of empty tanks.

305. Heat insulation

1. Heat insulation of tanks

Periphery of tanks is to be effectively heat insulated so as not to cool the hull excessively.

2. Heat insulating materials

The insulating materials are to be such that they withstand external forces applied during service and that their properties will not change remarkably when in contact with cargo.

306. Tank fittings

1. General

(1) Tanks are to be provided with necessary fittings for cargo handling as well as for safety.
(2) The openings provided on tanks are to be provided on domes extending above the weather deck, except where specially approved by the Society.
(3) No flexible coupling other than of bending tube type, is to be provided between the tank and the valve fitted to the tank.

2. Materials

Materials for tank fittings are to be such that they are not easily affected by cargo and they reserve sufficient mechanical properties at the lowest cargo temperature.

3. Stop valves

(1) A manual stop valve is to be provided on each piping connected to the tank, as close to the tank dome as possible, except the safety valves, vacuum relief valves and level gauges. Where the valve is remote-controlled, it is to be capable of being opened or closed manually.
(2) No stop valve is to be provided between the tank and the safety valves as well as the vacuum relief valves.

4. Pressure gauges and alarm devices for low pressure

A pressure gauging device which suitably indicates gas pressure in the tank is to be provided on each tank. It is to be of such type that the tank pressure can be checked near the dome and further the pressure is to be read at place from which surveillance is carried out in voyage and during cargo handling. Further, an alarm device is to be provided which operates at a pressure higher than the set pressure of the vacuum relief valve, when tank pressure decreases.

5. Thermometers

Means are to be provided for determining the temperature of the tank walls. Measuring points are to be arranged so that the temperature difference of the tank walls may be indicated.

6. Liquid level gauges and alarm devices

A liquid level gauging device is to be provided in each tank to determine the level of the liquid without opening the tank. Independent high level alarms are to be provided, which are to issue alarm signal at places where cargo handling is being watched or controlled.

7. Overpressure safety valves

(1) Two or more safety valves against overpressure are to be provided on each tank at the uppermost point of gas part. In case of pilot-type safety valves, a separate pressure detecting terminal is to be provided respectively.
(2) The total capacity of safety valves against overpressure is to be such that it is capable of discharging the amount specified in (A) or (B), whichever is the greater, at a pressure not exceeding 1.2 times the set pressure:
  (A) The total amount of gas at ambient temperature of 45°C by adding the amount of gas generated due to heat input into the tank to the gas quantity discharged during loading at a full capacity.
  (B) The quantity of gas to be generated by heat input into the tank in case of fire, represented by the amount of gas generated from the heat quantity obtained from the following formula. Where, however, specially approved by the Society in consideration of the hull structure and tank structure, the coefficient of 12,200 in the following formula may be reduced in the range down to 6,100. Further, where the shape construction, and layout of the tanks differ from those set forth in **102**. (2) of the Annex or where application of the following formula is not considered practical, the calculation method will be decided in each case.

$$Q_h = 12{,}200\,A^{0.82}$$

where

Q_h : Heat input (kcal/h)

A : Total surface area of the tank, excluding the surface area below the minimum draught in ballast condition (m^2)

8. Protection devices of tank against vacuum

The following protection devices are at least to be provided so as not to cause dangerous vacuum condition in each tank:

(1) Automatic stopping devices at low pressure for machinery, such as cargo pumps and refrigerating facilities which may cause vacuum condition in the tank. The pressure detecting arrangement of the automatic stopping device is to be separate from that of low pressure alarm specified in preceding **Par. 4.** However, the automatic stopping device may be considered as the alarm device, where the Society considers it to be equivalent to the alarm device in respect of its design.

(2) Vacuum relief valve which copes with the maximum unloading rate of the tank.

9. Precooling of tanks

Precooling arrangements are to be made on the tanks so as not to generate dangerous thermal stress at the time of loading.

307. Cargo piping systems

1. Application

The piping systems are to comply with the requirements in **307.** as well as with those for Class 1 piping specified **Pt 5, Ch 6** of the Rules.

2. Arrangement

All of the cargo pipings other than those installed in tanks, pump rooms and gas compressor rooms, are to be installed on the weather decks, except where approved by the Society.

3. Maximum working pressure, materials and others for cargo piping system

(1) The maximum working pressure of piping system is defined as the maximum value of the pressure of the system in ordinary service. Where additional pressure is applied by pumps, compressors, etc., the maximum value is to be decided taking account of such an additional pressure.
(2) Even where the maximum working pressure of the piping system is less than 0.5 MPa, the pipe and pipe fittings are to be so designed as to withstand the standard pressure of 0.5 MPa, except that of vent lines in **12.** below.
(3) The materials for the piping facilities are such that they are not easily affected by cargo and that they have sufficient mechanical properties even at the lowest cargo temperature.

4. Pipe joints

(1) Pipe joints, other than those for piping within tanks and those for vent piping, are to be butt-welded or flanged couplings, and the pipes and flanges are to be welded.
(2) Pipe flanges other than those for vent piping are generally to be of raised-face type.
(3) Screw joints of KS B 0222 with dimensions of PT 25 or less may be used at visible locations where they can be shut off by valves from tanks and pressure vessels for liquid and from the main pipes for cargo handling.

5. Expansion joints

Expansion joints are to be provided at suitable locations within the piping system to prevent generation of excessive stress due to expansion or contraction. The expansion joints are to be bent pipes or to be of other approved construction.

6. Prevention of mis-handling

(1) The piping devices for a number of tanks, some of which are for exclusive use for a certain cargo, are to be so arranged that an exclusive piping is to be provided individually for each different cargo, except where the common use of piping or mixing of cargoes will not cause any trouble.
(2) Where exclusive pipings are connected each other, means to avoid mis-operation is to be provided.

7. Shore connections

(1) At the connections between shore pipes for cargo handling (for both liquid and gas) and load headers of ship, shut-off valves are to be provided, each of which can be remotely shut off in case of emergency. The valves are to be such that they can shut off from other easily accessible locations than the regular place as well.
(2) Connections between shore pipes and ship's piping are to be so arranged as to be electrically connected each other.

8. Relief valves in pipe lines

A relief valve is to be provided on each pipe line in which the pressure may possibly rise above the maximum working pressure and on each pipe line in which the liquid may possibly be locked.

9. Pipe supports and fixings

All pipe lines are to be provided with adequate supports to prevent the weight of pipe lines from acting on valves and fittings and also to prevent excessive vibration. Pipe lines for use at low temperature are to be fixed so that adjoining hull structures may not be cooled excessively.

10. Earthing

Each pipe line is to be electrically connected and earthed effectively.

11. Cargo hoses

Cargo hoses equipped in ships are to be of materials not easily affected by cargoes and to be of suitable mechanical properties even at the working temperature, and are to be designed for a bursting pressure not less than 5 times the maximum working pressure (at least 2.5 MPa) to which they may be subjected.

12. Vent pipes

(1) Discharge from safety valves and relief valves is to be led to vent pipes. However, discharge from relief valves in pipe lines may be led into tanks, where effectiveness of relief valves is not lowered.
(2) The provisions in **203. 12** (2), (3) and (4) of this Annex are to apply.
(3) Each outlet end of vent pipes is to be located at a position 1/3 of the ship's breadth above the weather deck and where it is not liable to impair safety of the ship as far as practicable. At each outlet of the vent pipes, a suitable flame arrester is to be provided, and it is to be arranged so that the discharge may not blow out downward from the horizontal.

308. Cargo refrigerating facilities

1. Refrigerating facilities

At least two sets of refrigerating facilities are to be provided, and each of them is to be arranged for immediate use by switching.

2. Capacity

The capacity of refrigerating facilities is to be sufficient to maintain the cargo at the specified temperature, even in case where one set is out of service for 24 hours a day and only the remaining set or sets are in operation.

3. Re-liquefying facilities

(1) Where refrigerating facilities are of a type in which refrigerant is used, **Pt 9, Ch 1, 401. 1 to 4, 403. 3, 4, 404.** and **405.** of the Rules are to be applied to these refrigerating facilities.
(2) Where refrigerating facilities are of a type in which gas is directly liquefied under pressure, **204. 5** (1), (3) to (6) and 6 of this Annex as well as **Pt 9, Ch 1, 401. 1** to **4, 403. 4** (2), **404. 4** and **405.** of the Rules are to be applied.
(3) As for pressure vessels subjected to pressure of liquid and gas, the approved working pressure is to be at least 0.5 MPa and the requirements in **202. 1** to **4** of this Annex as well as **Pt 5, Ch 5** of the Rules are to be applied. As for safety valves, level gauges and other fittings, the requirements in **203. 9, 11, 13** (3) to (5) of this Annex are to be applied.

4. Automatic stopping devices against low pressure

The automatic stopping devices of refrigerating facilities specified in **306. 8** (1) of this Annex are to be so adjusted as to stop at a higher pressure than the set pressure of the vacuum relief valve on the tank. In addition, this automatic stopping device is not to lose its effectiveness even when the refrigerating facility is manually operated.

5. Earthing

All machinery and equipment for liquid and gas are to be earthed effectively.

309. Cargo handling facilities

1. Cargo handling facilities

In addition to the regular cargo pump facilities, any ship is to be provided with stand-by units and the units may be as follows:

(1) In case of a tank provided with two or more pumps, the stand-by units may be omitted in spite of being used.
(2) The stripper pump may be permitted with stand-by units.
(3) The eductor may be permitted with stand-by units.

2. Materials

The materials for cargo handling facilities are to be suitable for kind of cargo and temperature to be encountered in service.

3. Cargo pumps

The requirements in **204. 5** (1) to (5) of this Annex are also to apply.

4. Automatic stopping and remote stopping devices of cargo pumps

(1) Any pump is to be provided with an automatic stopping device or its equivalent to operate when liquid level in the tank reaches the predetermined low level, so as to protect the pump as well as its driving machinery.
(2) The automatic stopping device to operate at low pressure set forth in **306. 8** (1) of this Annex is to be so adjusted as to automatically stop at a higher pressure than the set pressure of the vacuum relief valve on the tank.
(3) The pumps are to be stopped from a remote location where cargo handling is watched or controlled.

5. Gas compressors and accessories

Where compressors are installed for delivery and loading of gas, the requirements in **308. 3** (2), (3) and **308. 4** of this Annex are to apply.

6. Earthing

All machinery and equipment for liquid and gas are to be electrically earthed effectively.

310. Ventilation system, etc.

1. Ventilation system, etc.

(1) The requirements in **205. 1** (1), (2), (4), 2 and **5** of this Annex are to apply.
(2) Tank holds are to be provided with bilge discharging facilities. The bilge suction pipe, however, is not to be led to non-dangerous spaces in the ship.

2. Installation of equipment causing ignition sources

Equipment which may cause ignition sources is not to be installed in the dangerous spaces specified in **102**. (7) of this Annex.

311. Electrical installations

1. Application

The electrical installations are to comply with these requirements as well as the requirements in **206.** of this Annex.

2. Power supply to cargo refrigerating facilities

Where all the machinery of the cargo refrigerating facilities specified in 308. of this Annex are electrically driven, the power supply is to be arranged from two or more generators, and the power supply to electric motors are to be made from circuits divided into at least two or more groups, through a main switch board or equivalent distribution board. ⚓

Annex 7A-2 Guidelines for the Evaluation of the Adequacy of Type C Tank Vent Systems

101. General

1. The tank outlet to the pressure relief valves is to remain in the vapour phase at the 98% liquid level, 15° of heel angle and 0.015 L of pitch angle.

2. Pressure relief valves which have been sized in accordance with **Pt 7, Ch 5, Sec 8** of the Rules, are to have adequate capacity.

3. To assure adequate relieving capacity condition, followings are to be complied with :

(1) The pressure drop in the vent pipe from the cargo tank to the pressure relief valve inlet ($\triangle p_{inlet}$) is not to exceed 3% of MARVS, at the pressure relief valve capacity required in Rules from equation **103.** (1) below, at 1.2 times maximum allowable relief valve setting (gauge pressure, hereafter MARVS) on all vapour flow.

(2) The blowdown ($\triangle p_{dose}$) is not to be less than $\triangle p_{inlet}$ + 0.02 × MARVS at the installed rated vapour capacity where required to assure stable operation of the pressure relief valve. This calculation is to be carried out at MARVS on all vapour flow. Pilot-operated valves can tolerate higher inlet-pipe pressure losses when the pilot senses at a point that is not affected by the inlet-pipe pressure drop.

4. The built-up back pressure in the vent piping from the pressure relief valve outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections which joint other tanks, is not to exceed the following values :

(1) For unbalanced pressure relief valves : 3 % MARVS.
Special consideration may be given in cases where the back pressure exceeds 10 % of MARVS at a tank pressure of 1.2 × MARVS; and

(2) For balanced pressure relief valves and pilot-operated pressure relief valves as advised by manufacturer : normally 30 % of MARVS for balanced pressure relief valves and 50 % of MARVS for pilot-operated pressure relief valves,
when assuming isenthalpic expansion of saturated liquid, at 1.2 × MARVS, through the pressure relief valve with the vent piping under fire exposure.

5. The built-up back pressure in the vent piping may be estimated by the procedures outlined in **102.**

6. A more accurate procedure for evaluating tank vent systems on flashing two-phase flow is to be consulted if these simplified procedures of **102.** do not demonstrate compliance with the preceding **3** and **4.**

102. Procedures

The following procedures are to be complied with to demonstrate the adequacy of a tank vent system to limit the pressure rise in a cargo tank to not greater than 1.2 × MARVS during all conditions, including fire conditions implicit in **Pt 7, Ch 5, 805. 2** of the Rules.

(1) Prepare a simplified flow sheet of the cargo tank vent system, identifying the fittings and the actual diameters and lengths of pipe.
Divide the system into sections between nodes at changes in pipe diameter and at inter-connections with flows from other relief valves.
List the fittings and their dynamic loss coefficients. Calculate the external surface area of the piping sections between the nodes.

(2) Calculate the pressure relief valve capacity (Q_{GCC}) of each tank pressure relief valve, in $\mathrm{m^3/s}$ of air at standard conditions in accordance with **Pt 7, Ch 5, 805. 2** of the Rules and note the installed rated capacity (Q_{IR}) of each pressure relief valve in $\mathrm{m^3/s}$ air at standard conditions at 1.2 × MARVS. The calculation is to be done for the highest gas factor of the products included in the cargo list. N-Butane has often the highest value for gas factor "G" in the Rules and usual1y determines the Rule minimum capacity.
Determine the mass flows for cargo conditions at 1.2 × MARVS through each pressure relief valve for the pressure relief valve capacity and for the installed rated capacity for both all vapour flow and for two phase cargo flow. Also calculate the mass flow at MARVS for the installed rated capacity on all vapour flow.

Equation in **103.** (1) may be used for all vapour mass flow and equations in **103.** (2), (3) and (4) may be used for two phase mass flow. Equation in **103.** (2) may be applied to multi-component mixtures whose boiling point range does not exceed 100 K.

(3) Estimate all the vapour flow pressure drop in the pipe from the cargo tank connection inlet flange, working from the known tank pressure towards the pressure relief valve. This pressure drop is calculated by using the difference in stagnation pressures. Therefore, the second term of equation in **103.** (5) (A) may be used for pipe sections of constant diameter. For contractions, equation in **103.** (5) (B) may be used.

(4) Check that the pressure drop at each pressure relief valve inlet complies with **101. 3** (1), at the pressure relief valve capacity for all vapour flow to assure adequate relief capacity. For the calculation, the vapour mass flow of product (W_g) from equation in **103.** (1) is to be used.
For control purposes, **101. 3** (1) is to be repeated using the pressure relief valve two-phase flow (W', equation in **103.** (4)) at 1.2 × MARVS and **101. 3** (2) by using the installed rated two-phase flow at MARVS. Both calculations are to give a smaller inlet pressure loss than the corresponding all vapour pressure loss.
Check that the blowdown ($\triangle p_{dose}$) complies with **101. 3** (2) to assure stable operation.

(5) Estimate the two-phase flow pressure in the discharge pipe at the location of discharge to the atmosphere. Equation in **103.** (6) may be used, with the pressure relief valve two-phase mass flow (W') to assure adequate relief capacity, to check if the exit pressure is greater than 0.1 MPa.

(6) Estimate the vapour fraction and two-phase density in the vent pipe at the exit to the atmosphere, assuming transfer of the fire heat flux of 108 $\mathrm{kW/m^2}$ through the uninsulated vent piping. Equations in **103.** (7) and (8) may be used.

(7) Estimate the built-up back pressure at the pressure relief valve outlet flange, commencing from the known vent pipe exit pressure, calculating the pressure drop between pipe nodes and working, section by section, back up the pipe to the pressure relief valve.
Equations in **103.** (7), (8) and (5) (A) may be used with iteration until the upstream node absolute pressure, vapour fraction and specific volume are justified and assuming that vapour is saturated.
At pipe diameter expansion fittings where fluid velocity is reduced, a pressure recovery generally occurs. This recovery is overestimated in case of two-phase flow when dynamic loss coefficients for single-phase flow are used. For the purpose of these guidelines, the static exit pressure of a conical expansion fitting is assumed to be equal to the static inlet pressure.

(8) Estimate the choking pressure(p_{ec}) at the exit of every section with the mass flux (G_p) in that section for the pipeline between the pressure relief valve and the vent exit. Equation in **103.** (6) may be used.
Compare the pressure distribution along the vent line as derived from preceding (5) to (7), with the different choking pressures for each section as derived from equation in **103.** (6).
If choking pressure at any location exceeds the corresponding calculated pressure derived from preceding (5) to (7), the calculation as described in preceding (5) to (7) is to be repeated commencing from choking point location and corresponding choking pressure, working back up the pipe to the pressure relief valve.
If choking pressure at more than one location exceeds the corresponding calculated pressure derived from preceding (5) to (7), the commencing point of the recalculation is to be taken as the choking location point giving the highest built-up back pressure.

(9) Check that the built-up back pressure at each pressure relief valve outlet complies with **101. 4.** at the pressure relief valve capacity for two-phase mass flow (W'), to assure stable operation of the valves, thus assuring adequate relief capacity.

(10) For conventional unbalanced valves only :
(A) If back pressure as derived from preceding (5) to (8) is within the range of 10 % to 20 % of MARVS, an additional evaluation is to be performed in order to decide whether the system is acceptable.
(B) The system is to perform with the following requirement: with one valve closed and all others discharging at the installed rated pressure relief valve capacity, and the back pressure is to be less than 10 % of MARVS.

103. Equations

The following equations may be used to demonstrate the adequacy of the vent system.

(1) For all vapour mass flow rate from tank through pressure relief valves

$$W_g = \frac{71 \cdot 10^3 \cdot F \cdot A^{0.82}}{h_{fg}} \quad (\mathrm{kg/s})$$

where

F : Fire exposure factor according to **Pt 7, Ch 5, 805.** of the Rules

A : External surface area of type C tank (m^2)

h_{fg} : Latent heat of vaporization of cargo at 1.2 × MARVS (J/kg)

(2) For isenthalpic flashing mass flux of liquid through pressure relief valve orifice
This equation is valid for multi-component mixtures whose boiling point range does not exceed 100 K.

$$G_v \approx h_{fg} \cdot \rho_g \left(\frac{1}{T_0 \cdot c} \right)^{\frac{1}{2}} \quad (\mathrm{kg/m^2 s})$$

where

h_{fg} : Latent heat of vaporization of cargo at 1.2 × MARVS (J/kg)

p_g : Vapour density 1.2 × MARVS and corresponding boiling temperature ($\mathrm{kg/m^3}$)

T_0 : Temperature of cargo at 1.2 × MARVS (K)

c : Liquid specific heat at 1.2 × MARVS (J/kgK)

(3) For two-phase mass flow rate through pressure relief valve is installed

$$W = G_v \cdot K_w \cdot A_v \quad (\mathrm{kg/s})$$

where

G_v : being taken from preceding (2) ($\mathrm{kg/m^2 s}$)

K_w : Pressure relief valve discharge coefficient on water(approx. 0.8 × measured K_d on air)

A_v : Actual orifice area of pressure relief valve (m^2)

(4) For pressure relief valve capacity for two-phase mass flow

$$W' = G_v \cdot K_w \cdot A_v \frac{Q_{GCC}}{Q_{IR}} \quad (\mathrm{kg/s})$$

where

Q_{GCC} : Pressure relief valve capacity of air at standard conditions in accordance with **Pt 7, Ch 5, 805. 2** of the Rules ($\mathrm{m^3/s}$)

Q_{IR}: Installed rated pressure relief valve capacity of air at T=273K and p=0.1013 MPa ($\mathrm{m^3/s}$)

(5) For the calculation of the static pressure difference in a pipe section of constant diameter in which the mass flux (G_p) is constant

(A) $$\Delta p = G_p^2 (v_e - v_i) + \frac{1}{2} \cdot G_p^2 \left(\frac{v_e + v_i}{2} \right) \left(4f \frac{L}{D} + \Sigma N \right) \quad (\mathrm{Pa})$$

where

G_p : Mass flux through the pipe section

$$G_P = \frac{W}{\pi D^2/4} \text{ or } \frac{W'}{\pi \cdot D^2/4} \quad (\mathrm{kg/m^2/s})$$

v_e : Two-phase specific volume at pipe section exit ($\mathrm{m^3/kg}$)
v_i : Two-phase specific volume at pipe section inlet ($\mathrm{m^3/kg}$)
f : Fanning friction factor f = 0.005 for two-phase fully turbulent flow
L : Length of pipe section (m)
D : Diameter of pipe section (m)
ΣN : Sum of dynamic loss coefficients for fittings in the pipe section, $N = 4f \cdot L/D$ equivalent (typical values of N are given in **Table 5**)

Table 5 Typical Values for Dynamic Loss Coefficient for Vent System Fittings

Fitting	$N(=4f \cdot L/D)$
Inlet pipe from tank to Pressure relief valve	
- Square-edged inlet	0.5
- Protruding conical inlet	0.15
- Conical reduction	0.10
Discharge piping from Pressure relief valve to mast vent exit	
- 45° bend	0.2
- 45° single-mitre elbow	0.45
- 90° long redius bend	0.3
- 90°short radius bend	0.5
- 90° double-mitre elbow	0.6
- Soft-tee	0.3
- Hard-tee	1.1
- Cowl mast vent exit	2.25
- Top-hat mast vent exit	4.5
- Flame screen(**Pt 7, Ch 5, 1710.** of the Rules)	1.4
(Note) N may vary with pipe diameter	

(B) For contractions, the difference in stagnation pressure is defined by :

$$\Delta p = \frac{1}{2} \cdot G_{p,e}^2 \cdot v_i N \quad (\mathrm{Pa})$$

where

N : Dynamic loss coefficients of the contraction
$G_{p,e}$: Mass flux at the exit of the contraction ($\mathrm{kg/m^2s}$)
v_i : Specific volume at the inlet of the contraction ($\mathrm{m^3/kg}$)

(6) For two-phase critical chocking pressure at vent mast exit or exit from any vent pipe section

$$p_{ec} = G_p \left(\frac{p_0 \omega}{\rho_0} \right)^{\frac{1}{2}} \quad (\mathrm{Pa})$$

where

G_p : as defined in preceding (5) (A)

p_0 : Cargo vapour pressure in tank at inlet to pressure relief valve (P_a)

ρ_0 : Cargo liquid density in tank at inlet to pressure relief valve at p_0 and T_0 (kg/m^3)

ω : Compressible flow parameter in tank at inlet to pressure relief valve

$$= \alpha_0 + (1 - \alpha_0) \frac{\rho_0 \cdot c \cdot T_0 \cdot p_0 \cdot (v_{go} - v_{fo})^2}{(h_{go} - h_{fo})^2}$$

where

α_0 : Inlet void fraction or vapour volume fraction at inlet to pressure relief valve
0, when assuming isenthalpic expansion of saturated liquid, at 1.2 × MARVS, through the pressure relief valve

c : See preceding (2)

T_0 : See preceding (2)

$(v_{go} - v_{fo})$: Difference in gaseous and liquid specific volume at temperature T_0 at inlet to pressure relief valve (m^3/kg)

$(h_{go} - h_{fo})$: Difference in gaseous and liquid enthalpy at temperature T_o at inlet to pressure relief valve (J/kg)

(7) For exit quality, or vapour mass fraction at pipe section exit

$$x_e = \frac{h_{fo} - h_{fe} + 1000 \cdot q \cdot \Sigma \frac{a}{W}}{h_{fg}}$$

(e.g. x_e = 0.3 ≡ 30 % quality ≡ 30 % vapour + 70 % liquid by mass)

where

h_{fo} : Liquid enthalpy in tank at inlet to pressure relief valve (J/kg)

h_{fe} : Liquid enthalpy at back pressure at pipe section exit (J/kg)

h_{fg} : Latent heat of vaporization at pipe section exit (J/kg)

q : Heat flux from fire exposure into vent pipe equal to 108 kW/m^2

a : Heated external surface area of vent pipe section (m^2)

W : Mass flow rate in vent pipe section (kg/s)

(8) For two-phase density(ρ) and specific volume (v)

$$\rho = \frac{\rho_g}{x} \quad (kg/m^3)$$

where

ρ_g : Saturated vapour density at pipe section inlet or exit (kg/m^3)

x : Vapour fraction at pipe section inlet or exit

$$v = \frac{1}{\rho} \quad (m^3/kg)$$

Annex 7B-1 Table of Summary of Minimum Requirements

Product name (column a)	The product name shall be used in the shipping document for any cargo offered for bulk shipments. Any additional name may be included in brackets after the product name. In some cases, the product names are not identical with the names given in previous issues of the Code
UN number (column b)	Deleted
Pollution category (column c)	The letter X, Y, Z means the pollution category assigned to each product under MARPOL Annex II
Hazards (column d)	*S* means that the product is included in the Rules because of its safety hazards; *P* means that the product is included in the Rules because of its pollution hazards; and *S*/*P* means that the product is included in the Rules because of both its safety and pollution hazards.
Ship type (column e)	1 : ship type 1 2 : ship type 2 3 : ship type 3
Tank type (column f)	1 : independent tank 2 : integral tank G : gravity tank P : pressure tank
Tank vents (column g)	Cont. : controlled venting Open : open venting
Tank environmental control (column h)	Inert : inerting Pad : liquid or gas padding Dry : drying Vent : natural or forced ventilation No : no special requirements under this code
Electrical equipment (column i)	Temperature classes (i') ; T1 to T6, - : indicates no requirements, blank : no information Apparatus groups(i") ; IIA, IIB or IIC, - : indicates no requirements, blank : no information Flash point (i"') ; Yes : flashpoint exceeding 60°C No : flashpoint not exceeding 60°C NF : nonflammable product
Gauging (column j)	O : open gauging R : restricted gauging C : closed gauging
Vapour detection (column k)	F : flammable vapours T : toxic vapours No : indicates no special requirements under this Code
Fire protection (column l)	A : alcohol-resistant foam or multi-purpose foam B : regular foam, encompasses all foams that are not of an alcohol-resistant type, including fluoroprotein and aqueous-film-forming foam (AFFF) C : water-spray D : dry chemical No : no special requirements under this chapter
Materials of construction (column m)	Deleted
Emergency equipment (column n)	Yes : see 1403. 1 No : no special requirements under this Chapter
Specific and operational requirements (column o)	When specific reference is made to chapter 15 and /or 16, these requirements shall be additional to the requirements in any other column.

a	c	d	e	f	g	h	i'	i"	i'"	j	k	l	n	o
Acetic acid	X	S/P	3	2G	Cont	No	T1	IIA	No	R	F	A	Yes	1511.2 to 1511.4, 1511.6 to 1511.8, 1519.6, 1602.7(16.2.9)(*)
Acetic anhydride	Z	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	A	Yes	1511.2 to 1511.4, 1511.6 to 1511.8, 1519.6
Acetochlor	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Acetone cyanohydrin	Y	S/P	2	2G	Cont	No	T1	IIA	Yes	C	T	A	Yes	1512., 1513., 1517. to 1519., 1606.1 to 1606.3
Acetonitrile	Z	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	A	No	1512., 1519.6
Acetonitrile (Low purity grade)	Y	S/P	3	2G	Cont	No	T1	IIA	No	R	F-T	A	No	1512.3, 1512.4, 1519.6
Acid oil mixture from soyabean, corn (maize) and sunflower oil refining	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Acrylamide solution(50% or less)	Y	S/P	2	2G	Open	No			NF	C	No	No	No	1512.3, 1513., 1519.6, 1606.1, 1602.7(16.2.9)(*)
Acrylic acid	Y	S/P	2	2G	Cont	No	T2	IIA	No	C	F-T	A	Yes	1511.2 to 1511.4, 1511.6 to 1511.8, 1512.3, 1512.4, 1513., 1517., 1519., 1606.1, 1602.7(16.2.9)(*)
Acrylonitrile	Y	S/P	2	2G	Cont	No	T1	IIB	No	C	F-T	A	Yes	1512., 1513., 1517., 1519.
Acrylonitrile-Styrene copolymer dispersion in polyether polyol	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Adiponitrile	Z	S/P	3	2G	Cont	No		IIB	Yes	R	T	A	No	1602.7(16.2.9)(*)
Alachlor technical (90% or more)	X	S/P	2	2G	Open	No			Yes	O	No	AC	No	1519.6, 1602.7(16.2.9)(*)
Alcohol (C9-C11) poly (2.5-9) ethoxylate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Alcohol (C6-C17) (secondary) poly(3-6)ethoxylates	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Alcohol (C6-C17) (secondary) poly(7-12)ethoxylates	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, l602.6, 1602.7(16.2.9)(*)
Alcohol (C12-C16) poly(1-6)ethoxylates	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Alcohol (C12-C16) poly(20+)ethoxylates	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Alcohol (C12-C16) poly(7-19)ethoxylates	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Alcohols (C13+)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Alcohols (C8-C11), primary, linear and essentially linear	Y	S/P	2	2G	Cont	No	-	-	Yes	R	T	ABC	No	1512.3, 1512.4, 1519.6, 1602.6, 1602.7(16.2.9)(*)
Alcohols (C12-C13), primary, linear and essentially linear	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Alcohols (C14-C18), primary, linear and essentially linear	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6
Alkanes (C6-C9)	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Iso-and cyclo-alkanes (C10-C11)	Y	P	3	2G	Cont	No	-	-	No	R	F	A	No	1519.6
Iso-and cyclo-alkanes (C12+)	Y	P	3	2G	Cont	No	-	-	No	R	F	A	No	
n-Alkanes (C10+)	Y	P	3	2G	Cont	No	-	-	No	R	F	A	No	1519.6
Alkaryl polyethers(C9-C20)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Alkenyl(C11+)amide	X	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Alkenyl (C16-C20) succinic anhydride	Z	S/P	3	2G	Cont	No			Yes	C	T	No	Yes	1512., 1517., 1519.
Alkyl acrylate-vinylpyridine copolymer in toluene	Y	P	2	2G	Cont	No			NO	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Alkylaryl phosphate mixtures (more than 40% Diphenyl tolyl phosphate, less than 0.02% ortho-isomers)	X	S/P	1	2G	Cont	No	T1	IIA	Yes	C	T	ABC	No	1512., 1517., 1519.
Alkylated (C4-C9) hindered phenols	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	BD	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Alkylbenzene, alkylindane, alkylindene mixture (each C12-C17)	Z	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Alkyl benzene distillation bottoms	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6
Alkylbenzene mixtures (containing at least 50% of toluene)	Y	S/P	3	2G	Cont	No	T1	IIA	No	C	F-T	ABC	No	1512., 1517., 1519..6
Alkyl(C3-C4) benzenes	Y	P	2	2G	Cont	No			NO	R	F	A	No	1519.6
Alkyl (C5-C8) benzenes	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Alkyl(C9+)benzenes	Y	P	3	2G	Open	No	-	-	Yes	O	No	AB	No	
Alkyl(C11-C17) benzene sulphonic acid	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Alkylbenzene sulphonic acid, sodium salt solution	Y	S/P	2	2G	Open	No	-	-	NF	O	No	No	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Alkyl (C12+) dimethylamine	X	S/P	1	2G	Cont	No	-	-	Yes	C	T	BCD	Yes	1512., 1517., 1519.
Alkyl dithiocarbamate (C19-C35)	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Alkyldithiothiadiazole (C6-C24)	Y	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Alkyl ester copolymer (C4-C20)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Alkyl (C8-C10)/(C12-C14):(40% or less/60% or more) polyglucoside solution (55% or less)	Y	P	3	2G	Open	No			Yes	O	No	No	No	1519.6, 1602.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i"	i'''	j	k	l	n	o
Alkyl (C8-C10)/(C12-C14):(60% or more/40% or less) polyglucoside solution(55% or less)	Y	P	3	2G	Open	No			Yes	O	No	No	No	1602.6, 1602.7(16.2.9)(*)
Alkyl(C7-C9) nitrates	Y	S/P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1520., 1606.1, 1606.2, 1606.3
Alkyl(C7-C11)phenol poly(4-12) ethoxylate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Alkyl (C8-C40) phenol sulphide	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Alkyl (C8-C9) phenylamine in aromatic solvents	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Alkyl (C9-C15) phenyl propoxylate	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Alkyl (C8-C10)/(C12-C14):(50%/50%) polyglucoside solution (55% or less)	Y	P	3	2G	Open	No			Yes	O	No	No	No	1602.6, 1602.7(16.2.9)(*)
Alkyl (C12-C14) polyglucoside solution (55% or less)	Y	P	3	2G	Open	No			Yes	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Alkyl (C8-C10) polyglucoside solution (65% or less)	Y	P	3	2G	Open	No			Yes	O	No	No	No	1602.6
Alkyl(C10-C20, saturated and unsaturated) phosphite	Y	P	2	2G	Open	No			Yes	O	No	A	No	1602.7(16.2.9)(*)
Alkyl sulphonic acid ester of phenol	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Allyl alcohol	Y	S/P	2	2G	Cont	No	T2	IIB	No	C	F-T	A	Yes	1512., 1517., 1519.
Allyl chloride	Y	S/P	2	2G	Cont	No	T2	IIA	No	C	F-T	A	Yes	1512., 1517., 1519.
Aluminium sulphate solution	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
2-(2-Aminoethoxy) ethanol	Z	S/P	3	2G	Open	No			Yes	O	No	AD	No	1519.6
Aminoethyldiethanolamine/ Aminoethylethanolamine solution	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Aminoethyl ethanolamine	Z	S/P	3	2G	Open	No	T2	IIA	Yes	O	No	A	No	
N-Aminoethylpiperazine	Z	S/P	3	2G	Cont	No			Yes	R	T	A	No	1519.6, 1602.7(16.2.9)(*)
2-Amino-2-methyl-1-propanol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Ammonia aqueous (28% or less)	Y	S/P	2	2G	Cont	No			NF	R	T	ABC	Yes	1519.6
Ammonium hydrogen phosphate solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Ammonium lignosulphonate solutions	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Ammonium nitrate solution (93% or less)	Z	S/P	2	1G	Open	No			NF	O	No	No	No	1502., 1511.4, 1511.6, 1518., 1519.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Ammonium polyphosphate solution	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Ammonium sulphate solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Ammonium sulphide solution (45% or less)	Y	S/P	2	2G	Cont	No			No	C	F-T	A	Yes	1512., 1517., 1519., 1606.1 to 1606.3
Ammonium thiosulphate solution(60% or less)	Z	P	3	2G	Open	No			NF	O	No	No	No	1602.7(16.2.9)(*)
Amyl acetate (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
n-Amyl alcohol	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Amyl alcohol, primary	Z	P	3	2G	Cont	No			No	R	F	AB	No	
sec-Amyl alcohol	Z	P	3	2G	Cont	No			No	R	F	AB	No	
tert-Amyl alcohol	Z	P	3	2G	Cont	No			No	R	F	A	No	
tert-Amyl methyl ether	X	P	2	2G	Cont	No	T3		No	R	F	A	No	1519.6
Aniline	Y	S/P	2	2G	Cont	No	T1	IIA	Yes	C	T	A	No	1512., 1517., 1519.
Aryl polyolefins (C11-C50)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Aviation alkylates (C8 paraffins and iso-paraffins BPT 95 - 120℃)	X	P	2	2G	Cont	No			No	R	F	B	No	1519.6
Barium long chain (C11-C50) alkaryl sulphonate	Y	S/P	2	2G	Open	No			Yes	O	No	AD	No	1512.3, 1519., 1602.6, 1602.7(16.2.9)(*)
Benzene and mixtures having 10% benzene or more(i)	Y	S/P	3	2G	Cont	No	T1	IIA	No	C	F-T	AB	No	1512.1, 1517., 1519.6, 1602.7(16.2.9)(*)
Benzene sulphonyl chloride	Z	S/P	3	2G	Cont	No			Yes	R	T	AD	No	1519.6, 1602.7(16.2.9)(*)
Benzenetricarboxylic acid, trioctyl ester	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Benzyl acetate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Benzyl alcohol	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Benzyl chloride	Y	S/P	2	2G	Cont	No	T1	IIA	Yes	C	T	AB	Yes	1512., 1513., 1517., 1519.
Brake fluid base mix: Poly (2-8)alkylene (C2-C3) glycols/Polyalkylene (C2-C10) glycols monoalkyl (C1-C4) ethers and their borate esters	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Bromochloromethane	Z	S/P	3	2G	Cont	No			NF	R	T	No	No	
Butene oligomer	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Butyl acetate (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Butyl acrylate (all isomers)	Y	S/P	2	2G	Cont	No	T2	IIB	No	R	F-T	A	No	1513., 1519.6, 1606.1, 1606.2
tert-Butyl alcohol	Z	P	3	2G	Cont	No			No	R	F	A	No	
Butylamine (all isomers)	Y	S/P	2	2G	Cont	No			No	R	F-T	A	Yes	1512., 1517., 1519.6
Butylbenzene (all isomers)	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Butyl benzyl phthalate	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Butyl butyrate (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Butyl/Decyl/Cetyl/Eicosyl methacrylate mixture	Y	S/P	2	2G	Cont	No			Yes	R	No	AD	No	1513., 1519.6, 1606.1, 1606.2
Butylene glycol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
1,2-Butylene oxide	Y	S/P	3	2G	Cont	Inert	T2	IIB	No	R	F	AC	No	1508.1 to 1508.7, 1508.12, 1508.13, 1508.16 to 1508.19, 1508.21, 1508.25, 1508.27, 1508.29, 1519.6
n-Butyl ether	Y	S/P	3	2G	Cont	Inert	T4	IIB	No	R	F-T	A	No	1504.6, 1512, 1519.6
Butyl methacrylate	Z	S/P	3	2G	Cont	No		IIA	No	R	F-T	AD	No	1513., 1519.6, 1606.1, 1606.2
n-Butyl propionate	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Butyraldehyde (all isomers)	Y	S/P	3	2G	Cont	No	T3	IIA	No	R	F-T	A	No	1519.6
Butyric acid	Y	S/P	3	2G	Cont	No			Yes	R	No	A	No	1511.2 to 1511.4, 1511.6 to 1511.8, 1519.6
gamma-Butyrolactone	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
Calcium carbonate slurry	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Calcium hydroxide slurry	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Calcium hypochlorite solution (15% or less)	Y	S/P	2	2G	Cont	No			NF	R	No	No	No	1519.6
Calcium hypochlorite solution (more than 15%)	X	S/P	1	2G	Cont	No			NF	R	No	No	No	1519,1602.7(16.2.9)(*)
Calcium lignosulphonate solutions	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Calcium long-chain alkaryl sulphonate(C11-C50)	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Calcium long-chain alkyl(C5-C10) phenate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Calcium long-chain alkyl(C11-C40) phenate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Calcium long-chain alkyl phenate sulphide (C8-C40)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Calcium long-chain alkyl salicylate(C13+)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Calcium nitrate/Magnesium nitrate/Potassium chloride solution	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
epsilon-Caprolactam (molten or aqueous solutions)	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Carbolic oil	Y	S/P	2	2G	Cont	No			Yes	C	F-T	A	No	1512., 1519.6, 1602.7(16.2.9)(*)
Carbon disulphide	Y	S/P	2	1G	Cont	Pad+ inert	T6	IIC	No	C	F-T	C	Yes	1503., 1512., 1519.
Carbon tetrachloride	Y	S/P	2	2G	Cont	No			NF	C	T	No	Yes	1512., 1517., 1519.6
Cashew nut shell oil(untreated)	Y	S/P	2	2G	Cont	No			Yes	R	T	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Castor oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Cetyl/Eicosyl methacrylate mixture	Y	S/P	2	2G	Open	No			Yes	O	No	AD	No	1513., 1519.6, 1602.7(16.2.9)(*), 1606.1, 1606.2
Chlorinated paraffins (C10-C13)	X	P	1	2G	Open	No			Yes	O	No	A	No	1519., 1602.6
Chlorinated paraffins (C14-C17) (with 50% chlorine or more, and less than 1% C13 or shorter chains)	X	P	1	2G	Open	No	-	-	Yes	O	No	A	No	1519.
Chloroacetic acid (80% or less)	Y	S/P	2	2G	Cont	No			NF	C	No	No	No	1511.2, 1511.4, 1511.6 to 1511.8, 1512.3, 1519., 1602.7(16.2.9)(*)
Chlorobenzene	Y	S/P	2	2G	Cont	No	T1	IIA	No	R	F-T	AB	No	1519.6
Chloroform	Y	S/P	3	2G	Cont	No			NF	R	T	No	Yes	1512., 1519.6
Chlorohydrins (crude)	Y	S/P	2	2G	Cont	No		IIA	No	C	F-T	A	No	1512., 1519.
4-Chloro-2-methylphenoxyacetic acid, dimethylamine salt solution	Y	P	2	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
o-Chloronitrobenzene	Y	S/P	2	2G	Cont	No			Yes	C	T	ABD	No	1512., 1517., 1518., 1519., 1602.6, 1602.7(16.2.9)(*)
1-(4-Chlorophenyl)-4,4-dimethyl-pentan-3-one	Y	P	2	2G	Open	No			Yes	O	No	ABD	No	1519.6, 1602.6, 1602.7(16.2.9)(*),
2-or 3-Chloropropionic acid	Z	S/P	3	2G	Open	No			Yes	O	No	A	No	1511.2 to 1511.4, 1511.6 to 1511.8, 1602.7(16.2.9)(*)
Chlorosulphonic acid	Y	S/P	1	2G	Cont	No			NF	C	T	No	Yes	1511.2 to 1511.8, 1512., 1516.1(15.16.2)(*), 1519.
m-Chlorotoluene	Y	S/P	2	2G	Cont	No			No	R	F-T	AB	No	1519.6
o-Chlorotoluene	Y	S/P	2	2G	Cont	No			No	R	F-T	AB	No	1519.6
p-Chlorotoluene	Y	S/P	2	2G	Cont	No			No	R	F-T	AB	No	1519.6, 1602.7(16.2.9)(*)
Chlorotoluenes (mixed isomers)	Y	S/P	2	2G	Cont	No			No	R	F-T	AB	No	1519.6
Choline chloride solutions	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Citric acid (70% or less)	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Coal tar	X	S/P	2	2G	Cont	No	T2	IIA	Yes	R	No	BD	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Coal tar naphtha solvent	Y	S/P	2	2G	Cont	No	T3	IIA	No	R	F-T	AD	No	1519.6, 1602.7(16.2.9)(*)
Coal tar pitch (molten)	X	S/P	2	1G	Cont	No	T2	IIA	Yes	R	No	BD	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Cocoa butter	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Coconut oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Coconut oil fatty acid	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Coconut oil fatty acid methyl ester	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Copper salt of long chain (C17+) alkanoic acid	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Corn Oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Cotton seed oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Creosote (coal tar)	X	S/P	2	2G	Cont	No	T2	IIA	Yes	R	T	AD	No	1512.3, 1512.4, 1519.6, 1602.6, 1602.7(16.2.9)(*)
Cresols (all isomers)	Y	S/P	2	2G	Open	No	T1	IIA	Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Cresylic acid, dephenolized	Y	S/P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
Cresylic acid, sodium salt solution	Y	S/P	2	2G	Open	No			Yes	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Crotonaldehyde	Y	S/P	2	2G	Cont	No	T3	IIB	No	R	F-T	A	Yes	1512., 1517., 1519.6
1,5,9-Cyclododecatriene	X	S/P	1	2G	Cont	No			Yes	R	T	A	No	1513., 1519., 1606.1, 1606.2
Cycloheptane	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Cyclohexane	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Cyclohexanol	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Cyclohexanone	Z	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	A	No	1519.6
Cyclohexanone, Cyclohexanol mixture	Y	S/P	3	2G	Cont	No			Yes	R	F-T	A	No	1519.6
Cyclohexyl acetate	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Cyclohexylamine	Y	S/P	3	2G	Cont	No	T3	IIA	No	R	F-T	AC	No	1519.6
1,3-Cyclopentadiene dimer (molten)	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Cyclopentane	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Cyclopentene	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
p-Cymene	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Decahydronaphthalene	Y	P	2	2G	Cont	No			No	R	F	AB	No	1519.6
Decanoic acid	X	P	2	2G	Open	No			Yes	O	No	A	No	1602.7(16.2.9)(*)
Decene	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Decyl acrylate	X	S/P	1	2G	Open	No	T3	IIA	Yes	O	No	ACD	No	1513., 1519., 1606.1, 1606.2
Decyl alcohol (all isomers)	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)(e)
Decyloxytetrahydrothiophene dioxide	X	S/P	2	2G	Cont	No			Yes	R	T	A	No	1519.6, 1602.7(16.2.9)(*)
Diacetone alcohol	Z	P	3	2G	Cont	No			No	R	F	A	No	
Dialkyl (C8-C9) diphenylamines	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Dialkyl (C7-C13) phthalates	X	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Dibromomethane	Y	S/P	2	2G	Cont	No			NF	R	T	No	No	1512.3, 1519.
Dibutylamine	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	ACD	No	1519.6
Dibutyl hydrogen phosphate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
2,6-Di-tert-butylphenol	X	P	1	2G	Open	No	-	-	Yes	O	No	ABCD	No	1519., 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Dibutyl phthalate	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Dichlorobenzene (all isomers)	X	S/P	2	2G	Cont	No	T1	IIA	Yes	R	T	ABD	No	1519.6
3,4-Dichloro-1-butene	Y	S/P	2	2G	Cont	No			No	C	F-T	ABC	Yes	1512.3, 1517., 1519.6
1,1-Dichloroethane	Z	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	A	Yes	1519.6
Dichloroethyl ether	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	A	No	1519.6
1,6-Dichlorohexane	Y	S/P	2	2G	Cont	No			No	R	T	AB	No	1519.6
2,2'-Dichloroisopropyl ether	Y	S/P	2	2G	Cont	No			Yes	R	T	ACD	No	1512., 1517., 1519.
Dichloromethane	Y	S/P	3	2G	Cont	No	T1	IIA	Yes	R	T	No	No	1519.6
2,4-Dichlorophenol	Y	S/P	2	2G	Cont	Dry			Yes	R	T	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
2,4-Dichlorophenoxyacetic acid, diethanolamine salt solution	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
2,4-Dichlorophenoxyacetic acid, dimethylamine salt solution(70% or less)	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
2,4-Dichlorophenoxyacetic acid, triisopropanolamine salt solution	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
1,1-Dichloropropane	Y	S/P	2	2G	Cont	No			No	R	F-T	AB	No	1512., 1519.6
1,2-Dichloropropane	Y	S/P	2	2G	Cont	No	T1	IIA	No	R	F-T	AB	No	1512., 1519.6
1,3-Dichloropropene	X	S/P	2	2G	Cont	No	T2	IIA	No	C	F-T	AB	Yes	1512., 1517. to 1519.
Dichloropropene/Dichloropropane mixtures	X	S/P	2	2G	Cont	No			No	C	F-T	ABD	Yes	1512., 1517. to 1519.
2,2-Dichloropropionic acid	Y	S/P	3	2G	Cont	Dry			Yes	R	No	A	No	1511.2, 1511.4, 1511.6, 1511.7, 1511.8, 1519.6, 1602.7(16.2.9)(*)
Diethanolamine	Y	S/P	3	2G	Open	No	T1	IIA	Yes	O	No	A	No	1602.6,1602.7(16.2.9)(*)
Diethylamine	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	A	Yes	1512., 1519.6
Diethylaminoethanol	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	AC	No	1519.6
2,6-Diethylaniline	Y	S/P	3	2G	Open	No			Yes	O	No	BCD	No	1519.6, 1602.7(16.2.9)(*)
Diethylbenzene	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Diethylene glycol dibutyl ether	Z	S/P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Diethylene glycol diethyl ether	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Diethylene glycol phthalate	Y	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Diethylenetriamine	Y	S/P	3	2G	Open	No	T2	IIA	Yes	O	No	A	No	1519.6
Diethylenetriaminepentaacetic acid, pentasodium salt solution	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Diethyl ether	Z	S/P	2	1G	Cont	Inert	T4	IIB	No	C	F-T	A	Yes	1504., 1514., 1519.
Di-(2-ethylhexyl) adipate	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
Di-(2-ethylhexyl) phosphoric acid	Y	S/P	2	2G	Open	No			Yes	O	No	AD	No	1519.6
Diethyl phthalate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Diethyl sulphate	Y	S/P	2	2G	Cont	No			Yes	C	T	A	No	1519.6

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Diglycidyl ether of bisphenol A	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Diglycidyl ether of bisphenol F	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
Diheptyl phthalate	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
Di-n-hexyl adipate	X	P	1	2G	Open	No			Yes	O	No	A	No	1519.
Dihexyl phthalate	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
Diisobutylamine	Y	S/P	2	2G	Cont	No			No	R	F-T	ACD	No	1512.3, 1519.6
Diisobutylene	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Diisobutyl ketone	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Diisobutyl phthalate	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Diisononyl adipate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Diisooctyl phthalate	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Diisopropanolamine	Z	S/P	3	2G	Open	No	T2	IIA	Yes	O	No	A	No	1602.7(16.2.9)(*)
Diisopropylamine	Y	S/P	2	2G	Cont	No	T2	IIA	No	C	F-T	A	Yes	1512., 1519.
Diisopropylbenzene (all isomers)	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Diisopropylnaphthalene	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
N,N-Dimethylacetamide	Z	S/P	3	2G	Cont	No	-	-	Yes	C	T	ACD	No	1512., 1517.
N,N-Dimethylacetamide solution (40% or less)	Z	S/P	3	2G	Cont	No			Yes	R	T	B	No	1512.1, 1517.
Dimethyl adipate	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Dimethylamine solution (45% or less)	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	ACD	No	1512., 1519.6
Dimethylamine solution (greater than 45% but not greater than 55%)	Y	S/P	2	2G	Cont	No			No	C	F-T	ACD	Yes	1512., 1517., 1519.
Dimethylamine solution (greater than 55% but not greater than 65%)	Y	S/P	2	2G	Cont	No			No	C	F-T	ACD	Yes	1512., 1514., 1517., 1519.
N,N-Dimethylcyclohexylamine	Y	S/P	2	2G	Cont	No			No	R	F-T	AC	No	1512., 1517., 1519.6
Dimethyl disulphide	Y	S/P	2	2G	Cont	No	T3	IIA	No	R	F-T	B	No	1512.3, 1512.4, 1519.6
N,N-Dimethyldodecylamine	X	S/P	1	2G	Open	No			Yes	O	No	B	No	1519.
Dimethylethanolamine	Y	S/P	3	2G	Cont	No	T3	IIA	No	R	F-T	AD	No	1519.6
Dimethylformamide	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	AD	No	1519.6
Dimethyl glutarate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Dimethyl hydrogen phosphite	Y	S/P	3	2G	Cont	No			Yes	R	T	AD	No	1512.1, 1519.6
Dimethyl octanoic acid	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Dimethyl phthalate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Dimethylpolysiloxane	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
2,2-Dimethylpropane-1,3-diol (molten or solution)	Z	P	3	2G	Open	No	-	-	Yes	O	No	AB	No	1602.7(16.2.9)(*)
Dimethyl succinate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Dinitrotoluene (molten)	X	S/P	2	2G	Cont	No			Yes	C	T	A	No	1512., 1517., 1519., 1521., 1602.6, 1602.7(16.2.9)(*), 1606.4
Dinonyl phthalate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Dioctyl phthalate	X	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
1,4-Dioxane	Y	S/P	2	2G	Cont	No	T2	IIB	No	C	F-T	A	No	1512., 1519., 1602.7(16.2.9)(*)
Dipentene	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Diphenyl	X	P	2	2G	Open	No			Yes	O	No	B	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Diphenylamine (molten)	Y	P	2	2G	Open	No	-	-	Yes	O	No	BD	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Diphenylamine, reaction product with 2,2,4-Trimethylpentene	Y	S/P	1	2G	Open	No			Yes	O	No	A	No	1519., 1602.6
Diphenylamines, alkylated	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Diphenyl/Diphenyl ether mixtures	X	P	2	2G	Open	No			Yes	O	No	B	No	1519.6, 1602.7(16.2.9)(*)
Diphenyl ether	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Diphenyl ether/Diphenyl phenyl ether mixture	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Diphenylmethane diisocyanate	Y	S/P	2	2G	Cont	Dry	-	-	Yes (a)	C	T(a)	ABC (b)D	No	1512., 1516.1(15.16.2)(*), 1517., 1519.6, 1602.6, 1602.7(16.2.9)(*)
Diphenylol propane-epichlorohydrin resins	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Di-n-propylamine	Y	S/P	2	2G	Cont	No			No	R	F-T	A	No	1512.3, 1519.6
Dipropylene glycol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Dithiocarbamate ester (C7-C35)	X	P	2	2G	Open	No			Yes	O	No	AD	No	1519.6, 1602.7(16.2.9)(*)
Ditridecyl adipate	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Ditridecyl phthalate	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Diundecyl phthalate	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Dodecane (all isomers)	Y	P	2	2G	Cont	No			No	R	F	AB	No	1519.6
tert-Dodecanethiol	X	S/P	1	2G	Cont	No	-	-	Yes	C	T	ABD	Yes	1512., 1517., 1519.
Dodecene (all isomers)	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Dodecyl alcohol	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Dodecylamine/Tetradecylamine mixture	Y	S/P	2	2G	Cont	No			Yes	R	T	AD	No	1519.6, 1602.7(16.2.9)(*)
Dodecylbenzene	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Dodecyl diphenyl ether disulphonate solution	X	S/P	2	2G	Open	No			NF	O	No	No	No	1519.6, 1602.6
Dodecyl hydroxypropyl sulphide	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Dodecyl methacrylate	Z	S/P	3	2G	Open	No			Yes	O	No	A	No	1513.

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Dodecyl/Octadecyl methacrylate mixture	Y	S/P	3	2G	Open	No	-	-	Yes	O	No	A	No	1513., 1519.6, 1602.6, 1606.1, 1606.2
Dodecyl/Pentadecyl methacrylate mixture	Y	S/P	2	2G	Open	No			Yes	O	No	AD	No	1513., 1519.6, 1606.1, 1606.2
Dodecyl phenol	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
Dodecyl Xylene	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Drilling brines (containing zinc salts)	X	P	2	2G	Open	No			Yes	O	No	No	No	1519.6
Drilling brines, including: calcium bromide solution, calcium chloride solution and sodium chloride solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Epichlorohydrin	Y	S/P	2	2G	Cont	No		IIB	No	C	F-T	A	Yes	1512., 1517., 1519.6
Ethanolamine	Y	S/P	3	2G	Open	No	T2	IIA	Yes	O	F-T	A	No	1602.7(16.2.9)(*)
2-Ethoxyethyl acetate	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Ethoxylated long chain (C16+) alkyloxyalkylamine	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Ethyl acetate	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Ethyl acetoacetate	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Ethyl acrylate	Y	S/P	2	2G	Cont	No	T2	IIB	No	R	F-T	A	Yes	1513., 1519.6, 1606.1, 1606.2
Ethylamine	Y	S/P	2	1G	Cont	No	T2	IIA	No	C	F-T	CD	Yes	1512., 1514., 1519.6
Ethylamine solutions (72% or less)	Y	S/P	2	2G	Cont	No			No	C	F-T	AC	Yes	1512., 1514., 1517., 1519.
Ethyl amyl ketone	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Ethylbenzene	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Ethyl tert-butyl ether	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Ethyl butyrate	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Ethylcyclohexane	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
N-Ethylcyclohexylamine	Y	S/P	2	2G	Cont	No			No	R	F-T	A	No	1519.6
S-Ethyl dipropylthiocarbamate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1602.7(16.2.9)(*)
Ethylene chlorohydrin	Y	S/P	2	2G	Cont	No	T2	IIA	No	C	F-T	AD	Yes	1512., 1517., 1519.
Ethylene cyanohydrin	Y	S/P	3	2G	Open	No		IIB	Yes	O	No	A	No	1519.6
Ethylenediamine	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	A	No	1519.6, 1602.7(16.2.9)(*)
Ethylenediaminetetraacetic acid, tetrasodium salt solution	Y	S/P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Ethylene dibromide	Y	S/P	2	2G	Cont	No			NF	C	T	No	Yes	1512., 1519.6, 1602.7(16.2.9)(*)
Ethylene dichloride	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	AB	No	1519.
Ethylene glycol	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Ethylene glycol acetate	Y	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Ethylene glycol butyl ether acetate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Ethylene glycol diacetate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6

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Ethylene glycol methyl ether acetate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Ethylene glycol monoalkyl ethers	Y	S/P	3	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Ethylene glycol phenyl ether	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Ethylene glycol phenyl ether/Diethylene glycol phenyl ether mixture	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Ethylene oxide/Propylene oxide mixture with an Ethylene oxide content of not more than 30% by mass	Y	S/P	2	1G	Cont	Inert	T2	IIB	No	C	F-T	AC	No	1508., 1512., 1514., 1519.
Ethylene-vinyl acetate copolymer (emulsion)	Y	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Ethyl-3-ethoxypropionate	Y	P	3	2G	Cont	No			No	R	No	A	No	1519.6
2-Ethylhexanoic acid	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
2-Ethylhexyl acrylate	Y	S/P	3	2G	Open	No	T3	IIB	Yes	O	No	A	No	1513., 1519.6, 1606.1, 1606.2
2-Ethylhexylamine	Y	S/P	2	2G	Cont	No			No	R	F-T	A	No	1512., 1519.6
2-Ethyl-2-(hydroxymethyl) propane-1,3-diol (C8-C10) ester	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Ethylidene norbornene	Y	S/P	2	2G	Cont	No			No	R	F-T	AD	No	1512.1, 1519.6
Ethyl methacrylate	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F-T	AD	No	1513., 1519.6, 1606.1, 1606.2
N-Ethylmethylallylamine	Y	S/P	2	2G	Cont	No	T2	IIB	No	C	F	AC	Yes	1512.3, 1517., 1519.
Ethyl propionate	Y	P	3	2G	Open	No			No	R	F	A	No	1519.6
2-Ethyl-3-propylacrolein	Y	S/P	3	2G	Cont	No		IIA	No	R	F-T	A	No	1519.6, 1602.7(16.2.9)(*)
Ethyl Toluene	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Fatty acid (saturated C13+)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Fatty acid methyl esters (m)	Y	S/P	2	2G	Cont	No	-	-	Yes	R	T	ABC	No	1512.3, 1512.4, 1519.6, 1602.6, 1602.7(16.2.9)(*)
Fatty acid, (C16+)	Y	P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6,
Fatty acid, 12+	Y	S/P	2	2G	Cont	No	-	-	Yes	R	T	ABC	No	1502.3, 1512.4, 1519.6, 1602.6, 1602.7(16.2.9)(*)
Fatty acid, C8-C10	Y	S/P	2	2G	Cont	No	-	-	Yes	R	T	ABC	No	1512.3, 1512.4, 1519., 1602.6, 1602.7(16.2.9)(*)
Fatty acids, essentially linear (C6-C18) 2-ethylhexyl ester	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
Ferric chloride solutions	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1511., 1519.6, 1602.7(16.2.9)(*)
Ferric nitrate/Nitric acid solution	Y	S/P	2	2G	Cont	No			NF	R	T	No	Yes	1511., 1519.
Fish oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Fluorosilicic acid (20-30%) in water solution	Y	S/P	3	1G	Cont	No	-	-	NF	R	T	No	Yes	1511., 1519.6,

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Formaldehyde solutions (45% or less)	Y	S/P	3	2G	Cont	No	T2	IIB	No	R	F-T	A	Yes	1519.6, 1602.7(16.2.9)(*)
Formamide	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Formic acid	Y	S/P	3	2G	Cont	No	T1	IIA	No	R	T(g)	A	Yes	1511.2 to 1511.4, 1511.6 to 1511.8, 1519.6, 1602.7(16.2.9)(*)
Furfural	Y	S/P	3	2G	Cont	No	T2	IIB	No	R	F-T	A	No	1519.6
Furfuryl alcohol	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Glucitol/glycerol blend propoxylated (containing less than 10% amines)	Z	S/P	3	2G	Cont	No	-	-	Yes	R	T	ABC	No	1512.3, 1512.4, 1519.6
Glutaraldehyde solutions (50% or less)	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6
Glycerol monooleate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Glycerol propoxylated	Z	S/P	3	2G	Cont	No	-	-	Yes	R	T	ABC	No	1512.3, 1512.4, 1519.6
Glycerol propoxylated and ethoxylated	Z	P	3	2G	Open	No	-	-	Yes	O	No	ABC	No	
Glycerol/sucrose blend propoxylated and ethoxylated	Z	P	3	2G	Open	No	-	-	Yes	O	No	ABC	No	
Glyceryl triacetate	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Glycidyl ester of C10 trialkylacetic acid	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Glycine, sodium salt solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Glycolic acid solution (70% or less)	Z	S/P	3	2G	Open	No	-	-	NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Glyoxal solution (40% or less)	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Glyoxylic acid solution (50 % or less)	Y	S/P	3	2G	Open	No	-	-	Yes	O	No	ACD	No	1511.2, 1511.3, 1511.4, 1511.6, 1511.7, 1511.8, 1519.6, 1602.7(16.2.9)(*), 1606.1, 1606.2, 1606.3
Glyphosate solution (not containing surfactant)	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Groundnut oil	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Heptane (all isomers)	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
n-Heptanoic acid	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Heptanol (all isomers) (d)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Heptene (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Heptyl acetate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
1-Hexadecylnaphthalene / 1,4-bis(hexadecyl)naphthalene mixture	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Hexamethylenediamine adipate (50% in water)	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Hexamethylenediamine (molten)	Y	S/P	2	2G	Cont	No			Yes	C	T	C	Yes	1512., 1517., 1518., 1519.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Hexamethylenediamine solution	Y	S/P	3	2G	Cont	No			Yes	R	T	A	No	1519.6
Hexamethylene diisocyanate	Y	S/P	2	1G	Cont	Dry	T1	IIB	Yes	C	T	AC (b)D	Yes	1512., 1517., 1516.1(15.16.2)(*), 1518., 1519.
Hexamethylene glycol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Hexamethyleneimine	Y	S/P	2	2G	Cont	No			No	R	F-T	AC	No	1519.6
Hexane (all isomers)	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
1,6-Hexanediol, distillation overheads	Y	S/P	3	2G	Cont	No	-	-	Yes	O	No	A	No	1512.3, 1512.4, 1519.6, 1602.7(16.2.9)(*)
Hexanoic acid	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
Hexanol	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
Hexene (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Hexyl acetate	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Hydrochloric acid	Z	S/P	3	1G	Cont	No			NF	R	T	No	Yes	1511.
Hydrogen peroxide solutions (over 60% but not over 70% by mass)	Y	S/P	2	2G	Cont	No			NF	C	No	No	No	1505.1, 1519.6
Hydrogen peroxide solutions(over 8% but not over 60% by mass)	Y	S/P	3	2G	Cont	No			NF	C	No	No	No	1505.2, 1518., 1519.6
2-Hydroxyethyl acrylate	Y	S/P	2	2G	Cont	No			Yes	C	T	A	No	1512., 1513., 1519.6, 1606.1, 1606.2
N-(Hydroxyethyl)ethylenediaminetriacetic acid, trisodium salt solution	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
2-Hydroxy-4-(methylthio)butanoic acid	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Illipe oil	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Isoamyl alcohol	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Isobutyl alcohol	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Isobutyl formate	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Isobutyl methacrylate	Z	P	3	2G	Cont	No	-	-	No	R	F	A	No	1512., 1513., 1517., 1606.1, 1606.2
Isophorone	Y	S/P	3	2G	Cont	No			Yes	R	No	A	No	1519.6
Isophoronediamine	Y	S/P	3	2G	Cont	No			Yes	R	T	A	No	1602.7(16.2.9)(*)
Isophorone diisocyanate	X	S/P	2	2G	Cont	Dry			Yes	C	T	ABD	No	1512., 1516.1(15.16.2)(*), 1517., 1519.6
Isoprene	Y	S/P	3	2G	Cont	No	T3	IIB	No	R	F	B	No	1513., 1514., 1519.6, 1606.1, 1606.2
Isopropanolamine	Y	S/P	3	2G	Open	No	T2	IIA	Yes	O	F-T	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Isopropyl acetate	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Isopropylamine	Y	S/P	2	2G	Cont	No	T2	IIA	No	C	F-T	CD	Yes	1512., 1514., 1519.
Isopropylamine(70% or less) solution	Y	S/P	2	2G	Cont	No			No	C	F-T	CD	Yes	1512., 1519.6, 1602.7(16.2.9)(*)
Isopropylcyclohexane	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Isopropyl ether	Y	S/P	3	2G	Cont	Inert			No	R	F	A	No	1504.6, 1513.3, 1519.6

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Lactic acid	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Lactonitrile solution (80% or less)	Y	S/P	2	1G	Cont	No			Yes	C	T	ACD	Yes	1512., 1513., 1517. to 1519., 1606.1, 1606.2, 1606.3
Lard	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Latex, ammonia(1% or less) inhibited	Y	S/P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Latex: Carboxylated styrene-Butadiene copolymer; Styrene-Butadiene rubber	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Lauric acid	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Ligninsulphonic acid, sodium salt solution	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Linseed oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Liquid chemical wastes	X	S/P	2	2G	Cont	No			No	C	F-T	A	Yes	1512., 1519.6, 2005.1
Long-chain alkaryl polyether (C11-C20)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Long-chain alkaryl sulphonic acid(C16-C60)	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Long-chain alkylphenate/Phenol sulphide mixture	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
L-Lysine solution (60% or less)	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Magnesium chloride solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Magnesium long-chain alkaryl sulphonate(C11-C50)	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Magnesium long-chain alkyl salicylate(C11+)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Maleic anhydride	Y	S/P	3	2G	Cont	No			Yes	R	No	AC (f)	No	1602.7(16.2.9)(*)
Mango kernel oil	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Mercaptobenzothiazol, sodium salt solution	X	S/P	2	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Mesityl oxide	Z	S/P	3	2G	Cont	No	T2	IIB	No	R	F-T	A	No	1519.6
Metam sodium solution	X	S/P	1	2G	Open	No			NF	O	No	No	No	1519., 1602.7(16.2.9)(*)
Methacryclic acid - alkoxypoly (alkylene oxide) methacrylate copolymer, sodium salt aqueous solution (45% or less)	Z	S/P	3	2G	Open	No	-	-	NF	O	No	AC	No	1602.7(16.2.9)(*)
Methacrylic acid	Y	S/P	3	2G	Cont	No			Yes	R	T	A	No	1513., 1519.6, 1602.7(16.2.9)(*), 1606.1

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Methacrylic resin in Ethylene dichloride	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	AB	No	1519., 1602.7(16.2.9)(*)
Methacrylonitrile	Y	S/P	2	2G	Cont	No			No	C	F-T	A	Yes	1512., 1513., 1517., 1519.
3-Methoxy-1-butanol	Z	P	3	2G	Cont	No			No	R	F	A	No	
3-Methoxybutyl acetate	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
N-(2-Methoxy-1-methyl ethyl)-2-ethyl-6-methyl chloroacetanilide	X	P	1	2G	Open	No			Yes	O	No	A	No	1519., 1602.6
Methyl acetate	Z	P	3	2G	Cont	No			No	R	F	A	No	
Methyl acetoacetate	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Methyl acrylate	Y	S/P	2	2G	Cont	No	T1	IIB	No	R	F-T	A	Yes	1513., 1519.6, 1606.1, 1606.2
Methyl alcohol	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Methylamine solutions (42% or less)	Y	S/P	2	2G	Cont	No			No	C	F-T	ACD	Yes	1512., 1517., 1519.
Methylamyl acetate	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Methylamyl alcohol	Z	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Methyl amyl ketone	Z	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Methylbutenol	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Methyl tert-butyl ether	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Methyl butyl ketone	Y	P	3	2G	Cont	No			No	R	F	AB	No	1519.6
Methylbutynol	Z	P	3	2G	Cont	No			No	R	F	A	No	
Methyl butyrate	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Methylcyclohexane	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Methylcyclopentadiene dimer	Y	P	2	2G	Cont	No			No	R	F	B	No	1519.6
Methylcyclopentadienyl manganese tricarbonyl	X	S/P	1	1G	Cont	No	-	-	Yes	C	T	ABCD	Yes	1512., 1518., 1519., 1602.7(16.2.9)(*)
Methyl diethanolamine	Y	S/P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
2-Methyl-6-ethyl aniline	Y	S/P	3	2G	Open	No			Yes	O	No	AD	No	1519.6
Methyl ethyl ketone	Z	P	3	2G	Cont	No			No	R	F	A	No	
2-Methyl-5-ethyl pyridine	Y	S/P	3	2G	Open	No		IIA	Yes	O	No	AD	No	1519.6
Methyl formate	Z	S/P	2	2G	Cont	No			No	R	F-T	A	Yes	1512., 1514., 1519.
2-Methyl-2-hydroxy-3-butyne	Z	S/P	3	2G	Cont	No		IIA	No	R	F-T	ABD	No	1519.6, 1602.7(16.2.9)(*)
Methyl isobutyl ketone	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Methyl methacrylate	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	A	No	1513., 1519.6, 1606.1, 1606.2
3-Methyl-3-methoxybutanol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Methyl naphthalene (molten)	X	S/P	2	2G	Cont	No			Yes	R	No	AD	No	1519.6
2-Methyl-1,3-propanediol	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
2-Methylpyridine	Z	S/P	2	2G	Cont	No			No	C	F	A	No	1512.3, 1519.6
3-Methylpyridine	Z	S/P	2	2G	Cont	No			No	C	F	AC	No	1512.3, 1519.
4-Methylpyridine	Z	S/P	2	2G	Cont	No			No	C	F-T	A	No	1512.3, 1519., 1602.7(16.2.9)(*)
N-Methyl-2-pyrrolidone	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Methyl salicylate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
alpha-Methylstyrene	Y	S/P	2	2G	Cont	No	T1	IIB	No	R	F-T	AD (j)	No	1513., 1519.6, 1606.1, 1606.2
3-(methylthio)propionaldehyde	Y	S/P	2	2G	Cont	No	T3	IIA	No	C	F-T	BC	Yes	1512., 1517., 1519.
Molybdenum polusulfide long chain alkyl dithiocarbamide complex	Y	S/P	2	2G	Cont	No	-	-	Yes	C	T	ABC	Yes	1512., 1517., 1519., 1602.6, 1602.7(16.2.9)(*)
Morpholine	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F	A	No	1519.6
Motor fuel anti-knock compounds (containing lead alkyls)	X	S/P	1	1G	Cont	No	T4	IIA	No	C	F-T	AC	Yes	1506., 1512., 1518., 1519.
Myrcene	X	P	2	2G	Cont	No	-	-	No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Naphthalene (molten)	X	S/P	2	2G	Cont	No	T1	IIA	Yes	R	No	AD	No	1519.6, 1602.7(16.2.9)(*)
Naphthalenesulphonic acid-Formaldehyde copolymer, sodium salt solution	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Neodecanoic acid	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Nitrating acid (mixture of sulphuric and nitric acids)	Y	S/P	2	2G	Cont	No			NF	C	T	No	Yes	1511., 1516.1(15.16.2)(*), 1517., 1519.
Nitric acid (70% and over)	Y	S/P	2	2G	Cont	No			NF	C	T	No	Yes	1511., 1519.
Nitric acid (less than 70%)	Y	S/P	2	2G	Cont	No			NF	R	T	No	Yes	1511., 1519.
Nitrilotriacetic acid, trisodium salt solution	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
Nitrobenzene	Y	S/P	2	2G	Cont	No	T1	IIA	Yes	C	T	AD	No	1512., 1517. to 1519., 1602.7(16.2.9)(*)
Nitroethane	Y	S/P	3	2G	Cont	No		IIB	No	R	F-T	A(f)	No	1519.6, 1606.1, 1606.2, 1606.4
Nitroethane(80%)/Nitropropane(20%)	Y	S/P	3	2G	Cont	No		IIB	No	R	F-T	A(f)	No	1519.6, 1606.1 to 1606.3
Nitroethane, 1-Nitropropane (each 15% or more) mixture	Y	S/P	3	2G	Cont	No	-	-	No	R	F	A	No	1519.6, 1602.6, 1606.1, 1606.2, 1606.3
o-Nitrophenol (molten)	Y	S/P	2	2G	Cont	No			Yes	C	T	AD	No	1512., 1519.6, 1602.6, 1602.7(16.2.9)(*)
1-or 2-Nitropropane	Y	S/P	3	2G	Cont	No	T2	IIB	No	R	F-T	A	No	1519.6
Nitropropane (60%)/Nitroethane (40%) mixture	Y	S/P	3	2G	Cont	No			No	R	F-T	A(f)	No	1519.6
o- or p-Nitrotoluenes	Y	S/P	2	2G	Cont	No		IIB	Yes	C	T	AB	No	1512., 1517., 1519.6
Nonane (all isomers)	X	P	2	2G	Cont	No			No	R	F	BC	No	1519.6
Nonanoic acid (all isomers)	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Non-edible industrial grade palm oil	Y	S/P	2	2G	Cont	No	-	-	Yes	R	No	ABC	No	1512.3, 1512.4, 1519.6, 1602.6, 1602.7(16.2.9)(*)
Nonene (all isomers)	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Nonyl alcohol (all isomers)	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Nonyl methacrylate monomer	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Nonylphenol	X	P	1	2G	Open	No			Yes	O	No	A	No	1519., 1602.6, 1602.7(16.2.9)(*)
Nonylphenol poly(4+) ethoxylate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Noxious liquid,NF,(1) n.o.s.(trade name..., contains...)ST1,Cat.X	X	P	1	2G	Open	No	-	-	Yes	O	No	A	No	1519., 1602.6
Noxious liquid,F,(2) n.o.s.(trade name..., contains...)ST1,Cat.X	X	P	1	2G	Cont	No	T3	IIA	No	R	F	A	No	1519., 1602.6
Noxious liquid,NF,(3) n.o.s.(trade name..., contains...)ST2,Cat.X	X	P	2	2G	Open	No	-		Yes	O	No	A	No	1519., 1602.6
Noxious liquid,F,(4) n.o.s.(trade name..., contains...)ST2,Cat.X	X	P	2	2G	Cont	No	T3	IIA	No	R	F	A	No	1519., 1602.6
Noxious liquid,NF,(5) n.o.s.(trade name..., contains...)ST2,Cat.Y	Y	P	2	2G	Open	No	-		Yes	O	No	A	No	1519., 1602.6, 1602.7(16.2.9)(*)(l)
Noxious liquid,F,(6) n.o.s.(trade name..., contains...)ST2,Cat.Y	Y	P	2	2G	Cont	No	T3	IIA	No	R	F	A	No	1519., 1602.6, 1602.7(16.2.9)(*)(l)
Noxious liquid,NF,(7) n.o.s.(trade name..., contains...)ST3,Cat.Y	Y	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519., 1602.6, 1602.7(16.2.9)(*)(l)
Noxious liquid,F,(8) n.o.s.(trade name..., contains...)ST3,Cat.Z	Y	P	3	2G	Cont	No	T3	IIA	No	R	F	A	No	1519., 1602.6, 1602.7(16.2.9)(*)(l)
Noxious liquid,NF,(9) n.o.s.(trade name..., contains...)ST3,Cat.Z	Z	P	3	2G	Open	No	-		Yes	O	No	A	No	
Noxious liquid,F,(10) n.o.s.(trade name..., contains...)ST3,Cat.Z	Z	P	3	2G	Cont	No	T3	IIA	No	R	F	A	No	
Octane (all isomers)	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Octanoic acid (all isomers)	Y	P	3	2G	Open	No	-	-	Yes	O	No	AB	No	1519.6
Octanol (all isomers)	Y	P	2	2G	Open	No			Yes	O	No	A	No	
Octene (all isomers)	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
n-Octyl acetate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Octyl aldehydes	Y	P	3	2G	Cont	No	-	-	No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Octyl decyl adipate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Olefin-Alkyl ester copolymer (molecular weight 2000+)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Olefin mixtures(C5-C7)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Olefin mixtures(C5-C15)	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Olefins (C13+, all isomers)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
alpha-Olefins(C6-C18) mixtures	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Oleic acid	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Oleum	Y	S/P	2	2G	Cont	No			NF	C	T	No	Yes	1511.2 to 1511.8, 1512.1, 1516.1(15.16.2)(*), 1517., 1519., 1602.6
Oleylamine	X	S/P	2	2G	Cont	No			Yes	R	T	A	No	1519.6, 1602.7(16.2.9)(*)
Olive oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Oxygenated aliphatic hydrocarbon mixture	Z	S/P	3	2G	Open	No	-	-	Yes	O	No	ABC	No	
Palm acid oil	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm fatty acid oil distillate	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm kernel acid oil	Y	S/P	2	2G	Open	No			Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm kernel oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm kernel olein	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm kernel stearin	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm mid-fraction	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm oil fatty acid methyl ester	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Palm olein	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Palm stearin	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Paraffin wax	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Paraldehyde	Z	S/P	3	2G	Cont	No	T3	IIB	No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Paraldehyde-ammonia reaction product	Y	S/P	2	2G	Cont	No			No	C	F-T	A	No	1512.3, 1519.
Pentachloroethane	Y	S/P	2	2G	Cont	No			NF	R	T	No	No	1512., 1517., 1519.6
1,3-Pentadiene	Y	P	3	2G	Cont	No			No	R	F-T	AB	No	1513., 1519.6, 1606.1 to 1606.3
Pentaethylenehexamine	X	S/P	2	2G	Open	No			Yes	O	No	B	Yes	1519.
Pentane (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1514., 1519.6
Pentanoic acid	Y	P	3	2G	Open	No			Yes	O	No	AB	No	1519.6
n-Pentanoic acid (64%)/2-Methyl butyric acid (36%) mixture	Y	S/P	2	2G	Open	No	T2		Yes	C	No	AD	No	1511.2 to 1511.4, 1511.6 to 1511.8, 1512.3, 1519.
Pentene (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1514., 1519.6
n-Pentyl propionate	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Perchloroethylene	Y	S/P	2	2G	Cont	No			NF	R	T	No	No	1512.1, 1512.2, 1519.6
Petrolatum	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Phenol	Y	S/P	2	2G	Cont	No	T1	IIA	Yes	C	T	A	No	1512., 1519., 1602.7(16.2.9)(*)
1-Phenyl-1-xylyl ethane	Y	P	3	2G	Open	No			Yes	O	No	AB	No	
Phosphate esters, alkyl (C12-C14)amine	Y	P	2	2G	Cont	No	-	-	N	R	F	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Phosphoric acid	Z	S/P	3	2G	Open	No			NF	O	No	No	No	1511.1 to 1511.4, 1511.6 to 1511.8, 1602.7(16.2.9)(*)
Phosphorous, yellow or white	X	S/P	1	1G	Cont	Pad+ (vent or inert)			No (c)	C	No	C	Yes	1507., 1519., 1602.7(16.2.9)(*)
Phthalic anhydride (molten)	Y	S/P	2	2G	Cont	No	T1	IIA	Yes	R	No	AD	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
alpha-Pinene	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
beta-Pinene	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Pine oil	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyacrylic acid solution (40% or less)	Z	S/P	3	2G	Open	No	-	-	Yes	O	No	AC	No	
Polyalkyl (C18-C22) acrylate in xylene	Y	P	2	2G	Cont	No			No	R	F	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Poly(2-8)alkylene glycol monoalkyl (C1-C6) ether	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Poly(2-8)alkylene glycol monoalkyl (C1-C6) ether acetate	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Polyalkyl (C10-C20) methacrylate	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyalkyl (C10-C18) methacrylate/ethylene-propylene copolymer mixture	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polybutene	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Polybutenyl succinimide	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Poly(2+)cyclic aromatics	X	P	1	2G	Cont	No			Yes	R	No	AD	No	1519., 1602.6, 1602.7(16.2.9)(*)
Polyethyler (molecular weight 1350+)	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6
Polyethylene glycol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Polyethylene glycol dimethyl ether	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Polyethylene polyamines	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Polyethylene polyamines (more than 50% C5-C20 paraffin oil)	Y	S/P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Polyferric sulphate solution	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6
Poly(iminoethylene)-graft-N-poly(ethyleneoxy) solution (90% or less)	Z	S/P	3	2G	Open	No	-	-	NF	O	No	AC	No	1602.7(16.2.9)(*)

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Polyisobutenamine in aliphatic (C10-C14) solvent	Y	P	3	2G	Open	No	T3	IIA	Yes	O	No	A	No	1519.6
Polyisobutenyl anhydride adduct	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Poly(4+)isobutylene	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Polymethylene polyphenyl isocyanate	Y	S/P	2	2G	Cont	Dry			Yes (a)	C	T(a)	A	No	1512., 1516.1(15.16.2)(*), 1519.6, 1602.7(16.2.9)(*)
Polyolefin (molecular weight 300+)	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefin amide alkeneamine (C17+)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Polyolefin amide alkeneamine borate (C28-C250)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefinamine (C28-C250)	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Polyolefinamine in alkyl (C2-C4) benzenes	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefinamine in aromatic solvent	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefin aminoester salts (molecular weight 2000+)	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefin anhydride	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefin ester (C28-C250)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefin phenolic amine (C28-C250)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Polyolefin phosphorosulphide, barium derivative (C28-C250)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Poly(20)oxyethylene sorbitan monooleate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Poly(5+) propylene	Y	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Polypropylene glycol	Z	S/P	3	2G	Cont	No			Yes	O	No	ABC	No	1519.6
Polysiloxane	Y	P	3	2G	Cont	No			No	R	F	AB	No	1519.6, 1602.7(16.2.9)(*)
Potassium chloride solution(10% or more)	Z	S/P	3	2G	Open	No	-	-	NF	O	No	A	No	1602.7(16.2.9)(*)
Potassium hydroxide solution	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6
Potassium oleate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Potassium thiosulphate (50% or less)	Y	P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
n-Propanolamine	Y	S/P	3	2G	Open	No			Yes	O	No	AD	No	1519.6, 1602.7(16.2.9)(*)
beta-Propiolactone	Y	S/P	2	2G	Cont	No		IIA	Yes	R	T	A	No	1519.6
Propionaldehyde	Y	S/P	3	2G	Cont	No			No	R	F-T	A	Yes	1517., 1519.6
Propionic acid	Y	S/P	3	2G	Cont	No	T1	IIA	No	R	F	A	Yes	1511.2 to 1511.4, 1511.6 to 1511.8, 1519.6
Propionic anhydride	Y	S/P	3	2G	Cont	No	T2	IIA	Yes	R	T	A	No	1519.6

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Propionitrile	Y	S/P	2	1G	Cont	No	T1	IIB	No	C	F-T	AD	Yes	1512., 1517. to 1519.
n-Propyl acetate	Y	P	3	2G	Cont	No			No	R	F	AB	No	1519.6
n-propyl alcohol	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
n-Propylamine	Z	S/P	2	2G	Cont	Inert	T2	IIA	No	C	F-T	AD	Yes	1512., 1519.
Propylbenzene (all isomers)	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Propylene glycol methyl ether acetate	Z	P	3	2G	Cont	No			No	R	F	A	No	
Propylene glycol monoalkyl ether	Z	P	3	2G	Cont	No			No	R	F	AB	No	
Propylene glycol phenyl ether	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Propylene oxide	Y	S/P	2	2G	Cont	Inert	T2	IIB	No	C	F-T	AC	No	1508., 1512.1, 1514., 1519.
Propylene tetramer	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Propylene trimer	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Pyridine	Y	S/P	2	2G	Cont	No	T1	IIA	No	R	F	A	No	1519.6
Pyrolysis gasoline(containing benzene)	Y	S/P	2	2G	Cont	No	T3	IIA	No	C	F-T	AB	No	1512., 1517., 1519.6
Rapeseed oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Rapeseed oil (low erucic acid containing less than 4% free fatty acids)	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Rape seed oil fatty acid methyl esters	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6
Resin oil, distilled	Y	S/P	2	2G	Cont	No	T1	IIA	No	C	F-T	ABC	No	1512., 1517., 1519.6
Rice bran oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Rosin	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Safflower oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Shea butter	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Sodium alkyl(C14-C17) sulphonates (60-65% solution)	Y	P	2	2G	Open	No			NF	O	No	No	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Sodium aluminosilicate slurry	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Sodium benzoate	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Sodium borohydride (15% or less)/Sodium hydroxide solution	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Sodium carbonate solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Sodium chlorate solution (50% or less)	Z	S/P	3	2G	Open	No			NF	O	No	No	No	1509., 1519.6, 1602.7(16.2.9)(*)
Sodium dichromate solution (70% or less)	Y	S/P	2	2G	Open	No			NF	C	No	No	No	1512.3, 1519.

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Sodium hydrogen sulphide (6% or less)/Sodium carbonate (3% or less) solution	Z	P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Sodium hydrogen sulphite solution (45% or less)	Z	S/P	3	2G	Open	No			NF	O	No	No	No	1602.7(16.2.9)(*)
Sodium hydrosulphide/Ammonium sulphide solution	Y	S/P	2	2G	Cont	No			No	C	F-T	A	Yes	1512., 1514., 1517., 1519., 1606.1 to 1606.3
Sodium hydrosulphide solution (45% or less)	Z	S/P	3	2G	Cont	Vent or pad (gas)			NF	R	T	No	No	1519.6, 1602.7(16.2.9)(*)
Sodium hydroxide solution	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Sodium hypochlorite solution (15% or less)	Y	S/P	2	2G	Cont	No	-	-	NF	R	No	No	No	1519.6
Sodium nitrite solution	Y	S/P	2	2G	Open	No			NF	O	No	No	No	1512.3(1), 1512.3(2), 1519., 1602.7(16.2.9)(*)
Sodium petroleum sulphonate	Y	S/P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
Sodium poly(4+) acrylate solutions	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	1602.7(16.2.9)(*)
Sodium silicate solution	Y	P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Sodium sulphide solution (15% or less)	Y	S/P	3	2G	Cont	No			NF	C	T	No	No	1519.6, 1602.7(16.2.9)(*)
Sodium sulphite solution (25% or less)	Y	P	3	2G	Open	No			NF	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Sodium thiocyanate solution (56% or less)	Y	P	3	2G	Open	No			Yes	O	No	No	No	1519.6, 1602.7(16.2.9)(*)
Soyabean oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Styrene monomer	Y	S/P	3	2G	Cont	No	T1	IIA	No	R	F	AB	No	1513., 1519.6, 1606.1, 1606.2
Sulphohydrocarbon(C3-C88)	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Sulpholane	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Sulphur (molten)	Z	S	3	1G	Open	Vent or pad (gas)	T3		Yes	O	F-T	No	No	1510., 1602.7(16.2.9)(*)
Sulphuric acid	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1511., 1516.1(15.16.2)(*), 1519.6
Sulphuric acid, spent	Y	S/P	3	2G	Open	No			NF	O	No	No	No	1511., 1516.1(15.16.2)(*), 1519.6
Sulphurized fat (C14-C20)	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Sulphurized polyolefinamide alkene (C28-C250) amine	Z	P	3	2G	Open	No	-	-	Yes	O	No	A	No	
Sunflower seed oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)

a	c	d	e	f	g	h	i'	i"	i"'	j	k	l	n	o
Tall oil, crude	Y	S/P	2	2G	Cont	No	-	-	Yes	C	T	ABC	Yes	1512., 1517., 1519., 1602.6
Tall oil, distilled	Y	P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6
Tall oil fatty acid(resin acids less than 20%)	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6
Tall oil pitch	Y	S/P	2	2G	Cont	No	-	-	Yes	C	T	ABC	Yes	1512., 1517., 1519., 1602.6, 1602.7(16.2.9)(*)
Tallow	Y	P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Tallow fatty acid	Y	P	2	2G	Open	No	-	-	Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Tetrachloroethane	Y	S/P	2	2G	Cont	No			NF	R	T	No	No	1512., 1517., 1519.6
Tetraethylene glycol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Tetraethylene pentamine	Y	S/P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Tetrahydrofuran	Z	S	3	2G	Cont	No	T3	IIB	No	R	F-T	A	No	1519.6
Tetrahydronaphthalene	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Tetramethylbenzene (all isomers)	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Titanium dioxide slurry	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
Toluene	Y	P	3	2G	Cont	No			No	R	F	A	No	1519.6
Toluenediamine	Y	S/P	2	2G	Cont	No			Yes	C	T	AD	Yes	1512., 1517., 1519., 1602.6, 1602.7(16.2.9)(*)
Toluene diisocyanate	Y	S/P	2	2G	Cont	Dry	T1	IIA	Yes	C	F-T	AC (b)D	Yes	1512., 1516.1(15.16.2)(*), 1517., 1519., 1602.7(16.2.9)(*)
o-Toluidine	Y	S/P	2	2G	Cont	No			Yes	C	T	A	No	1512., 1517., 1519.
Tributyl phosphate	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
1,2,3-Trichlorobenzene (molten)	X	S/P	1	2G	Cont	No			Yes	C	T	ACD	Yes	1512.1, 1517., 1519., 1602.6, 1602.7(16.2.9)(*)
1,2,4-Trichlorobenzene	X	S/P	1	2G	Cont	No			Yes	R	T	AB	No	1519., 1602.7(16.2.9)(*)
1,1,1-Trichloroethane	Y	P	3	2G	Open	No			Yes	O	No	A	No	1519.6
1,1,2-Trichloroethane	Y	S/P	3	2G	Cont	No			NF	R	T	No	No	1512.1, 1519.6
Trichloroethylene	Y	S/P	2	2G	Cont	No	T2	IIA	Yes	R	T	No	No	1512., 1517., 1519.6
1,2,3-Trichloropropane	Y	S/P	2	2G	Cont	No			Yes	C	T	ABD	No	1512., 1517., 1519.
1,1,2-Trichloro-1,2,2-Trifluoroethane	Y	P	2	2G	Open	No			NF	O	No	No	No	1519.6
Tricresyl phosphate (containing 1% or more ortho-isomer)	Y	S/P	1	2G	Cont	No	T2	IIA	Yes	C	No	AB	No	1512.3, 1519., 1602.6
Tricresyl phosphate (containing less than 1% ortho-isomer)	Y	S/P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
Tridecane	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6
Tridecanoic acid	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Tridecyl acetate	Z	P	3	2G	Open	No	-	-	Yes	O	No	AB	No	1519.6
Triethanolamine	Z	S/P	3	2G	Open	No		IIA	Yes	O	No	A	No	1602.7(16.2.9)(*)
Triethylamine	Y	S/P	2	2G	Cont	No	T2	IIA	No	R	F-T	AC	Yes	1512., 1519.6

a	c	d	e	f	g	h	i'	i''	i'''	j	k	l	n	o
Triethylbenzene	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Triethylenetetramine	Y	S/P	2	2G	Open	No	T2	IIA	Yes	O	No	A	No	1519.6
Triethyl phosphate	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Triethylphosphite	Z	S/P	3	2G	Cont	No			No	R	F-T	AB	No	1512.1, 1519.6, 1602.7(16.2.9)(*)
Triisopropanolamine	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Triisopropylated phenyl phosphates	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
Trimethylacetic acid	Y	S/P	2	2G	Cont	No			Yes	R	No	A	No	1511.2 to 1511.8, 1519.6, 1602.6, 1602.7(16.2.9)(*)
Trimethylamine solution (30% or less)	Z	S/P	2	2G	Cont	No			No	C	F-T	AC	Yes	1512., 1514., 1519., 1602.7(16.2.9)(*)
Trimethylbenzene (all isomers)	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Trimethylol propane propoxylated	Z	S/P	3	2G	Open	No	-	-	Yes	O	No	ABC	No	
2,2,4-Trimethyl-1,3-pentane diol diisobutyrate	Z	P	3	2G	Open	No			Yes	O	No	AB	No	
2,2,4-Trimethyl-1,3-pentane diol-1-isobutyrate	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
1,3,5-Trioxane	Y	S/P	3	2G	Cont	No			No	R	F	AD	No	1519.6, 1602.7(16.2.9)(*)
Tripropylene glycol	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Trixylyl phosphate	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.6
Tung oil	Y	S/P	2 (k)	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Turpentine	X	P	2	2G	Cont	No			No	R	F	A	No	1519.6
Undecanoic acid	Y	P	2	2G	Open	No			Yes	O	No	A	No	1602.6, 1602.7(16.2.9)(*)
1-Undecene	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Undecyl alcohol	X	P	2	2G	Open	No			Yes	O	No	A	No	1519.6, 1602.7(16.2.9)(*)
Urea/Ammonium nitrate solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Urea/Ammonium nitrate solution (containing less than 1% free ammonia)	Z	S/P	3	2G	Cont	No			NF	R	T	A	No	1602.7(16.2.9)(*)
Urea/Ammonium phosphate solution	Y	P	2	2G	Open	No			Yes	O	No	A	No	1519.6
Urea solution	Z	P	3	2G	Open	No			Yes	O	No	A	No	
Valeraldehyde (all isomers)	Y	S/P	3	2G	Cont	Inert	T3	IIB	No	R	F-T	A	No	1504.6, 1519.6
Vegetable acid oil (m)	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Vegetable fatty acid distillates (m)	Y	S/P	2	2G	Open	No	-	-	Yes	O	No	ABC	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Vinyl acetate	Y	S/P	3	2G	Cont	No	T2	IIA	No	R	F	A	No	1513., 1519.6, 1606.1, 1606.2
Vinyl ethyl ether	Z	S/P	2	1G	Cont	Inert	T3	IIB	No	C	F-T	A	Yes	1504., 1513., 1514., 1519., 1606.1, 1606.2
Vinylidene chloride	Y	S/P	2	2G	Cont	Inert	T2	IIA	No	R	F-T	B	Yes	1513., 1514., 1519.6, 1606.1, 1606.2

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Vinyl neodecanoate	Y	S/P	2	2G	Open	No			Yes	O	No	AB	No	1513., 1519.6, 1606.1, 1606.2
Vinyltoluene	Y	S/P	2	2G	Cont	No		IIA	No	R	F	AB	No	1513., 1519.6, 1606.1, 1606.2
Waxes	Y	P	2	2G	Open	No	-	-	Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
White spirit, low(15-20%) aromatic	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)
Xylenes	Y	P	2	2G	Cont	No			No	R	F	A	No	1519.6, 1602.7(16.2.9)(*)(h)
Xylenes/ethylbenzene (10% or more) mixture	Y	P	2	2G	Cont	No	-	-	No	R	F	A	No	1519.6
Xylenol	Y	S/P	2	2G	Open	No		IIA	Yes	O	No	AB	No	1519.6, 1602.7(16.2.9)(*)
Zinc alkaryl dithiophosphate (C7-C16)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6, 1602.7(16.2.9)(*)
Zinc alkenyl carboxamide	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6
Zinc alkyl dithiophosphate (C3-C14)	Y	P	2	2G	Open	No			Yes	O	No	AB	No	1519.6, 1602.6

Notes ;

Subindex (a)	If the product to be carried contains flammable solvents such that the flashpoint does not exceed 60℃, then special electrical systems and a flammable-vapour detector shall be provided.
Subindex (b)	Although water is suitable for extinguishing open-air fires involving chemicals to which this footnote applies, water shall not be allowed to contaminate closed tanks containing these chemicals because of the risk of hazardous gas generation.
Subindex (c)	Phosphorus, yellow or white is carried above its autoignition temperature and therefore flashpoint is not appropriate. Electrical equipment requirements may be similar to those for substances with a flashpoint above 60℃.
Subindex (d)	Requirements are based on those isomers having a flashpoint of 60℃, or less; some isomers have a flashpoint greater than 60℃, and therefore the requirements based on flammability would not apply to such isomers.
Subindex (e)	Applies to n-decyl alcohol only.
Subindex (f)	Dry chemical shall not be used as fire extinguishing media
Subindex (g)	Confined spaces shall be tested for both formic acid vapours and carbon monoxide gas, a decomposition product.
Subindex (h)	Applies to p-xylene only.
Subindex (i)	For mixtures containing no other components with safety hazards and where the pollution category is Y or less
Subindex (j)	Only certain alcohol-resistant foams are effective
Subindex (k)	Requirements for Ship Type identified in column e might be subject to regulation 4.1.3 of Annex II of MARPOL 73/78
Subindex (l)	Applicable when the melting point is equal to or greater than 0°C.
Subindex (m)	From vegetable oils specified in the IBC Code.
Subindex (*)	The number in a parenthesis in the column "o" is the number of IBC Code equivalent to the number of this regulation.

Annex 7B-2 List of products to which the Code does not apply

Product name	Pollution Category
Acetone	Z
Alcoholic beverages, n.o.s.	Z
Apple juice	OS
n-Butyl alcohol	Z
sec-Butyl alcohol	Z
Calcium nitrate solutions (50% or less)	Z
Clay slurry	OS
Coal slurry	OS
Diethylene glycol	Z
Ethyl alcohol	Z
Ethylene carbonate	Z
Glucose solution	OS
Glycerine	Z
Hexamethylenetetramine solutions	Z
Hexylene glycol	Z
Hydrogenated starch hydrolysate	OS
Isopropyl alcohol	Z
Kaolin slurry	OS
Lecithin	OS
Magnesium hydroxide slurry	Z
Maltitol solution	OS
N-Methylglucamine solution (70% or less)	Z
Methyl propyl ketone	Z
Molasses	OS
Noxious liquid, (11) n.o.s. (trade name ...., contains ....) Cat. Z	Z
Non-noxious liquid, (12) n.o.s. (trade name ...., contains ....) Cat. OS	OS
Polyaluminium chloride solution	Z
Polyglycerin, sodium salt solution (containing less than 3% sodium hydroxide)	Z
Potassium formate solutions	Z
Propylene carbonate	Z
Propylene glycol	Z
Sodium acetate solutions	Z
Sodium sulphate solutions	Z
Sorbitol solution	OS
Sulphonated polyacrylate solution	Z
Tetraethyl silicate monomer/oligomer (20% in ethanol)	Z
Triethylene glycol	Z
Vegetable protein solution (hydrolysed)	OS
Water	OS

Annex 7B-3 Index of Products Carried in Bulk

1. For the Chapter 19 of IBC Code, the first column of the Index of Products Carried in Bulk (hereafter referred to as .the Index.) provides the so called Index Name. Where the Index Name is in capital and in bold, the Index Name is identical to the Product Name in either chapter 17 or chapter 18. The second column listing the relevant Product Name is therefore empty. Where the Index Name is in non-bold lower case it reflects a synonym for which the Product Name in either chapter 17 or chapter 18 is given in the second column. The relevant chapter of the IBC Code is reflected in the third column. The fourth column gives the UN Numbers of products, which were available up to February 2001.

2. The Index has been developed for information purposes only. None of the Index Names indicated in non-bold lower case in the first column shall be used as Product Name on the shipping document.

3. Prefixes forming an integral part of the name are shown in ordinary (roman) type and are taken into account in determining the alphabetical order of entries. These include such prefixes as:

Mono Di Tri Tetra Penta Iso Bis Neo Ortho Cyclo

4. Prefixes that are disregarded for purposes of alphabetical order are in italics and include the following:

n- (normal-)

sec- (secondary-)

tert- (tertiary-)

o- (ortho-)

m- (meta-)

p- (para-)

N-

O-

sym- (symmetrical)

uns- (unsymmetrical)

dl-

cis-

trans-

(E)-

(Z)-

alpha- (α-)

beta- (β-)

gamma- (γ-)

epsilon- (ε-)

Annex 7B-4 Criteria for assigning carriage requirements for products subject to the IBC Code

101. Introduction

1. The following criteria are guidelines for the determination of pollution classification and assignment of appropriate carriage requirements for bulk liquid cargoes being considered as candidates for entry into the IBC Code or annexes 1, 3 or 4 of MEPC.2/Circs.

2. In developing such criteria, every effort has been made to follow the criteria and cut off points developed under the Global Harmonized System (GHS).

3. Although the criteria are intended to be closely defined in order to establish a uniform approach, it must be emphasized that these are guidelines only and, where human experience or other factors indicates the need for alternative arrangements, these shall always be taken into account. Where deviations from the criteria have been recognized, they shall be properly recorded with justifications.

102. Contents

This chapter contains the following:
(1) minimum safety and pollution criteria for products subject to chapter 17 of the IBC Code;
(2) criteria used to assign the minimum carriage requirements for products, which meet the safety or pollution criteria to make them subject to chapter 17 of the IBC Code;
(3) criteria used for special requirements in chapter 15 of the IBC Code to be included in column o of chapter 17 of the IBC Code;
(4) criteria used for special requirements in chapter 16 of the IBC Code to be included in column o of chapter 17 of the IBC Code; and
(5) definitions of properties used within this chapter.

103. Minimum safety and pollution criteria for products subject to chapter 17 of the IBC Code

Products are deemed to be hazardous and subject to chapter 17 of the IBC Code if they meet one or more of the following criteria:
(1) inhalation LC_{50} < 20 mg/l/4h (see definitions in paragraph 107.1(1));
(2) dermal LD_{50} < 2000 mg/kg (see definitions in paragraph 107.1(2));
(3) oral LD_{50} < 2000 mg/kg (see definitions in paragraph 107.1(3));
(4) toxic to mammals by prolonged exposure (see definitions in paragraph 2107.2);
(5) cause skin sensitization (see definitions in paragraph 107.3);
(6) cause respiratory sensitization (see definitions in paragraph 2107.4);
(7) corrosive to skin (see definitions in paragraph 107.5);
(8) have a Water Reactive Index (WRI) of > 1 (see definitions in paragraph 107.6);
(9) require inertion, inhibition, stabilization, temperature control or tank environmental control in order to prevent a hazardous reaction (see definitions in paragraph 107.10);
(10) flash point < 23℃; and have an explosive/flammability range (expressed as a percentage by volume in air) of > 20%;
(11) autoignition temperature of < 200℃; and
(12) classified as pollution category X or Y or meeting the criteria for rules 11 to 13 under paragraph 104.5(1).

104. Criteria used to assign the minimum carriage requirements for products, which meet the minimum safety or pollution criteria to make them subject to chapter 17 of the IBC Code

1. Column a - Product Name

The International Union of Pure and Applied Chemistry (IUPAC) name shall be used as far as possible but, where this is unnecessarily complex, then a technically correct and unambiguous alternative chemical name may be used.

2. Column b . Deleted

3. Column c - Pollution Category

Column c identifies the pollution category assigned to each product under Annex II of MARPOL 73/78.

4. Column d - Hazards

An .S. is assigned to column d if any of the safety criteria described in paragraphs 103.1.(1) to 103.1.(11) are met.

A .P. is assigned to column d if the product meets the criteria for assigning Ship Type 1 to 3 as defined by rules 1 to 14 in paragraph 104.5.

5. Column e - Ship Type

(1) The basic criteria for assigning Ship Types based on the GESAMP Hazard Profile are shown in the table below. An explanation of the details in the columns is provided in appendix 1 of MARPOL Annex II. Selected rules, identified in this table, are specified in section (2) for assigning specific Ship Types.

Number	A1	A2	B1	B2	D3	E2	Ship Type
1			≥5				1
2	≥4	NR	4		CMRTNI		
3	≥4	NR			CMRTNI		2
4			4				
5	≥4		3				
6		NR	3				
7				≥1			
8						Fp	
9					CMRTNI	F	
10			≥2			S	
11	≥4						3
12		NR					
13			≥1				
14	All other category Y Substances						
15	All other category Z Substances, All "Other Substances" (OS)						NA

(2) The Ship Type is assigned according to the following criteria:

(A) Ship Type 1:
Inhalation LC_{50} < 0.5 mg/l/4h; and/or
Dermal LD_{50} < 50 mg/kg; and/or
Oral LD_{50} < 5 mg/kg; and/or
Autoignition temperature < 65℃; and/or
Explosive range > 50% v/v in air and the flash point < 23℃; and/or
Rules 1 or 2 of the table shown in (1)

(B) Ship Type 2:
Inhalation LC_{50} > 0.5 mg/l/4h - < 2 mg/l/4h; and/or
Dermal LD_{50} > 50 mg/kg - < 1000 mg/kg; and/or
OralLD50 > 5 mg/kg - < 300 mg/kg; and/or
WRI=2;
Autoignition temperature < 200℃; and/or
Explosive range > 40% v/v in air and the flash point < 23℃; and/or

Any of the rules 3 to 10 of the table shown in (1)

(C) Ship Type 3:
Any of the minimum safety or pollution criteria for bulk liquid cargoes subject to chapter 17 of the IBC Code not meeting the requirements for ship types 1 or 2 and not meeting rule 15 of the table shown in (1)

6. Column f - Tank type

(1) The tank type is assigned according to the following criteria:

(A) Tank type 1G:
Inhalation LC_{50} < 0.5 ㎎/l/4h; and/or
Dermal LD_{50} < 200 ㎎/㎏); and/or
Autoignition temperature < 65℃; and/or
Explosive range > 40% v/v in air and the flash point < 23℃; and/or
WRI=2

(B) Tank type 2G:
Any of the minimum safety or pollution criteria for bulk liquid cargoes subject to chapter 17 or the IBC Code not meeting the requirements for tank type 1G.

7. Column g - Tank vents

(1) The tank venting arrangements are assigned according to the following criteria:

(A) Controlled:
Inhalation LC_{50} < 10 ㎎/l/4h; and/or
Toxic to mammals by prolonged exposure; and/or
Respiratory sensitizer; and/or
Special carriage control needed; and/or
Flash point < 60℃
Corrosive to skin (< 4 h exposure)

(B) Open:
Any of the minimum safety or pollution criteria for bulk liquid cargoes subject to chapter 17 or the IBC Code not meeting the requirements for controlled tank vents.

8. Column h - Tank environmental control

(1) The Tank environmental control conditions are assigned according to the following criteria:

(A) Inert:
Autoignition temperature < 200℃; and/or
Reacts with air to cause a hazard; and/or
Explosive range > 40% and the flash point < 23℃.
Dry: WRI > 1

(B) Pad : Only applies to specific products identified on a case by case basis.

(C) Vent: Only applies to specific products identified on a case by case basis.

(D) No: Where the above criteria do not apply, (inerting requirements may be required under SOLAS)

9. Column i - Electrical equipment

(1) If the flash point of the product is < 60℃ or the product is heated to within 15℃ of its flash point then the electrical equipment required are assigned according to the following criteria, else .-. is assigned in column i. and i...

(A) Column i. - Temperature class:
T1 Autoignition temperature > 450℃
T2 Autoignition temperature > 300℃ but < 450℃
T3 Autoignition temperature > 200℃ but < 300℃
T4 Autoignition temperature > 135℃ but < 200℃
T5 Autoignition temperature > 100℃ but < 135℃
T6 Autoignition temperature > 85℃ but < 100℃

(B) Column i.. - Apparatus group:

Apparatus group	MESG at 20 ℃ (mm)	MIC ratio product/methane
IIA	≥ 0.9	> 0.8
IIB	0.5 < but < 0.9	0.45 ≤ but ≤ 0.8
IIC	≤ 0.5	< 0.45

(a) The tests shall be carried out in accordance with the procedures described in IEC 60079-1-1:2002 and IEC 79-3.

(b) For gases and vapours it is sufficient to make only one determination of either the Maximum Experimental Safe Gap (MESG) or the Minimum Igniting Current (MIC) provided that:

(i) for Group IIA: the MESG > 0.9 mm or the MIC ratio > 0.9.

(ii) for Group IIB: the MESG is > 0.55 mm and < 0.9 mm; or the MIC ratio is > 0.5 and <0.8.

(iii) for Group IIC: the MESG is < 0.5 mm or the MIC ratio is <0.45.

(c) It is necessary to determine both the MESG and the MIC ratio when:

(i) The MIC ratio determination only has been made, and the ratio is between 0.8 and 0.9, when an MESG determination will be required;

(ii) The MIC ratio determination only has been made, and the ratio is between 0.45 and 0.5, when an MESG determination will be required; or

(iii) The MESG only has been found, and is between 0.5 mm and 0.55 mm, when an MIC ratio determination will be required.

(C) Column i... Flash point: > 60℃ : Yes
< 60℃ : No
Non-flammable : NF

10. Column j - Gauging

(1) The type of gauging equipment permitted is assigned according to the following criteria:

(A) Closed:
Inhalation LC_{50} < 2 mg/l/4h; and/or
Dermal LD_{50} < 1000 mg/kg; and/or
Toxic to mammals by prolonged exposure; and/or
Respiratory sensitizer; and/or
Corrosive to skin (< 3 min exposure).

(B) Restricted:
Inhalation LC50 > 2 - < 10 mg/l/4h; and/or
Special carriage control indicates Inerting required; and/or
Corrosive to skin (>3 min - < 1 h exposure); and/or
Flash point < 60℃.

(C) Open:
Any of the minimum safety or pollution criteria for bulk liquid cargoes subject to chapter 17 or the IBC Code not meeting the requirements for closed or restricted gauging.

11. Column k - Vapour detection

(1) The type of vapour detection equipment required is determined by the following criteria:

(A) Toxic (T) :
Inhalation LC_{50} < 10 mg/l/4h, and/or
Respiratory sensitizer; and/or
Toxic by prolonged exposure.

(B) Flammable (F) : Flash point < 60℃

(C) No : Where the above criteria do not apply.

12. Column l - Fire protection equipment

(1) The appropriate fire-fighting media are defined as being appropriate according to the following criteria related to the properties of the product:

(A) Solubility > 10% (>100000 mg/l) : A Alcohol-resistant foam.

(B) Solubility < 10% (<100000 mg/l/4h) : A Alcohol-resistant foam; and/or : B Regular foam.

(C) WRI = 0 : C Water spray (generally used as a coolant and can be used with A and/or B providing that the WRI=0).

(D) WRI >1 : D Dry chemical.
(E) No : No requirements under this Code.
(2) Note: all appropriate media shall be listed.

13. Column m . Deleted.

14. Column n - Emergency Equipment

(1) The requirement to have personnel emergency equipment on board is identified by .Yes. in column n according to the following criteria:
Inhalation LC_{50} < 2 mg/l/4h; and/or
Respiratory sensitizer; and/or
Corrosive to skin (< 3 min exposure); and/or
WRI=2
(2) No: indicates that the above criteria do not apply.

105. Criteria for special requirements in chapter 15 to be included in column o

1. The assignment of special requirements in column o shall normally follow clear criteria based on the data supplied in the reporting form. Where it is considered appropriate to deviate from such criteria, this shall be clearly documented in such a way that it can easily be retrieved on demand.

2. The criteria for making reference to the special requirements identified in chapters 15 and 16 are defined below with comments where relevant.

3. Paragraphs 15.2 to 15.10 and 15.20

Paragraphs 15.2 to 15.10 and 15.20 identify specific products by name with special carriage requirements that cannot be easily accommodated in any other way.

4. Paragraph 15.11 - Acids

Paragraph 15.11 applies to all acids unless they:
(1) are organic acids - when only paragraphs 15.11.2 to 15.11.4 and paragraphs 15.11.6 to 15.11.8 apply; or
(2) do not evolve hydrogen - when paragraph 15.11.5 need not apply.

5. Paragraph 15.12 - Toxic products

(1) All of paragraph 15.12 is added to column o according to the following criteria:
Inhalation LC_{50} < 2 mg/l/4h; and/or
the product is a respiratory sensitizer; and/or
the product is toxic to mammals by prolonged exposure.
(2) Paragraph 15.12.3 is added to column o according to the following criteria:
Inhalation LC_{50} > 2 - < 10 mg/l/4h; and/or
Dermal LD_{50} < 1000 mg/kg; and/or
Oral LD_{50} < 300 mg/kg.
(3) Paragraph 15.12.4 is added to column o according to the following criterion:
Inhalation LC_{50} > 2 - < 10 mg/l/4h.

6. Paragraph 15.13 - Cargoes protected by additives

The requirement to assign paragraph 15.13 to column o is based on the information related to the products tendency to polymerise, decompose, oxidise or undergo other chemical changes which may cause a hazard under normal carriage conditions and which would be prevented by the addition of appropriate additives.

7. Paragraph 15.14 - Cargoes with a vapour pressure greater than atmospheric at 37.8℃ The requirement to assign paragraph 15.14 to column o is based on the following criterion : Boiling point < 37.8℃

8. Paragraph 15.16 - Cargo contamination

Paragraph 15.16.1 is deleted.
Paragraph 15.16.2 is added to column o according to the following criterion:
WRI > 1

9. Paragraph 15.17 - Increased ventilation requirements

Paragraph 15.17 shall be added to column o according to the following criteria:
Inhalation LC_{50} > 0.5 - < 2 mg/l/4h; and/or
Respiratory sensitizer; and/or
Toxic to mammals by prolonged exposure; and/or
Corrosive to skin (< 1 h exposure time).

10. Paragraph 15.18 - Special cargo pump-room requirements

Paragraph 15.18 shall be added to column o according to the following criterion:
Inhalation LC_{50} < 0.5 mg/l/4h

11. Paragraph 15.19 - Overflow control

(1) Paragraph 15.19 shall be added to column o according to the following criteria:
Inhalation LC_{50} < 2 mg/l/4h; and/or
Dermal LD_{50} < 1000 mg/kg; and/or
Oral LD_{50} < 300 mg/kg; and/or
Respiratory sensitizer; and/or
Corrosive to skin (< 3 min exposure); and/or
Autoignition temperature < 200℃; and/or
Explosive range > 40% v/v in air and flash point < 23℃; and/or
Classified as ship type 1 on pollution grounds.

(2) Only paragraph 15.19.6 shall apply if the product has any of the following properties:
Inhalation LC_{50} > 2 mg/l/4h - < 10 mg/l/4h; and/or
Dermal LD_{50} > 1000 mg/kg - < 2000 mg/kg; and/or
Oral LD_{50} > 300 mg/kg - < 2000 mg/kg; and/or
Skin sensitizer; and/or
Corrosive to skin (> 3 min - < 1 h exposure); and/or
Flash point <60℃; and/or
Classified as ship type 2 on pollution grounds; and/or
Pollution category X or Y.

12. Paragraph 15.21 . Temperature sensors

Paragraph 15.21 is added to column o according to the heat sensitivity of the product. This requirement is related to pumps in cargo pump rooms only.

106. Criteria for special requirements in chapter 16 to be included in column o

1. Paragraphs 16.1 to 16.2.5 and 16.3 to 16.5

These apply to all cargoes and so are not referenced specifically in column o.

2. Paragraph 16.2.6

Paragraph 16.2.6 is added to column o for products, which meet the following criteria:
Pollution Category X or Y and viscosity > 50 mPa.s at 20℃

3. Paragraph 16.2.7

Paragraph 16.2.7 is added to column o for products, which meet the following criterion:
Melting point > 0℃.

4. Paragraph 16.6 . Cargo not to be exposed to excessive heat

Paragraphs 16.6.2 to 1606.4 are added to column o for products, which are identified as requiring temperature control during carriage.

107. Definitions

1. Acute mammalian toxicity

(1) Acutely toxic by inhalation*

Inhalation toxicity (LC_{50})	
Hazard level	mg/l/4h
High	≤ 0.5
Moderately high	0.5 < but ≤ 2
Moderate	2 < but ≤ 10
Slight	10 < but ≤ 20
Negligible	20 <

(2) Acutely toxic in contact with skin

Dermal toxicity (LD_{50})	
Hazard Level	mg/kg
High	≤ 50
Moderately high	50 < but ≤ 200
Moderate	200 < but ≤ 1000
Slight	1000 < but ≤ 2000
Negligible	2000 <

(3) Acutely toxic if swallowed

Oral toxicity (LD_{50})	
Hazard Level	mg/kg
High	≤ 5
Moderately high	5 < but ≤ 50
Moderate	50 < but ≤ 300
Slight	300 < but ≤ 2000
Negligible	2000 <

* All inhalation toxicity data are assumed to be associated with vapours and not mists or sprays, unless indicated otherwise.

2. Toxic to mammals by prolonged exposure

(1) A product is classified as toxic by prolonged exposure if it meets any of the following criteria: it is known to be, or suspected of being a carcinogen, mutagen, reprotoxic, neurotoxic, immunotoxic or exposure below the lethal dose is known to cause specific organ oriented systemic toxicity (TOST) or other related effects.

(2) Such effects may be identified from the GESAMP Hazard Profile of the product or other recognized sources of such information.

3. Skin sensitization

(1) A product is classified as a skin sensitizer:
if there is evidence in humans that the substance can induce sensitization by skin contact in a substantial number of persons; or
where there are positive results from an appropriate animal test.

(2) When an adjuvant type test method for skin sensitization is used, a response of at least 30% of the animals is considered as positive. For a non-adjuvant test method a response of at least 15% of the animals is considered positive.

(3) When a positive result is obtained from the Mouse Ear Swelling Test (MEST) or the Local Lymph Node Assay (LLNA), this may be sufficient to classify the product as a skin sensitizer.

4. Respiratory sensitization

A product is classified as a respiratory sensitizer:

(1) if there is evidence in humans that the substance can induce specific respiratory hypersensitivity; and/or
(2) where there are positive results from an appropriate animal test; and/or
(3) where the product is identified as a skin sensitizer and there is no evidence to show that it is not a respiratory sensitizer.

5. Corrosive to skin*

Hazard Level	Exposure time to cause full thickness necrosis of skin	Observation time
Severely corrosive to skin	≤ 3 min	≤ 1 h
Highly corrosive to skin	3 min < but ≤ 1 h	≤ 14 days
Moderately corrosive to skin	1 h < but ≤ 4 h	≤ 14 days

* Products that are corrosive to skin are, for the purpose of assigning relevant carriage requirements, deemed to be corrosive by inhalation.

6. Water reactive substances

These are classified into three groups as follows:

Water reactive index (WRI)	Definition
2	Any chemical which, in contact with water, may produce a toxic, flammable or corrosive gas or aerosol.
1	Any chemical which, in contact with water, may generate heat or produce a non-toxic, non-flammable or non corrosive gas.
0	Any chemical which, in contact with water, would not undergo a reaction to justify a valve of 1 or 2.

7. Air reactive substances

Air reactive substances are products which react with air to cause a potentially hazardous situation, e.g. the formation of peroxides which may cause an explosive reaction.

8. Electrical apparatus - Temperature Class (for products which either have a flashpoint of < 60℃ or are heated to within 15℃ of their flashpoint)

(1) The Temperature Class is defined by the International Electrotechnical Commission (IEC) as: The highest temperature attained under practical conditions of operation within the rating of the apparatus (and recognized overloads, if any, associated therewith) by any part of any surface, the exposure of which to an explosive atmosphere may involve a risk.
(2) The Temperature Class of the electrical apparatus is assigned by selecting the Maximum Surface Temperature which is closest to, but less than, the product's autoignition temperature (see 21.4.9.(1)(A)).

9. Electrical apparatus - Apparatus group (for products with a flashpoint of < 60℃)

(1) This refers to intrinsically safe and associated electrical apparatus for explosive gas atmospheres which the IEC divide into the following groups:
  (A) Group I: for mines susceptible to firedamp (not used by IMO); and
  (B) Group II: for applications in other industries - further sub-divided according to its Maximum Experimental Safe Gap (MESG) and/or the Minimum Igniting Current (MIC) of the gas/vapour into groups IIA, IIB and IIC.
(2) This property cannot be determined from other data associated with the product; it has to be either measured or assigned by assimilation with related products in an homologous series.

10. Special carriage control conditions

(1) Special carriage control conditions refer to specific measures that need to be taken in order to either prevent a hazardous reaction. They include:

(A) Inhibition: the addition of a compound (usually organic) that retards or stops an undesired chemical reaction such as corrosion, oxidation or polymerization;

(B) Stabilization: the addition of a substance (stabilizer) that tends to keep a compound, mixture or solution from changing its form or chemical nature. Such stabilizers may retard a reaction rate, preserve a chemical equilibrium, act as antioxidants, keep pigments and other components in emulsion form or prevent the particles in colloidal suspension from precipitating;

(C) Inertion: the addition of a gas (usually nitrogen) in the ullage space of a tank that prevents the formation of a flammable cargo/air mixture;

(D) Temperature control: the maintenance of a specific temperature range for the cargo in order to prevent a hazardous reaction or to keep the viscosity low enough to allow the product to be pumped; and

(E) Padding and venting: only applies to specific products identified on a case by case basis.

11. Flammable cargoes

(1) A cargo is defined as flammable according to the following criteria:

IBC Code descriptor	Flash point (degree Centigrade)
Highly flammable	< 23
Flammable	$23 \leq$ but ≤ 60

(2) It should be noted that flash points of mixtures and aqueous solutions need to be measured unless all of the components are non-flammable.

(3) It should be noted that the carriage of bulk liquid cargoes which have a flash point of <60℃ is subject to other SOLAS regulations. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 7 SHIPS OF SPECIAL SERVICE (Ch 5,6)

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Rules for the Classification of Steel Ships

Part 8 Fire Protection and Fire Extinction

Rules

2011

Guidance Relating to the Rules for the Classification of Steel ships

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Part 8

Fire Protection and Fire Extinction

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KOREAN REGISTER OF SHIPPING

APPLICATION OF
PART 8 "FIRE PROTECTION AND FIRE EXTINCTION"

1. Unless expressly specified otherwise, the requirements in this Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.

2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date 1 January 2011 (regardless of the contract date for construction)

CHAPTER 5 SPECIAL REQUIREMENTS

Section 2 Carriage of dangerous goods

- 201. 1 has been amended.
- 201. 6 (1) has been amended.
- Table 8.5.1, Table 8.5.2 and Table 8.5.3 of 202. have been amended.

Effective Date 1 July 2011

CHAPTER 2 PREVENTION OF FIRE AND EXPLOSION

Section 1 Prevention of ignition probability

- 101. 2 (5) (B) has been amended.

Section 2 Prevention of fire growth potential

- 202. 2 (1) has been amended.

CHAPTER 3. SUPPRESSION OF FIRE

Section 3 Containment of fire

- 303. 1 (1) and (2) have been amended.
- 303. 2 (1) has been amended.

CHAPTER 5. SPECIAL REQUIREMENTS

Section 2 Carriage of dangerous goods

- 203. has been deleted.

CONTENTS

CHAPTER 1 FIRE PROTECTION, FIRE DETECTION AND FIRE EXTINCTION

SECTION 1 General

101. Application

1. Unless expressly specified otherwise, where ships not less than 500 tons gross tonnage and Passengers ships are engaged in international voyage, those construction of fire protection, fire detection and fire extinction shall be complied with the requirements of this Part. However, for cargo ships less than 500 tons gross tonnage or cargo ships not engaged international voyage or fishing vessels they may apply to the requirements in accordance with **the Guidance** as provided separatedly.

2. In addition to para 1 they shall also be complied with the International Conventions of SOLAS and the National Regulations of the country in which the ships is registered.

3. Despite of para 1 and 2 for the ships not applied to the SOLAS but applied to the Ships Safety Law or Fishing vessel Law of Korea those fire-fighting system shall be in accordance with the relevant requirements specified by these Laws.

102. Plans and documents

1. The following plans and documents are to be submitted to the Society for approval before the work is commenced.

(1) Plans of construction for fire protection (details of construction for fire protection and arrangements of closing appliances of openings, etc.)
(2) Plans for details of escape route and width of escape route, etc. (Calculation method of stairway width for Passenger ships)
(3) Plans of fire control plan showing clearly for each deck the control station, the various fire section enclosed by "A" class divisions, the sections enclosed by "B" class divisions together with particulars of the fire detection and fire alarm systems, the sprinkler installations, the fire-extinguishing appliances, means of access to different compartments, decks, etc., and the ventilating system including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fan serving each section. (Refer to the Guidance)
(4) Other plans and documents deemed necessary by the Society. (Refer to the Guidance)

103. Definitions

1. Accommodation spaces are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, game and hobby rooms, barber shops, pantries containing no cooking appliances and similar spaces;(Refer to the Guidance)

2. ″A″ class divisions are those divisions formed by bulkheads and decks which comply with the following criteria:

(1) they are constructed of steel or other equivalent material;
(2) they are suitably stiffened;
(3) they are insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140 ℃ above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180 ℃ above the original temperature, within the time listed below:
class "A-60" 60 min
class "A-30" 30 min
class "A-15" 15 min
class "A-0" 0 min
(4) they are constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test; and
(5) the Society has required a test of a prototype bulkhead or deck in accordance with the Fire

Test Procedures Code to ensure that it meets the requirements above for integrity and temperature rise.

3. Atriums are public spaces within a single main vertical zone spanning three or more open decks.

4. "B" class divisions are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following criteria:

(1) they are constructed of approved non-combustible materials and all materials used in the construction and erection of "B" class divisions are non-combustible, with the exception that combustible veneers may be permitted provided they meet other appropriate requirements of this chapter;

(2) they have an insulation value such that the average temperature of the unexposed side will not rise more than 140 ℃ above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225 ℃ above the original temperature, within the time listed below:

class "B-15" 15 min

class "B-0" 0 min

(3) they are constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test; and

(4) the Society has required a test of a prototype division in accordance with the Fire Test Procedures Code to ensure that it meets the above requirements for integrity and temperature rise.

5. Bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

6. Cargo area is that part of the ship that contains cargo holds, cargo tanks, slop tanks and cargo pump-rooms including pump-rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above-mentioned spaces.

7. Cargo ship is any ship which is not a passenger ship.

8. Cargo spaces are spaces used for cargo, cargo oil tanks, tanks for other liquid cargo and trunks to such spaces.

9. Central control station is a control station in which the following control and indicator functions are centralized:

(1) fixed fire detection and fire alarm systems;

(2) automatic sprinkler, fire detection and fire alarm systems;

(3) fire door indicator panels;

(4) fire door closure;

(5) watertight door indicator panels;

(6) watertight door closures;

(7) ventilation fans;

(8) general/fire alarms;

(9) communication systems including telephones; and

(10) microphones to public address systems.

10. "C" class divisions are divisions constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet the requirements of this Part.

11. Chemical tanker is a ship specified in **Pt 7, Ch 6** of the Rules of Steel Ship.

12. Closed ro-ro spaces are ro-ro spaces which are neither open ro-ro spaces nor weather decks.

13. Closed vehicle spaces are vehicle spaces which are neither open vehicle spaces nor weather decks.

14. Combination carrier is a cargo ship designed to carry both oil and solid cargoes in bulk.

15. Combustible material is any material other than a non-combustible material.

16. Continuous "B" class ceilings or linings are those "B" class ceilings or linings which terminate at an "A" or "B" class division.

17. Continuously manned central control station is a central control station which is continuously manned by a responsible member of the crew.

18. Control stations are those spaces in which the ship's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire control equipment is centralized. Spaces where the fire recording or fire control equipment is centralized are also considered to be a fire control station. (Refer to the Guidance)

19. Crude oil is any oil occurring naturally in the earth whether or not treated to render it suitable for transportation and includes crude oil where certain distillate fractions may have been removed from or added to.

20. Dangerous goods are those goods referred to in the IMDG Code of IMO.

21. Deadweight is the difference in tonnes between the displacement of a ship in water of a specific gravity of 1.025 at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship.

22. Fire Safety Systems Code means the International Code for Fire Safety Systems as adopted by the International Maritime Organization.

23. Fire Test Procedures Code means the International Code for Application of Fire Test Procedures as adopted by the International Maritime Organization.

24. Flashpoint is the temperature in degrees Celsius (closed cup test) at which a product will give off enough flammable vapour to be ignited, as determined by an approved flashpoint apparatus.

25. Gas carrier is a ship specified in **Pt 7, Ch 5** of the Rules of Steel Ships.

26. Helideck is a purpose-built helicopter landing area located on a ship including all structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters.

27. Helicopter facility is a helideck including any refuelling and hangar facilities.

28. Lightweight is the displacement of a ship in tonnes without cargo, fuel, lubricating oil, ballast water, fresh water and feedwater in tanks, consumable stores, and passengers and crew and their effects.

29. Low flame spread means that the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the Fire Test Procedures Code.

30. Machinery spaces are machinery spaces of category A and other spaces containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

31. Machinery spaces of category A are those spaces and trunks to such spaces which contain either:
(1) internal combustion machinery used for main propulsion;
(2) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(3) any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

32. Main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by "A" class divisions, the mean length and width of which on any deck does not in general exceed 40 m.

33. Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750 ℃, this being determined in accordance with the Fire Test Procedures Code.

34. Oil fuel unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0.18 MPa. (Refer to the Guidance)

35. Open ro-ro spaces are those ro-ro spaces that are either open at both ends or have an opening at one end, and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10 % of the total area of the space sides.

36. Open vehicle spaces are those vehicle spaces either open at both ends, or have an opening at one end and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10 % of the total area of the space sides.

37. Passenger ship is a ship which carries more than twelve passengers.

38. Prescriptive requirements means the construction characteristics, limiting dimensions, or fire safety systems

39. Public spaces are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

40. Rooms containing furniture and furnishings of restricted fire risk are those rooms containing furniture and furnishings of restricted fire risk (whether cabins, public spaces, offices or other types of accommodation) in which:

(1) case furniture such as desks, wardrobes, dressing tables, bureaux, dressers, are constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2 mm may be used on the working surface of such articles;
(2) free-standing furniture such as chairs, sofas, tables, are constructed with frames of non-combustible materials;
(3) draperies, curtains and other suspended textile materials have qualities of resistance to the propagation of flame not inferior to those of wool having a mass of mass 0.8 kg/m^2, this being determined in accordance with the Fire Test Procedures Code;
(4) floor coverings have low flame spread characteristics;
(5) exposed surfaces of bulkheads, linings and ceilings have low flame-spread characteristics;
(6) upholstered furniture has qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code; and
(7) bedding components have qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code.

41. Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship in which motor vehicles with fuel in their tanks for their own propulsion or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction. (Refer to the Guidance)

42. Ro-ro passenger ship means a passenger ship with ro-ro spaces or special category spaces.

43. Steel or other equivalent material means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy with appropriate insulation).

44. Sauna is a hot room with temperatures normally varying between 80 ℃ ~ 120 ℃ where the heat is provided by a hot surface (e.g. by an electrically-heated oven). The hot room may also include the space where the oven is located and adjacent bathrooms.

45. Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces. (Refer to the Guidance)

46. Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

47. A standard fire test is a test in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve in accordance with the test method specified in the Fire Test Procedures Code.

48. Tanker is a cargo ship constructed or adapted for the carriage in bulk of liquid cargoes of an inflammable nature. (Refer to the Guidance)

49. Vehicle spaces are cargo spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion. (Refer to the Guidance)

50. Weather deck is a deck which is completely exposed to the weather from above and from at least two sides.

51. Periodically unattended machinery space is a machinery space of UMA ship specified in **Pt 9, Ch 3** of the Rules.

52. Cabin balcony is an open deck space which is provided for the exclusive use of the occupants of a single cabin and has direct access from such a cabin.

53. Safety centre is a control station dedicated to the management of emergency situations. Safety systems' operation, control and/or monitoring are an integral part of the safety centre.

104. Other Operation Requirements.

For fire protection, fire detection and fire extinction, those operation requirements which contain operational readiness and maintenance, onboard training and drills and cargo handling operation shall be in accordance with the Guidance as provided separately. ⚓

CHAPTER 2 PREVENTION OF FIRE AND EXPLOSION

SECTION 1 Prevention of ignition probability

101. Arrangements for oil fuel, lubrication oil and other flammable oils

1. The following limitations shall apply to the use of oil as fuel

(1) Except as otherwise permitted by this paragraph, no oil fuel with a flashpoint of less than 60 ℃ shall be used;

(2) In emergency generators oil fuel with a flashpoint of not less than 43 ℃ may be used;

(3) The use of oil fuel having a flashpoint of less than 60 ℃ but not less than 43 ℃ may be permitted (e.g., for feeding the emergency fire pump's engines and the auxiliary machines which are not located in the machinery spaces of category A) subject to the following:

(A) fuel oil tanks except those arranged in double bottom compartments shall be located outside of machinery spaces of category A;

(B) provisions for the measurement of oil temperature are provided on the suction pipe of the oil fuel pump;

(C) stop valves and/or cocks are provided on the inlet side and outlet side of the oil fuel strainers; and

(D) pipe joints of welded construction or of circular cone type or spherical type union joint are applied as much as possible,

(4) In cargo ships the use of fuel having a lower flashpoint than otherwise specified paragraph above for example crude oil, may be permitted provided that such fuel is not stored in any machinery space and subject to the approval of the complete installation.

2. In a ship in which oil fuel is used, the arrangements for the storage, distribution and utilization of the oil fuel shall be such as to ensure the safety of the ship and persons on board and shall at least comply with the following provisions.

(1) As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding 0.18 MPa shall be placed in a concealed position such that defects and leakage can readily be observed. The machinery spaces in way of such parts of the oil fuel system shall be adequately illuminated.

(2) The ventilation of machinery spaces shall be sufficient under normal conditions to prevent accumulation of oil vapour.

(3) Oil fuel tanks are to comply with the following requirements. (Refer to the Guidance)

(A) Fuel oil, lubrication oil and other flammable oils shall not be carried in forepeak tanks. (Refer to the Guidance)

(B) As far as practicable, oil fuel tanks shall be part of the ships structure and shall be located outside machinery spaces of category A. Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides shall be contiguous to the machinery space boundaries, and shall preferably have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces shall be kept to a minimum. Where such tanks are situated within the boundaries of machinery spaces of category A they shall not contain oil fuel having a flashpoint of less than 60 ℃. In general, the use of free-standing oil fuel tanks shall be avoided. When such tanks are employed their use shall be prohibited in category A machinery spaces on passenger ships. Where permitted, they shall be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized spill oil tank. (Refer to the Guidance)

(C) No oil fuel tank shall be situated where spillage or leakage therefrom can constitute a fire or explosion hazard by falling on heated surfaces.

(D) Oil fuel pipes, which, if damaged, would allow oil to escape from a storage, settling or daily service tank having a capacity of 500 liters and above situated above the double bottom, shall be fitted with a cock or valve directly on the tank capable of being closed from a safe position outside the space concerned in the event of a fire occurring in the space in which such tanks are situated. In the special case of deep tanks situated in any shaft or pipe tunnel or similar space, valves on the tank shall be fitted, but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such an additional valve is fitted in the machinery space it shall be operated from a position outside this space. The controls for remote operation of the valve for the emergency generator fuel tank shall be in a separate location from the controls for remote operation of other valves for tanks located in machinery spaces.

(E) Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank shall be provided. (Refer to the Guidance)

(a) Where sounding pipes are used, they shall not terminate in any space where the risk of ignition of spillage from the sounding pipe might arise. In particular, they shall not terminate in passenger or crew spaces. As a general rule, they shall not terminate in machinery spaces. However, where considers that these latter requirements are impracticable, it may permit termination of sounding pipes in machinery spaces on condition that all of the following requirements are met:

(i) an oil-level gauge is provided meeting the requirements of paragraph (b);

(ii) the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the oil fuel in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition; and

(iii) the termination of sounding pipes are fitted with self-closing blanking devices and with a small-diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that oil fuel is not present. Provisions shall be made so as to ensure that any spillage of oil fuel through the control cock involves no ignition hazard.

(b) Other oil-level gauges may be used in place of sounding pipes subject to the following conditions:

(i) in passenger ships, such gauges shall not require penetration below the top of the tank and their failure or overfilling of the tanks shall not permit release of fuel; and

(ii) in cargo ships, the failure of such gauges or overfilling of the tank shall not permit release of fuel into the space. The use of cylindrical gauge glasses is prohibited. It may be permitted to use oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks.

(c) The means prescribed in paragraph (b) which are acceptable shall be maintained in the proper condition to ensure their continued accurate functioning in service.

(4) Provisions shall be made to prevent overpressure in any oil tank or in any part of the oil fuel system, including the filling pipes served by pumps on board. Air and overflow pipes and relief valves shall discharge to a position where there is no risk of fire or explosion from the emergence of oils and vapour and shall not lead into crew spaces, passenger spaces nor into special category spaces, closed ro-ro cargo spaces, machinery spaces or similar spaces.

(5) Oil fuel piping is to comply with the following requirements.

(A) Oil fuel pipes and their valves and fittings shall be of steel or other approved material, except that restricted use of flexible pipes shall be permissible in positions where they are necessary. Such flexible pipes and end attachments shall be of approved fire-resisting materials of adequate strength and shall be constructed to the satisfaction of the Society. For valves, fitted to oil fuel tanks and which are under static pressure, steel or spheroidal-graphite cast iron may be accepted. However, ordinary cast iron valves may be used in piping systems where the design pressure is lower than 7 bar and the design temperature is below 60 ℃. (Refer to the Guidance)

(B) External high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel injectors shall be protected with a jacketed piping system capable of containing fuel from a high-pressure line failure. A jacketed pipe incorporates an outer pipe into which the high-pressure fuel pipe is placed, forming a permanent assembly. The jacketed piping system shall include a means for collection of leakages and arrangements and shall be provided with an alarm in case of a fuel line failure. If non-metallic materials are used for shielding purpose, they are to be of approved types. (Refer to the Guidance)

(C) Oil fuel lines shall not be located immediately above or near units of high temperature including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by paragraph (6). As far as practicable, oil fuel lines shall be arranged far apart from hot surfaces, electrical installations or other sources of ignition and shall be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition. The number of joints in such piping systems shall be kept to a minimum.

(D) Components of a diesel engine fuel system shall be designed considering the maximum peak pressure which will be experienced in service, including any high pressure pulses which are generated and transmitted back into the fuel supply and spill lines by the action of fuel injection pumps. Connections within the fuel supply and spill lines shall be constructed having regard to their ability to prevent pressurized oil fuel leaks while in service and after maintenance.
(E) In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines, shall be provided. The means of isolation shall not affect the operation of the other engines and shall be operable from a position not rendered inaccessible by a fire on any of the engines.
(F) Where it may be permitted to convey oil and combustible liquids through accommodation and service spaces, the pipes conveying oil or combustible liquids shall be of a material approved by the Society having regard to the fire risk.
(6) Protection of high temperature surfaces is to be taken as follows.
(A) Surfaces with temperatures above 220 ℃ which may be impinged as a result of a fuel system failure shall be properly insulated.
(B) Precautions shall be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

3. Arrangements for lubricating oil is to comply with the following requirements.

(1) The arrangements for the storage, distribution and utilization of oil used in pressure lubrication systems shall be such as to ensure the safety of the ship and persons on board. The arrangements made in machinery spaces of category A, and whenever practicable in other machinery spaces, shall at least comply with the provisions of **Par 2** (1), **2** (3) (C), **2** (3) (D), **2** (3) (E), **2** (4), **2** (5) (A), **2** (5) (C) and **2** (6) except that:
(A) this does not preclude the use of sight-flow glasses in lubricating systems provided that they are shown by testing to have a suitable degree of fire resistance; and
(B) sounding pipes may be authorized in machinery spaces; however, the requirements of **Par 2** (3) (E) (a) (i) and **2** (3) (E) (a) (iii) need not be applied on condition that the sounding pipes are fitted with appropriate means of closure;

(2) The provisions of **Par 2** (3) (D) shall also apply to lubricating oil tanks except those having a capacity less than 500 liters, storage tanks on which valves are closed during the normal operation mode of the ship, or where it is determined that an unintended operation of a quick closing valve on the oil lubricating tank would endanger the safe operation of the main propulsion and essential auxiliary machinery. (Refer to the Guidance)

4. Arrangements for other flammable oils is to comply with the following requirements.The arrangements for the storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems shall be such as to ensure the safety of the ship and persons on board. Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

In locations where means of ignition are present, such arrangements shall at least comply with the provisions of **Par 2** (3) (C), **2** (3) (E), **2** (5) (C) and **2** (6) and with the provisions of **Par 2** (4) and **2** (5) (A) in respect of strength and construction.

5. In addition to the requirements of **Par 1** to **4,** the oil fuel and lubricating oil systems in a periodically unattended machinery space shall comply with the following:

(1) where daily service oil fuel tanks are filled automatically, or by remote control, means shall be provided to prevent overflow spillages. Other equipment which treats flammable liquids automatically (e.g. oil fuel purifiers) which, whenever practicable, shall be installed in a special space reserved for purifiers and their heaters, shall have arrangements to prevent overflow spillages; and
(2) where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high temperature alarm shall be provided if the flashpoint of the oil fuel can be exceeded.

102. Arrangements for gasous fuel for domestic purpose

Gaseous fuel systems used for domestic purposes shall be approved by the Society. Storage of gas bottles shall be located on the open deck or in a well ventilated space which opens only to the open deck.

103. Miscellaneous items of ignition sources and ignitability

1. Electric radiators, if used, shall be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiators shall be fitted with an element so exposed that clothing, curtains, or other similar materials can be scorched or set on fire by heat from the element.

2. Waste receptacles shall be constructed of non-combustible materials with no openings in the sides or bottom. (Refer to the Guidance)

3. In spaces where penetration of oil products is possible, the surface of insulation shall be impervious to oil or oil vapours. (Refer to the Guidance)

4. Primary deck coverings, if applied within accommodation and service spaces and control stations, or if applied on cabin balconies of passenger ships shall be of approved material which will not readily ignite, this being determined in accordance with the Fire Test Procedures Code.

104. Cargo areas of tankers

1. Separation of cargo oil tanks is to taken as follows.

(1) Cargo pump-rooms, cargo tanks, slop tanks and cofferdams shall be positioned forward of machinery spaces. However, oil fuel bunker tanks need not be forward of machinery spaces. Cargo tanks and slop tanks shall be isolated from machinery spaces by cofferdams, cargo pump-rooms, oil bunker tanks or ballast tanks. Pump-rooms containing pumps and their accessories for ballasting those spaces situated adjacent to cargo tanks and slop tanks and pumps for oil fuel transfer, shall be considered as equivalent to a cargo pump-room within the context of this regulation provided that such pump-rooms have the same safety standard as that required for cargo pump-rooms. Pump-rooms intended solely for ballast or oil fuel transfer, however, need not comply with the requirements of **Ch 3, 408.** The lower portion of the pump-room may be recessed into machinery spaces of category A to accommodate pumps, provided that the deck head of the recess is in general not more than one third of the moulded depth above the keel, except that in the case of ships of not more than 25,000 tonnes deadweight, where it can be demonstrated that for reasons of access and satisfactory piping arrangements this is impracticable, the Society may permit a recess in excess of such height, but not exceeding one half of the moulded depth above the keel. (Refer to the Guidance)

(2) Main cargo control stations, control stations, accommodation and service spaces (excluding isolated cargo handling gear lockers) shall be positioned aft of cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces, but not necessarily aft of the oil fuel bunker tanks and ballast tanks, and shall be arranged in such a way that a single failure of a deck or bulkhead shall not permit the entry of gas or fumes from the cargo tanks into an accommodation space, main cargo control stations, control station, or service spaces. A recess provided in accordance with paragraph (1) above need not be taken into account when the position of these spaces is being determined. (Refer to the Guidance)

(3) However, where deemed necessary, the Society may permit main cargo control stations, control stations, accommodation and service spaces forward of the cargo tanks, slop tanks and spaces which isolate cargo and slop tanks from machinery spaces, but not necessarily forward of oil fuel bunker tanks or ballast tanks. Machinery spaces, other than those of category A, may be permitted forward of the cargo tanks and slop tanks provided they are isolated from the cargo tanks and slop tanks by cofferdams, cargo pump-rooms, oil fuel bunker tanks or ballast tanks, and have at least one portable fire extinguisher. In cases where they contain internal combustion machinery, one approved foam-type extinguisher of at least 45 liters capacity or equivalent shall be arranged in addition to portable fire extinguishers. If operation of a semi-portable fire extinguisher is impracticable, this fire extinguisher may be replaced by two additional portable fire extinguishers. Accommodation spaces, main cargo control spaces, control stations and service spaces shall be arranged in such a way that a single failure of a deck or bulkhead shall not permit the entry of gas or fumes from the cargo tanks into such spaces. In addition, where deemed necessary for the safety or navigation of the ship, the Society may permit machinery spaces containing internal combustion machinery not being main propulsion machinery having an

output greater than 375 kW to be located forward of the cargo area provided the arrangements are in accordance with the provisions of this paragraph. (Refer to the Guidance)

(4) Combination carriers only are to comply with the following requirements.

(A) The slop tanks shall be surrounded by cofferdams except where the boundaries of the slop tanks, where slop may be carried on dry cargo voyages, are part of the hull, main cargo deck, cargo pump-room bulkhead or oil fuel bunker tank. These cofferdams shall not be open to a double bottom, pipe tunnel, pump-room or other enclosed space, nor shall they be used for cargo or ballast and shall not be connected to piping systems serving oil cargo or ballast. Means shall be provided for filling the cofferdams with water and for draining them. Where the boundary of a slop tank is part of the cargo pump-room bulkhead, the pump-room shall not be open to the double bottom, pipe tunnel or other enclosed space; however, openings provided with gastight bolted covers may be permitted; (Refer to the Guidance)

(B) Means shall be provided for isolating the piping connecting the pump-room with the slop tanks referred to in paragraph (A). The means of isolation shall consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement shall be located adjacent to the slop tanks, but where this is unreasonable or impracticable, it may be located within the pump-room directly after the piping penetrates the bulkhead. A separate permanently installed pumping and piping arrangement incorporating a manifold, provided with a shut-off valve and a blank flange, shall be provided for discharging the contents of the slop tanks directly to the open deck for disposal to shore reception facilities when the ship is in the dry cargo mode. When the transfer system is used for slop transfer in the dry cargo mode, it shall have no connection to other systems. Separation from other systems by means of removal of spool pieces may be accepted;

(C) Hatches and tank cleaning openings to slop tanks shall only be permitted on the open deck and shall be fitted with closing arrangements. Except where they consist of bolted plates with bolts at watertight spacing, these closing arrangements shall be provided with locking arrangements under the control of the responsible ship's officer; and

(D) Where cargo wing tanks are provided, cargo oil lines below deck shall be installed inside these tanks. However, the Society may permit cargo oil lines to be placed in special ducts provided there are capable of being adequately cleaned and ventilated to the satisfaction of the Society. Where cargo wing tanks are not provided, cargo oil lines below deck shall be placed in special ducts.

(5) Where the fitting of a navigation position above the cargo area is shown to be necessary, it shall be for navigation purposes only and it shall be separated from the cargo tank deck by means of an open space with a height of at least 2 m. The fire protection requirements for such a navigation position shall be that required for control stations, as specified in regulation **Ch 3, 301. 4** (2) and other provisions for tankers, as applicable.

(6) Means shall be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of a height of at least 300 mm, extending from side to side. Special consideration shall be given to the arrangements associated with stern loading. (Refer to the Guidance)

2. Restriction on boundary openings is to comply with the following requirements

(1) Except as permitted in paragraph (2) access doors, air inlets and openings to accommodation spaces, service spaces, control stations and machinery spaces shall not face the cargo area. They shall be located on the transverse bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least 4 % of the length of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance need not exceed 5 m. (Refer to the Guidance)

(2) The Society may permit access doors in boundary bulkheads facing the cargo area or within the 5m limits specified in paragraph (1), to main cargo control stations and to such service spaces used as provision rooms, store-rooms and lockers, provided they do not give access directly or indirectly to any other space containing or providing for accommodation, control stations or service spaces such as galleys, pantries or workshops, or similar spaces containing sources of vapour ignition. The boundary of such a space shall be insulated to "A-60" standard, with the exception of the boundary facing the cargo area. Bolted plates for the removal of machinery may be fitted within the limits specified in paragraph (1). Wheelhouse doors and windows may be located within the limits specified in paragraph (1) so long as they are designed to ensure

that the wheelhouse can be made rapidly and efficiently gas and vapour tight. (Refer to the Guidance)

(3) Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in paragraph (1) shall be of the fixed (non-opening) type. Such windows and sidescuttles, except wheelhouse windows, shall be constructed to "A-60" class standard except that "A-0" class standard is acceptable for windows and side scuttles outside the limit specified in **Ch 3, 301. 4** (2) (E).

(4) Where there is permanent access from a pipe tunnel to the main pump-room, a watertight door shall be fitted complying with the relevant requirements and, in addition, with the following: (Refer to the Guidance)

(A) in addition to the bridge operation, the watertight door shall be capable of being manually closed from outside the main pump-room entrance; and

(B) the watertight door shall be kept closed during normal operations of the ship except when access to the pipe tunnel is required.

(5) Permanent approved gastight lighting enclosures for illuminating cargo pump-rooms may be permitted in bulkheads and decks separating cargo pump-rooms and other spaces provided they are of adequate strength and the integrity and gastightness of the bulkhead or deck is maintained.

(6) The arrangement of ventilation inlets and outlets and other deckhouse and superstructure boundary space openings shall be such as to complement the provisions of **Par 3** and **Ch 3, 505.** Such vents, especially for machinery spaces, shall be situated as far aft as practicable. Due consideration in this regard shall be given when the ship is equipped to load or discharge at the stern. Sources of ignition such as electrical equipment shall be so arranged as to avoid an explosion hazard.

3. Cargo tank venting is to comply with the following requirements.

(1) The venting systems of cargo tanks are to be entirely distinct from the air pipes of the other compartments of the ship. The arrangements and position of openings in the cargo tank deck from which emission of flammable vapours can occur shall be such as to minimize the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. In accordance with this general principle, the criteria in paragraphs (2) to (5) and **Ch 3, 505.** will apply.

(2) Venting arrangements are to comply with the following requirements

(A) The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

(B) Where the arrangements are combined with other cargo tanks, either stop valves or other acceptable means shall be provided to isolate each cargo tank. Where stop valves are fitted, they shall be provided with locking arrangements which shall be under the control of the responsible ship's officer. There shall be a clear visual indication of the operational status of the valves or other acceptable means. Where tanks have been isolated, it shall be ensured that relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced. Any isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with **Ch 3, 505. 1** (1). (Refer to the Guidance)

(C) If cargo loading and ballasting or discharging of a cargo tank or cargo tank group is intended, which is isolated from a common venting system, that cargo tank or cargo tank group shall be fitted with a means for over-pressure or under-pressure protection as required in **Ch 3, 505. 3** (2).

(D) The venting arrangements shall be connected to the top of each cargo tank and shall be self-draining to the cargo tanks under all normal conditions of trim and list of the ship. Where it may not be possible to provide self-draining lines, permanent arrangements shall be provided to drain the vent lines to a cargo tank.

(3) The venting system shall be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices shall comply with the requirements established on the basis of **the guidelines** developed by the IMO Organization. Ullage openings shall not be used for pressure equalization. They shall be provided with self-closing and tightly sealing covers. Flame arresters and screens are not permitted in these openings. (Refer to the Guidance)

(4) Vent outlets for cargo handling and ballasting are to comply with the following requirements.

(A) Vent outlets for cargo loading, discharging and ballasting required by **Ch 3, 505. 1** (2) shall: (Refer to the Guidance)

(a) permit the free flow of vapour mixtures; or permit the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/s ;

(b) be so arranged that the vapour mixture is discharged vertically upwards;

(c) where the method is by free flow of vapour mixtures, be such that the outlet shall be not less than 6 m above the cargo tank deck or fore and aft catwalk if situated within 4 m of the catwalk and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard; and

(d) where the method is by high-velocity discharge, be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard. These outlets shall be provided with high velocity devices of an approved type.

(B) The arrangements for the venting of vapours displaced from the cargo tanks during loading and ballasting shall comply with **Par 3** and **Ch 3, 505.** and shall consist of either one or more mast risers, or a number of high-velocity vents. The inert gas supply main may be used for such venting.

(5) In combination carriers, the arrangements for isolating slop tanks containing oil or oil residues from other cargo tanks shall consist of blank flanges which will remain in position at all times when cargoes other than liquid cargoes are carried.

4. Ventilation is to comply with the following requirements.

(1) Cargo pump-rooms shall be mechanically ventilated and discharges from the exhaust fans shall be led to a safe place on the open deck. The ventilation of these rooms shall have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of air changes shall be at least 20 per hour, based upon the gross volume of the space. The air ducts shall be arranged so that all of the space is effectively ventilated. The ventilation shall be of the suction type using fans of the non-sparking type. (Refer to the Guidance)

(2) In combination carriers, cargo spaces and any enclosed spaces adjacent to cargo spaces shall be capable of being mechanically ventilated. The mechanical ventilation may be provided by portable fans. An approved fixed gas warning system capable of monitoring flammable vapours shall be provided in cargo pump-rooms, pipe ducts and cofferdams, as referred to in **Par 1** (4) adjacent to slop tanks. Suitable arrangements shall be made to facilitate measurement of flammable vapours in all other spaces within the cargo area. Such measurements shall be made possible from the open deck or easily accessible positions.

5. Inert gas systems is to comply with the following requirements. (Refer to the Guidance)

(1) For tankers of 20,000 tons deadweight and upwards, the protection of the cargo tanks shall be achieved by a fixed inert gas system in accordance with the requirements of the Fire Safety Systems Code, except that, in lieu of the above, the Society, after having given consideration to the ship's arrangement and equipment, may accept other fixed installations if they afford protection equivalent to the above. The requirements for alternative fixed installations shall comply with the requirements in paragraph (6).

(2) Tankers operating with a cargo tank cleaning procedure using crude oil washing, irrespective of its age, shall be fitted with an inert gas system complying with the requirements of the Fire Safety Systems Code and with fixed tank washing machines.

(3) Tankers required to be fitted with inert gas systems shall comply with the following provisions: (Refer to the Guidance)

(A) double hull spaces shall be fitted with suitable connections for the supply of inert gas;

(B) where hull spaces are connected to a permanently fitted inert gas distribution system, means shall be provided to prevent hydrocarbon gases from the cargo tanks entering the double hull spaces through the system; and

(C) where such spaces are not permanently connected to an inert gas distribution system, appropriate means shall be provided to allow connection to the inert gas main.

(4) The requirements for inert gas systems contained in the Fire Safety Systems Code need not be applied to:

(A) chemical tankers and gas carriers that comply with the requirements for inert gas systems on chemical tankers established on the basis of the guidelines developed by the IMO Organization; or

(B) chemical tankers and gas carriers when carrying flammable cargoes other than crude oil or petroleum products such as cargoes listed in the International Bulk Chemical Code, provided that the capacity of tanks used for their carriage does not exceed 3,000 m^3 and the individual nozzle capacities of tank washing machines do not exceed 17.5 m^3/h and the total combined throughput from the number of machines in use in a cargo tank at any one time does not exceed 110 m^3/h.

(5) General requirements for inert gas systems are to comply with the following requirements.

(A) The inert gas system shall be capable of inerting, purging and gas freeing empty tanks and maintaining the atmosphere in cargo tanks with the required oxygen content.

(B) The inert gas system referred to in paragraph (A) shall be designed, constructed and tested in accordance with the Fire Safety Systems Code.

(C) Tankers fitted with a fixed inert gas system shall be provided with a closed ullage system.

(6) Where an installation equivalent to a fixed inert gas system is installed, it shall:

(A) be capable of preventing dangerous accumulations of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations; and

(B) be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.

6. Inerting, purging and gas freeing are to comply with the following requirements.

(1) Arrangements for purging and/or gas freeing shall be such as to minimize the hazards due to dispersal of flammable vapours in the atmosphere and to flammable mixtures in a cargo tank.

(2) The procedure for cargo tank purging and/or gas freeing shall be carried out in accordance with the requirements specified in the Guidance.

(3) The arrangements for inerting, purging or gas-freeing of empty tanks as required in paragraph **5** (5) (A) shall be to the satisfaction of the Society and shall be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimized and that : (Refer to the Guidance)

(A) on individual cargo tanks, the gas outlet pipe, if fitted, shall be positioned as far as practicable from the inert gas/air inlet and in accordance with paragraph **3** and **Ch 3, 505.** The inlet of such outlet pipes may be located either at deck level or at not more than 1 m above the bottom of the tank;

(B) the cross-sectional area of such gas outlet pipe referred to in paragraph (A) shall be such that an exit velocity of at least 20 m/s can be maintained when any three tanks are being simultaneously supplied with inert gas. Their outlets shall extend not less than 2 m above deck level; and

(C) each gas outlet referred to in paragraph (B) shall be fitted with suitable blanking arrangements.

7. Gas measurement is to comply with the following requirements. (Refer to the Guidance)

(1) Tankers shall be equipped with at least one portable instrument for measuring flammable vapour concentrations, together with a sufficient set of spares. Suitable means shall be provided for the calibration of such instruments. (Refer to the Guidance)

(2) Arrangements for gas measurement in double hull and double bottom spaces are to comply with the following requirements.

(A) Suitable portable instruments for measuring oxygen and flammable vapour concentrations shall be provided. In selecting these instruments, due attention shall be given to their use in combination with the fixed gas-sampling-line systems referred to in paragraph (B).

(B) Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces shall be fitted with permanent gas sampling lines. The configuration of gas sampling lines shall be adapted to the design of such spaces.

(C) The materials of construction and the dimensions of gas sampling lines shall be such as to prevent restriction. Where plastic materials are used, they shall be electrically conductive.

8. Double hull and double bottom spaces shall be fitted with suitable connections for the supply of air.

9. Drip pans for collecting cargo residues in cargo lines and hoses shall be provided in the area of pipe and hose connections under the manifold area. Cargo hoses and tank washing hoses shall have electrical continuity over their entire lengths including couplings and flanges (except shore connections) and should be earthed for removal of electrostatic charges.

10. Protection of cargo pump-rooms is to complied with the following requirements.

(1) cargo pumps, ballast pumps and stripping pumps, installed in cargo pump-rooms and driven by shafts passing through pump-room bulkheads shall be fitted with temperature sensing devices for bulkhead shaft glands, bearings and pump casings. A continuous audible and visual alarm signal shall be automatically effected in the cargo control room or the pump control station;

(2) lighting in cargo pump-rooms, except emergency lighting, shall be interlocked with ventilation such that the ventilation shall be in operation when switching on the lighting. Failure of the ventilation system shall not cause the lighting to go out;

(3) a system for continuous monitoring of the concentration of hydrocarbon gases shall be fitted. Sampling points or detector heads shall be located in suitable positions in order that potentially dangerous leakages are readily detected. When the hydrocarbon gas concentration reaches a pre-set level which shall not be higher than 10 % of the lower flammable limit, a continuous audible and visual alarm signal shall be automatically effected in the pump-room, engine control room, cargo control room and navigation bridge to alert personnel to the potential hazard ; and (Refer to the Guidance)

(4) all pump-rooms shall be provided with bilge level monitoring devices together with appropriately located alarms.

SECTION 2 Prevention of fire growth potential

201. Control of air supply and flammable liquid to the spaces

1. Closing appliances and stopping devices of ventilation are to comply with the following requirements.

(1) The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate whether the shutoff is open or closed. (Refer to the Guidance)

(2) Power ventilation of accommodation spaces, service spaces, cargo spaces, control stations and machinery spaces shall be capable of being stopped from an easily accessible position outside the space being served. This position shall not be readily cut off in the event of a fire in the spaces served. (Refer to the Guidance)

(3) **In passenger ships carrying more than 36 passengers**, power ventilation, except machinery space and cargo space ventilation and any alternative system which may be required under **Ch 3, 202.** shall be fitted with controls so grouped that all fans may be stopped from either of two separate positions which shall be situated as far apart as practicable. Fans serving power ventilation systems to cargo spaces shall be capable of being stopped from a safe position outside such spaces.

2. Means of control in machinery spaces are to comply with the following requirements.

(1) Means of control shall be provided for opening and closure of skylights, closure of openings in funnels which normally allow exhaust ventilation and closure of ventilator dampers.

(2) Means of control shall be provided for stopping ventilating fans. Controls provided for the power ventilation serving machinery spaces shall be grouped so as to be operable from two positions, one of which shall be outside such spaces. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.

(3) Means of control shall be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators (purifiers). However, paragraphs (4) and (5) need not apply to oily water

separators.

(4) The controls required in paragraphs (1) to (3) and in **101. 2** (3) (D) shall be located outside the space concerned so they will not be cut off in the event of fire in the space they serve.

(5) In passenger ships, the controls required in paragraphs (1) to (4) and in **Ch 3, 202. 3** and **Ch 3, 304. 2** (3) and the controls for any required fire-extinguishing system shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Such positions shall have a safe access from the open deck.

3. Means of control in periodically unattended machinery spaces is to comply with the additional following requirements. (Refer to the Guidance)

(1) For periodically unattended machinery spaces, the Society shall give special consideration to maintaining the fire integrity of the machinery spaces, the location and centralization of the fire-extinguishing system controls, the required shutdown arrangements (e.g. ventilation, fuel pumps, etc.) and that additional fire-extinguishing appliances and other fire-fighting equipment and breathing apparatus may be required.

(2) In passenger ships, these requirements shall be at least equivalent to those of machinery spaces normally attended.

202. Fire protection materials (Refer to the Guidance)

1. Non-combustible materials are to be used as follows.

(1) Insulating materials shall be non-combustible, except in cargo spaces, mail rooms, baggage rooms and refrigerated compartments of service spaces. Vapour barriers and adhesives used in conjunction with insulation, as well as the insulation of pipe fittings for cold service systems, need not be of non-combustible materials, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics. (Refer to the Guidance)

(2) In passenger ships, except in cargo spaces, partial bulkheads or decks used to screen or to separate adjacent cabin balconies, all linings, grounds, draught stops and ceilings shall be of non-combustible material except in mail rooms, baggage rooms, saunas or refrigerated compartments of service spaces. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment shall also be of non-combustible materials.

(3) In cargo ships, all linings, ceilings, draught stops and their associated grounds shall be of non-combustible materials in the following spaces:

(A) in accommodation and service spaces and control stations for ships where Method IC is specified as referred to in **Ch 3, 301. 3** (1); and

(B) in corridors and stairway enclosures serving accommodation and service spaces and control stations for ships where Method IIC and IIIC are specified as referred to in **Ch 3, 301. 3** (1).

2. Use of combustible materials is to be permitted as follows. (Refer to the Guidance)

(1) In passenger ships, "A", "B" or "C" class divisions in accommodation, services spaces and cabin balconies which are faced with combustible materials, facings, mouldings, decorations and veneers shall comply with the provisions of paragraphs (3) to (5) and **Sec 3.** However, traditional wooden benches and wooden linings on bulkheads and ceilings are permitted in saunas and such materials need not be subject to the calculations prescribed in paragraphs (3) and (4). However, the provisions of paragraph 3.2.3 need not be applied to cabin balconies.

(2) In cargo ships, non-combustible bulkheads, ceilings and linings fitted in accommodation and service spaces may be faced with combustible materials, facings, mouldings, decorations and veneers provided such spaces are bounded by non-combustible bulkheads, ceilings and linings in accordance with the provisions of paragraphs (3) to (5) and **Sec 3.**

(3) Combustible materials used on the surfaces and linings specified in paragraph (1), (2) shall have a calorific value not exceeding 45 MJ/m^2 of the area for the thickness used. The requirements of this paragraph are not applicable to the surfaces of furniture fixed to linings or bulkheads.

(4) Combustible materials used in accordance with paragraph (1), (2) shall comply with the following requirements:

(A) The total volume of combustible facings, mouldings, decorations and veneers in accommodation and service spaces shall not exceed a volume equivalent to 2.5 mm veneer on the combined area of the walls and ceiling linings. Furniture fixed to linings, bulkheads or decks need not be included in the calculation of the total volume of combustible materials; and

(B) In the case of ships fitted with an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code, the above volume may include some combustible material used for erection of "C" class divisions.

(5) The following surfaces shall have low flame-spread characteristics in accordance with the Fire Test Procedures Code: (Refer to the Guidance)

(A) In passenger ships:

(a) exposed surfaces in corridors and stairway enclosures and of bulkhead and ceiling linings in accommodation and service spaces (except saunas) and control stations; and

(b) surfaces and grounds in concealed or inaccessible spaces in accommodation and service spaces and control stations.

(c) exposed surfaces of cabin balconies, except for natural hard wood decking systems.

(B) In cargo ships:

(a) exposed surfaces in corridors and stairway enclosures and of ceilings in accommodation and service spaces (except saunas) and control stations; and

(b) surfaces and grounds in concealed or inaccessible spaces in accommodation and service spaces and control stations.

3. Furniture in stairway enclosures of passenger ships shall be limited to seating. It shall be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk determined in accordance with the Fire Test Procedure Code, and shall not restrict the passenger escape route. The Society may permit additional seating in the main reception area within a stairway enclosure if it is fixed, non-combustible and does not restrict the passenger escape route. Furniture shall not be permitted in passenger and crew corridors forming escape routes in cabin areas. In addition to the above, lockers of non-combustible material, providing storage for non-hazardous safety equipment required by these regulations, may be permitted. Drinking water dispensers and ice cube machines may be permitted in corridors provided they are fixed and do not restrict the width of the escape routes. This applies as well to decorative flower or plant arrangements, statues or other objects of art such as paintings and tapestries in corridors and stairways.

4. On passenger ships, furniture and furnishings on cabin balconies shall comply with regulations **Ch 1, 103. 40** (1),(2),(3),(6) and (7) unless such balconies are protected by a fixed pressure water-spraying and fixed fire detection and fire alarm systems complying with regulations **Ch 3, 108.** and **Ch 3, 405. 1** (3).

SECTION 3 Prevention of smoke generation potential and toxicity

301. Paints, vanishes and other finishes

1. Paints, varnishes and other finishes used on exposed interior surfaces shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code. (Refer to the Guidance)

2. Paints, varnishes and other finishes used on exposed surfaces of passenger ship cabin balconies, excluding natural hard wood decking systems, shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code.

302. Primary deck coverings

1. Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not give rise to smoke or toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code. (Refer to the Guidance)

2. Primary deck coverings on passenger ship cabin balconies shall not give rise to smoke, toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code. ⚓

CHAPTER 3 SUPPRESSION OF FIRE

SECTION 1 Detection and Alarm

101. General requirements

1. A fixed fire detection and fire alarm system shall be provided in accordance with the Fire Safety Systems Code. (Refer to the Guidance)

2. A fixed fire detection and fire alarm system and a sample extraction smoke detection system required in this regulation and other regulations in this part shall be of an approved type and comply with the Fire Safety Systems Code. (Refer to the Guidance)

3. Where a fixed fire detection and fire alarm system is required for the protection of spaces other than those specified in **103. 1** at least one detector complying with the Fire Safety Systems Code shall be installed in each such space.

4. Initial and periodical tests are also to be complied with ;

(1) The function of fixed fire detection and fire alarm systems required by the relevant regulations of this chapter shall be tested under varying conditions of ventilation after installation.

(2) The function of fixed fire detection and fire alarm systems shall be periodically tested to the satisfaction of the Society by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond.

5. A fixed fire detection and fire alarm system for passenger ships shall be capable of remotely and individually identifying each detector and manually operated call point.

102. Protection of machinery spaces

1. A fixed fire detection and fire alarm system shall be installed in: (Refer to the Guidance)

(1) periodically unattended machinery spaces;

(2) machinery spaces where the installation of automatic and remote control systems and equipment has been approved in lieu of continuous manning of the space; and

(3) machinery spaces where the main propulsion and associated machinery including sources of main source of electrical power are provided with various degrees of automatic or remote control and are under continuous manned supervision from a control room.

2. The fixed fire detection and fire alarm system required in **Par 1** (1) shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detectors shall not be permitted. The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in sufficient places to ensure that the alarms are heard and observed on the navigating bridge and by a responsible engineer officer. When the navigating bridge is unmanned the alarm shall sound in a place where a responsible member of the crew is on duty. (Refer to the Guidance)

103. Protection of accommodation and service spaces and control stations

1. Smoke detectors shall be installed in all stairways, corridors and escape routes within accommodation spaces as provided in **Par 2, 3** and **4.** Consideration shall be given to the installation of special purpose smoke detectors within ventilation ducting.

2. For passenger ships carrying more than 36 passengers, a fixed fire detection and fire alarm system shall be installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors, stairways and escape routes within accommodation spaces. Smoke detectors need not be fitted in private bathrooms and galleys. Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with a fixed fire detection and alarm system. Detectors fitted in cabins, when activated, shall also be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located.

3. For passenger ships carrying not more than 36 passengers, there shall be installed throughout each separate zone, whether vertical or horizontal, in all accommodation and service spaces and, where it is considered necessary, in control stations, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc., either:

(1) a fixed fire detection and fire alarm system so installed and arranged as to detect the presence of fire in such spaces and providing smoke detection in corridors, stairways and escape routes within accommodation spaces. Detectors fitted in cabins, when activated, shall also be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located.; or

(2) an automatic sprinkler, fire detection and fire alarm system of an approved type complying with the relevant requirements of the Fire Safety Systems Code and so installed and arranged as to protect such spaces and, in addition, a fixed fire detection and fire alarm system and so installed and arranged as to provide smoke detection in corridors, stairways and escape routes within accommodation spaces.

4. In passenger ships, the entire main vertical zone containing the atrium shall be protected throughout with a smoke detection system.

5. For Cargo ships, accommodation and service spaces and control stations of cargo ships shall be protected by a fixed fire detection and fire alarm system and/or an automatic sprinkler, fire detection and fire alarm system as follows depending on a protection method adopted in accordance with **301. 3** (1). (Refer to the Guidance)

(1) Method IC
A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

(2) Method IIC
An automatic sprinkler, fire detection and fire alarm system of an approved type complying with the relevant requirements of the Fire Safety Systems Code shall be so installed and arranged as to protect accommodation spaces, galleys and other service spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

(3) Method IIIC
A fixed fire detection and fire alarm system shall be so installed and arranged as to detect the presence of fire in all accommodation spaces and service spaces providing smoke detection in corridors, stairways and escape routes within accommodation spaces, except spaces which afford no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

104. Protection of cargo spaces in passenger ships

A fixed fire detection and fire alarm system or a sample extraction smoke detection system shall be provided in any cargo space which, in the opinion of the Society, is not accessible, except where it is shown to the satisfaction that the ship is engaged on voyages of such short duration that it would be unreasonable to apply this requirement.

105. Manually operated call points

Manually operated call points complying with the Fire Safety Systems Code shall be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point shall be located at each exit into the outside. Manually operated call points shall be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

106. Fire patrols in passenger ships

1. For ships carrying more than 36 passengers an efficient patrol system shall be maintained so that an outbreak of fire may be promptly detected. Each member of the fire patrol shall be trained to be familiar with the arrangements of the ship as well as the location and operation of any equipment he may be called upon to use.

2. The construction of ceiling and bulkheads shall be such that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible places, except where in the opinion of the Society there is no risk of fire originating in such places.

3. Each member of the fire patrol shall be provided with a two-way portable radiotelephone apparatus.

107. Fire alarm signalling systems in passenger ships

1. Passenger ships shall at all times when at sea, or in port (except when out of service), be so manned or equipped as to ensure that any initial fire alarm is immediately received by a responsible member of the crew.

2. The control panel of fixed fire detection and fire alarm systems shall be designed on the fail-safe principle (e.g. an open detector circuit shall cause an alarm condition).

3. Passenger ships carrying more than 36 passengers shall have the fire detection alarms for the systems required by **103. 2** centralized in a continuously manned central control station. In addition, controls for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location. The ventilation fans shall be capable of reactivation by the crew at the continuously manned control station. The control panels in the central control station shall be capable of indicating open or closed positions of fire doors and closed or off status of the detectors, alarms and fans. The control panel shall be continuously powered and shall have an automatic change-over to standby power supply in case of loss of normal power supply. The control panel shall be powered from the main source of electrical power and the emergency source of electrical power unless other arrangements are permitted by the regulations, as applicable.

4. A special alarm, operated from the navigation bridge or fire control station, shall be fitted to summon the crew. This alarm may be part of the ship's general alarm system and shall be capable of being sounded independently of the alarm to the passenger spaces.

108. Protection of cabin balconies on passenger ships

A fixed fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code shall be insulated on cabin balconies of ships to which regulation **Sec. 2, 202. 4** applies, when furniture and furnishings on such balconies are not as defined in regulations **Sec. 1, 103. 40** (1),(2),(3),(6) and (7).

SECTION 2 Control of smoke speed

201. Protection of control stations outside machinery space

Practicable measures shall be taken for control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained so that, in the event of fire, the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided and air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimized. At the discretion of the Society, such requirements need not apply to control stations situated on, and opening on to, an open deck or where local closing arrangements would be equally effective. The ventilation system serving safety centres may be derived from the ventilation system serving the navigation bridge, unless located in an adjacent main vertical zone. (Refer to the Guidance)

202. Release of smoke from machinery spaces

1. The provisions of this paragraph shall apply to machinery spaces of category A and, where the Society considers desirable, to other machinery spaces.

2. Suitable arrangements shall be made to permit the release of smoke, in the event of fire, from the space to be protected, subject to the provisions of **304. 2** (1). The normal ventilation systems may be acceptable for this purpose.

3. Means of control shall be provided for permitting the release of smoke and such controls shall be located outside the space concerned so that, in the event of fire, they will not be cut off from the space they serve.

4. In passenger ships, the controls required by **Par 3** shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Such positions shall have a safe access from the open deck.

203. Draft stops

Air spaces enclosed behind ceilings, panelling or linings shall be divided by close-fitting draught stops spaced not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck. (Refer to the Guidance)

204. Smoke extraction systems in atriums of passenger ships

Atriums shall be equipped with a smoke extraction system. The smoke extraction system shall be activated by the required smoke detection system and be capable of manual control. The fans shall be sized such that the entire volume within space can be exhausted in 10 min or less.

SECTION 3 Containment of fire

301. Thermal and structural boundaries

1. Ships of all types shall be subdivided into spaces by thermal and structural divisions having regard to the fire risks of the space. (Refer to the Guidance)

2. For passenger ships the following requirements are to be complied with :

(1) Main vertical zones and horizontal zones are to be complied with the following requirements.

(A) In ships carrying **more than 36 passengers,** the hull, superstructure and deckhouses shall be subdivided into main vertical zones by "A-60" class divisions. Steps and recesses shall be kept to a minimum, but where they are necessary they shall also be "A-60" class divisions. Where a category ⑤,⑨,⑩ defined in paragraph (3) (B) (b) is on one side or where fuel oil tanks are on both sides of the division the standard may be reduced to "A-0".

(B) In ships carrying **not more than 36 passengers,** the hull, superstructure and deckhouses in way of accommodation and service spaces shall be subdivided into main vertical zones by "A" class divisions. These divisions shall have insulation values in accordance with tables in paragraph (4).

(C) As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck. The length and width of main vertical zones may be extended to a maximum of 48 m in order to bring the ends of main vertical zones to coincide with watertight subdivision bulkheads or in order to accommodate a large public space extending for the whole length of the main vertical zone provided that the total area of the main vertical zone is not greater than 1,600 m^2 on any deck. The length or width of a main vertical zone is the maximum distance between the furthermost points of the bulkheads bounding it. (Refer to the Guidance)

(D) Such bulkheads shall extend from deck to deck and to the shell or other boundaries.

(E) Where a main vertical zone is subdivided by horizontal "A" class divisions into horizontal zones for the purpose of providing an appropriate barrier between a zone with sprinklers and a zone without sprinklers, the divisions shall extend between adjacent main vertical zone bulkheads and to the shell or exterior boundaries of the ship and shall be insulated in accordance with the fire insulation and integrity values given in **Table 8.3.4.**

(F) On ships designed for special purposes, such as automobile or railroad car ferries, where the provision of main vertical zone bulkheads would defeat the purpose for which the ship is intended, equivalent means for controlling and limiting a fire shall be substituted and specifically approved by the Society. Service spaces and ship stores shall not be located on ro-ro decks unless protected in accordance with the applicable regulations.

(G) However, in a ship with special category spaces, such spaces shall comply with the applicable provisions of **Ch 5, Sec 3** and where such compliance would be inconsistent with other requirements for passenger ships specified in this chapter, the requirements of **Ch 6, Sec 3** shall prevail.

(2) Bulkheads within a main vertical zone are to be complied with the following requirements.

(A) For ships carrying **more than 36 passengers,** bulkheads which are not required to be "A" class divisions shall be at least "B" class or "C" class divisions as prescribed in the tables in paragraph (3).

(B) For ships carrying **not more than 36 passengers,** bulkheads within accommodation and service spaces which are not required to be "A" class divisions shall be at least "B" class or "C" class divisions as prescribed in the tables in paragraph (4). In addition, corridor bulkheads, where not required to be "A" class, shall be "B" class divisions which shall extend from deck to deck except:

(a) when continuous "B" class ceilings or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining shall be of material which, in thickness and composition, is acceptable in the construction of "B" class divisions, but which shall be required to meet "B" class integrity standards only in so far as is reasonable and practicable in the opinion of the Society; and

(b) in the case of a ship protected by an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code, the corridor bulkheads may terminate at a ceiling in the corridor provided such bulkheads and ceilings are of "B" class standard in compliance with paragraph (4). All doors and frames in such bulkheads shall be of non-combustible materials and shall have the same fire integrity as the bulkhead in which they are fitted.

(C) Bulkheads required to be "B" class divisions, except corridor bulkheads as prescribed in paragraph (B), shall extend from deck to deck and to the shell or other boundaries. However, where a continuous "B" class ceiling or lining is fitted on both sides of a bulkhead which is at least of the same fire resistance as the adjoining bulkhead, the bulkhead may terminate at the continuous ceiling or lining. (Refer to the Guidance)

(3) Fire integrity of bulkheads and decks in ships carrying **more than 36 passengers** are to be complied with the following requirements.

(A) In addition to complying with the specific provisions for fire integrity of bulkheads and decks of passenger ships, the minimum fire integrity of all bulkheads and decks shall be as prescribed in **Tables 8.3.1** and **8.3.2.** Where, due to any particular structural arrangements in the ship, difficulty is experienced in determining from the tables the minimum fire integrity value of any divisions, such values shall be determined to the satisfaction of the Society. (Refer to the Guidance)

(B) The following requirements shall govern application of the tables:

(a) **Table 8.3.1** shall apply to bulkheads not bounding either main vertical zones or horizontal zones. **Table 8.3.2** shall apply to decks not forming steps in main vertical zones nor bounding horizontal zones.

(b) For determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, such spaces are classified according to their fire risk as shown in categories ① to ⑭ below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in **Tables 8.3.1** and **8.3.2.** The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

① Control stations
Spaces containing emergency sources of power and lighting.
Wheelhouse and chartroom.
Spaces containing the ship's radio equipment.
Fire control stations
Control room for propulsion machinery when located outside the propulsion machinery space.
Spaces containing centralized fire alarm equipment.
Spaces containing centralized emergency public address system stations and equipment.

② Stairways
Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) for passengers and crew and enclosures thereto.
In this connection a stairway which is enclosed at only one level shall be regarded as part of the space from which it is not separated by a fire door.

③ Corridors
Passenger and crew corridors and lobbies.

④ Evacuation stations and external escape routes
Survival craft stowage area.
Open deck spaces and enclosed promenades forming lifeboat and liferaft embarkation and lowering stations.
Assembly stations, internal and external.
External stairs and open decks used for escape routes.
The ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferaft and evacuation slide embarkation areas.

⑤ Open deck spaces
Open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and lowering stations. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings. Air spaces (the space outside superstructures and deckhouses).

⑥ Accommodation spaces of minor fire risk
Cabins containing furniture and furnishings of restricted fire risk.
Offices and dispensaries containing furniture and furnishings of restricted fire risk.
Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of less than 50 m^2.

⑦ Accommodation spaces of moderate fire risk
Spaces as in category ⑥ above but containing furniture and furnishings of other than restricted fire risk.
Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of 50 m^2 or more.
Isolated lockers and small store-rooms in accommodation spaces having areas less than 4 m^2 (in which flammable liquids are not stowed).
Motion picture projection and film stowage rooms. Diet kitchens (containing no open flame).
Cleaning gear lockers (in which flammable liquids are not stowed).
Laboratories (in which flammable liquids are not stowed).
Pharmacies.
Small drying rooms (having a deck area of 4 m^2 or less).
Specie rooms.
Operating rooms.

⑧ Accommodation spaces of greater fire risk
Public spaces containing furniture and furnishings of other than restricted fire risk

and having a deck area of 50 m^2 or more.
Barber shops and beauty parlours. Saunas.
Sale shops.

⑨ Sanitary and similar spaces
Communal sanitary facilities, showers, baths, water closets, etc.
Small laundry rooms.
Indoor swimming pool area.
Isolated pantries containing no cooking appliances in accommodation spaces.
Private sanitary facilities shall be considered a portion of the space in which they are located.

⑩ Tanks, voids and auxiliary machinery spaces having little or no fire risk
Water tanks forming part of the ship's structure.
Voids and cofferdams.
Auxiliary machinery spaces which do not contain machinery having a pressure lubrication system and where storage of combustibles is prohibited, such as:
ventilation and air-conditioning rooms;
windlass room; steering gear room;
stabilizer equipment room;
electrical propulsion motor room;
rooms containing section switchboards and purely electrical equipment other than oil-filled electrical transformers (above 10 kVA) ;
shaft alleys and pipe tunnels;
spaces for pumps and refrigeration machinery (not handling or using flammable liquids).
Closed trunks serving the spaces listed above.
Other closed trunks such as pipe and cable trunks.

⑪ Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk
Cargo oil tanks.
Cargo holds, trunkways and hatchways.
Refrigerated chambers.
Oil fuel tanks (where installed in a separate space with no machinery).
Shaft alleys and pipe tunnels allowing storage of combustibles.
Auxiliary machinery spaces as in category ⑩ which contain machinery having a pressure lubrication system or where storage of combustibles is permitted.
Oil fuel filling stations.
Spaces containing oil-filled electrical transformers (above 10 kVA).
Spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines of power output up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.
Closed trunks serving the spaces listed above.

⑫ Machinery spaces and main galleys
Main propulsion machinery rooms (other than electric propulsion motor rooms) and boiler rooms.
Auxiliary machinery spaces other than those in categories ⑩ and ⑪ which contain internal combustion machinery or other oil-burning, heating or pumping units.
Main galleys and annexes.
Trunks and casings to the spaces listed above.

⑬ Store-rooms, workshops, pantries, etc.
Main pantries not annexed to galleys.
Main laundry.
Large drying rooms (having a deck area of more than 4 m^2)
Miscellaneous stores.
Mail and baggage rooms.
Garbage rooms.
Workshops (not part of machinery spaces, galleys, etc.).
Lockers and store-rooms having areas greater than 4 m^2, other than those spaces that have provisions for the storage of flammable liquids.

⑭ Other spaces in which flammable liquids are stowed

Paint lockers.
Store-rooms containing flammable liquids (including dyes, medicines, etc.).
Laboratories (in which flammable liquids are stowed)

Table 8.3.1 Bulkheads not bounding either main vertical zones or horizontal zones (more than 36 passengers)

Spaces		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
Control stations	①	B-0a	A-0	A-0	A-0	A-0	A-60	A-60	A-60	A-0	A-0	A-60	A-60	A-60	A-60
Stairways	②		A-0a	A-0	A-0	A-0	A-0	A-15	A-15	A-0c	A-0	A-15	A-30	A-15	A-30
Corridors	③			B-15	A-60	A-0	B-15	B-15	B-15	B-15	A-0	A-15	A-30	A-0	A-30
Evacuation stations and external escape routes	④					A-0	A-60b.d	A-60b.d	A-60b.d	A-0d/-	A-0	A-0b	A-60b	A-0b	A-0b
Open deck spaces	⑤						A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of minor fire risk	⑥						B-0	B-0	B-0	C	A-0	A-0	A-30	A-0	A-30
Accommodation spaces of moderate fire risk.	⑦							B-0	B-0	C	A-0	A-15	A-60	A-15	A-60
Accommodation spaces of greater fire risk.	⑧								B-0	C	A-0	A-30	A-60	A-15	A-60
Sanitary and similar spaces	⑨									C	A-0	A-0	A-0	A-0	A-0
Tanks, voids and auxiliary machinery spaces having little no fire risk	⑩										A-0a	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo spaces, cargo and other oil thanks and other similar spaces of moderate fire risk	⑪											A-0a/-	A-0	A-0	A-15
Machinery spaces and main galleys	⑫												A-0a	A-0	A-60
Store-rooms, workshops, pantries, etc.	⑬													A-0a	A-0
Other spaces in which flammable liquids are stowed	⑭														A-30

Table 8.3.2 Decks not forming steps in main vertical zones nor bounding horizontal zones (more than 36 passengers)

Spaces below ↓ Space above →		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
Control stations	①	A-30	A-30	A-15	A-0	A-0	A-0	A-15	A-30	A-0	A-0	A-0	A-60	A-0	A-60
Stairways	②	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-30
Corridors	③	A-15	A-0	A-0a	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-30	A-0	A-30
Evacuation stations and external escape routes	④	A-0	A-0	A-0	A-0	-	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Open deck spaces	⑤	A-0	A-0	A-0	A-0	-	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of minor fire risk	⑥	A-60	A-15	A-0	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of moderate fire risk.	⑦	A-60	A-15	A-15	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of greater fire risk.	⑧	A-60	A-15	A-15	A-60	A-0	A-15	A-15	A-30	A-0	A-0	A-0	A-0	A-0	A-0
Sanitary and similar spaces	⑨	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Tanks, voids and auxiliary machinery spaces having little no fire risk	⑩	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0a	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo spaces, cargo and other oil thanks and other similar spaces of moderate fire risk	⑪	A-60	A-60	A-60	A-60	A-0	A-0	A-15	A-30	A-0	A-0	A-0a	A-0	A-0	A-30
Machinery spaces and main galleys	⑫	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30	A-30a	A-0	A-60
Store-rooms, workshops, pantries, etc.	⑬	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0	A-0
Other spaces in which flammable liquids are stowed	⑭	A-60	A-60	A-60	A-60	A-0	A-30	A-60	A-60	A-0	A-0	A-0	A-0	A-0	A-0

Note: To be applied to **Tables 8.3.1** and **8.3.2**

a Where adjacent spaces are in the same numerical category and superscript "a" appears, a bulkhead or deck between such spaces need not be fitted if deemed unnecessary by the Society. For example, in category ⑫ a bulkhead need not be required between a galley and its annexed pantries provided the pantry bulkhead and decks maintain the integrity of the galley boundaries. A bulkhead is, however, required between a galley and machinery space even though both spaces are in category ⑫.

b The ship's side, to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to liferafts and evacuation slides may be reduced to "A-30".

c Where public toilets are installed completely within the stairway enclosure, the public toilet bulkhead within the stairway enclosure can be of "B" class integrity.

d Where spaces of categories ⑥,⑦,⑧ and ⑨ are located completely within the outer perimeter of the assembly station, the bulkheads of these spaces are allowed to be of "B-0" class integrity. Control positions for audio, video and light installations may be considered as part of the assembly station.

(c) Where a single value is shown for the fire integrity of a boundary between two spaces, that value shall apply in all cases;

(d) Notwithstanding the provisions of paragraph (2) there are no special requirements for material or integrity of boundaries where only a dash appears in the tables; and

(C) Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing wholly or in part, to the required insulation and integrity of a division.

(D) Construction and arrangement of saunas are to comply with the following requirements.

(a) The perimeter of the sauna shall be of "A" class boundaries and may include changing rooms, showers and toilets. The sauna shall be insulated to A-60 standard against other spaces except those inside of the perimeter and spaces of categories ⑤,⑨ and ⑩.

(b) Bathrooms with direct access to saunas may be considered as part of them. In such cases, the door between sauna and the bathroom need not comply with fire safety requirements.

(c) The traditional wooden lining on the bulkheads and ceiling are permitted in the sauna. The ceiling above the oven shall be lined with a non-combustible plate with an air gap of at least 30 mm. The distance from the hot surfaces to combustible materials shall be at least 500 mm or the combustible materials shall be protected (e.g. non-combustible plate with an air gap of at least 30 mm).

(d) The traditional wooden benches are permitted to be used in the sauna.

(e) The sauna door shall open outwards by pushing.

(f) Electrically heated ovens shall be provided with a timer.

(4) Fire integrity of bulkheads and decks in ships carrying **not more than 36 passengers**

(A) In addition to complying with the specific provisions for fire integrity of bulkheads and decks of passenger ships, the minimum fire integrity of bulkheads and decks shall be as prescribed in **Tables 8.3.3** and **8.3.4.**

(B) The following requirements govern application of the tables:

(a) **Tables 8.3.3** and **8.3.4** shall apply respectively to the bulkheads and decks separating adjacent spaces.

(b) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories ① to ⑪ below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in **Tables 8.3.3** and **8.3.4** The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

① Control stations
Spaces containing emergency sources of power and lighting.
Wheelhouse and chartroom.
Spaces containing the ship's radio equipment.
Fire control stations.
Control room for propulsion machinery when located outside the machinery space.
Spaces containing centralized fire alarm equipment.
② Corridors
Passenger and crew corridors and lobbies.
③ Accommodation spaces
Spaces as defined in **Ch 1, 103. 1** excluding corridors.
④ Stairways
Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.
In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.
⑤ Service spaces (low risk)
Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.
⑥ Machinery spaces of category A
Spaces as defined in **Ch 1, 103. 31.**
⑦ Other machinery spaces
Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces).
Spaces as defined in **Ch 1, 103. 30** excluding machinery spaces of category A.
⑧ Cargo spaces
All spaces used for cargo (including cargo oil tanks) and trunkways and hatchways to such spaces, other than special category spaces.
⑨ Service spaces (high risk)
Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, saunas and workshops other than those forming part of the machinery spaces.
⑩ Open decks
Open deck spaces and enclosed promenades having little or no fire risk. Enclosed promenades should have no significant fire risk, meaning that furnishing should be restricted to deck furniture. In addition, such spaces should be naturally ventilated by permanent openings. Air spaces (the space outside superstructures and deck-houses).
⑪ Special category spaces and ro-ro spaces
Spaces as defined in **Ch 1, 103. 41** and **46**.

(c) In determining the applicable fire integrity standard of a boundary between two spaces within a main vertical zone or horizontal zone which is not protected by an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code or between such zones neither of which is so protected, the higher of the two values given in the tables shall apply;
(d) In determining the applicable fire integrity standard of a boundary between two spaces within a main vertical zone or horizontal zone which is protected by an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code or between such zones both of which are so protected, the lesser of the two values given in the tables shall apply. Where a zone with sprinklers and a zone without sprinklers meet within accommodation and service spaces, the higher of the two values given in the tables shall apply to the division between the zones;

(C) Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.
(D) External boundaries which are required in **501.** to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of passenger ships to have "A" class integrity. Similarly, in such

boundaries which are not required to have "A" class integrity, doors may be constructed of materials which are to the satisfaction of the Society.

(E) Saunas shall comply with paragraph (3) (D).

Table 8.3.3 Fire integrity of bulkheads separating adjacent spaces (not more than 36 passengers)

Spaces		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
Control stations	①	A-0c	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60
Corridors	②		Ce	B-0e	A-0a B-0e	B-0e	A-60	A-0	A-0	A-15 A-0d	*	A-15
Accommodation spaces	③			Ce	A-0a B-0e	B-0e	A-60	A-0	A-0	A-15 A-0d	*	A-30 A-0d
Stairways	④				A-0a B-0e	A-0a B-0e	A-60	A-0	A-0	A-15 A-0d	*	A-15
Service spaces (low risk)	⑤					Ce	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	⑥						*	A-0	A-0	A-60	*	A-60
Other Machinery spaces	⑦							A-0b	A-0	A-0	*	A-0
Cargo spaces	⑧								*	A-0	*	A-0
Service spaces (high risk)	⑨									A-0b	*	A-30
Open decks	⑩											A-0
Special category and ro-ro spaces	⑪											A-0

Table 8.3.4 Fire integrity of decks separating adjacent spaces (not more than 36 passengers)

Spaces below ↓ Space above →		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
Control stations	①	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-30
Corridors	②	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Accommodation spaces	③	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30 A-0d
Stairways	④	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-0
Service spaces (low risk)	⑤	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	⑥	A-60	A-60	A-60	A-60	A-60	*	A-60f	A-30	A-60	*	A-60
Other Machinery spaces	⑦	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	⑧	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0
Service spaces (high risk)	⑨	A-60	A-30 A-0d	A-30 A-0d	A-30 A-0d	A-0	A-60	A-0	A-0	A-0	*	A-30
Open decks	⑩	*	*	*	*	*	*	*	*	*	-	A-0
Special category and ro-ro spaces	⑪	A-60	A-15	A-30 A-0d	A-15	A-0	A-30	A-0	A-0	A-30	A-0	A-0

Notes : To be applied to both **Tables 8.3.3** and **8.3.4** as appropriate.

a. For clarification as to which applies, see paragraphs (2) and (5).

b. Where spaces are of the same numerical category and superscript b appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, (e.g. in category ⑨). A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A-0" bulkhead.

c. Bulkhead separating the wheelhouse and chartroom from each other may have a "B-0" rating. No fire rating is required for those partitions separating the navigation bridge and the safety centre when the latter is within the navigation bridge.

d. See paragraphs (B) (c) and (B) (d).

e. For the application of paragraph (1) (B) "B-0" and "C", where appearing in **Table 8.3.3,** shall be read as "A-0".

f. Fire insulation need not be fitted if the machinery space in category ⑦, in the opinion of the Society, has little or no fire risk.

* Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material, but is not required to be of "A" class standard. However, where a deck, except in a category ⑩ space, is penetrated for the passage of elec-

tric cables, pipes and vent ducts, such penetrations should be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-fighting system is fitted. For the application of paragraph (1) (B), an asterisk, where appearing in **Table 8.3.4,** except for categories ⑧ and ⑩, shall be read as “A-0".

(5) Protection of stairways and lifts in accommodation area are to comply with following requirements.

(A) Stairways shall be within enclosures formed of "A" class divisions, with positive means of closure at all openings, except that:

(a) a stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or self-closing doors in one 'tween-deck space. When a stairway is closed in one 'tween-deck space, the stairway enclosure shall be protected in accordance with the tables for decks in paragraphs (3) or (4); and

(b) stairways may be fitted in the open in a public space, provided they lie wholly within the public space.

(B) Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one 'tween-deck to another and shall be provided with means of closing so as to permit the control of draught and smoke. Machinery for lifts located within stairway enclosures shall be arranged in a separate room, surrounded by steel boundaries, except that small passages for lift cables are permitted. Lifts which open into spaces other than corridors, public spaces, special category spaces, stairways and external areas shall not open into stairways included in the means of escape.

(6) Arrangement of cabin balconies is to comply with the following requirements.
Non-load bearing partial bulkheads which separate adjacent cabin balconies shall be capable of being opened by the crew from each side for the purpose of fighting fires.

(7) Protection of atriums is to comply with the following requirements

(A) Atriums shall be within enclosures of "A"class divisions having a fire rating determined in accordance with **Tables 8.3.2** and **8.3.4**, as applicable

(B) Decks separating spaces within atriums shall have a fire rating determined in acccordance with **Tables 8.3.2** and **8.3.4**, as applicable

3. Cargo Ships except tankers are to comply with the following requirements.

(1) Methods of protection in accommodation area are to comply with the following requirements.

(A) One of the following methods of protection shall be adopted in accommodation and service spaces and control stations:

(a) Method IC
The construction of internal divisional bulkheads of non-combustible "B" or "C" class divisions generally without the installation of an automatic sprinkler, fire detection and fire alarm system in the accommodation and service spaces, except as required by **103. 5** (1);

(b) Method IIC
The fitting of an automatic sprinkler, fire detection and fire alarm system as required by **103. 5** (2) for the detection and extinction of fire in all spaces in which fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheads; or

(c) Method IIIC
The fitting of a fixed fire detection and fire alarm system as required by **103. 5** (2), in spaces in which a fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheads, except that in no case must the area of any accommodation space or spaces bounded by an "A" or "B" class division exceed 50 m^2 Consideration may be given by the Society to increasing this area for public spaces. (Refer to the Guidance)

(B) The requirements for the use of non-combustible materials in the construction and insulation of boundary bulkheads of machinery spaces, control stations, service spaces, etc., and the protection of the above stairway enclosures and corridors will be common to all three methods outlined in paragraph (1) (A).

(2) Bulkheads within accommodation area are to comply with the following requirements.

(A) Bulkheads required to be "B" class divisions shall extend from deck to deck and to the shell or other boundaries. However, where a continuous "B" class ceiling or lining is fitted on both sides of the bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

(B) Method IC
Bulkheads not required by this or other regulations for cargo ships to be "A" or "B" class divisions, shall be of at least "C" class construction.

(C) Method IIC
There shall be no restriction on the construction of bulkheads not required by this or other regulations for cargo ships to be "A" or "B" class divisions except in individual cases where "C" class bulkheads are required in accordance with **Table 8.3.5.**

(D) Method IIIC
There shall be no restriction on the construction of bulkheads not required for cargo ships to be "A" or "B" class divisions except that the area of any accommodation space or spaces bounded by a continuous "A" or "B" class division must in no case exceed 50 m^2, except in individual cases where "C" class bulkheads are required in accordance with **Table 8.3.5.** Consideration may be given by the Society to increasing this area for public spaces.

(3) Fire integrity of bulkheads and decks are to comply with the following requirements.

(A) In addition to complying with the specific provisions for fire integrity of bulkheads and decks of cargo ships, the minimum fire integrity of bulkheads and decks shall be as prescribed in **Tables 8.3.5** and **8.3.6.**

(B) The following requirements shall govern application of the tables:

(a) **Tables 8.3.5** and **8.3.6** shall apply respectively to the bulkheads and decks separating adjacent spaces.

(b) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories ① to ⑪ below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in **Tables 8.3.5** and **8.3.6** The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

① Control stations
Spaces containing emergency sources of power and lighting.
Wheelhouse and chartroom.
Spaces containing the ship's radio equipment.
Fire control stations.
Control room for propulsion machinery when located outside the machinery space.
Spaces containing centralized fire alarm equipment.

② Corridors
corridors and lobbies.

③ Accommodation spaces
Spaces as defined in **Ch 1, 103. 1** excluding corridors.

④ Stairways Interior stairway, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto. In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

⑤ Service spaces (low risk)
Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.

⑥ Machinery spaces of category A
Spaces as defined in **Ch 1, 103. 31.**

⑦ Other machinery spaces
Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces).
Spaces as defined in **Ch 1, 103. 30** excluding machinery spaces of category A.

⑧ Cargo spaces
All spaces used for cargo (including cargo oil tanks) and trunkways and hatchways to such spaces.

⑨ Service spaces (high risk)
Galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, and work shops other than those forming part of the machinery spaces.

⑩ Open decks
Open deck spaces and enclosed promenades having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings.
Air spaces (the space outside superstructures and deckhouses).

⑪ Ro-ro and vehicle spaces
Ro-ro spaces and Vehicle spaces as defined in **Ch 1, 103. 41** and **49.**

Table 8.3.5 Fire integrity of bulkheads separating adjacent spaces (Cargo Ships except tankers)

Spaces		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
Control stations	①	A-0e	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60
Corridors	②		C	B-0	B-0 A-0c	B-0	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	③			Ca,b	B-0 A-0c	B-0	A-60	A-0	A-0	A-0	*	A-30
Stairways	④				B-0 A-0c	B-0 A-0c	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	⑤					C	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	⑥						*	A-0	A-0g	A-60	*	A-60f
Other machinery spaces	⑦							A-0d	A-0	A-0	*	A-0
Cargo spaces	⑧								*	A-0	*	A-0
Service spaces (high risk)	⑨									A-0d	*	A-30
Open decks	⑩										-	A-0
Ro-ro spaces and vehicle spaces	⑪											* h

Table 8.3.6 Fire integrity of decks separating adjacent space (Cargo Ships except tankers)

Spaces below ↓ Space above →		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
Control stations	①	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-60
Corridors	②	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	③	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Stairways	④	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	⑤	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	⑥	A-60	A-60	A-60	A-60	A-60	*	A-60i	A-30	A-60	*	A-60
Other machinery spaces	⑦	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	⑧	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0
Service spaces (high risk)	⑨	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0d	*	A-30
Open decks	⑩	*	*	*	*	*	*	*	*	*	-	*
Ro-ro spaces and vehicle spaces	⑪	A-60	A-30	A-30	A-30	A-0	A-60	A-0	A-0	A-30	*	* h

Note: To be applied to **Tables 8.3.5** and **8.3.6** as appropriate.

a. No special requirements are imposed upon bulkheads in methods IIC and IIIC fire protection.
b. In case of method IIIC "B" class bulkheads of "B-0" rating shall be provided between spaces or groups of spaces of 50 m^2 and over in area.
c. For clarification as to which applies, see paragraphs (2) and (4).
d. Where spaces are of the same numerical category and superscript d appear, a bulkhead or deck of the rating shown in the tables is only required when the adjacent

spaces are for a different purpose (e.g. in category ⑨). A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A-0" bulkhead.

e. Bulkheads separating the wheelhouse, chartroom and radio room from each other may have a "B-0" rating.
f. An "A-0" rating may be used if no dangerous goods are intended to be carried or if such goods are stowed not less than 3 m horizontally from such a bulkhead.
g. For cargo spaces in which dangerous goods are intended to be carried, **Ch 5, 202. 8** applies.
h. Bulkheads and decks separating ro-ro spaces shall be capable of being closed reasonably gastight and such divisions shall have "A" class integrity in so far as reasonable and practicable, if in the opinion of the Society it has little or no fire risk.
i. Fire insulation need not be fitted if the machinery in category ⑦ if, in the opinion of the Society, it has little or no fire risk.
* Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of "A" class standard. However, where a deck, except an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations should be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-fighting system is fitted.

(C) Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.
(D) External boundaries which are required in **501.** to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of cargo ships to have "A" class integrity. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be constructed of materials which are to the satisfaction of the Society.
(E) Saunas shall comply with **Par 2** (3) (D).

(4) Protection of stairways and lift trunks in accommodation spaces, service spaces and control stations are to comply with the following requirements.
(A) Stairways which penetrate only a single deck shall be protected, at a minimum, at one level by at least "B-0" class divisions and self-closing doors. Lifts which penetrate only a single deck shall be surrounded by "A-0" class divisions with steel doors at both levels. Stairways and lift trunks which penetrate more than a single deck shall be surrounded by at least "A-0" class divisions and be protected by self-closing doors at all levels. (Refer to the Guidance)
(B) On ships having accommodation for 12 persons or less, where stairways penetrate more than a single deck and where there are at least two escape routes direct to the open deck at every accommodation level, the "A-0" requirements of paragraph (A) may be reduced to "B-0".

4. Tankers are to comply with the following requirements.

(1) For tankers, only method IC as defined in **Par 3** (1) (A) shall be used.

(2) Fire integrity of bulkheads and decks are to comply with the following requirements.
(A) the minimum fire integrity of bulkheads and decks shall be as prescribed in **Tables 8.3.7** and **8.3.8.**
(B) The following requirements shall govern application of the tables:
(a) **Tables 8.3.7** and **8.3.8** shall apply respectively to the bulkhead and decks separating adjacent spaces;
(b) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories ① to ⑩ below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller,

enclosed areas within a space that have less than 30 % communicating openings to that space are considered separate areas. The fire integrity of the boundary bulkheads and decks of such smaller spaces shall be as prescribed in **Tables 8.3.7** and **8.3.8** The number in parentheses preceding each category refers to the applicable column or row in the tables ;

① Control stations
Spaces containing emergency sources of power and lighting.
Wheelhouse and chartroom.
Spaces containing the ship's radio equipment.
Fire control stations.
Control room for propulsion machinery when located outside the machinery space.
Spaces containing centralized fire alarm equipment.

② Corridors
Corridors and lobbies.

③ Accommodation spaces
Spaces as defined in **Ch 1, 103. 1** excluding corridors.

④ Stairways
Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto. In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

⑤ Service spaces (low risk)
Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.

⑥ Machinery spaces of category A
Spaces as defined in **Ch 1, 103. 31.**

⑦ Other machinery spaces
Electrical equipment rooms (auto-telephone exchange and air-conditioning duct spaces).
Spaces as defined in **Ch 1, 103. 30** excluding machinery spaces of category A.

⑧ Cargo pump-rooms
Spaces containing cargo pumps and entrances and trunks to such spaces.

⑨ Service spaces (high risk)
Galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids and work shops other than those forming part of the machinery spaces.

⑩ Open decks
Open deck spaces and enclosed promenades having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings.
Air spaces (the space outside superstructures and deckhouses).

(C) Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

(D) External boundaries which are required in **501.** to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of tankers to have "A" class integrity. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be constructed of materials which are to the satisfaction of the Society.

(E) Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation, shall be constructed of steel and insulated to "A-60" standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. The distance of 3 m shall be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation shall be carried up to the underside of the deck of the navigation bridge. (Refer to the Guidance)

(F) Skylights to cargo pump-rooms shall be of steel, shall not contain any glass and shall be capable of being closed from outside the pump-room.

(G) Construction and arrangement of saunas shall comply with **Ch 3, 301. 2** (3) (D).

Table 8.3.7 Fire integrity of bulkheads separating adjacent spaces (Tankers)

Spaces		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Control stations	①	A-0c	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*
Corridors	②		C	B-0	B-0 A-0a	B-0	A-60	A-0	A-60	A-0	*
Accommodation spaces	③			C	B-0 A-0a	B-0	A-60	A-0	A-60	A-0	*
Stairways	④				B-0 A-0a	B-0 A-0a	A-60	A-0	A-60	A-0	*
Service spaces (low risk)	⑤					C	A-60	A-0	A-60	A-0	*
Machinery spaces of category A	⑥						*	A-0	A-0d	A-60	*
Other machinery spaces	⑦							A-0b	A-0	A-0	*
Cargo pump-rooms	⑧								*	A-60	*
Service spaces (high risk)	⑨									A-0b	*
Open decks	⑩										-

Table 8.3.8 Fire integrity of decks separating adjacent space (Tankers)

Spaces below ↓ Space above →		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Control stations	①	A-0	A-0	A-0	A-0	A-0	A-60	A-0	-	A-0	*
Corridors	②	A-0	*	*	A-0	*	A-60	A-0	-	A-0	*
Accommodation spaces	③	A-60	A-0	*	A-0	*	A-60	A-0	-	A-0	*
Stairways	④	A-0	A-0	A-0	*	A-0	A-60	A-0	-	A-0	*
Service spaces (low risk)	⑤	A-15	A-0	A-0	A-0	*	A-60	A-0	-	A-0	*
Machinery spaces of category A	⑥	A-60	A-60	A-60	A-60	A-60	*	A-60e	A-0	A-60	*
Other machinery spaces	⑦	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*
Cargo pump-rooms	⑧	-	-	-	-	-	A-0d	A-0	*	-	*
Service spaces (high risk)	⑨	A-60	A-0	A-0	A-0	A-0	A-60	A-0	-	A-0b	*
Open decks	⑩	*	*	*	*	*	*	*	*	*	-

Notes: To be applied to **Tables 8.3.7** and **8.3.8** as appropriate.

a. For clarification as to which applies, see **Par 3** (2) and (4).

b. Where spaces are of the same numerical category and superscript b appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g. in category ⑨). A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A-0" bulkhead.

c. Bulkheads separating the wheelhouse, chartroom and radio room from each other may have a "B-0" rating.

d. Bulkheads and decks between cargo pump-rooms and machinery spaces of category A may be penetrated by cargo pump shaft glands and similar gland penetrations, provided that gas tight seals with efficient lubrication or other means of ensuring the permanence of the gas seal are fitted in way of the bulkheads or deck. (Refer to the Guidance)

e. Fire insulation need not be fitted if the machinery space in category ⑦ if, in the opinion of the Society, it has little or no fire risk.

* Where an asterisk appears in the table, the division is required to be of steel or other equivalent material, but is not required to be of "A" class standard. However, where a deck, except an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations should be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-fighting system is fitted.

302. Penetration in fire-resisting divisions and prevention of heat transmission

(Refer to the Guidance)

1. Where "A" class divisions are penetrated, such penetrations shall be tested in accordance with the Fire Test Procedures Code, subject to the provisions of **303. 1** (1) (E). In the case of ventilation ducts, **306. 1** (2) and **306. 3** (1) apply. However, where a pipe penetration is made of steel or equivalent material having a thickness of 3 mm or greater and a length of not less than 900 mm (preferably 450 mm on each side of the division), and no openings, testing is not required. Such penetrations shall be suitably insulated by extension of the insulation at the same level of the division.

2. Where "B" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired, subject to the provisions of **306. 3** (2). Pipes other than steel or copper that penetrate "B" class divisions shall be protected by either:

(1) a fire tested penetration device, suitable for the fire resistance of the division pierced and the type of pipe used; or

(2) a steel sleeve, having a thickness of not less than 1.8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or more and not less than 600 mm for pipe diameters of less than 150 mm (preferably equally divided to each side of the division). The pipe shall be connected to the ends of the sleeve by flanges or couplings; or the clearance between the sleeve and the pipe shall not exceed 2.5 mm; or any clearance between pipe and sleeve shall be made tight by means of non-combustible or other suitable material.

3. Uninsulated metallic pipes penetrating "A" or "B" class divisions shall be of materials having a melting temperature which exceeds 950 ℃ for "A-0" and 850 ℃ for "B-0" class divisions.

4. In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers. The insulation of a deck or bulkhead shall be carried past the penetration, intersection or terminal point for a distance of at least 450 mm in the case of steel and aluminium structures. If a space is divided with a deck or a bulkhead of "A" class standard having insulation of different values, the insulation with the higher value shall continue on the deck or bulkhead with the insulation of the lesser value for a distance of at least 450 mm. (Refer to the Guidance)

303. Protection of openings in fire resisting divisions

1. Openings in bulkheads and decks in **passenger ships** are to comply with the following requirements. (Refer to the Guidance)

(1) Openings in "A" class divisions shall satisfy the following requirements.

(A) Except for hatches between cargo, special category, store, and baggage spaces, and between such spaces and the weather decks, openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.

(B) The construction of doors and door frames in "A" class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkheads in which the doors are situated, this being determined in accordance with the Fire Test Procedures Code. Such doors and door frames shall be constructed of steel or other equivalent material. Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

(C) Watertight doors need not be insulated.

(D) It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.

(E) Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than power-operated watertight doors and those which are normally locked, shall satisfy the following requirements:

(a) the doors shall be self-closing and be capable of closing with an angle of inclination of up to 3.5° opposing closure;

(b) the approximate time of closure for hinged fire doors shall be no more than 40s and no less than 10s from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding doors shall be of no more than 0.2 m/s and no less than 0.1 m/s with the ship in upright position;

(c) the doors, except those for emergency escape trunks, shall be capable of remote release from the continuously manned central control station, either simultaneously or in groups and shall be capable of release also individually from a position at both sides of the door. Release switches shall have an on-off function to prevent automatic resetting of the system;

(d) hold-back hooks not subject to central control station release are prohibited;

(e) a door closed remotely from the central control station shall be capable of being re-opened from both sides of the door by local control. After such local opening, the door shall automatically close again;

(f) indication must be provided at the fire door indicator panel in the continuously manned central control station whether each door is closed;

(g) the release mechanism shall be so designed that the door will automatically close in the event of disruption of the control system or central power supply;

(h) local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated after disruption of the control system or central power supply at least ten times (fully opened and closed) using the local controls;

(i) disruption of the control system or central power supply at one door shall not impair the safe functioning of the other doors;

(j) remote-released sliding or power-operated doors shall be equipped with an alarm that sounds at least 5s but no more than 10s after the door being released from the central control station and before the door begins to move and continues sounding until the door is completely closed;

(k) a door designed to re-open upon contacting an object in its path shall re-open not more than 1 m from the point of contact;

(l) double-leaf doors equipped with a latch necessary for their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the system;

(m) doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in paragraphs (a) and (j);

(n) the components of the local control system shall be accessible for maintenance and adjusting;

(o) power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire and be in accordance with the Fire Test Procedures Code. This system shall satisfy the following requirements:

(i) the control system shall be able to operate the door at the temperature of at least 200 ℃ for at least 60 min, served by the power supply;

(ii) the power supply for all other doors not subject to fire shall not be impaired; and

(iii) at temperatures exceeding 200 ℃ the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945 ℃.

(F) In ships carrying **not more than 36 passengers**, where a space is protected by an automatic sprinkler fire detection and alarm system complying with the provisions the Fire Safety Systems Code or fitted with a continuous "B" class ceiling, openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the "A" class integrity requirements in so far as is reasonable and practicable in the opinion of the Society.

(G) The requirements for "A" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles, provided that there is no requirement for such boundaries to have "A" class integrity in paragraph (3) (C). The requirements for "A" class integrity of the outer boundaries of the ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing lifesaving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

(H) Except for watertight doors, weathertight doors (semi-watertight doors), doors leading to the open deck and doors which need to be reasonably gastight, all "A" class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port of material, construction and fire resistance which is equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges or, in the case of sliding doors, nearest the opening.

(I) Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The operating position shall be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper shall be of steel or other equivalent material and, if necessary, insulated to comply with the requirements of **302. 1.** The damper shall be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

(2) Openings in "B" class divisions shall satisfy the following requirements.

(A) Doors and door frames in "B" class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions, this being determined in accordance with the Fire Test Procedure Code except that ventilation openings may be permitted in the lower portion of such doors. Where such opening is in or under a door the total net area of any such opening or openings shall not exceed 0.05 m^2. Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit is permitted where the cross-sectional area of the duct does not exceed 0.05 m^2. All ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible. Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm. (Refer to the Guidance)

(B) Cabin doors in "B" class divisions shall be of a self-closing type. Hold-back hooks are not permitted. (Refer to the Guidance)

(C) The requirements for "B" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and sidescuttles. Similarly, the requirements for "B" class integrity shall not apply to exterior doors in superstructures and deckhouses. For ships carrying **not more than 36 passengers**, the Society may permit the use of combustible materials in doors separating cabins from the individual interior sanitary spaces such as showers.

(D) In ships carrying **not more than 36 passengers**, where an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code is fitted:

(a) openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the "B" class integrity requirements in so far as is reasonable and practicable in the opinion of the Society; and

(b) openings in corridor bulkheads of "B" class materials shall be protected in accordance with the provisions of **301. 2** (2).

(3) Windows and side scuttles shall satisfy the following requirements.

(A) Windows and side scuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of paragraph (1) (F) and of paragraph (2) (C) apply, shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted, this being determined in accordance with the FTP Code.

(B) Notwithstanding the requirements of **Tables 8.3.1** to **8.3.4,** windows and sidescuttles in bulkheads separating accommodation and service spaces and control stations from weather shall be constructed with frames of steel or other suitable material. The glass shall be retained by a metal glazing bead or angle.

(C) Windows facing life-saving appliances, embarkation and assembly stations, external stairs and open decks used for escape routes, and windows situated below liferaft and escape slide embarkation areas shall have fire integrity as required in **Table 8.3.1.** Where automatic dedicated sprinkler heads are provided for windows, "A-0" windows may be accepted as equivalent. To be considered under this paragraph, the sprinkler heads must either be :

(a) dedicated heads located above the windows, and installed in addition to the conventional ceiling sprinklers; or

(b) conventional ceiling sprinkler heads arranged such that the window is protected by an average application rate of at least 5 litres/(min • m^2) and the additional window area is included in the calculation of the area of coverage; or

(c) water-mist nozzles that have been tested and approved in accordance with the quidelines approved by the IMO.

Windows located in the ship's side below the lifeboat embarkation area shall have fire integrity at least equal to "A-0" class. :

2. Doors in fire-resisting divisions in **cargo ships** are to comply with the following requirements.

(1) The fire resistance of doors shall be equivalent to that of the division in which they are fitted, this being determined in accordance with the Fire Test Procedures Code. Doors approved as "A" class without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm and a non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door. Doors approved as "B" class without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm. Doors and door frames in "A" class divisions shall be constructed of steel. Doors in "B" class divisions shall be non-combustible. Doors fitted in boundary bulkheads of machinery spaces of category A shall be reasonably gastight and self-closing. In ships constructed according to method IC, the Society may permit the use of combustible materials in doors separating cabins from individual interior sanitary accommodation such as showers. (Refer to the Guidance)

(2) Doors required to be self-closing shall not be fitted with hold-back hooks. However, hold-back arrangements fitted with remote release devices of the fail-safe type may be utilized.

(3) In corridor bulkheads ventilation openings may be permitted in and under the doors of cabins and public spaces. Ventilation openings are also permitted in "B" class doors leading to lavatories, offices, pantries, lockers and store rooms. Except as permitted below, the openings shall be provided only in the lower half of a door. Where such an opening is in or under a door the total net area of any such opening or openings shall not exceed 0.05 m^2. Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit is permitted where the cross-sectional area of the duct does not exceed 0.05 m^2. Ventilation openings, except those under the door, shall be fitted with a grille made of non-combustible material. (Refer to the Guidance)

(4) Watertight doors need not be insulated.

304. Protection of openings in machinery space boundaries

1. The provision of this paragraph shall apply to machinery spaces of category A and, where the Society considers it desirable, to other machinery spaces.

2. Protection of openings in machinery space boundaries shall satisfy the following requirements.

(1) The number of skylights, doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

(2) Skylights shall be of steel and shall not contain glass panels.

(3) Means of control shall be provided for closing power-operated doors or actuating release mechanisms on doors other than power-operated watertight doors. The control shall be located outside the space concerned, where they will not be cut off in the event of fire in the space it serves.

(4) In passenger ships, the means of control required in paragraph (3) shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Such positions shall have safe access from the open deck.

(5) In passenger ships, doors, other than power-operated watertight doors shall be so arranged that positive closure is assured in case of fire in the space by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3.5° opposing closure, and having a fail-safe hold-back arrangement, provided with a remotely operated release device. Doors for emergency escape trunks need not be fitted with a fail-safe hold-back facility and a remotely operated release device.

(6) Windows shall not be fitted in machinery space boundaries. However, this does not preclude the use of glass in control rooms within the machinery spaces.

305. Protection of cargo space boundaries

1. In passenger ships carrying **more than 36 passengers**, the boundary bulkheads and decks of special category and ro-ro spaces shall be insulated to "A-60" class standard. However, where a category ⑤,⑨,⑩ space, as defined in **301. 2** (3), is on one side of the division the standard may be reduced to "A-0". Where fuel oil tanks are below a special category space, the integrity of the deck between such spaces may be reduced to "A-0" standard.

2. In passenger ships carrying **not more than 36 passengers**, the boundary bulkheads of special category spaces shall be insulated as required for category ⑪ spaces in **Table 8.3.3** and the horizontal boundaries as required for category ⑧ spaces in **Table 8.3.4.**

3. In passenger ships carrying **not more than 36 passengers** the boundary bulkheads and decks of closed and open ro-ro spaces shall have a fire integrity as required for category ⑧ spaces in **Table 8.3.3** and the horizontal boundaries as required for category ⑧ spaces in **Table 8.3.4.**

4. In passenger ships, indicators shall be provided on the navigating bridge which shall indicate when any fire door leading to or from the special category spaces is closed.

5. In tankers, for the protection of cargo tanks carrying crude oil and petroleum products having a flashpoint not exceeding 60 ℃, materials readily rendered ineffective by heat shall not be used for valves, fittings, tank opening covers, cargo vent piping, and cargo piping so as to prevent the spread of fire to the cargo. (Refer to the Guidance)

306. Ventilation systems (Refer to the Guidance)

1. Duct and dampers are to comply with the following requirements.

(1) Ventilation ducts shall be of steel or equivalent material. However, short ducts, not generally exceeding 2 m in length and with a free cross-sectional area not exceeding 0.02 m^2, need not be steel or equivalent subject to the following conditions : (Refer to the Guidance)

(A) subject to (B), the ducts are made of a material which has low flame spread characteristics;

(B) the ducts shall be made of heat resisting non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value not exceeding 45 MJ/m^2 of their surface area for the thickness used;

(C) the ducts are only used at the end of the ventilation device; and

(D) the ducts are not situated less than 600 mm, measured along the duct, from an opening in an "A" or "B" class division including continuous "B" class ceiling.

(2) The following arrangements shall be tested in accordance with the Fire Test Procedures Code:

(A) fire dampers, including their relevant means of operation; and

(B) duct penetrations through "A" class divisions. However, the test is not required where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding.

2. Arrangement of ducts are to comply with the following requirements. (Refer to the Guidance)

(1) The ventilation systems for machinery spaces of category A, vehicle spaces, ro-ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation systems serving other spaces. Except that the galley ventilation systems on cargo ships of less than 4,000 gross tonnage and in passenger ships carrying not more than 36 passengers, need not be completely separated, but may be served by separate ducts from a ventilation unit serving other spaces. In any case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit. Ducts provided for the ventilation of machinery spaces of category A, galleys, vehicle spaces, ro-ro spaces or special category spaces shall not pass through accommodation spaces, service spaces or control stations unless they comply with the conditions specified in paragraphs (A) to (D) or (E) and (F) below:

(A) the ducts are constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of which are up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of which are between 300 mm and 760 mm having a thickness obtained by interpolation;

(B) the ducts are suitably supported and stiffened;

(C) the ducts are fitted with automatic fire dampers close to the boundaries penetrated; and

(D) the ducts are insulated to "A-60" class standard from the machinery spaces, galleys, vehicle spaces, ro-ro spaces or special category spaces to a point at least 5 m beyond each fire damper; or
(E) the ducts are constructed of steel in accordance with paragraphs (A) and (B); and
(F) the ducts are insulated to "A-60" class standard throughout the accommodation spaces, service spaces or control stations; except that penetrations of main zone divisions shall also comply with the requirements of **303. 1** (1) (H).

(2) Ducts provided for ventilation to accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, galleys, vehicle spaces, ro-ro spaces or special category spaces unless they comply with the conditions specified in paragraphs (1) (A) to (1) (C) or (1) (E) and (1) (F):
(A) the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro space or special category space are constructed of steel in accordance with paragraphs (1) (A) and (1) (B);
(B) automatic fire dampers are fitted close to the boundaries penetrated; and
(C) the integrity of the machinery space, galley, vehicle space, ro-ro space or special category space boundaries is maintained at the penetrations; or
(D) the ducts where they pass through a machinery space of category A, galley, vehicle space, ro-ro space or special category space are constructed of steel in accordance with paragraphs (1) (A) and (1) (B); and
(E) the ducts are insulated to "A-60" standard within the machinery space, galley, vehicle space, ro-ro space or special category space; except that penetrations of main zone divisions shall also comply with the requirements of **303. 1** (1) (H).

3. Details of duct penetrations are to comply with the following requirements.

(1) Where a thin plated duct with a free cross-sectional area equal to, or less than, 0.02 m^2 passes through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of the deck, wholly laid on the lower side of the decks pierced. Where ventilation ducts with a free cross-sectional area exceeding 0.02 m^2 pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve. However, where such ducts are of steel construction and pass through a deck or bulkhead, the ducts and sleeves shall comply with the following:
(A) The sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes; and
(B) Ducts with a free cross-sectional area exceeding 0.075 m^2 shall be fitted with fire dampers in addition to the requirements of paragraph (A). The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the bulkhead or deck. The damper shall be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce. Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection door on which a plate reporting the identification number of the fire damper is provided. The fire damper identification number shall also be placed on any remote controls required. (Refer to the Guidance)

(2) Ventilation ducts with a free cross-sectional area exceeding 0.02 m^2 passing through "B" class bulkheads shall be lined with steel sheet sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length.

4. Ventilation systems for passenger ships carrying more than 36 passengers shall be in compliance with the following additional requirements.

(1) In general, the ventilation fans shall be so disposed that the ducts reaching the various spaces remain within the main vertical zone.

(2) Where ventilation systems penetrate decks, precautions shall be taken, in addition to those

relating to the fire integrity of the deck required by **302. 1** and **303. 1** (1) (E), to reduce the likelihood of smoke and hot gases passing from one 'tween-deck space to another through the system. In addition to insulation requirements contained in **Par 4**, vertical ducts shall, if necessary, be insulated as required by the appropriate **Tables 8.3.1** and **8.3.2.**

(3) Except in cargo spaces, ventilation ducts shall be constructed of the following materials:

(A) ducts not less than 0.075 m^2 in free cross-sectional area and all vertical ducts serving more than a single 'tween-deck space shall be constructed of steel or other equivalent material;

(B) ducts less than 0.075 m^2 in free cross-sectional area other than the vertical ducts referred to in paragraph (A), shall be constructed of steel or equivalent materials. Where such ducts penetrate "A" or "B" class division due regard shall be given to ensuring the fire integrity of the division; and

(C) short length of duct, not in general exceeding 0.02 m^2 in free cross-sectional area nor 2 m in length, need not be steel or equivalent provided that all of the following conditions are met:

(a) subject to (b), the duct is constructed of a material which has low flame spread characteristics;

(b) the ducts shall be made of heat resisting non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value not exceeding 45 MJ/m^2 of their surface area for the thickness used;

(c) the duct is used only at the terminal end of the ventilation system; and

(d) the duct is not located closer than 600 mm measured along its length to a penetration of an "A" or "B" class division, including continuous "B" class ceilings.

(4) Stairway enclosures shall be ventilated and served by an independent fan and duct system which shall not serve any other spaces in the ventilation systems.

(5) Exhaust ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.

5. Exhaust ducts from galley ranges are to comply with the following requirements. (Refer to the Guidance)

(1) For passenger ships carrying **more than 36 passengers** are to comply with the following requirements. exhaust ducts from galley ranges shall meet the requirements of **306. 2** (1) (E) and **306. 2** (1) (F) and shall be fitted with: (Refer to the Guidance)

(A) a grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;

(B) a fire damper located in the lower end of the duct which is automatically and remotely operated, and in addition a remotely operated fire damper located in the upper end of the duct;

(C) a fixed means for extinguishing a fire within the duct;

(D) remote-control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in paragraph (B) and for operating the fire-extinguishing system, which shall be placed in a position close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

(E) suitably located hatches for inspection and cleaning.

(2) Exhaust ducts from ranges for cooking equipment installed on open decks shall conform to (1), as applicable, when passing through accommodation spaces or spaces containing combustible materials.

(3) For cargo ships and passenger ships carrying not more than 36 passenger ships, where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed of "A" class divisions. Each exhaust duct shall be fitted with: (Refer to the Guidance)

(A) a grease trap readily removable for cleaning;

(B) a fire damper located in the lower end of the duct and, in addition, a fire damper in the upper end of the duct;

(C) arrangements, operable from within the galley, for shutting off the exhaust fans; and

(D) fixed means for extinguishing a fire within the duct.

(4) Exhaust ducts from main laundries in ships carrying more than 36 passengers shall be fitted with:
(A) filters readily removable for cleaning purposes;
(B) a fire damper located in the lower end of the duct which is automatically and remotely operated;
(C) remote-control arrangements for shutting off the exhaust fans and supply fans from within the spaces and for operating the fire damper mentioned in (B); and
(D) suitably located hatches for inspection and cleaning

SECTION 4 Fire fighting

401. Water supply systems

1. Fire mains and hydrants are to comply with the following requirements.

(1) Materials readily rendered ineffective by heat shall not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them. The arrangement of pipes and hydrants shall be such as to avoid the possibility of freezing. Suitable drainage provisions shall be provided for fire main piping. Isolation valves shall be installed for all open deck fire main branches used for purposes other than fire fighting. In ships where deck cargo may be carried, the positions of the hydrants shall be such that they are always readily accessible and the pipes shall be arranged as far as practicable to avoid risk of damage by such cargo.

(2) The arrangements for the ready availability of water supply shall be provided as follows.
(A) Passenger ships shall satisfy the following requirements.
(a) in case of 1,000 gross tonnage and upwards such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of one required fire pump;
(b) in case of less than 1,000 gross tonnage by automatic start of at least one fire pump or by remote starting from the navigation bridge of at least one fire pump. If the pump starts automatically or if the bottom valve cannot be opened from where the pump is remotely started, the bottom valve shall always be kept open; and
(c) if fitted with periodically unattended machinery spaces, the Society shall determine provisions for fixed water fire-extinguishing arrangement for such spaces equivalent to those required for normally attended machinery spaces;
(B) Cargo ships shall satisfy the following requirements.
With a periodically unattended machinery space or when only one person is required on watch, there shall be immediate water delivery from the fire main system at a suitable pressure, either by remote starting of one of the main fire pumps with remote starting from the navigating bridge and fire control station, if any, or permanent pressurization of the fire main system by one of the main fire pumps, except that the Society may waive this requirement for cargo ships of less than 1,600 gross tonnage if the fire pump starting arrangement in the machinery space is in an easily accessible position.

(3) The diameter of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously, except that in the case of cargo ships the diameter need only be sufficient for the discharge of 140 m^3/h.

(4) Isolating valves and relief valves are to comply with the following requirements.
(A) Isolating valves to separate the section of the fire main within the machinery space containing the main fire pump or pumps from the rest of the fire main shall be fitted in an easily accessible and tenable position outside the machinery spaces. The fire main shall be so arranged that when the isolating valves are shut all the hydrants on the ship, except those in the machinery space referred to above, can be supplied with water by another fire pump or an emergency fire pump. The emergency fire pump, its seawater inlet, and suction and delivery pipes and isolating valves shall be located outside the machinery space. If this arrangement cannot be made, the sea-chest may be fitted in the machinery space if the valve is remotely controlled from a position in the same compartment as the emergency

pump and the suction pipe is as short as practicable. Short lengths of suction or discharge piping may penetrate the machinery space, provided they are enclosed in a substantial steel casing, or are insulated to A-60 class standards. The pipes shall have substantial wall thickness, but in no case less than 11 mm, and shall be welded except for the flanged connection to the sea inlet valve. (Refer to the Guidance)

(B) A valve shall be fitted to serve each fire hydrant so that any fire hose may be removed while the fire pumps are in operation.

(C) Relief valves shall be provided in conjunction with fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves shall be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(D) In tankers, isolation valves shall be fitted in the fire main at poop front in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in case of fire or explosion.

(5) Number and position of hydrants are to comply with the following requirements.

(A) The number and position of hydrants shall be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated and any part of any cargo space when empty, any ro-ro space or any vehicle space in which latter case the two jets shall reach any part of the space, each from a single length of hose. Furthermore, such hydrants shall be positioned near the accesses to the protected spaces.

(B) In addition to the requirements in the paragraph (A), passenger ships shall comply with the following:

(a) in the accommodation, service and machinery spaces the number and position of hydrants shall be such that the requirements of paragraph (A) may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed; and

(b) where access is provided to a machinery space of category A at a low level from an adjacent shaft tunnel, two hydrants shall be provided external to, but near the entrance to that machinery space. Where such access is provided from other spaces, in one of those spaces two hydrants shall be provided near the entrance to the machinery space of category A. Such provision need not be made where the tunnel or adjacent spaces are not part of the escape route.

(6) With the two pumps simultaneously delivering water through the nozzles specified in **Par 3** (3), with the quantity of water as specified in **Par 1** (3), through any adjacent hydrants, the following minimum pressures shall be maintained at all hydrants: (Refer to the Guidance)

(A) for passenger ships:

4,000 gross tonnage and upwards	0.40 MPa
less than 4000 gross tonnage	0.30 MPa

(B) for cargo ships,

6,000 gross tonnage and upwards	0.27 MPa
less than 6,000 gross tonnage;	0.25 MPa

(C) the maximum pressure at any hydrant shall not exceed that at which the effective control of a fire hose can be demonstrated.

(7) International shore connection is to comply with the following requirements. (Refer to the Guidance)

(A) Ships of 500 gross tonnage and upwards shall be provided with at least one international shore connection complying with the Fire Safety Systems Code.

(B) Facilities shall be available enabling such a connection to be used on either side of the ship.

2. Fire pumps are to be comply with the following requirements. (Refer to the Guidance)

(1) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil and that if they are subject to occasional duty for the transfer or pumping of oil fuel, suitable change-over arrangements are fitted.

(2) Ships shall be provided with independently driven fire pumps as follows:

(A) in passenger ships of:

- 4,000 gross tonnage and upwards at least three
- less than 4,000 gross tonnage at least two

(B) in cargo ships of:
- 1,000 gross tonnage and upwards at least two
- less than 1,000 gross tonnage at least two power driven pumps, one of which shall be independently driven.

(3) Arrangement of fire pumps and fire main shall satisfy the following requirements.(Refer to the Guidance)

(A) The arrangement of sea connections, fire pumps and their sources of power shall be as to ensure that:

(a) in passenger ships of l,000 gross tonnage and upwards, in the event of a fire in any one compartment all the fire pumps will not be put out of action; and

(b) in passenger ships of less than 1,000 gross tonnage and in cargo ships, if a fire in any one compartment could put all the pumps out of action, there shall be an alternative means consisting of an emergency fire pump complying with the provisions of the Fire Safety Systems Code with its source of power and sea connection located outside the space where the main fire pumps or their sources of power are located. (Refer to the Guidance)

(B) The space containing the emergency fire pump (Refer to the Guidance) is to satisfy the following requirements.

(a) The space containing the fire pump shall not be contiguous to the boundaries of machinery spaces of category A or those spaces containing main fire pumps. Where this is not practicable, the common bulkhead between the two spaces shall be insulated to a standard of structural fire protection equivalent to that required for a control station in regulation **301. 3** (3). (Refer to the Guidance)

(b) No direct access shall be permitted between the machinery space and the space containing the emergency fire pump and its source of power. When this is impracticable, the Society may accept an arrangement where the access is by means of an airlock with the door of the machinery space being of A-60 class standard, and the other door being at least steel, both reasonably gastight, self-closing and without any hold back arrangements. Alternatively, the access may be through a watertight door capable of being operated from a space remote from the machinery space and the space containing the emergency fire pump and unlikely to be cut off in the event of fire in those spaces. In such cases, a second means of access to the space containing the emergency fire pump and its source of power shall be provided. (Refer to the Guidance)

(c) Ventilation arrangements to the space containing the independent source of power for the emergency fire pump shall be such as to preclude, as far as practicable, the possibility of smoke from a machinery space fire entering or being drawn into that space.

(C) In addition, in cargo ships where other pumps, such as general service, bilge and ballast, etc., are fitted in a machinery space, arrangements shall be made to ensure that at least one of these pumps, having the capacity and pressure required by **Par 1** (6) (B) and **2** (4) (B) is capable of providing water to the fire main. (Refer to the Guidance)

(4) Capacity of fire pumps are to comply with the following requirements.

(A) The required fire pumps shall be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in **Par 1** (6), as follows:

(a) pumps in passenger ships, the quantity of water is not less than two thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping; and

(b) pumps in cargo ships, other than any emergency pump, the quantity of water is not less than four thirds of the required quantity to be dealt with by each of the independent bilge pumps in a passenger ship of the same dimension when employed in bilge pumping, provided that in no cargo ship need the total required capacity of the fire pumps exceed 180 m^3/h.

(B) Each of the required fire pumps (other than any emergency pump required in **Par 2** (3) (A) (b) for cargo ships) shall have a capacity not less than 80 % of the total required capacity divided by the minimum number of required fire pumps but in any case not less than 25 m^3/h and each such pump shall in any event be capable of delivering at least the two required jets of water. These fire pumps shall be capable of supplying the fire main system under the required conditions. Where more pumps than the minimum of required pumps are installed such additional pumps shall have a capacity of at least 25 m^3/h and shall be capable of delivering at least the two jets of water required in **Par 1** (5) (A).

3. Fire hoses and nozzles are to comply with the following requirements. (Refer to the Guidance)

(1) Fire hoses shall be of non-perishable material approved and shall be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Each hose shall be provided with a nozzle and the necessary couplings. Hoses specified in this chapter as "fire hoses" shall, together with any necessary fittings and tools, be kept ready for use in conspicuous positions near the water service hydrants or connections. Additionally, in interior locations in passenger ships carrying more than 36 passengers fire hoses shall be connected to the hydrants at all times. Fire hoses shall have a length of at least 10 m, but not more than:

(A) 15 m in machinery spaces;
(B) 20 m in other spaces and open decks; and
(C) 25 m for open decks on ships with a maximum breadth in excess of 30 m.

Unless one hose and nozzle is provided for each hydrant in the ship, there shall be complete interchangeability of hose couplings and nozzles.

(2) Number and diameter of fire hoses are to comply with the following requirements.

(A) Ships shall be provided with fire hoses the number and diameter of which shall be to the satisfaction of the Society.
(B) In passenger ships, there shall be at least one fire hose for each of the hydrants required by **Par 1** (5) and these hoses shall be used only for the purposes of extinguishing fires or testing the fire-extinguishing apparatus at fire drills and surveys.
(C) In cargo ships of 1,000 gross tonnage and upwards, the number of fire hoses to be provided shall be one for each 30 m length of the ship and one spare but in no case less than five in all. This number does not include any hoses required in any engine or boiler room. The Society may increase the number of hoses required so as to ensure that hoses in sufficient number are available and accessible at all times, having regard to the type of ship and the nature of trade in which the ship is employed. Ships carrying dangerous goods in accordance with the Rules for Classification of Steel Ships, **Ch. 5, Sec 2** shall be provided with 3 hoses and nozzles, in addition to those required above; and in cargo ships of less than 1,000 gross tonnage, the number of fire hoses to be provided shall be calculated in accordance with this paragraph. However, the number of hoses shall in no case be less than three.

(3) Size and types of nozzles are to comply with the following requirements.

(A) For the purposes of this chapter, standard nozzle sizes shall be 12 mm, 16 mm and 19 mm or as near thereto as possible. Larger diameter nozzles may be permitted at the discretion of the Society.
(B) For accommodation and service spaces, a nozzle size greater than 12 mm need not be used.
(C) For machinery spaces and exterior locations, the nozzle size shall be such as to obtain the maximum discharge possible from two jets at the pressure mentioned in **Par 1** (6) from the smallest pump, provided that a nozzle size greater than 19 mm need not be used.
(D) Nozzles shall be of an approved dual-purpose type (i.e., spray/jet type) incorporating a shutoff.

402. Portable fire extinguisher

1. Portable fire extinguishers shall comply with the requirements of the Fire Safety Systems Code. (Refer to the Guidance)

2. Arrangement of fire extinguishers shall satisfy the following requirements. (Refer to the Guidance)

(1) Accommodation spaces, service spaces and control stations shall be provided with portable fire extinguishers of appropriate types and in sufficient number to the satisfaction of the Society. Ships of 1,000 gross tonnage and upwards shall carry at least five portable fire extinguishers.
(2) One of the portable fire extinguishers intended for use in any space shall be stowed near the entrance to that space.
(3) Carbon dioxide fire extinguishers shall not be placed in accommodation spaces. In control stations and other spaces containing electrical or electronic equipment or appliances necessary for the safety of the ship, fire extinguishers should be provided whose extinguishing media are neither electrically conductive nor harmful to the equipment and appliances.

(4) Fire extinguishers shall be situated ready for use at easily visible places, which can be reached quickly and easily at any time in the event of a fire, and in such a way that their serviceability is not impaired by the weather, vibration or other external factors. Portable fire extinguishers shall be provided with devices which indicate whether they have been used.

3. Spare charges shall satisfy the following requirements.

(1) Spare charges shall be provided for 100 % of the first 10 extinguishers and 50 % of the remaining fire extinguishers capable of being recharged on board. Not more than 60 total spare charges are required. Instructions for recharging shall be carried on board.

(2) For fire extinguishers which cannot be recharged onboard, additional portable fire extinguishers of the same quantity, type, capacity and number as determined in paragraph (1) above shall be provided in lieu of spare charges.

403. Fixed fire - extinguishing systems

1. Types of fixed fire extinguishing systems shall satisfy the following requirements.

(1) A fixed fire extinguishing system required by **404.** below may be any of the following systems:

(A) a fixed gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code; (Refer to the Guidance)

(B) a fixed high-expansion foam fire-extinguishing system complying with the provisions of the Fire Safety Systems Code; and (Refer to the Guidance)

(C) a fixed pressure water-spraying fire-extinguishing system complying with the provisions of the Fire Safety Systems Code. (Refer to the Guidance)

(2) Where a fixed fire-extinguishing system not required by this chapter is installed, it shall meet the requirements of the relevant regulations of this chapter and the Fire Safety Systems Code.

(3) Fire-extinguishing systems using Halon 1211, 1301, and 2402 and perfluorocarbons shall be prohibited.

(4) In general, the Society shall not permit the use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems. Where the use of steam is permitted, it shall be used only in restricted areas as an addition to the required fire-extinguishing system and shall comply with the requirements of the Fire Safety System Code.

2. Where a fixed gas fire-extinguishing system is used, openings which may admit air to, or allow gas to escape from, a protected space shall be capable of being closed from outside the protected space.

3. When the fire extinguishing medium is stored outside a protected space, it shall be stored in a room which is located behind the forward collision bulkhead, and is used for no other purposes. Any entrance to such a storage room shall preferably be from the open deck and shall be independent of the protected space. If the storage space is located below deck, it shall be located no more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck. Spaces which are located below deck or spaces where access from the open deck is not provided, shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour. Access doors shall open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces shall be gastight. For the purpose of the application of **Tables 8.3.1** to **8.3.8,** such storage rooms shall be treated as fire control stations.

4. Pumps, other than those serving the fire main, required for the provision of water for fire-extinguishing systems required by this chapter, their sources of power and their controls shall be installed outside the space or spaces protected by such systems and shall be so arranged that a fire in the space or spaces protected will not put any such system.

404. Fire extinguishing arrangements in machinery spaces

1. Machinery spaces containing oil-fired boilers or oil fuel units shall satisfy the following requirements. (Refer to the Guidance)

(1) Machinery spaces of category A containing oil-fired boilers or oil fuel units shall be provided with any one of the fixed fire-extinguishing systems in **403. 1** In each case, if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine-room, the combined engine and boiler rooms shall be considered as one compartment.

(2) Additional fire-extinguishing arrangements

(A) There shall be in each boiler room or at an entrance outside of the boiler room at least one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code.

(B) There shall be at least two portable foam extinguishers or equivalent in each firing space in each boiler room and in each space in which a part of the oil fuel installation is situated. There shall be not less than one approved foam-type extinguisher of at least 135 liters capacity or equivalent in each boiler room. These extinguishers shall be provided with hoses on reels suitable for reaching any part of the boiler room. In the case of domestic boilers of less than 175 kW an approved foam-type extinguisher of at least 135 liters capacity is not required.

(C) In each firing space there shall be a receptacle containing at least 0.1 m^3 sand, sawdust impregnated with soda, or other approved dry material, along with a suitable shovel for spreading the material. An approved portable extinguisher may be substituted as an alternative.

2. Machinery spaces containing internal combustion machinery shall satisfy the following requirements. (Refer to the Guidance)

(1) Machinery spaces of category A containing internal combustion machinery shall be provided with one of the fixed fire-extinguishing systems in **403. 1.**

(2) Additional fire-extinguishing arrangements are to comply with the following requirements.

(A) There shall be at least one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code.

(B) There shall be in each such space approved foam-type fire extinguishers, each of at least 45 liters capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards. In addition, there shall be provided a sufficient number of portable foam extinguishers or equivalent which shall be so located that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space. For smaller spaces of cargo ships the Society may consider relaxing this requirement.

3. Machinery spaces containing steam turbines or enclosed steam engines shall satisfy the following requirements.

(1) In spaces containing steam turbines or enclosed steam engines used for main propulsion or other purposes having in the aggregate a total output of not less than 375 kW, one of the fire-extinguishing systems specified in **403. 1** shall be provided if such spaces are periodically unattended.

(2) Additional fire-extinguishing arrangements are to comply with the following requirements.

(A) There shall be approved foam fire extinguishers each of at least 45 liters capacity or equivalent sufficient in number to enable foam or its equivalent to be directed on to any part of the pressure lubrication system, on to any part of the casings enclosing pressure lubricated parts of the turbines, engines or associated gearing, and any other fire hazards. However, such extinguishers shall not be required if protection, at least equivalent to that required by this subparagraph, is provided in such spaces by a fixed fire-extinguishing system fitted in compliance with **403. 1.**

(B) There shall be a sufficient number of portable foam extinguishers or equivalent which shall be so located that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space, except that such extinguishers shall not be required in addition to any provided in compliance with **404. 1** (2) (B).

4. Where, in the opinion of the Society, a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in **Par 1, 2** and **3,** there shall be provided in, or adjacent to, that space such a number of approved portable fire extinguishers or other means of fire extinction as the Society may deem sufficient.

5. In passenger ships carrying more than 36 passengers, each machinery space of category A shall be provided with at least two suitable water fog applicators. (Refer to the Guidance)

6. Fixed local application fire-fighting systems shall comply with the following requirements. (Refer to the Guidance)

(1) It shall apply to passenger ships of 500 gross tonnage and above and cargo ships of 2000 gross tonnage and above.
(2) Machinery spaces of category A above 500 m^3 in volume shall, in addition to the fixed fire-extinguishing system required in **404. 1** (1), be protected by an approved type of fixed water-based or equivalent local application fire-fighting system, based on the guidelines developed by the IMO Organization. In the case of periodically unattended machinery spaces, the fire fighting system shall have both automatic and manual release capabilities. In the case of continuously manned machinery spaces, the fire-fighting system is only required to have a manual release capability.
(3) Fixed local application fire-fighting systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:
(A) the fire hazard portions of internal combustion machinery used for the ship's main propulsion and power generation; (Refer to the Guidance)
(B) boiler fronts;
(C) the fire hazard portions of incinerators; and
(D) purifiers for heated fuel oil.
(4) Activation of any local application system shall give a visual and distinct audible alarm in the protected space and at continuously manned stations. The alarm shall indicate the specific system activated. The system alarm requirements described within this paragraph are in addition to, and not a substitute for, the detection and fire alarm system required elsewhere in this chapter.

405. Fire-extinguishing arrangements in control stations, accommodation and service spaces

1. Sprinkler and water spray systems in passenger ships shall satisfy the following requirements.

(1) Passenger ships carrying more than 36 passengers shall be equipped with an automatic sprinkler, fire detection and fire alarm system of an approved type complying with the requirements of the Fire Safety Systems Code in all control stations, accommodation and service spaces, including corridors and stairways. Alternatively, control stations, where water may cause damage to essential equipment, may be fitted with an approved fixed fire-extinguishing system of another type. Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with an automatic sprinkler system. (Refer to the Guidance)
(2) In passenger ships carrying not more than 36 passengers, when a fixed smoke detection and fire alarm system complying with the provisions of the Fire Safety Systems Code is provided only in corridors, stairways and escape routes within accommodation spaces, an automatic sprinkler system shall be installed in accordance with regulation **103. 3** (2).
(3) A fixed pressure water-spraying fire-extinguishing system complying with the provisions of the Fire Safety Systems Code shall be installed on cabin balconies of ships to which regulation **Sec. 2, 202. 4** applies, where furniture and furnishings on such balconies are not as defined in regulations **Sec. 1, 103. 40** (1),(2),(3),(6) and (7).

2. In cargo ships in which method IIC specified in regulation **301. 3** (1) (A) (b) is adopted, an automatic sprinkler, fire detection and fire alarm system shall be fitted in accordance with the requirements in regulation **103. 5** (2).

3. Spaces containing flammable liquid shall satisfy the following requirements.

(1) Paint lockers shall be protected by:
(A) a carbon dioxide system, designed to give a minimum volume of free gas equal to 40 % of the gross volume of the protected space.
(B) a dry powder system, designed for at least 0.5 kg/m^3 ;
(C) a water spraying or sprinkler system, designed for 5 litres/m^2 min. Water spraying systems may be connected to the fire main of the ship; or

(D) a system providing equivalent protection, as determined by the Society. In any case, the system shall be operable from outside the protected space.

(2) Flammable liquid lockers shall be protected by an appropriate fire-extinguishing arrangement approved by the Society. (Refer to the Guidance)

(3) For lockers of a deck area of less than 4 m^2, which do not give access to accommodation spaces, a carbon dioxide portable fire extinguisher sized to provide a minimum volume of free gas equal to 40 % of the gross volume of the space may be accepted in lieu of a fixed system. A discharge port shall be arranged in the locker to allow the discharge of the extinguisher without having to enter into the protected space. The required portable fire extinguisher shall be stowed adjacent to the port. Alternatively, a port or hose connection may be provided to facilitate the use of fire main water. (Refer to the Guidance)

4. Deep-fat cooking equipment

Deep-fat cooking equipment installed in enclosed spaces or on open decks shall be fitted with the following:

(1) an automatic or manual extinguishing system tested to an international standard acceptable to the IMO;*

(2) a primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(3) arrangements for automatically shutting off the electrical power upon activation of the extinguishing system;

(4) an alarm for indicating operation of the extinguishing system in the galley where the equipment is installed; and

(5) controls for manual operation of the extinguishing system which are clearly labelled for ready use by the crew.

406. Fire-extinguishing arrangements in cargo spaces

1. Fixed gas fire-extinguishing systems for general cargo shall satisfy the following requirements. (Refer to the Guidance)

(1) Except as provided for in **Par 2,** the cargo spaces of passenger ships of 1,000 gross tonnage and upwards shall be protected by a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code or by a fixed high expansion foam fire-extinguishing system which gives equivalent protection.

(2) Where it is shown to the satisfaction of the Society that a passenger ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirements of paragraph (1) and also in ships of less than 1,000 gross tonnage, the arrangements in cargo spaces shall be to the satisfaction of the Society, provided that the ship is fitted with steel hatch covers and effective means of closing all ventilators and other openings leading to the cargo spaces.

(3) Except for ro-ro and vehicle spaces, cargo spaces on cargo ships of 2,000 gross tonnage and upwards shall be protected by a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code, or by a fire-extinguishing system which gives equivalent protection. (Refer to the Guidance)

(4) The Society may exempt from the requirements of **Par 1** (3) and 2, cargo spaces of any cargo ship if constructed, and solely intended for, the carriage of ore, coal, grain, unseasoned timber, non-combustible cargoes or cargoes which, in the opinion of the Society, constitute a low fire risk*. Such exemptions may be granted only if the ship is fitted with steel hatch covers and effective means of closing ventilators and other openings leading to the cargo spaces. The Society shall issue an exemption certificate concerned and shall ensure that the list of cargoes the ship is permitted to carry is attached to the exemption certificate. (Refer to the Guidance)

2. A ship engaged in the carriage of dangerous goods in any cargo spaces shall be provided with a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code or with a fire-extinguishing system which, in the opinion of the Society, gives equivalent protection for the cargoes carried. (Refer to the Guidance)

407. Cargo tank protection

1. Fixed deck foam systems shall satisfy the following requirements. (Refer to the Guidance)
(1) For tankers of 20,000 tonnes deadweight and upwards, a fixed deck foam system shall be provided in accordance with the requirements of the Fire Safety Systems Code, except that, in lieu of the above, the Society, after having given consideration to the ship's arrangement and equipment, may accept other fixed installations if they afford protection equivalent to the above. The requirements for alternative fixed installations shall comply with the requirements in paragraph (2).
(2) In accordance with paragraph (1), where the Society accepts an equivalent fixed installation in lieu of the fixed deck foam system, the installation shall:
(A) be capable of extinguishing spill fires and also preclude ignition of spilled oil not yet ignited; and
(B) be capable of combating fires in ruptured tanks.
(3) Tankers of less than 20,000 tonnes deadweight shall be provided with a deck foam system complying with the requirements of the Fire Safety Systems Code.

408. Protection of cargo pump room

1. Each cargo pump-room shall be provided with one of the following fixed fire-extinguishing systems operated from a readily accessible position outside the pump-room. Cargo pump-rooms shall be provided with a system suitable for machinery spaces of category A. (Refer to the Guidance)
(1) A carbon dioxide system complying with the provisions the Fire Safety Systems Code and with the following requirements : (Refer to the Guidance)
(A) the alarms giving audible warning of the release of fire-extinguishing medium shall be safe for use in a flammable cargo vapour/air mixture; and
(B) a notice shall be exhibited at the controls stating that due to the electrostatic ignition hazard, the system is to be used only for fire extinguishing and not for inerting purposes.
(2) A high-expansion foam system complying with the provisions of the Fire Safety Systems Code, provided that the foam concentrate supply is suitable for extinguishing fires involving the cargoes carried.
(3) A fixed pressure water-spraying system complying with the provisions of the Fire Safety Systems Code.

2. Where the extinguishing medium used in the cargo pump-room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate need not be more than the maximum required for the largest compartment.

409. Fire-fighter's outfit

1. Fire-fighter's outfits shall comply with the Fire Safety Systems Code. (Refer to the Guidance)

2. Number of fire-fighter's outfits shall satisfy the following requirements.
(1) Ships shall carry at least two fire-fighter's outfits.
(2) In addition, in passenger ships there shall be provided:
(A) for every 80 m, or part thereof, of the aggregate of the lengths of all passenger spaces and service spaces on the deck which carries such spaces or, if there is more than one such deck, on the deck which has the largest aggregate of such lengths, two fire-fighter's outfits and, in addition, two sets of personal equipment, each set comprising the items stipulated in the Fire Safety Systems Code. In passenger ships carrying more than 36 passengers, two additional fire-fighter's outfits shall be provided for each main vertical zone. However, for stairway enclosures which constitute individual main vertical zones and for the main vertical zones in the fore or aft end of a ship which do not contain spaces of categories ⑥,⑦,⑧, ⑫ defined in regulation **301. 2** (3), no additional fire-fighter's outfits are required; and
(B) ships carrying more than 36 passengers, for each pair of breathing apparatus there shall be provided one water fog applicator which shall be stored adjacent to such apparatus.
(3) In addition, in tankers, two fire-fighter's outfits shall be provided.
(4) The Society may require additional sets of personal equipment and breathing apparatus, having

due regard to the size and type of the ship.

(5) Two spare charges shall be provided for each required breathing apparatus. Passenger ships carrying not more than 36 passengers and cargo ships that are equipped with suitably located means for fully recharging the air cylinders free from contamination, need carry only one spare charge for each required apparatus. In passenger ships carrying more than 36 passengers, at least two spare charges for each breathing apparatus shall be provided.

(6) Passenger ships carrying more than 36 passengers shall be fitted with a suitably located means for fully recharging breathing air cylinders, free from contamination. The means for recharging shall be either :

(A) breathing air compressors supplied from the main and emergency switchboard, or independently driven, with a minimum capacity of 60 ℓ/min per required breathing apparatus, not to exceed 420 ℓ/min ; or

(B) self-contained high-pressure storage systems of suitable pressure to recharge the breathing apparatus used on board, with a capacity of at least 1,200 ℓ per required breathing apparatus, not to exceed 50,000 ℓ of free air.

3. Storage of fire-fighter's outfits shall satisfy the following requirements.

(1) The fire-fighter's outfits or sets of personal equipment shall be kept ready for use in an easily accessible location that is permanently and clearly marked and, where more than one fire-fighter's outfit or more than one set of personal equipment is carried, they shall be stored in widely separated positions.

(2) In passenger ships, at least two fire-fighter's outfits and, in addition, one set of personal equipment shall be available at any one position. At least two fire-fighter's outfits shall be stored in each main vertical zone.

SECTION 5 Structural integrity

501. Material of hull, superstructures, structural bulkheads, decks and deckhouses

The hull, superstructures, structural bulkheads, decks and deckhouses shall be constructed of steel or other equivalent material. For the purpose of applying the definition of steel or other equivalent material as given in **Ch 1, 103. 43** the "applicable fire exposure" shall be according to the integrity and insulation standards given in **Tables 8.3.1** to **8.3.4.** For example, where divisions such as decks or sides and ends of deckhouses are permitted to have "B-0" fire integrity, the "applicable fire exposure shall be half an hour. (Refer to the Guidance)

502. Structure of aluminium alloy

1. Unless otherwise specified in **501.,** in cases where any part of the structure is of aluminium alloy, the following shall apply:

(1) the insulation of aluminium alloy components of "A" or "B" class divisions, except structure which, in the opinion of the Society, is non-load-bearing, shall be such that the temperature of the structural core does not rise more than 200 ℃ above the ambient temperature at any time during the applicable fire exposure to the standard fire test; and (Refer to the Guidance)

(2) special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and "A" and "B" class divisions to ensure:

(A) that for such members supporting lifeboat and liferaft areas and "A" class divisions, the temperature rise limitation specified in paragraph (1) shall apply at the end of one hour; and

(B) that for such members required to support "B" class divisions, the temperature rise limitation specified in paragraph (1) shall apply at the end of half an hour.

503. Machinery spaces of category A

1. Crowns and casings of machinery spaces of category A shall be of steel construction and shall be insulated as required by **Tables 8.3.5** and **8.3.7,** as appropriate. (Refer to the Guidance)

2. The floor plating of normal passageways in machinery spaces of category A shall be made of steel.

504. Materials of overboard fittings

Materials readily rendered ineffective by heat shall not be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding. (Refer to the Guidance)

505. Protection of cargo tank structure against pressure or vacuum in tankers

1. The venting arrangements shall be so designed and operated as to ensure that neither pressure nor vacuum in cargo tanks shall exceed design parameters and be such as to provide for

(1) the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves; and (Refer to the Guidance)

(2) the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

2. Openings for pressure release required by paragraph (1) shall have as great a height as is practicable above the cargo tank deck to obtain maximum dispersal of flammable vapours, but in no case less than 2 m above the cargo tank deck; and be arranged at the furthest distance practicable but not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard. Anchor windlass and chain locker openings constitute an ignition hazard. (Refer to the Guidance)

3. Safety measures in cargo tanks shall satisfy the following requirements.

(1) Provisions shall be made to guard against liquid rising in the venting system to a height which would exceed the design head of cargo tanks. This shall be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and cargo tank filling procedures. For the purposes of this regulation, spill valves are not considered equivalent to an overflow system.

(2) A secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent over-pressure or under-pressure in the event of failure of the arrangements in **Par 1. (2)** Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required in **Par 1. (2),** with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment shall also provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank. (Refer to the Guidance)

(3) Pressure/vacuum valves required by **Par 1. (1)** may be provided with a bypass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided there shall be suitable indicators to show whether the bypass is open or closed.

(4) One or more pressure/vacuum-breaking devices shall be provided to prevent the cargo tanks from being subject to:

(A) a positive pressure, in excess of the test pressure of the cargo tank, if the cargo were to be loaded at the maximum rated capacity and all other outlets are left shut; and

(B) a negative pressure in excess of 700 mm water gauge if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system required by regulation **Ch 2, 104. 3** (1) or on individual cargo tanks. The location and design of the devices shall be in accordance with regulation **Ch 2, 104. 3** and **505.**

4. Vent outlets for cargo loading, discharging and ballasting required by **Par 1.** shall be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1.25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The master shall be provided with information regarding the maximum permissible loading rate for each cargo tank and in the case of combined venting systems, for each group of cargo tanks. (Refer to the Guidance) ⚓

CHAPTER 4 ESCAPE

SECTION 1 Notification of crew and passengers

101. General emergency alarm system

A general emergency alarm system required by SOLAS shall be used for notifying crew and passengers of a fire.

102. Public address systems in passenger ships

A public address system or other effective means of communication complying with the requirements of SOLAS shall be available throughout the accommodation and service spaces and control stations and open decks.

SECTION 2 Means of escape

201. General requirements

1. Unless expressly provided otherwise in this regulation, at least two widely separated and ready means of escape shall be provided from all spaces or group of spaces.

2. Lifts shall not be considered as forming one of the means of escape as required by this regulation.

202. Means of escape from control stations, accommodation and service spaces

1. The following requirements shall comply with.

(1) Stairways and ladders shall be so arranged as to provide ready means of escape to the lifeboat and liferaft embarkation deck from passenger and crew accommodation spaces and from spaces in which the crew is normally employed, other than machinery spaces.

(2) Unless expressly provided otherwise in this regulation, a corridor, lobby, or part of a corridor from which there is only one route of escape shall be prohibited. Dead-end corridors used in service areas which are necessary for the practical utility of the ship, such as fuel oil stations and athwartship supply corridors, shall be permitted, provided such dead-end corridors are separated from crew accommodation areas and are inaccessible from passenger accommodation areas. Also, a part of a corridor that has a depth not exceeding its width is considered a recess or local extension and is permitted.

(3) All stairways in accommodation and service spaces and control stations shall be of steel frame construction except where the Society sanctions the use of other equivalent material.

(4) If a radiotelegraph station has no direct access to the open deck, two means of escape from or access to, the station shall be provided, one of which may be a porthole or window of sufficient size or other means to the satisfaction of the Society. (Refer to the Guidance)

(5) Doors in escape routes shall, in general, open in-way of the direction of escape, except that:

(A) individual cabin doors may open into the cabins in order to avoid injury to persons in the corridor when the door is opened; and

(B) doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and for access.

2. Means of escape in **passenger** ships shall comply with the following requirements.

(1) Escape from spaces below the bulkhead deck shall satisfy the following requirements.

(A) Below the bulkhead deck two means of escape, at least one of which shall be independent of watertight doors, shall be provided from each watertight compartment or similarly restricted space or group of spaces. Exceptionally, the Society may dispense with one of the means of escape for crew spaces that are entered only occasionally, if the required escape route is independent of watertight doors.

(B) Where the Society has granted dispensation under the provisions of paragraph (A), this sole means of escape shall provide safe escape. However, stairways shall not be less than 800 mm in clear width with handrails on both sides.

(2) Above the bulkhead deck there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces at least one of which shall give access to a stairway forming a vertical escape.

(3) Stairway enclosures in accommodation and service spaces shall have direct access from the corridors and be of a sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for non-hazardous safety equipment and open information counters are permitted. Only corridors, lifts, public toilets, special category spaces and open ro-ro spaces to which any passengers carried can have access, other escape stairways required by paragraph (4) (A) and external areas are permitted to have direct access to these stairway enclosures. Public spaces may also have direct access to stairway enclosures except for the backstage of a theatre. Small corridors or "lobbies" used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of 4.5 m^2, a width of no less than 900 mm and contain a fire hose station.

(4) Details of means of escape shall satisfy the following requirements.

(A) At least one of the means of escape required by paragraphs (1) (A) and (2) shall consist of a readily accessible enclosed stairway, which shall provide continuous fire shelter from the level of its origin to the appropriate lifeboat and liferaft embarkation decks, or to the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting in accordance with regulation of SOLAS and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck shall have fire integrity, including insulation values, in accordance with **Tables 8.3.1** to **8.3.4,** as appropriate.

(B) Protection of access from the stairway enclosures to the lifeboat and liferaft embarkation areas shall be provided either directly or through protected internal routes which have fire integrity and insulation values for stairway enclosures as determined by **Tables 8.3.1** to **8.3.4,** as appropriate.

(C) Stairways serving only a space and a balcony in that space shall not be considered as forming one of the required means of escape.

(D) Each level within an atrium shall have two means of escape, one of which shall give direct access to an enclosed vertical means of escape meeting the requirements of paragraph (A).

(E) The widths, number and continuity of escapes shall be in accordance with the requirements in the Fire Safety Systems Code. (Refer to the Guidance)

(5) Marking of escape routes shall satisfy the following requirements.

(A) In addition to the emergency lighting required by regulations of SOLAS, the means of escape, including stairways and exits, shall be marked by lighting or photoluminescent strip indicators placed not more than 300 mm above the deck at all points of the escape route including angles and intersections. The marking must enable passengers to identify the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip will not result in the marking being ineffective. Additionally, escape route signs and fire equipment location markings shall be of photoluminescent material or marked by lighting. The Society shall ensure that such lighting or photoluminescent equipment has been evaluated, tested and applied in accordance with the Fire Safety Systems Code. (Refer to the Guidance)

(B) In passenger ships carrying more than 36 passengers, the requirements of the paragraph (A) shall also apply to the crew accommodation areas.

(C) In lieu of the escape route lighting system required by (A), alternative evacuation guidance systems may be accepted if approved by the Society based on the guidelines developed by the IMO.

(6) Normally locked doors that form part of an escape route shall satisfy the following requirements.

(A) Cabin and stateroom doors shall not require keys to unlock them from inside the room. Neither shall there be any doors along any designated escape route which require keys to unlock them when moving in the direction of escape.
(B) Escape doors from public spaces that are normally latched shall be fitted with a means of quick release. Such means shall consist of a door-latching mechanism incorporating a device that releases the latch upon the application of a force in the direction of escape flow. Quick release mechanisms shall be designed and installed to the satisfaction of the Society and, in particular:
(a) consist of bars or panels, the actuating portion of which extends across at least one half of the width of the door leaf, at least 760 mm and not more than 1120 mm above the deck;
(b) cause the latch to release when a force not exceeding 67 N is applied; and
(c) not be equipped with any locking device, set screw or other arrangement that prevents the release of the latch when pressure is applied to the releasing device.

3. Means of escape in cargo ships shall comply with the following requirements. (Refer to the Guidance)

(1) At all levels of accommodation there shall be provided at least two widely separated means of escape from each restricted space or group of spaces.
(2) Below the lowest open deck the main means of escape shall be a stairway and the second escape may be a trunk or a stairway. (Refer to the Guidance)
(3) Above the lowest open deck the means of escape shall be stairways or doors to an open deck or a combination thereof. (Refer to the Guidance)
(4) No dead-end corridors having a length of more than 7 m shall be accepted. (Refer to the Guidance)
(5) The width, number and continuity of escape routes shall be in accordance with the requirements in the Fire Safety Systems Code.
(6) Exceptionally the Society may dispense with one of the means of escape, for crew spaces that are entered only occasionally, if the required escape route is independent of watertight doors.

4. Emergency escape breathing devices shall comply with the following requirements.

(1) Emergency escape breathing devices shall comply with the Fire Safety Systems Code. Spare emergency escape breathing devices shall be kept onboard. (Refer to the Guidance)
(2) All ships shall carry at least two emergency escape breathing devices within accommodation spaces.
(3) In passenger ships, at least two emergency escape breathing devices shall be carried in each main vertical zone.
(4) In passenger ships carrying more than 36 passengers, two emergency escape breathing devices, in addition to those required in paragraph (3) above, shall be carried in each main vertical zone.
(5) However, paragraphs (3) and (4) do not apply to stairway enclosures which constitute individual main vertical zones and for the main vertical zones in the fore or aft end of a ship which do not contain spaces of categories ⑥,⑦,⑧,⑫ defined in **Ch 3, 301. 2** (3).

203. Means of escape from machinery spaces

1. Means of escape from each machinery space in passenger ships shall comply with the following provisions. (Refer to the Guidance)

(1) Where the space is below the bulkhead deck the two means of escape shall consist of either:
(A) two sets of steel ladders as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate life boat and liferaft embarkation decks. One of these ladders shall be located within a protected enclosure that satisfies **Ch 3, 301. 2** (3), category ②, or **Ch 3, 301. 2** (4), category ④, as appropriate, from the lower part of the space it serves to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800 mm × 800 mm, and shall have emergency lighting provisions; or
(B) one steel ladder leading to a door in the upper part of the space from which access is

provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

(2) Where the space is above the bulkhead deck, the two means of escape shall be as widely separated as possible and the doors leading from such means of escape shall be in a position from which access is provided to the appropriate lifeboat and liferaft embarkation decks. Where such means of escape require the use of ladders, these shall be of steel.

(3) In a ship of less than 1,000 gross tonnage, the Society may dispense with one of the means of escape, due regard being paid to the width and disposition of the upper part of the space. In a ship of 1,000 gross tonnage and above, the Society may dispense with one means of escape from any such space, including a normally unattended auxiliary machinery space, so long as either a door or a steel ladder provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space. In the steering gear space, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

(4) Two means of escape shall be provided from a machinery control room located within a machinery space, at least one of which will provide continuous fire shelter to a safe position outside.

2. Means of escape from each machinery space in cargo ships shall comply with the following provisions. (Refer to the Guidance)

(1) Except as provided in paragraph (2), two means of escape shall be provided from each machinery space of category A. In particular, one of the following provisions shall be complied with:

(A) two sets of steel ladders as widely separated as possible leading to doors in the upper part of the space similarly separated and from which access is provided to the open deck. One of these ladders shall be located within a protected enclosure that satisfies **Ch 3, 301. 2** (3), category ④, from the lower part of the space it serves to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The enclosure shall have minimum internal dimensions of at least 800 mm × 800 mm, and shall have emergency lighting provisions; or

(B) one steel ladder leading to a door in the upper part of the space from which access is provided to the open deck and, additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

(2) In a ship of less than 1,000 gross tonnage, the Society may dispense with one of the means of escape required under paragraph (1), due regard being paid to the dimension and disposition of the upper part of the space. In addition, the means of escape from machinery spaces of category A need not comply with the requirement for an enclosed fire shelter listed in paragraph (1) (A). In the steering gear space, a second means of escape shall be provided when the emergency steering position is located in that space unless there is direct access to the open deck.

(3) From machinery spaces other than those of category A, two escape routes shall be provided except that a single escape route may be accepted for spaces that are entered only occasionally, and for spaces where the maximum travel distance to the door is 5 m or less. (Refer to the Guidance)

3. Emergency escape breathing devices shall satisfy the following requirements.(Refer to the Guidance)

(1) On all ships, within the machinery spaces, emergency escape breathing devices shall be situated ready for use at easily visible places, which can be reached quickly and easily at any time in the event of fire. The location of emergency escape breathing devices shall take into account the layout of the machinery space and the number of persons normally working in the spaces.*

(2) The number and location of these devices shall be indicated in the fire control plan required in regulation of SOLAS.

(3) Emergency escape breathing devices shall comply with the Fire Safety Systems Code. (Refer to the Guidance)

204. Means of escape on passenger ships from special category and open ro-ro spaces to which any passengers carried can have access

1. In special category and open ro-ro spaces to which any passengers carried can have access, the number and locations of the means of escape both below and above the bulkhead deck shall be to the satisfaction of the Society and, in general, the safety of access to the embarkation deck shall be at least equivalent to that provided for under **202. 2** (1) (A), **202. 2** (2), **202. 2** (4) (A), **202. 2** (4) (B). Such spaces shall be provided with designated walkways to the means of escape with a breadth of at least 600 mm. The parking arrangements for the vehicles shall maintain the walkways clear at all times.

2. One of the escape routes from the machinery spaces where the crew is normally employed shall avoid direct access to any special category space.

205. Means of escape from ro-ro spaces

At least two means of escape shall be provided in ro-ro spaces where the crew are normally employed. The escape routes shall provide a safe escape to the lifeboat and liferaft embarkation decks and shall be located at the fore and aft ends of the space. (Refer to the Guidance)

206. Additional requirements from ro-ro passenger ships

1. The following requirements shall comply with..

(1) Escape routes shall be provided from every normally occupied space on the ship to an assembly station. These escape routes shall be arranged so as to provide the most direct route possible to the assembly station, and shall be marked with symbols based on the guidelines developed by the IMO.

(2) The escape route from cabins to stairway enclosures shall be as direct as possible, with a minimum number of changes in direction. It shall not be necessary to cross from one side of the ship to the other to reach an escape route. It shall not be necessary to climb more than two decks up or down in order to reach an assembly station or open deck from any passenger space.

(3) External routes shall be provided from open decks, as referred to in paragraph (2), to the survival craft embarkation stations.

(4) Where enclosed spaces adjoin an open deck, openings from the enclosed space to the open deck shall, where practicable, be capable of being used as an emergency exit.

(5) Escape routes shall not be obstructed by furniture and other obstructions. With the exception of tables and chairs which may be cleared to provide open space, cabinets and other heavy furnishings in public spaces and along escape routes shall be secured in place to prevent shifting if the ship rolls or lists. Floor coverings shall also be secured in place. When the ship is underway, escape routes shall be kept clear of obstructions such as cleaning carts, bedding, luggage and boxes of goods.

2. Instruction for safe escape shall be in accordance with the following requirements.

(1) Decks shall be sequentially numbered, starting with "1" at the tank top or lowest deck. The numbers shall be prominently displayed at stair landings and lift lobbies. Decks may also be named, but the deck number shall always be displayed with the name.

(2) Simple "mimic" plans showing the "you are here" position and escape routes marked by arrows, shall be prominently displayed on the inside of each cabin door and in public spaces. The plan shall show the directions of escape and shall be properly oriented in relation to its position on the ship.

3. Strength of handrails and corridors shall comply with the following requirements.

(1) Handrails or other handholds shall be provided in corridors along the entire escape route so that a firm handhold is available at every step of the way, where possible, to the assembly stations and embarkation stations. Such handrails shall be provided on both sides of longitudinal corridors more than 1.8 m in width and transverse corridors more than 1 m in width. Particular attention shall be paid to the need to be able to cross lobbies, atriums and other large open spaces along escape routes. Handrails and other handholds shall be of such strength as to withstand a distributed horizontal load of 750 N/m applied in the direction of the centre of the

corridor or space, and a distributed vertical load of 750 N/m applied in the downward direction. The two loads need not be applied simultaneously.

(2) The lowest 0.5 m of bulkheads and other partitions forming vertical divisions along escape routes shall be able to sustain a load of 750 N/m to allow them to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.

4. Escape routes shall be evaluated by an evacuation analysis early in the design process. The analysis shall be used to identify and eliminate, as far as practicable, congestion which may develop during an abandonment, due to normal movement of passengers and crew along escape routes, including the possibility that crew may need to move along these routes in a direction opposite the movement of passengers. In addition, the analysis shall be used to demonstrate that escape arrangements are sufficiently flexible to provide for the possibility that certain escape routes, assembly stations, embarkation stations or survival craft may not be available as a result of a casualty. ⚓

CHAPTER 5 SPECIAL REQUIREMENTS

SECTION 1 Helicopter facilities

101. Application

1. In addition ships equipped with helidecks shall comply with the requirements of this regulation.

2. Where helicopters land or conduct winching operations on an occasional or emergency basis on ships without helidecks, fire-fighting equipment fitted in accordance with the requirements in **Ch 3** may be used. This equipment shall be made readily available in close proximity to the landing or winching areas during helicopter operations.

3. Notwithstanding the requirements of **Par 2** above, ro-ro passenger ships without helidecks shall comply with the relevant regulation of the Convention. (Refer to the Guidance)

102. Structure

1. In general, the construction of the helidecks shall be of steel or other equivalent materials. If the helideck forms the deckhead of a deckhouse or superstructure, it shall be insulated to "A-60" class standard.

2. If the Society permits aluminium or other low melting point metal construction that is not made equivalent to steel, the following provisions shall be satisfied:

(1) if the platform is cantilevered over the side of the ship, after each fire on the ship or on the platform, the platform shall undergo a structural analysis to determine its suitability for further use; and

(2) if the platform is located above the ship's deckhouse or similar structure, the following conditions shall be satisfied:

(A) the deckhouse top and bulkheads under the platform shall have no openings;

(B) windows under the platform shall be provided with steel shutters; and

(C) after each fire on the platform or in close proximity, the platform shall undergo a structural analysis to determine its suitability for further use.

103. Means of escape

A helideck shall be provided with both a main and an emergency means of escape and access for fire fighting and rescue personnel. These shall be located as far apart from each other as is practicable and preferably on opposite sides of the helideck.

104. Fire-fighting appliances

1. In close proximity to the helideck, the following fire-fighting appliances shall be provided and stored near the means of access to that helideck:

(1) at least two dry powder extinguishers having a total capacity of not less than 45 kg;

(2) carbon dioxide extinguishers of a total capacity of not less than 18 kg or equivalent;

(3) a suitable foam application system consisting of monitors or foam making branch pipes capable of delivering foam to all parts of the helideck in all weather conditions in which helicopters can operate. The system shall be capable of delivering a discharge rate as required in table for at least five minutes;

Category	Helicopter overall length	Discharge rate foam solution(L/min)
H1	up to but not including 15 m	250
H2	from 15 m up to but not including 24 m	500
H3	from 24 m up to but not including 35 m	800

(4) the principal agent shall be suitable for use with salt water and conform to performance standards not inferior to those acceptable to the IMO Organization;

(5) at least two nozzles of an approved dual-purpose type (jet/spray) and hoses sufficient to reach any part of the helideck;
(6) in addition to the requirements of regulation **Ch 3, 409.,** two sets of fire-fighter's outfits; and
(7) at least the following equipment shall be stored in a manner that provides for immediate use and protection from the elements:
- adjustable wrench;
- blanket, fire resistant;
- cutters, bolt 60 cm;
- hook, grab or salving;
- hacksaw, heavy duty complete with 6 spare blades;
- ladder;
- lift line 5 mm diameter x 15 m in length;
- pliers, side cutting;
- set of assorted screwdrivers; and
- harness knife complete with sheath.

105. Drainage facilities

Drainage facilities in way of helidecks shall be constructed of steel and shall lead directly overboard independent of any other system and shall be designed so that drainage does not fall onto any part of the ship.

106. Helicopter refueling and hanger facilities

1. Where the ship has helicopter refuelling and hangar facilities, the following requirements shall be complied with:
(1) a designated area shall be provided for the storage of fuel tanks which shall be:
(A) as remote as is practicable from accommodation spaces, escape routes and embarkation stations; and
(B) isolated from areas containing a source of vapour ignition;
(2) the fuel storage area shall be provided with arrangements whereby fuel spillage may be collected and drained to a safe location;
(3) tanks and associated equipment shall be protected against physical damage and from a fire in an adjacent space or area;
(4) where portable fuel storage tanks are used, special attention shall be given to:
(A) design of the tank for its intended purpose;
(B) mounting and securing arrangements;
(C) electric bonding; and
(D) inspection procedures;
(5) storage tank fuel pumps shall be provided with means which permit shutdown from a safe remote location in the event of a fire. Where a gravity fuelling system is installed, equivalent closing arrangements shall be provided to isolate the fuel source;
(6) the fuel pumping unit shall be connected to one tank at a time. The piping between the tank and the pumping unit shall be of steel or equivalent material, as short as possible, and protected against damage;
(7) electrical fuel pumping units and associated control equipment shall be of a type suitable for the location and potential hazards;
(8) fuel pumping units shall incorporate a device which will prevent over-pressurization of the delivery or filling hose;
(9) equipment used in refuelling operations shall be electrically bonded;
(10)"NO SMOKING" signs shall be displayed at appropriate locations;
(11)hanger, refuelling and maintenance facilities shall be treated as category 'A' machinery spaces with regard to structural fire protection, fixed fire-extinguishing and detection system requirements;
(12)enclosed hanger facilities or enclosed spaces containing refuelling installations shall be provided with mechanical ventilation, as required by regulation **302.** for closed ro-ro spaces of cargo ships. Ventilation fans shall be of non-sparking type; and
(13)electric equipment and wiring in enclosed hanger or enclosed spaces containing refuelling installations shall comply with regulations **302. 2, 302. 3, 302. 4.**

107. Operations manual and fire- fighting service

1. Each helicopter facility shall have an operations manual, including a description and a checklist of safety precautions, procedures and equipment requirements. This manual may be part of the ship's emergency response procedures.

2. The procedures and precautions to be followed during refuelling operations shall be in accordance with recognized safe practices and contained in the operations manual.

3. Fire-fighting personnel consisting of at least two persons trained for rescue and fire-fighting duties and fire-fighting equipment shall be immediately available at all times when helicopter operations are expected.

4. Fire-fighting personnel shall be present during refuelling operations. However, the fire-fighting personnel shall not be involved with refuelling activities.

5. On-board refresher training shall be carried out and additional supplies of fire-fighting media shall be provided for training and testing of the equipment.

SECTION 2 Carriage of dangerous goods

201. General requirements

1. In addition, ship types and cargo spaces, referred to in **Par 2**, intended for the carriage of dangerous goods shall comply with the requirements of this regulation, as appropriate, except when carrying dangerous goods in limited quantities and excepted quantities unless such requirements have already been met by compliance with the requirements elsewhere in this chapter. The types of ships and modes of carriage of dangerous goods are referred to in **Par 2.** and in **Table 8.5.1.** Cargo ships of less than 500 gross tonnage shall comply with this regulation, but Society may reduce the requirements and such reduced requirements shall be recorded in the document of compliance referred to in **203.**

2. The following ship types and cargo spaces shall govern the application of **Tables 8.5.1** and **8.5.2**:

(1) ships and cargo spaces not specifically designed for the carriage of freight containers, but intended for the carriage of dangerous goods in packaged form including goods in freight containers and portable tanks;
(2) purpose-built container ships and cargo spaces intended for the carriage of dangerous goods in freight containers and portable tanks. (Refer to the Guidance)
(3) ro-ro ships and ro-ro spaces intended for the carriage of dangerous goods. (Refer to the Guidance)
(4) ships and cargo spaces intended for the carriage of solid dangerous goods in bulk; and
(5) ships and cargo spaces intended for carriage of dangerous goods other than liquids and gases in bulk in shipborne barges.

202. Special requirements

Unless otherwise specified, the following requirements shall govern the application of **Tables 8.5.1, 8.5.2** and **8.5.3** to both "on-deck" and "under-deck" stowage of dangerous goods where the numbers of the following paragraphs are indicated in the first column of the tables.

1. Water supplies shall satisfy the following requirements. (Refer to the Guidance)

(1) Arrangements shall be made to ensure immediate availability of a supply of water from the fire main at the required pressure either by permanent pressurization or by suitably placed remote arrangements for the fire pumps.
(2) The quantity of water delivered shall be capable of supplying four nozzles of a size and at pressures as specified in **Ch. 3, 401.** capable of being trained on any part of the cargo space when empty. This amount of water may be applied by equivalent means to the satisfaction of the Society. (Refer to the Guidance)
(3) Means shall be provided for effectively cooling the designated underdeck cargo space by at least 5 litres/min per square meter of the horizontal area of cargo spaces, either by a fixed arrange-

ment of spraying nozzles or flooding the cargo space with water. Hoses may be used for this purpose in small cargo spaces and in small areas of larger cargo spaces at the discretion of the Society. However, the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces. The drainage system shall be sized to remove no less than 125 % of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible, the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Society in its approval of the stability information.

(4) Provision to flood a designated under-deck cargo space with suitable specified media may be substituted for the requirements in paragraph (3). (Refer to the Guidance)

(5) The total required capacity of the water supply shall satisfy paragraphs (2) and (3), if applicable, simultaneously calculated for the largest designated cargo space. The capacity requirements of paragraph (2) shall be met by the total capacity of the main fire pump(s) not including the capacity of the emergency fire pump, if fitted. If a drencher system is used to satisfy paragraph (3), the drencher pump shall also be taken into account in this total capacity calculation.

2. Electrical equipment and wiring shall not be fitted in enclosed cargo spaces or vehicle spaces unless it is essential for operational purposes in the opinion of the Society. However, if electrical equipment is fitted in such spaces, it shall be of a certified safe type* for use in the dangerous environments to which it may be exposed unless it is possible to completely isolate the electrical system (e.g. by removal of links in the system, other than fuses). Cable penetrations of the decks and bulkheads shall be sealed against the passage of gas or vapour. Through runs of cables and cables within the cargo spaces shall be protected against damage from impact. Any other equipment which may constitute a source of ignition of flammable vapour shall not be permitted. (Refer to the Guidance)

3. Ro-ro spaces shall be fitted with a fixed fire detection and fire alarm system complying with the requirements of the Fire Safety Systems Code. All other types of cargo spaces shall be fitted with either a fixed fire detection and fire alarm system or a sample extraction smoke detection system complying with the requirements of the Fire Safety Systems Code. If a sample extraction smoke detection system is fitted, particular attention shall be made to the Fire Safety Systems Code in order to prevent the leakage of toxic fumes into occupied areas.

4. Ventilation arrangement shall satisfy the following requirements. (Refer to the Guidance)

(1) Adequate power ventilation shall be provided in enclosed cargo spaces. The arrangement shall be such as to provide for at least six air changes per hour in the cargo space based on an empty cargo space and for removal of vapours from the upper or lower parts of the cargo space, as appropriate. (Refer to the Guidance)

(2) The fans shall be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings. (Refer to the Guidance)

(3) Natural ventilation shall be provided in enclosed cargo spaces intended for the carriage of solid dangerous goods in bulk, where there is no provision for mechanical ventilation.

5. Bilge pumping shall satisfy the following requirements. (Refer to the Guidance)

(1) Where it is intended to carry flammable (liquids with flash point less than 23 ℃) or toxic liquids in enclosed cargo spaces, the bilge pumping system shall be designed to protect against inadvertent pumping of such liquids through machinery space piping or pumps. Where large quantities of such liquids are carried, consideration shall be given to the provision of additional means of draining those cargo spaces.

(2) If the bilge drainage system is additional to the system served by pumps in the machinery space, the capacity of the system shall be not less than 10 m^3/h per cargo space served. If the additional system is common, the capacity need not exceed 25 m^3/h. The additional bilge system need not be arranged with redundancy. (Refer to the Guidance)

(3) Whenever flammable or toxic liquids are carried, the bilge line into the machinery space shall be isolated either by fitting a blank flange or by a closed lockable valve. (Refer to the Guidance)

(4) Enclosed spaces outside machinery spaces containing bilge pumps serving cargo spaces intended for carriage of flammable or toxic liquids should be fitted with separate mechanical ventilation giving at least 6 air changes per hour. If the space has access from another enclosed space, the door shall be self-closing.

(5) If bilge drainage of cargo spaces is arranged by gravity drainage, the drainage shall be either led directly overboard or to a closed drain tank located outside the machinery spaces. The tank shall be provided with a vent pipe to a safe location on the open deck. Drainage from a cargo space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the cargo space above.

6. Personnel protection shall satisfy the following requirements

(1) Four sets of full protective clothing resistant to chemical attack shall be provided in addition to the fire-fighter's outfits required by **Ch 3, 409.** and shall be selected taking into account the hazards associated with the chemicals being transported and the recognized standards developed according to the class and physical state. The protective clothing shall cover all skin, so that no part of the body is unprotected. (Refer to the Guidance)

(2) At least two self-contained breathing apparatuses additional to those required by **Ch 3, 409.** shall be provided. Two spare charges suitable for use with the breathing apparatus shall be provided for each required apparatus. Passenger ships carrying not more than 36 passengers and cargo ships that are equipped with suitably located means for fully recharging the air cylinders free from contamination, need carry only one spare charge for each required apparatus. (Refer to the Guidance)

7. Portable fire extinguishers with a total capacity of at least 12 kg of dry powder or equivalent shall be provided for the cargo spaces. These extinguishers shall be in addition to any portable fire extinguishers required elsewhere in this chapter.

8. Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to "A-60" class standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to "A-60" class standard. (Refer to the Guidance)

9. Each open ro-ro space having a deck above it and each space deemed to be a closed ro-ro space not capable of being sealed, shall be fitted with an approved fixed pressure water-spraying system for manual operation which shall protect all parts of any deck and vehicle platform in the space, except that the Society may permit the use of any other fixed fire-extinguishing system that has been shown by full-scale test to be no less effective. However, the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces. The drainage system shall be sized to remove no less than 125 % of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Society in its approval of the stability information.*

10. Separation of ro-ro spaces shall satisfy the following requirements.

(1) In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and an adjacent open ro-ro space. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, such separation need not be provided if the ro-ro space is considered to be a closed cargo space over its entire length and shall fully comply with the relevant special requirements of this regulation.

(2) In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and the adjacent weather deck. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, a separation need not be provided if the arrangements of the closed ro-ro spaces are in accordance with those required for the dangerous goods carried on adjacent weather deck.

Table 8.5.1 Application of the requirements to different modes of carriage of dangerous goods in ships and cargo spaces.

Regulation 201.2 / Section 2	Weather decks .1 to .5 inclusive	.1 Not specifically designed	.2 Container cargo spaces	.3 Closed ro-ro cargo spaces5	.3 Open ro-ro cargo spaces	.4 Solid dangerous goods in bulk	.5 Shipborne barges
202.1.(1)	x	x	x	x	x	For application of requirements of regulation **Sec. 202** to different classes of dangerous goods. see **table 8.5.2**	x
202.1.(2)	x	x	x	x	x		-
202.1.(3)	-	x	x	x	x		x
202.1.(4)	-	x	x	x	x		x
202.2	-	x	x	x	x		x[4]
202.3	-	x	x	x	-		x[4]
202.4.(1)	-	x	x[1]	x	-		x[4]
202.4.(2)	-	x	x[1]	x	-		x[4]
202.5	-	x	x	x	-		-
202.6.(1)	x	x	x	x	x		-
202.6.(2)	x	x	x	x	x		-
202.7	x	x	-	-_	x		-
202.8	x	x	x[2]	x	x		-
202.9	-	-	-	x3	x		-
202.10.(1)	-	-	-	x	-		-
202.10.(2)	-	-	-	x	-		-

Where "x" appears in **Table 8.5.1** it means this requirement is applicable to all classes of dangerous goods as given in the appropriate line of **Table 8.5.3**, except as indicated by the notes.

Notes :

1. For classes 4 and 5.1 solids not applicable to closed freight containers. For classes 2, 3, 6.1 and 8 when carried in closed freight containers, the ventilation rate may be reduced to not less than two air changes per hour. For classes 4 and 5.1 liquids when carried in closed freight containers, the ventilation rate may be reduced to not less than two air changes per hour. For the purpose of this requirement, a portable tank is a closed freight container.
2. Applicable to decks only.
3. Applies only to closed ro-ro spaces, not capable of being sealed.
4. In the special case where the barges are capable of containing flammable vapours or alternatively if they are capable of discharging flammable vapours to a safe space outside the barge carrier compartment by means of ventilation ducts connected to the barges, these requirements may be reduced or waived to the satisfaction of the Society.
5. Special category spaces shall be treated as closed ro-ro spaces when dangerous goods are carried.

Table 8.5.2 Application of the requirements to different classes of dangerous goods for ships and cargo spaces carrying solid dangerous goods in bulk

Class	4.1	4.2	4.36	5.1	6.1	8	9
Section 2							
202.1.(1)	x	x	-	x	-	-	x
202.1.(2)	x	x	-	x	-	-	x
202.2	x	x[7]	x	x[8]	-	-	x[8]
202.4.(1)	-	x[7]	x	-	-	-	-_
202.4.(2)	x[9]	x[7]	x	x[7,9]	-	-	x[7,9]
202.4.(3)	x	x	x	x	x	x	x
202.6	x	x	x	x	x	x	x
202.8	x	x	x	x[7]	_-	-_	x[10]

Notes:

6. The hazards of substances in this class which may be carried in bulk are such that special consideration must be given by the Society to the construction and equipment of

the ship involved in addition to meeting the requirements enumerated in this table.
7. Only applicable to Seedcake containing solvent extractions, to Ammonium nitrate and to Ammonium nitrate fertilizers.
8. Only applicable to Ammonium nitrate and to Ammonium nitrate fertilizers. However, a degree of protection in accordance with standards contained in the International Electrotechnical Commission publication 60079, Electrical Apparatus for Explosive Gas Atmospheres, is sufficient.
9. Only suitable wire mesh guards are required.
10. The requirements of the International Maritime Solid Bulk Cargoes (IMSBC) Code, as amended, are sufficient.

Table 8.5.3 Application of the requirements to different classes of dangerous goods except solid dangerous goods in bulk

Class	1.1 to 1.6	1.4S	2.1	2.2	2.3 flammable[20]	2.3 non-flammable	3 FP[15] < 23℃	3 23℃ ≤FP[15] ≤60 ℃	4.1	4.2	4.3 liquids[21]	4.3 solids	5.1	5.2[16]	6.1 liquids FP[15]< 23℃	6.1 liquids 23℃≤ FP[15]≤ 60℃	6.1 liquids	6.1 solids	8 liquids FP[15]< 23℃	8 liquids 23℃≤ FP[15]≤ 60℃	8 liquids	8 solids	9
Sec 2																							
202.1.(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
202.1.(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-
202.1.(3)	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
202.1.(4)	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
202.2	x	-	x	-	x	-	x	-	-	-	x[18]	-	-	-	x	-	-	-	x	-	-	-	x[17]
202.3	x	x	x	x	-	x	x	x	x	x	x	x	x	-	x	x	x	x	x	x	x	x	-
202.4.(1)	-	-	x	-	-	x	x	-	x[11]	x[11]	x	x	x[11]	-	x	x	-	x[11]	x	x	-	-	x[11]
202.4.(2)	-	-	x	-	-	-	x	-	-	-	-	-	-	-	x	-	-	-	x	-	-	-	x[17]
202.5	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	x	x	-	x	x[19]	x[19]	-	-
202.6	-	-	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x[14]
202.7	-	-	-	-	-	-	x	x	x	x	x	x	x	-	x	x	-	-	x	x	-	-	-
202.8	x[12]	-	x	x	x	x	x	x	x	x	x	x	x[13]	x	x	x	-	-	x	x	-	-	-
202.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
202.10.(1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
202.10.(2)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Notes

11. When "mechanically-ventilated spaces" are required by the International Maritime Dangerous Goods Code, as amended.
12. Stow 3 m horizontally away from the machinery space boundaries in all cases.
13. Refer to the International Maritime Dangerous Goods Code, as amended.
14. As appropriate to the goods to be carried.
15. FP means flashpoint.
16. Under the provisions of the IMDG Code, stowage of class 5.2 dangerous goods under deck or in enclosed ro-ro spaces is prohibited.
17. Only applicable to dangerous goods evolving flammable vapour listed in the IMDG Code.
18. Only applicable to dangerous goods having a flashpoint less than 23ºC listed in the IMDG Code.
19. Only applicable to dangerous goods having a subsidiary risk class 6.1.
20. Under the provisions of the IMDG Code, stowage of class 2.3 having subsidiary risk class 2.1 under deck or in enclosed ro-ro spaces is prohibited.
21. Under the provisions of the IMDG Code, stowage of class 4.3 liquids having a flashpoint less than 23ºC under deck or in enclosed ro-ro spaces is prohibited.

SECTION 3 Protection of vehicle, special category and ro-ro spaces

301. General requirements

1. In addition, as appropriate, vehicle, special category and ro-ro spaces shall comply with the requirements of this regulation.

2. Basic principles for passenger ships shall be satisfied as follows.

(1) The basic principle underlying the provisions of this regulation is that the main vertical zoning required by **Ch 3, 301.** may not be practicable in vehicle spaces of passenger ships and, therefore, equivalent protection must be obtained in such spaces on the basis of a horizontal zone concept and by the provision of an efficient fixed fire-extinguishing system. Based on this concept, a horizontal zone for the purpose of this regulation may include special category spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m. (Refer to the Guidance)

(2) The basic principle underlying the provisions of paragraph (1) are also applicable to ro-ro spaces.

(3) The requirements of ventilation systems, openings in "A" class divisions and penetrations in "A" class divisions for maintaining the integrity of vertical zones in this chapter shall be applied equally to decks and bulkheads forming the boundaries separating horizontal zones from each other and from the remainder of the ship.

302. Precaution against ignition of flammable vapours in closed vehicle spaces closed ro-ro spaces and special category spaces

1. Ventilation systems shall be satisfied as follows.

(1) There shall be provided an effective power ventilation system sufficient to give at least the following air changes. The Society may require an increased number of air changes when vehicles are being loaded and unloaded.

(A) In case passenger ships
Special category spaces ; 10 air changes per hour
Closed ro-ro and vehicle spaces other than special category spaces for ships carrying more than 36 passengers ; 10 air changes per hour
Closed ro-ro and vehicle spaces other than special category spaces for ships carrying not more than 36 passengers ; 6 air changes per hour

(B) In case cargo ships ; 6 air changes per hour

(2) Performance of ventilation systems shall be satisfied as follows.

(A) In passenger ships, the power ventilation system required in para. (1) shall be separated from other ventilation systems and shall be in operation at all times when vehicles are in such spaces. Ventilation ducts serving such cargo spaces capable of being effectively sealed shall be separated for such space. The system shall be capable of being controlled from a position outside such spaces.

(B) In cargo ships, ventilation fans shall normally be run continuously whenever vehicles are on board. Where this is impracticable, they shall be operated for a limited period daily as weather permits and in any case for a reasonable period prior to discharge, after which period the ro-ro or vehicle space shall be proved gas-free. One or more portable combustible gas detecting instruments shall be carried for this purpose. The system shall be entirely separate from other ventilating systems. Ventilation ducts serving ro-ro or vehicle spaces shall be capable of being effectively sealed for each cargo space. The system shall be capable of being controlled from a position outside such spaces.

(C) The ventilation system shall be such as to prevent air stratification and the formation of air pockets.

(3) Means shall be provided on the navigation bridge to indicate any loss of the required ventilating capacity. (Refer to the Guidance)

(4) Closing appliances and ducts shall be satisfied as follows.

(A) Arrangements shall be provided to permit a rapid shutdown and effective closure of the ventilation system from outside of the space in case of fire, taking into account the weather and sea conditions. (Refer to the Guidance)

(B) Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel. In passenger ships, ventilation ducts that pass through other horizontal zones or machinery spaces shall be "A-60" class steel ducts constructed in accordance with **Ch 3, 306. 2.**

(5) Permanent openings in the side plating, the ends or deckhead of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces. (Refer to the Guidance)

2. Electrical equipment and wiring shall be satisfied as follows.

(1) Except as provided in paragraph (2), electrical equipment and wiring shall be of a type suitable for use in an explosive petrol and air mixture. (Refer to the Guidance)

(2) In case of other than special category spaces below the bulkhead deck, notwithstanding the provisions in paragraph (1), above a height of 450 mm from the deck and from each platform for vehicles, if fitted, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment of a type so enclosed and protected as to prevent the escape of sparks shall be permitted as an alternative on condition that the ventilation system is so designed and operated as to provide continuous ventilation of the cargo spaces at the rate of at least ten air changes per hour whenever vehicles are on board. (Refer to the Guidance)

3. Electrical equipment and wiring, if installed in an exhaust ventilation duct, shall be of a type approved for use in explosive petrol and air mixtures and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition. (Refer to the Guidance)

4. Other equipment which may constitute a source of ignition of flammable vapours shall not be permitted.

5. Scuppers shall not be led to machinery or other spaces where sources of ignition may be present.

303. Detection and alarm

(Refer to the Guidance)

1. Except as provided in **Par 3** (1), there shall be provided a fixed fire detection and fire alarm system complying with the requirements of the Fire Safety Systems Code. The fixed fire detection system shall be capable of rapidly detecting the onset of fire. The type of detectors and their spacing and location shall be to the satisfaction of the Society taking into account the effects of ventilation and other relevant factors. After being installed the system shall be tested under normal ventilation conditions and shall give an overall response time to the satisfaction of the Society.

2. Except open ro-ro spaces, open vehicle spaces and special category spaces, a sample extraction smoke detection system complying with the requirements of the Fire Safety Systems Code may be used as an alternative of the fixed fire detection and fire alarm system required in **Par 1.**

3. Special category spaces shall be satisfied as follows.

(1) An efficient fire patrol system shall be maintained in special category spaces. However, if an efficient fire patrol system is maintained by a continuous fire watch at all times during the voyage, a fixed fire detection and fire alarm systems is not required.

(2) Manually operated call points shall be spaced so that no part of the space is more than 20 m from a manually operated call point, and one shall be placed close to each exit from such spaces.

304. Structure protection

Notwithstanding the provisions of **Ch 3, 301. 2,** in passenger ships carrying more than 36 passengers, the boundary bulkheads and decks of special category spaces and ro-ro spaces shall be insulated to "A-60" class standard. However, where a category ⑤,⑨,⑩ space, as defined in regulation **Ch 3, 301. 2** (3), is on one side of the division the standard may be reduced to "A-0". Where fuel oil tanks are below a special category space or a ro-ro space, the integrity of the deck between such spaces, may be reduced to "A-0" standard.

305. Fire-extinction

(Refer to the Guidance)

1. Fixed fire-extinguishing systems shall satisfy the following requirements.

(1) Vehicle spaces and ro-ro spaces which are not special category spaces and are capable of being sealed from a location outside of the cargo spaces shall be fitted with a fixed gas fire-extinguishing system which shall comply with the provisions of the Fire Safety Systems Code, except that:

(A) if a carbon dioxide system is fitted, the quantity of gas available shall be at least sufficient to give a minimum volume of free gas equal to 45 % of the gross volume of the largest such cargo space which is capable of being sealed, and the arrangements shall be such as to ensure that at least two thirds of the gas required for the relevant space shall be introduced within 10 min; (Refer to the Guidance)

(B) any other fixed inert gas fire-extinguishing system or fixed high expansion foam fire-extinguishing system may be fitted provided the Society is satisfied that an equivalent protection is achieved; and

(C) as an alternative, a system meeting the requirements of paragraph (2) may be fitted.

(2) Ro-ro and vehicle spaces not capable of being sealed and special category spaces shall be fitted with an approved fixed pressure water spraying system for manual operation which shall protect all parts of any deck and vehicle platform in such spaces. Such water spray systems shall have:

(A) a pressure gauge on the valve manifold;

(B) clear marking on each manifold valve indicating the spaces served;

(C) instructions for maintenance and operation located in the valve room; and

(D) a sufficient number of drainage valves.

(3) The Society may permit the use of any other fixed fire-extinguishing system* that has been shown that it is not less effective by a full-scale test in conditions simulating a flowing petrol fire in a vehicle space or a ro-ro space in controlling fires likely to occur in such a space.

(4) When fixed pressure water-spraying systems are provided, in view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks during the operation of the fixed pressure water-spraying system; the following arrangements shall be provided:

(A) in passenger ships: (Refer to the Guidance)

(a) in the spaces above the bulkhead deck, scuppers shall be fitted so as to ensure that such water is rapidly discharged directly overboard, taking into account the guidelines of MSC.1/Circ.1320;

(b) in ro-ro passenger ships discharge valves for scuppers, fitted with positive means of closing operable from a position above the bulkhead deck in accordance with the requirements of the International Convention on Load Lines in force, shall be kept open while the ships are at sea;

(c) any operation of valves referred to in paragraph (a) shall be recorded in the log-book;

(d) in the spaces below the bulkhead deck, the Society may require pumping and drainage facilities to be provided additional to the requirements of regulation of SOLAS. In such case, the drainage system shall be sized to remove no less than 125 % of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles, taking into account the guidelines of MSC.1/Circ.1320. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment;

(B) in cargo ships,

the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces. In such case, the drainage system shall be sized to remove no less than 125 % of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles, taking into account the guidelines of MSC.1/Circ.1320. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. If this is not possible the adverse effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by the Society in its approval of the stability information.* Such information shall be included in the stability information supplied to the master as required by regulation of SOLAS.

(5) On all ships, for closed vehicles and ro-ro spaces and special category spaces, where fixed pressure water-spraying systems are fitted, means shall be provided to prevent the blockage of drainage arrangements, taking into account the guidelines of MSC.1/Circ.1320. Ships constructed before 1 January 2010 shall comply with the requirements of this paragraph by the first survey after 1 January 2010.

2. Portable fire extinguishers shall satisfy the following requirements.

(1) Portable extinguishers shall be provided at each deck level in each hold or compartment where vehicles are carried, spaced not more than 20 m apart on both sides of the space. At least one portable fire-extinguisher shall be located at each access to such a cargo space.

(2) In addition to the provision of paragraph (1), the following fire extinguishing appliances shall be provided in vehicle, ro-ro and special category spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion:

(A) at least three water-fog applicators; and

(B) one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code, provided that at least two such units are available in the ship for use in such ro-ro spaces.

SECTION 4 Qualitative failure analysis for propulsion and steering on passenger ships

401. Application

Qualitative failure analysis for propulsion and steering on passenger ships shall apply to the requirements in accordance with the Guidance as provided separately. (Refer to the Guidance) ⚓

KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 8

Fire Protection and Fire Extinction

GA-08-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF
PART 8 "FIRE PROTECTION AND FIRE EXTINCTION"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.

2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date 1 July 2010

CHAPTER 3. SUPPRESSION OF FIRE

Section 4 Fire fighting
- 403. 1 (2) (B) (a) has been amended.

Effective Date 1 July 2011

CHAPTER 2. PREVENTION OF FIRE AND EXPLOSION

Section 1 Prevention of ignition probability
- 101. 3 has been amended.
- Fig 8.2.1 of 101. has been amended.

Section 2 Prevention of fire growth potential
- 201. 2 has been newly added.

CHAPTER 3. SUPPRESSION OF FIRE

Section 3 Containment of fire
- 301. 1 has been amended.

Section 4 Fire fighting
- 401. 1 and 4 have been amended.
- < Minimum numbers and distribution of portable fire extinguishers in the various types of spaces on board ships > Notes (7) of 402. has been newly added.

CHAPTER 5. SPECIAL REQUIREMENTS

Section 2 Carriage of dangerous goods
- 202. 4 (7) and 11 have been amended.

Annex 8-2. Penetrations through Divisions
- 2 has been amended.

Annex 8-3. Special Requirements for Ships which are not engaged in international voyage or Ships of less than 500 gross tonnage

(Fire-fighting system of ships which are subject to the Ships Safety Law of the Korean Government, but not SOLAS, shall follow the relevant requirements)

- 16 (3) has been amended.
- 16 (5) has been newly added.

CONTENTS

CHAPTER 1 FIRE PROTECTION, FIRE DETECTION AND FIRE EXTINCTION

SECTION 1 General

101. Application

1. In applying **101. 1** of the Rules, "the guidance specified separatedly" means that the following requirements should be complied with ;

(1) Ships of less than 500 tons gross tonnage should be in accordance with **Annex 8-3** special requirements of the Guidance.

(2) Ships which are not engaged in international voyage, and Ships for restricted service (Classification Equipment Notation "C" or "S") should be in accordance with **Annex 8-3** special requirements of the Guidance.

(3) Fishing vessels should be in accordance with **Annex 8-4** alleviation requirements of the Guidance.

2. In applying **101.** of the Rules, where the Government the flag of which a ship is to be entitled to fly does not authorize this Society to carry out the statutory inspection on behalf of it, the requirements of fire-fighting systems may not be applied.

102. Plans and documents

1. In applying **102. 1** (3) of the Rules, where the Fixed local application fire-fighting systems is intended for inspection by this Society, the following plans and documents shall be submitted for approval.

(1) Diagrams of piping and instrument.
(2) Diagrams of control system.
(3) Piping arrangements and hydraulic calculation sheets.
(4) Plans for pump including performance curve.
(5) Specifications of location and dimension on the protected area.
(6) Others considered necessary by this Society.

2. In applying **102. 1** (4) of the Rules, where inert gas system is intended for inspection by this Society, the following plans and documents shall be submitted for approval. Where, however, the system is the one already approved by the Society, they may be omitted from submission.

(1) Plans
(a) General arrangements of inert gas systems including the control systems and monitoring systems.
(b) Details of each component consisting of inert gas systems.
(c) Piping diagram system for the distribution of inert gas.
(d) Other plans and documents considered necessary by the Society.
(2) Documents
(a) Instructions and operation manual of the inert gas system (including the notice related to the safety of the operators).
(b) Other drawings and data considered necessary by the Society.
(3) The instructions and operation manual specified in (2) (a) are to be carried on board the ship.

103. Definitions

1. In applying **103. 1** of the Rules, pantries containing no cooking appliances may contain the following devices. However, a dining room containing such appliances is not to be regarded as a pantry.

(1) Coffee automats, toasters, dish washers, microwave ovens, water boilers and similar appliances each of them with a maximum power of 5 kW.

(2) Electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 2 kW and a surface temperature not above 150 °C.

2. In applying **103. 18** of the Rules, the following are to be included.

(1) Spaces containing the following battery sources regardless of battery capacity are to be included in control spaces, where the emergency source of power is located.
(A) Emergency batteries in separate battery room for power supply from black-out until start of emergency generator,
(B) Emergency batteries in separate battery room as reserve source of energy to radio telegraph installation,
(C) Batteries for start of emergency generator, and
(D) In principle, all emergency batteries required in pursuance of the related provisions of **Pt 6, Ch 1** to the Rules.
(2) Main navigational equipment includes, in particular, the steering stand and the compass, radar and direction-finding equipment. However, steering gear rooms containing an emergency steering position are not considered to be control stations.
(3) Where in the fixed fire-extinguishing systems there are no specific requirements for the centralization within a control station of major components of a system, such major components may be placed in spaces which are not considered to be a control station.

3. In applying **103. 34** of the Rules, “Oil fuel unit" includes any equipment used for the preparation and delivery of oil fuel for inert gas generators or turbines. Oil fuel transfer pumps are not considered as oil fuel units.

4. In applying **103. 41** of the Rules, "Spaces not normally subdivided in any way" means those spaces which are not subdivided in longitudinal direction by watertight bulkheads or gastight bulkheads.

5. In applying **103. 45** of the Rules, pantries containing cooking appliances may contain the following devices. However, any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded as galleys.
(1) Coffee automats, toasters, dish washers, microwave ovens, water boilers and similar appliances each of them with a power of more than 5 kW.
(2) Electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 5 kW.

6. In applying **103. 48** of the Rules, the following requirements for tankers are to be applied.
(1) Requirements for tankers in this chapter shall apply to tankers carrying crude oil or petroleum products having a flashpoint not exceeding 60 ℃ (closed cup test), as determined by an approved flashpoint apparatus, and a Reid vapour pressure which is below the atmospheric pressure or other liquid products having a similar fire hazard.
(2) Where liquid cargoes other than those referred to in (1) above or liquefied gases which introduce additional fire hazards are intended to be carried, additional safety measures shall be required, having due regard to the provisions of the International Bulk Chemical Code, the Bulk Chemical Code, the International Gas Carrier Code, and the Gas Carrier Code, as appropriate. A liquid cargo with a flashpoint of less than 60 degrees C for which a regular foam fire-fighting system complying with the Fire Safety Systems Code is not effective, is considered to be a cargo introducing additional fire hazards in this context. The following additional measures are required:
(A) the foam shall be of alcohol resistant type;
(B) the type of foam concentrates for use in chemical tankers shall be to the satisfaction of the Society taking into account the guidelines developed by the IMO; and
Refer to the Guidelines for performance and testing criteria and surveys of expansion foam concentrates for fire-extinguishing systems for chemical tankers (MSC/Circ.799).
(C) the capacity and application rates of the foam extinguishing system shall comply with chapter 11 of the International Bulk Chemical Code, except that lower application rates may be accepted based on performance tests. For tankers fitted with inert gas systems, a quantity of foam concentrate sufficient for 20 min of foam generation may be accepted;
Refer to the Information on flashpoint and recommended fire-fighting media for chemicals to which neither the IBC nor BCH Codes apply (MSC/Circ.553).
(3) For the purpose of this regulation, a liquid cargo with a vapour pressure greater than 1.013 bar absolute at 37.8 degrees C is considered to be a cargo introducing additional fire hazards. Ships carrying such substances shall comply with the requirements of the IBC Code. When ships operate in restricted areas and at restricted times, the Society concerned may agree to waive the requirements for refrigeration systems in accordance with requirements of the International Bulk Chemical Code.

(4) Liquid cargoes with a flashpoint exceeding 60 degrees C other than oil products or liquid cargoes subject to the requirements of the International Bulk Chemical Code are considered to constitute a low fire risk, not requiring the protection of a fixed foam extinguishing system.

(5) Tankers carrying petroleum products with a flashpoint exceeding 60 degrees C (closed cup test), as determined by an approved flashpoint apparatus, shall comply with the following requirements.

(A) The requirements for cargo ships other than tankers

(B) Isolation valves shall be fitted in the fire main at poop front in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in case of fire or explosion.

(C) In addition, in tankers, two fire-fighter's outfits shall be provided.

(D) In lieu of the fixed fire extinguishing system required in cargo spaces, they shall be fitted with a fixed deck foam system which shall comply with the provisions of the Fire Safety Systems Code.

(6) Combination carriers shall not carry cargoes other than oil unless all cargo spaces are empty of oil and gas-freed or unless the arrangements provided in each case have been be approved by the Society taking into account the guidelines developed by the IMO.
Refer to the Guidelines for inert gas systems (MSC/Circ.353), as amended by MSC/Circ.387 comply with the provisions of the Fire Safety Systems Code.

(7) Chemical tankers and gas carriers shall comply with the requirements for tankers, except where alternative and supplementary arrangements are provided to the satisfaction of the Society, having due regard to the provisions of the International Bulk Chemical Code and the International Gas Carrier Code, as appropriate.

7. In applying **103. 49** of the Rules, "vehicle spaces" means those cargo spaces other than ro/ro spaces.

104. Other Operation Requirements.

1. In applying **104.** of the Rules, "the Guidance as provided separatedly" means the **Annex 8-6** of the Guidance. And alternative design and arrangements for fire safety shall be in accordance with the relevant requirements of SOLAS. ⚓

CHAPTER 2 PREVENTION OF FIRE AND EXPLOSION

SECTION 1 Prevention of ignition probability

101. Arrangements for oil fuel, lubrication oil and other flammable oils

1. In applying **101. 2** (3) of the Rules, Oil fuel in storage tanks should not to be heated to temperatures within 10 °C below the flash point of the fuel oil, except that where oil fuel in service tanks, settling tanks and any other tanks in supply system is heated the following arrangements should be provided:
(1) the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to below 60 °C, or the outlet of the vent pipes is located 3 m away from a source of ignition;
(2) the vent pipes are fitted with flame screens;
(3) there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable) ;
(4) enclosed spaces are not located directly over such fuel tanks, except for vented cofferdams ;
(5) electrical equipment is not fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

2. In applying **101. 2** (3) (A) of the Rules, when the ship of 400 tons gross tonnage and above is applied to the MARPOL convention, oil shall not be carried in a forepeak tank or a tank forward of the collision bulkhead.

3. In applying **101. 2** (3) (B) of the Rules, the one shown in **Fig 8.2.1** of the Guidance is to be referred to as the standard arrangement of fuel oil tanks in machinery spaces of category A. And "free standing oil tanks" are to be kept to a minimum.

4. In applying **101. 2** (3) (D) and 3 (2) of the Rules, when a filling pipes for fuel oil tank or lubricating oil tank are fitted at the place of the tank top nearby or above the overflow pipes, it is considered that there is no worry about the leakage arising from the damages.

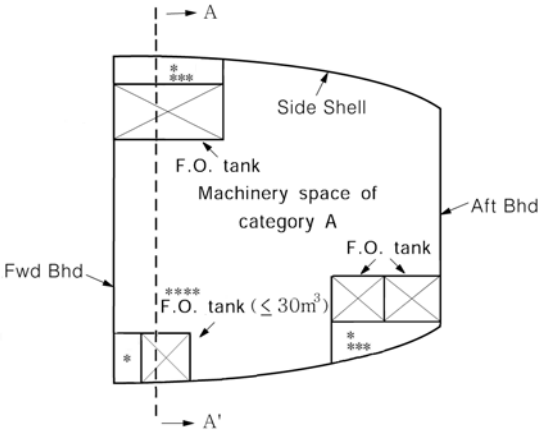
5. In applying **101. 2** (3) (E) of the Rules, short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge provided an overflow system is fitted. And level switches may be used below the tank top provided they are contained in a steel enclosure or other enclosure not capable of being destroyed by fire.

6. In applying **101. 2** (5) (A) of the Rules, hose clamps and similar types of attachments for flexible pipes should not be permitted.

7. In applying **101. 2** (5) (B) of the Rules, engines having single cylinder, multi-cylinder engines having separate fuel pumps and those having multiple fuel injection pump units are included, however, this regulation do not apply to gas turbine and lifeboat engines. A suitable enclosure on engine having an 375 kW or less may be used as an alternative to the jacketed piping system as following requirements.
(1) The enclosure is to have a similar function to jacketed pipes i.e., prevent spray from a damaged injector pipe impinging on a hot surface.
(2) The enclosure is to completely surround the injection pipes except that existing "cold" engine surfaces may be considered as part of the enclosure.
(3) All engine parts within the enclosure are to have a surface temperature not exceeding 220 °C when the engine is running at its maximum rating.
(4) The enclosure is to have sufficient strength and cover area to resist the effects of high pressure spray from a failed fuel pipe in service, prevent hot parts from being sprayed and restrict the area that can be reached by leaked fuel. Where the enclosure is not of metallic construction, it is to be made of non-combustible, non oil-absorbing material.
(5) Screening by the use of reinforced tapes is not acceptable as a suitable enclosure.
(6) Where leaked oil can reach hot surfaces, suitable drainage arrangements are to be fitted to enable rapid passage of leaked oil to a safe location which may be a drain tank. Leaked fuel flow onto "cold" engine surfaces can be accepted, provided that it is prevented from leaking onto hot surfaces by means of screens or other arrangements.
(7) Where the enclosure has penetrations to accommodate high pressure fittings, the penetrations are

to be a close fit to prevent leakage.

Plan



* Cofferdam

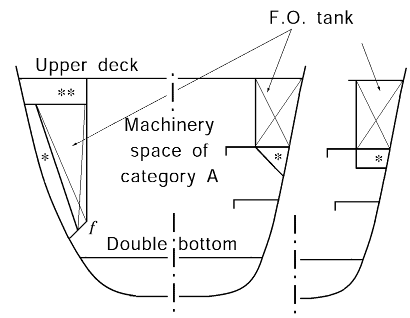
Requirements for cofferdam:

1. To be gas-tigth.
2. To be provided with sounding devices, air pipes and fittings for drainage(drain plug. etc.).

*** Where the requirements of MARPOL I/12A are met(aggregate oil fuel capacity of 600 m^3 and above)

**** "Small oil fuel tank" is an oil fuel tank with a maximum individual capacity no greater than 30 m^3

Section A-A'



f : Tank bottom may be knuckled only due to reasons of workmanship.

** : In case where the tip plates of fuel oil tanks are not common with upper deck and machinery is installed above fuel oil tanks, rooms for auxiliary machinery which are considered to have little fire risks, such as pipe passages for those other than flammable liquids, fan rooms, air conditioning machinery room, refrigerating machinery room, rooms for hydraulic system may be provided.

Fig 8.2.1

102. Arrangements for gaseous fuel for domestic purpose

In applying **102.** of the Rules, a portion of open deck, recessed into a deck structure, machinery casing, deck house, etc., utilized for the exclusive storage of gas bottles is considered acceptable, provided that such a recess has an unobstructed opening, except for small appurtenant structures, such as opening corner radii, small sills, pillars, etc.(The opening may be provided with grating walls and door) and the depth of such a recess is not greater than 1 m. A portion of open deck meeting the above should be considered as open deck in applying **Ch 3, 301. tables 8.3.1** to **8.3.8** of the Rules.

103. Miscellaneous items of ignition sources and ignitability

1. In applying **103. 2** of the Rules, this regulation is not intended to preclude the use of containers constructed of combustible materials in galleys, pantries, bars, garbage handling or storage spaces and incinerator rooms provided they are intended purely for the carriage of wet waste, glass bottles and metal cans and are suitably marked.

2. In applying **103. 3** of the Rules, "spaces where penetration of oil products is possible" means the spaces located in the vicinity of all types of equipment (purifiers, pumps and tanks) and pipe fittings (valves, flanges, strainers, flowmeters, etc.) handling oils (fuel oil, lubricating oil, hydraulic oil and thermal oil) with possible involvement of oils or oil vapours leaked or splashed during operation or in maintenance work to reach out thermal insulation. However, these do not apply to thermal insulation of pipes in machinery spaces. The fire insulation in such spaces can be covered by metal sheets (not perforated) or by vapour-proof glass cloth accurately sealed at the joint.

104. Cargo areas of tankers

1. In applying **104. 1** (1) of the Rules, “cofferdam” mean, for the purpose of this regulation, an isolating space between two adjacent steel bulkheads or decks. The minimum distance between the two bulkheads or decks should be sufficient for safe access and inspection. In order to meet the single failure principle, in the particular case when a corner-to-corner situation occurs, this principle may be met by welding a diagonal plate across the corner. And ballast pump rooms are also to comply with **Pt 7, Ch 1, 1004.** of the Rules and then the lower part of the ballast pump rooms may be recessed into machinery space of category A to the same extent as provided for cargo pump rooms. And pump-rooms intended solely for ballast transfer or fuel oil transfer need not comply with the requirements of **104. 10** of the Rules.
Void spaces or ballast water tank protecting fuel oil tank as shown in **Fig 8.2.2**, need not be considered as "cargo area" defined in **Ch 1, 103. 6** of the Rules even though they have a cruciform contact with the cargo oil tank or slop tank.

The void space protecting fuel oil tank is not considered as a cofferdam specified in this paragraph. There is no objection to the locations of the void space shown in **Fig 8.2.2**, even though they have a cruciform contact with the slop tank.

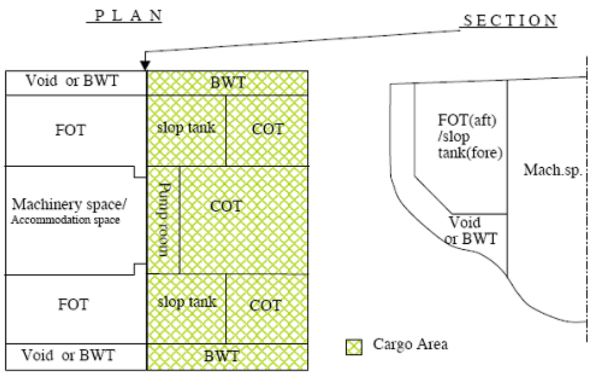


Fig 8.2.2

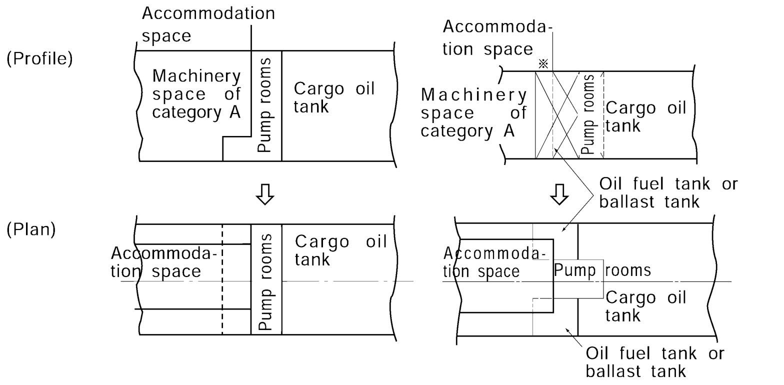
2. In applying **104. 1** (2) of the Rules, arrangement of main cargo control stations, control stations, accommodation spaces and service spaces is to comply with the following requirements:

(A) Main cargo control stations, control stations, accommodation spaces and service spaces (including chain lockers) are not to make point contact or linear contact with cargo oil tanks or s1op tanks. However, they may make point contact or linear contact with cargo pump rooms and cofferdams.

(B) Main cargo control stations, control stations, accommodation spaces and service spaces need not be arranged aft of the recess of the lower parts of cargo pump rooms and ballast pump rooms into machinery spaces of category A accepted under the requirements of **Ch 2, 104. 1** (1) of the Rules and aft of the oil fuel tanks or ballast tanks (see **Fig 8.2.3**).

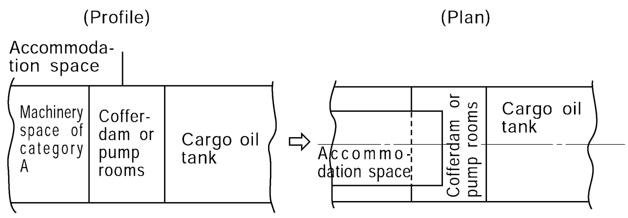
Fig 8.2.3 Arramgements of accommodation spaces, cargo oil tanks and machinery spaces of category A

Acceptable



※ Consideration is to be given to the requirements or **Pt 3, Ch 15, 304.** of the Rules.

Not acceptable



3. In applying **104. 1** (3) of the Rules, lamp rooms, store rooms, paint rooms, lockers, etc. independently provided at the bow section which are seldom accessed by persons may be provided in cargo areas other than cargo tanks and slop tanks such as the upper part of the ballast tanks, cofferdams, etc. or ship side adjoining thereto. (see **Fig 8.2.4**).

4. In applying **104. 1** (2) & (3) of the Rules, Paint lockers, regardless of their use, cannot be located above the tanks and spaces defined in the para. (2) for oil tankers and the cargo area for chemical tankers.

5. In applying **104. 1** (4) of the Rules, the arrangements and separation of spaces in combination carriers are to comply with the requirements for ore/oil carriers specified in **Pt 7, Ch 2, 206.** and **207.** of the Rules, and the requirements of **Pt 7, Ch 3, Sec 15** of the Rules for bulk/oil carriers.

6. In applying **104. 1** (6) of the Rules, "a permanent continuous coaming" means a suitable place between the aft extreme end of cargo oil tanks and the front bulkheads of deckhouses and it is not to be made lower than 50 mm above the upper edge of shear strakes (see **Fig 8.2.5**). And special consideration for stern loading means that foam extinguishers or equivalent are to be provided in addition to the requirements of **Pt 7, Ch 1, 1002. 4** (4) and **1006.** of the Rules, and further, oil drip pans in sufficient size or spillage coaming are to be provided.

7. In applying **104. 2.** (1) of the Rules, lamp rooms, store rooms, paint rooms and lockers, etc., which are arranged in forecastle independently from the group of accommodation spaces and are not normally accessed by persons are not regarded as service spaces. And access to forecastle spaces containing sources of ignition may be permitted through doors facing cargo area provided the doors are located outside hazardous areas as defined in **(KR C) IEC Publication 60092-502.**

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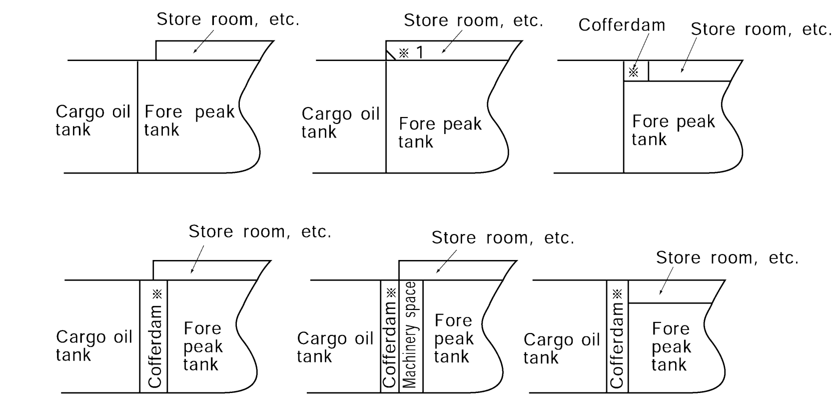
<tr><td>Acceptable</td><td>

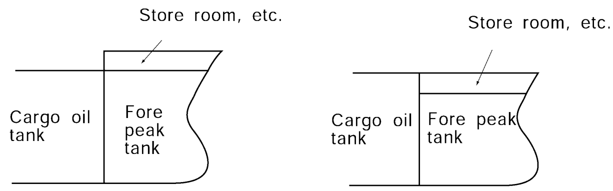
※ The minimum distance between the two bulkheads or decks of cofferdam is to be sufficient for safe access and inspection. No cargo, wastes or other goods are not to be contained in cofferdams.
※1 In order to meet the single failure principle, in the particular case when a corner-to-corner situation occurs, this principle may be met by welding a diagonal plate across the corner.</td></tr>
<tr><td>Not acceptable</td><td>
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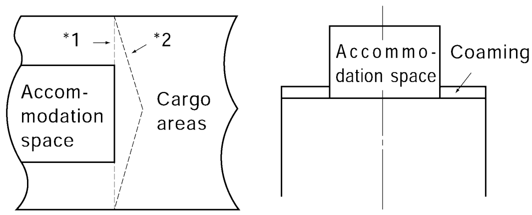
Fig 8.2.4



Coaming : *1 or * 2 , whichever is possible

Fig. 8.2.5 Coaming preventing spill into accommodation spaces and service spaces

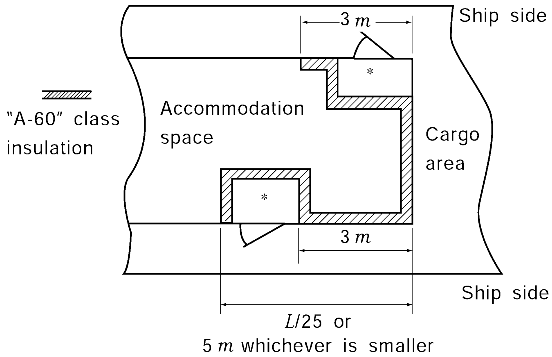
8 In applying **104. 2** (2) of the Rules, the boundaries of spaces, where application of "A-60" class insulation is required, are to be insulated as exemplified in **Fig 8.2.6**. The ceilings and floors of spaces with asterisk are also to be applied with "A-60" class insulation. Incidentally, remote-controlled type foam tanks may be provided in these spaces.

And wheelhouse doors and wheelhouse windows which can be made rapidly and efficiently gas and vapour tight are to be such doors and windows that are provided with packing and clamping fittings, and are to be tested for gas tightness. Where hose tests are adopted instead of gas tightness, the following hose tests are to be carried out.

(1) Nozzle diameter is to be minimum 12 mm.

(2) Water pressure just before the nozzle is to be not less than 2 bar.

(3) Distance between the nozzle and the doors or windows is to be maximum 1.5 m.



* The ceilings and floors of spaces with asterisk are also to be applied with "A−60" class insulation.

Fig. 8.2.6 A−60 class insulation to be required.

9. In applying **104. 2** (4) of the Rules, the Pipe ducts in double bottom under cargo oil tanks shall comply with the following requirements.

(1) They should not communicate with the engine room.

(2) Provision shall be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.

(3) In the duct, provision shall be made for adequate mechanical ventilation.

10. In applying **104. 3** (2) (B) of the Rules, where the arrangements are in common combined with other cargo oil tanks, the arrangement and method in order to isolate each cargo oil tank are to be as follows.

(1) Where the arrangements are in common combined with other cargo oil tanks. (See **Fig 8.2.7**)

(A) It is to be install the stop valve etc. to isolate each cargo oil tank in order to prevent fire and explosion in specific cargo oil tank from spreading other cargo oil tank pass through vent system.

(B) Stop valve is to be closed except loading and unloading and fitted in a locks in order not to mistaken operation and managed by responsible person.

(C) Even though stop valves are closed, PV valves are to installed with bypassing type for the stop valve in cargo tanks for the capable of controlling of a change of pressure occurring by a change of temperature at sea. In this case, where the cargo tank has a negative pressure, PV valves are to be constructed with the independent suction valves which are able to inhale the air form the outside.

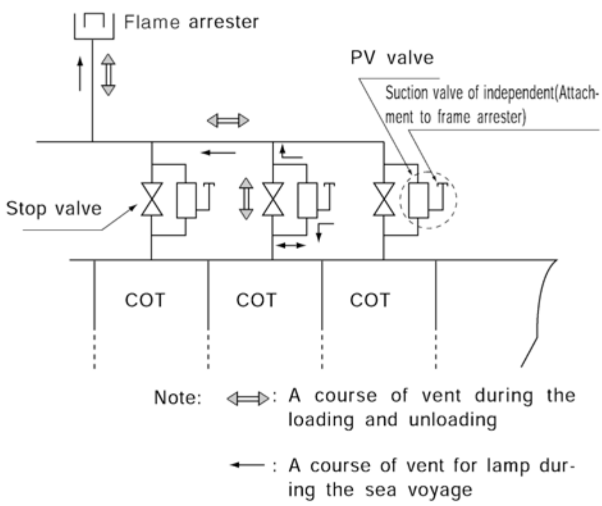


Fig. 8.2.7 **Examples of isolation of cargo oil tank**

11. In applying **104. 3** (3) of the Rules, refer to MSC/Circ.677 on revised standards for the design, testing and locating of devices to prevent the passage of flame into cargo tanks in tankers and to

MSC/Circ.450/Rev.1 on revised factors to be taken into consideration when designing cargo tank venting and gas-freeing arrangements. And ullage openings do not include cargo tank openings that are fitted with standpipe arrangements with its own manually operated shutoff valve. Examples include the common 1" to 2" diameter standpipe arrangements that are used for sampling, monitoring or measuring of ullage/temperature/interface, oxygen, liquid and hand dipping in the cargo tank. And ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

And then the designs, arrangements, tests of devices to prevent the passage of flame are to be in accordance with followings. The devices are to be type approved by this Society.

(1) The venting system is to be provided with devices to prevent the passage of flame into the cargo oil tanks.
 (A) Flame screens, flame arresters or detonation flame arrester are to be fitted at the following openings.
  (a) Air suction inlets, through which vapours cannot be vented to atmosphere, of the venting system for preventing the vacuum in the tanks specified **Ch 3, 505. 1** (1) of the Rules.
  (b) Air suction inlets, through which vapours cannot be vented to atmosphere, of the venting systems for preventing the vacuum in the tank specified in **Ch 3, 505. 1** (2) of the Rules.
 (B) Flame arrester, detonation flame arresters or high velocity vents are to be fitted for the following openings.
  (a) Openings for pressure release specified in **Ch 3, 505. 2**, of the Rules.
  (b) Vent outlets specified in **Ch 2, 104. 3** (4) (A) (c) of the Rules.
  (c) Discharge outlets specified in **Ch 2, 104. 6** (3) (B) of the Rules.
 (C) For the vent outlets specified in **Ch 2, 104, 3** (4) (A) (d) of the Rules, the high velocity device is to be fitted.
(2) For determining the size of the devices to avoid pressure exceeding allowable one of vacuum in cargo tanks during loading of discharging calculations of pressure losses are to be carried out. The following parameters are to be taken into account.
 (A) Loading/discharging rates
 (B) Gas release
 (C) Pressure loss across the devices, taking into account the resistance coefficient
 (D) Pressure loss in the venting system
 (E) Pressure at which the vent opens if a high velocity device is used
 (F) Density of the mixture of the saturated vapour and air
(3) Tests and inspection
 (A) The tests and inspection for the individual product are to be carried out in accordance with followings.
  (a) Construction inspection
  (b) Hydraulic test(only for high velocity valves)
  (c) Confirmation of the pressure at which the valve opens and closes
 (B) On board test
 It is to be ascertained by a suitable method that the high velocity valves can be operable smoothly after installed on board.
(4) Test report
 A test report for each finished device is to be prepared. This is to include
 (A) detailed drawings of the device
 (B) types of tests conducted. Where in-line devices are tested, this information is to include the maximum pressures and velocities observed in the test
 (C) specific advice on approved attachments
 (D) types of cargo for which the device is approved drawings of the test rig
 (E) in the case of high velocity vent, the pressures at which the device opens and closes in the efflux velocity
 (F) all the information marked on the device in following (6)
(5) Manufacturer's instruction manual
 The manufacturer is to supply a copy of the instruction manual, which is to be kept on board the tanker and which is to include followings.
 (A) installation instructions

(B) operating instructions
(C) maintenance requirements, including cleaning
(D) copy of the laboratory report referred to in (8)
(E) flow test data, including flow rates under both positive and negative pressures, operating sensitivity, flow resistance and velocity, are to be provided.

(6) Marking of device
Each device is to be permanently marked, or have a permanently fixed tag made of stainless steel or other corrosion-resistant material, to indicate
(A) manufacturer's name or trade mark
(B) style, type, model or other manufacturer's designation for the device
(C) size of the outlet for which the device is approved
(D) approved location for installation, including maximum or minimum length of pipe, if any, between the device and the atmosphere
(E) direction of flow through the device
(F) indication of the test laboratory and report number
(G) compliance with the requirements of MSC/Circ.677

12. In applying **104. 3** (4) (A) of the Rules, electrical equipment fitted in compliance with (KS C) IEC 60092-502 is not considered to be a source of ignition or ignition hazard.

13. In applying **104. 4** (1) of the Rules, ventilation fan of non-sparking type is to be comply with the following requirements.

(1) Design criteria
(A) Air gap
The air gap between the impeller and the casing is not to be less than 0,1 of the shaft diameter in way of the impeller bearing but not less than 2 mm. It need not be more than 13 mm.
(B) Protection screen
Protection screens of not more than 13 mm square mesh are to be fitted in the opening of ventilation ducts on the open deck to prevent the entrance of objects into the fan housing.

(2) Materials
(A) Impeller and housing
The impeller and the housing in way of the impeller are to be made of alloys which are recognised as being spark proof by appropriate test.
(B) Electrostatic charges
Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials. Furthermore, the installation on board of the ventilation units is to be such as to ensure the safe bonding to the hull of the units themselves.
(C) Acceptable Combination of Materials
Tests may not be required for fans having the following combinations:
(a) Impellers and/or housings of nonmetallic material, due regard being paid to the elimination of static electricity,
(b) Impellers and casings of non-ferrous materials,
(c) Impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness on non-ferrous materials is fitted in way of the impeller,
(d) Any combination of ferrous (including austenitic stainless steel) impellers and casings with not less than 13 mm design tip clearance.
(D) Unacceptable Combination of Materials
The following impellers and housings are considered as sparking and are not permitted:
(a) Impellers of an aluminium alloy or magnesium alloy and a ferrous housing, regardless of tip clearance,
(b) Housing made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance,
(c) Any combination of ferrous impeller and casings with less than 13 mm design tip clearance.

(3) Notwithstanding the requirements specified above, fans for which non-sparking property test is carried out in the presence of the Surveyor with satisfactory results may be considered as a non-sparking type. This test may be omitted for fans having test results considered as appropriate by the Society.

(4) In case where non-metal materials are used, the antistatic property is to be verified by a method as considered adequate by the Society. Those with an electric resistance not exceeding $1\times10^4 \sim 10^8\ \Omega$ (British Standard BS 2050)or those with an electrical conductivity of 1×10^{-10} S/m or less may be considered to have antistatic property.

14. In applying **104. 5** of the Rules, refer to **Annex 8-5** and the Regulation for inert gas systems on chemical tankers adapted by the IMO by resolution A.567(14) and Corr.1. And in case where liquid-filled type devices are provided as the pressure/vacuum breaking devices, a heating system is to be provided if such liquid is likely to freeze.

15. In applying **104. 5** (3) of the Rules, "a permanently fitted inert gas distribution system" means that the branch lines for the supply of inert gas into the double hull spaces are to be connected to the position between the inert gas regulating valve and the water seal or equivalent measures. And in case not permanently connected to an inert gas distribution system "appropriate means" means the arrangement consist of portable pipes or flexible hoses and blanking flange.

16. In applying **104. 6** (2) of the Rules, "the Guidance as provided separated" means **Annex 8-6 21** special requirements of the Guidance.

17. In applying **104. 6** (3) of the Rules, the outlets mentioned in (A) (B) (C) are to be located in compliance with **104. 3** (4) (A) (c) of the Rules as far as the horizontal distance is concerned.

18. In applying **104. 7** of the Rules, oil tankers carrying oil and solid cargo in bulk alternately, are to be complied with the following items.

(1) Pump rooms, ducts for cargo oil piping and cofferdams (only those adjacent to slop tanks) are to be provided with fixed gas detectors which are to satisfaction of the Society.
(2) Appropriate measurements are to be taken so as to detect flammable gases in cargo oil tanks and spaces adjacent to cargo oil tanks (except para (1) above) at a place in open decks or easily accessible place.
(3) With regard to (2) above, in case of oil tanks including gas carriers or chemical tankers, gas analysing units of the sampling type with non-explosion-proof measuring equipment outside gas dangerous zones may be installed in areas outside cargo areas (e.g. in cargo control room, navigation bridge or engine room) when mounted on the forward bulkhead provided that the following requirements are satisfactory.
(A) Sampling lines are not to run through gas dangerous spaces, except where permitted under (E) below.
(B) The gas sampling pipes are to be equipped with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location.
(C) Bulkhead penetrations of sample pipes between safe and dangerous areas are to be of approved type and have same fire integrity as the division penetrated. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead on the gas safe side.
(D) The gas detection equipment including sample piping, sample pumps, solenoids, analysing units, etc. is to be located in a reasonably gastight (e.g. a fully enclosed steel cabinet with a gasketed door) which is to be monitored by its own sampling point. At gas concentrations above 30 % LFL inside the steel cabinet the entire gas analysing unit is to be automatically shut down.
(E) Where the cabinet cannot be arranged directly on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units, and are to be routed on their shortest ways.

19. In applying **104. 7** (1) of the Rules, a sufficient set of spares should be considered as being satisfied when a minimum of two such instruments are provided onboard. And all tankers subject to a flashpoint 60 °C below are to be equipped with two(2) portable flammable gas detectors (for oil tankers fitted with inert gas systems, to be capable of measuring concentrations of flammable vapours in inerted atmosphere) and two(2) portable O_2 analysers. Ships having closed ro/ro spaces or ships having oil recovery equipment or developing oil fences are to be provided with one(1) flammable gas detector which is satisfied by the Society. The flammable gas detector is to comply with the following items:

(1) It is to be convenient for carrying and easy to handle.
(2) Metallic parts are to be of anti-corrosive material or to be treated equivalent thereto.
(3) It is to be capable of sufficiently detecting gas of the density of one twenty of explosive limit

of flammable gas.

(4) It is to sufficiently operate at the temperature of -10 °C to 40 °C.

(5) There is not to be abnormality when it is dropped at 10 m high.

(6) It is to be of safe structure for the flammable gas to be detected.

(7) Suitable means is to be provided for the calibration of such instruments.

20. In applying **104. 10** (3) of the Rules, Sampling points or detector heads located in suitable position is to be at the exhaust ventilation duct and lower parts of the pump room above floor plates and the sampling time is reasonably short.

SECTION 2 Prevention of fire growth potential

201. Control of air supply and flammable liquid to the spaces

1. In applying **201. 1** (1) of the Rules, it need not comply with the requirement of details of duct penetrations specified **Ch 3, 306. 3** of the Rules.

2. In applying **201. 1** (1) of the Rules, Battery room ventilators are to be fitted with a means of closing for conditions of following (1) to (3). And where a battery room ventilator is fitted with a closing device, then a warning notice stating, for example "This closing device is to be kept open and only closed in the event of fire or other emergency − Explosive gas", is to be provided at the closing device to mitigate the possibility of inadvertent closing.

(1) The battery room does not open directly onto an exposed deck.
(2) The ventilation opening for the battery room is required to be fitted with a closing device according to the Load Line Convention (i.e. the height of the opening does not extend to more than 4.5 m above the deck for position 1 or to more than 2.3 m above the deck in position 2
(3) The battery room is fitted with a fixed gas fire extinguishing system.

3. In applying **201. 1** (2) of the Rules, the fan in cabin temperature unit is not to be applied, if it is not capable of supplying outside air to the cabin when the power ventilation is shut down.

4. In applying **201. 3** of the Rules, these requirement applies to machinery spaces of category A.

202. Fire protection materials

1. In applying **202.** of the Rules, in accommodation spaces, service spaces and control stations, details of fire protection materials for restricted use of combustible materials are to be in accordance with **Annex 8-1** of the Guidance regardless of the type of material used.

2. In applying **202. 1** (1) of the Rules, grounds, gratings, linings, ceilings, and internal divisions with associated doors used in refrigerated compartments may not be of the non-combustible materials. "cold service systems" means refrigeration systems and chilled water piping for air- conditioning systems, i.e systems with temperatures below ambient air and sea water..

3. In applying **202. 2** of the Rules, a division consisting of a non-combustible core and combustible veneers may be accepted as a B or C class division, provided that the non-combustible core is tested in accordance with the FTP code part 1, that the B class division is tested in accordance with the FTP code, part 3, and that the veneers are tested in accordance with the FTP code part 5 and part 2 , if applicable.

4. In applying **202. 2** (5) **o**f the Rules, "concealed spaces or inaccessible spaces" is, for instance, the spaces in the rear side of ceilings, spaces between lining and shell plating, spaces in double-plated bulkheads and other similar spaces. And "having low flame-spread characteristics" means those combustible materials which passed the following tests in accordance with the requirements specified in the Guidance for Approval of Manufacturing Process and Type Approval, Etc.

(1) Flame propagation test (2) Smoking test (3) Toxic gas test

SECTION 3 Prevention of Smoke generation potential and toxicity

301. Paints, vanishes and other finishes

In applying **301.** of the Rules, this regulation only applies to accommodation spaces, service spaces, control stations as well as stairway enclosures. "Other finishes" mean combustible flooring of deck covering and combustible veneers applied on surfaces of bulkheads, linings and ceilings. However, those surface materials used for handrails and non-skid strips of stairs or other surface materials used only for equally small areas of application may not be required to satisfy these requirements. And It does not apply to furniture. Vibration damping rubber may be used unless it forms a part of the structural integrity.

302. Primary deck coverings

In applying **302.** of the Rules, "Primary deck coverings" means the first combustible layer of a floor construction which is applied directly on the top of deck plating and is inclusive of any primary coat, anti-corrosive compound or adhesive which is necessary to provide protection or adhesion to the deck plating. In this case, "the first layer" means the materials forming deck covering excluding "A" class deck (including insulation materials), non-combustible materials and fire retardant surface floorings. Finishes such as plastic tile and latex used as primary deck covering are also to comply with Resolution A.687(17). ⚓

CHAPTER 3 SUPPRESSION OF FIRE

SECTION 1 Detection and Alarm

101. General requirements

1. In applying **101. 1** of the Rules, fixed fire detection and fire alarm system are also to be complied with the following requirements, and herein "Section means group of fire detection and manually operated call points as reported in the indicating units, and then "Loop" means electrical circuit linking detectors of various sections and connected to the control panel.

(1) Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

(2) The fixed fire detection and fire alarm system shall not be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel. And then watertight doors which also serve as fire doors are not to be closed automatically in case of fire detection.

(3) The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships.

(4) Fixed fire detection and fire alarm systems with a zone address identification capability shall be so arranged that:

(A) means are provided to ensure that any fault (e.g. power break, short circuit, earth) occurring in the loop will not render the whole loop ineffective;

(B) all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatics);

(C) the first initiated fire alarm will not prevent any other detector from initiating further fire alarms; and

(D) no loop will pass through a space twice. When this is not practical (e.g. for large public spaces), the part of the loop which by necessity passes through the space for a second time shall be installed at the maximum possible distance from the other parts of the loop. However, the requirement that a system be so arranged to ensure that any fault occurring in the loop will not render the whole loop ineffective, is considered satisfied when a fault occurring in the loop only rendered ineffective a part of the loop not being larger than a section of a system without means of remotely identifying each detector.

(5) There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fixed fire detection and fire alarm system, one of which shall be an emergency source. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system and should be complied with the following requirements.

(A) Continuity of power supply

(a) Operation of the automatic changeover switch or a failure of one of the power supplies shall not result in permanent or temporary degradation of the fixed fire detection and fire alarm system.

(b) Where the fixed fire detection and fire alarm system would be degraded by the momentary loss of power, a source of stored energy having adequate capacity shall be provided to ensure the continuous operation during changeover between power supplies.

(c) Connection of electrical power supplies to an automatic changeover switch shall be arranged such that a failure will not result in the loss of all supplies to the automatic changeover switch.

(B) Emergency supply

(a) The fixed fire detection and fire alarm system emergency power may be supplied by an accumulator battery or from the emergency switchboard. Where the system is supplied from an accumulator battery, the arrangements are to comply with the following requirements.

(i) The accumulator battery shall have the capacity to operate the fire detection system under normal and alarm conditions during the period required by SOLAS

Chapter Ⅱ-1, Regulation 42 or 43(as applicable) for the emergency source of power supply

(ii) The rating of the charge unit, on restoration of the input power, shall be sufficient to recharge the batteries while maintaining the output supply to the fire detection system.

(iii) The accumulator batteries are to be suitably located for use in an emergency

(b) Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and fire alarm system is supplied from the emergency switchboard, it shall run from this switchboard to the automatic changeover switch without passing through any other switchboard

(6) Detectors are to be complied with the requirement as follows,

(A) Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered by the Society provided that they are no less sensitive than such detectors. Flame detectors shall only be used in addition to smoke or heat detectors.

(B) Smoke detectors required in all stairways, corridors and escape routes within accommodation spaces shall be certified to operate before the smoke density exceeds 12.5 % obscuration per meter, but not until the smoke density exceeds 2 % obscuration per meter. Smoke detectors to be installed in other spaces shall operate within sensitivity limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.

(C) Heat detectors shall be certified to operate before the temperature exceeds 78 ℃ but not until the temperature exceeds 54 ℃, when the temperature is raised to those limits at a rate less than 1 ℃ per minute. At higher rates of temperature rise, the heat detector shall operate within temperature limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.

(D) The operation temperature of heat detectors in drying rooms and similar spaces of a normal high ambient temperature may be up to 130 ℃, and up to 140 ℃ in saunas.

(E) All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance.

(7) Installation is to be complied with the requirements as follows,

(A) Detectors and manually operated call points shall be grouped into sections.

(B) A section of fire detectors which covers a control station, a service space or an accommodation space shall not include a machinery space of category A. For fixed fire detection and fire alarm systems with remotely and individually identifiable fire detectors, a loop covering sections of fire detectors in accommodation, service spaces and control station shall not include sections of fire detectors in machinery spaces of category A.

(C) Where the fixed fire detection and fire alarm system does not include means of remotely identifying each detector individually, no section covering more than one deck within accommodation spaces, service spaces and control stations shall normally be permitted except a section which covers an enclosed stairway. In order to avoid delay in identifying the source of fire, the number of enclosed spaces included in each section shall be limited as determined by the Society. In no case shall more than 50 enclosed spaces be permitted in any section. If the system is fitted with remotely and individually identifiable fire detectors, the sections may cover several decks and serve any number of enclosed spaces.

(D) In passenger ships, if there is no fixed fire detection and fire alarm system capable of remotely and individually identifying each detector, a section of detectors shall not serve spaces on both sides of the ship nor on more than one deck and neither shall it be situated in more than one main vertical zone except that the same section of detectors may serve spaces on more than one deck if those spaces are located in the fore or aft end of the ship or if they protect common spaces on different decks (e.g. fan rooms, galleys, public spaces, etc.). In ships of less than 20 m in breadth, the same section of detectors may serve spaces on both sides of the ship. In passenger ships fitted with individually identifiable fire detectors, a section may serve spaces on both sides of the ship and on several decks but shall not be situated in more than one main vertical zone.

(E) Positioning of detectors is to be complied with as follows,

(a) Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely shall be avoided. Detectors which are located on the overhead shall be a minimum distance of 0.5 m away from bulkheads, except in corridors, lockers and stairways.

(b) The maximum spacing of detectors shall be complied with as follows,

Type of detector	Maximum floor area per detector	Maximum distance apart between centers	Maximum distance away from bulkheads
Heat	37 m^2	9 m	4.5 m
Smoke	74 m^2	11 m	5.5 m

The Society may require or permit different spacing to that specified in the above table if based upon test data which demonstrate the characteristics of the detectors.

(F) Arrangement of electric wiring is to be complied with as follows,

(a) Electrical wiring which forms part of the system shall be so arranged as to avoid galleys, machinery spaces of category A, and other enclosed spaces of high fire risk except where it is necessary to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply.

(b) A loop of fire detection systems with a zone address identification capability shall not be damaged at more than one point by a fire.

(8) For system control requirements, visual and audible fire signals is to be complied with as follows,

(A) The activation of any detector or manually operated call point shall initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within 2 minutes an audible alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A. This alarm sounder system need not be an integral part of the detection system. Refer to the Code on Alarms and Indicators as adopted by the IMO by resolution A.830(19).

(B) The control panel shall be located on the navigating bridge or in the continuously manned central control station.

(C) Indicating units shall, as a minimum, denote the section in which a detector has been activated or manually operated call point has been operated. At least one unit shall be so located that it is easily accessible to responsible members of the crew at all times. One indicating unit shall be located on the navigating bridge if the control panel is located in the main fire control station.

(D) Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

(E) Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power or fault conditions as appropriate. Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

(9) Suitable instructions and component spares for testing and maintenance shall be provided.

2. In applying **101. 2** of the Rules, Sample extraction smoke detection systems is also to be complied with as follows,

(1) Any required system shall be capable of continuous operation at all times except that systems operating on a sequential scanning principle may be accepted, provided that the interval between scanning the same position twice gives an overall response time to the satisfaction of the Society.

(2) The system shall be designed, constructed and installed so as to prevent the leakage of any toxic or flammable substances or fire-extinguishing media into any accommodation and service space, control station or machinery space.

(3) The system and equipment shall be suitably designed to withstand supply voltage variations and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships and to avoid the possibility of ignition of a flammable gas air mixture.

(4) The system shall be of a type that can be tested for correct operation and restored to normal surveillance without the renewal of any component.

(5) An alternative power supply for the electrical equipment used in the operation of the system shall be provided.

(6) Components are to be complied with the following requirements.
(A) The sensing unit shall be certified to operate before the smoke density within the sensing chamber exceeds 6.65 % obscuration per meter.
(B) Duplicate sample extraction fans shall be provided. The fans shall be of sufficient capacity to operate under normal ventilation conditions in the protected area and shall give an overall response time to the satisfaction of the Society.
(C) The control panel shall permit observation of smoke in the individual sampling pipe.
(D) Means shall be provided to monitor the airflow through the sampling pipes so designed as to ensure that as far as practicable equal quantities are extracted from each interconnected accumulator.
(E) Sampling pipes shall be a minimum of 12 mm internal diameter except when used in conjunction with fixed gas fire-extinguishing systems when the minimum size of pipe shall be sufficient to permit the fire-extinguishing gas to be discharged within the appropriate time.
(F) Sampling pipes shall be provided with an arrangement for periodically purging with compressed air.
(7) Smoke accumulators are to be complied with the following requirements.
(A) At least one smoke accumulator shall be located in every enclosed space for which smoke detection is required. However, where a space is designed to carry oil or refrigerated cargo alternatively with cargoes for which a smoke sampling system is required, means may be provided to isolate the smoke accumulators in such compartments for the system. Such means shall be to the satisfaction of the Society.
(B) Smoke accumulators shall be located for optimum performance and shall be spaced so that no part of the overhead deck area is more than 12 m measured horizontally from an accumulator. Where systems are used in spaces which may be mechanically ventilated, the position of the smoke accumulators shall be considered having regard to the effects of ventilation.
(C) Smoke accumulators shall be positioned where impact or physical damage is unlikely to occur.
(D) Not more than four accumulators shall be connected to each sampling point.
(E) Smoke accumulators from more than one enclosed space shall not be connected to the same sampling point.
(8) Sampling pipes are to be complied with the following requirements.
(A) The sampling pipe arrangements shall be such that the location of the fire can be readily identified.
(B) Sampling pipes shall be self-draining and suitably protected from impact or damage from cargo working.
(9) For system control requirements, visual and audible fire signals are to be complied with the following requirements.
(A) The control panel shall be located on the navigating bridge or in the continuously manned central control station.
(B) Clear information shall be displayed on or adjacent to the control panel designating the spaces covered.
(C) The detection of smoke or other products of combustion shall initiate a visual and audible signal at the control panel and the navigating bridge or continuously manned central control station.
(D) Power supplies necessary for the operation of the system shall be monitored for loss of power. Any loss of power shall initiate a visual and audible signal at the control panel and the navigating bridge which shall be distinct from a signal indicating smoke detection.
(10) Suitable instructions and component spares shall be provided for the testing and maintenance of the system.

102. Protection of machinery spaces

1. In applying **102. 1** of the Rules, these requirement applies to machinery spaces of category A.

2. In applying **102. 2** of the Rules, the fire detecting system for unattended machinery spaces shall be complied with the following requirements.

(1) An automatic fire detection system is to be fitted in the machinery spaces.

(2) The system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm.
(3) The fire detection indicating panel is to be located on the navigating bridge, fire control station, or other accessible place where a fire in the machinery space will not render it inoperative.
(4) The fire detection indicating panel is to indicate the place of the detected fire in accordance with the arranged fire zones by means of a visual signal. Audible signals clearly distinguishable in character from any other audible signals shall be audible throughout the navigating bridge and the accommodation area of the personnel responsible for the operation of the machinery space.
(5) Fire detectors are to be of types, and so located, that they will rapidly detect the onset of fire in conditions normally present in the machinery space. Consideration is to be given to avoiding false alarms. The type and location of detectors are to be approved by the Classification Society and a combination of detector types is recommended in order to enable the system to react to more than one type of fire symptom.
(6) Fire detector zones are to be arranged in a manner that will enable the operating staff to locate the seat of the fire. The arrangement and the number of loops and the location of detector heads is to be approved in each case. Air currents created by the machinery are not to render the detection system ineffective.
(7) When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements are to be ensured to fix and identify the set point.
(8) When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a present time.
(9) The fire detection indicating panel is to be provided with facilities for functional testing.
(10) The fire detecting system shall be fed automatically from the emergency source of power by a separate feeder if the main source of power fails.
(11) Facilities are to be provided in the fire detecting system to release manually the fire alarm from the places of passageways having entrances to engine and boiler rooms, navigating bridge, and control station in engine room.

103. Protection of accommodation and service spaces and control stations

In applying **103. 5** of the Rules, as for the methods of divisions and protections for accommodation spaces and service spaces, **Fig 8.3.1** is to be referred to as the standard arrangements. And in case of ships built in accordance with Method IIIC, the detection system is only relevant to the accommodation block and then service spaces built away from the accommodation block need not be fitted with a fixed fire detection system.

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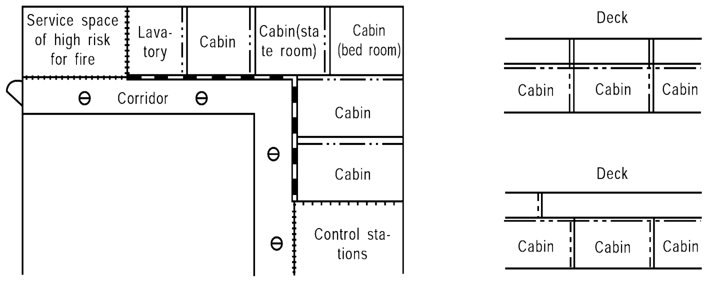
<tr><td>IC method</td><td>
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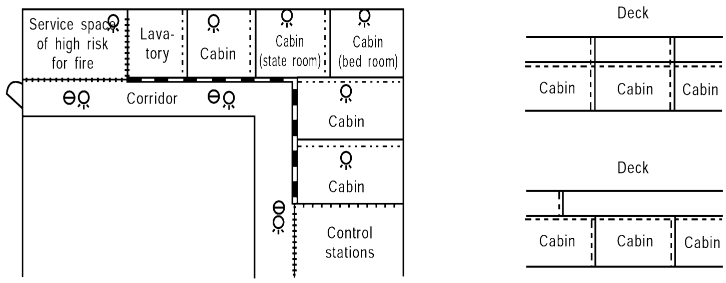
<tr><td>IIC method</td><td>
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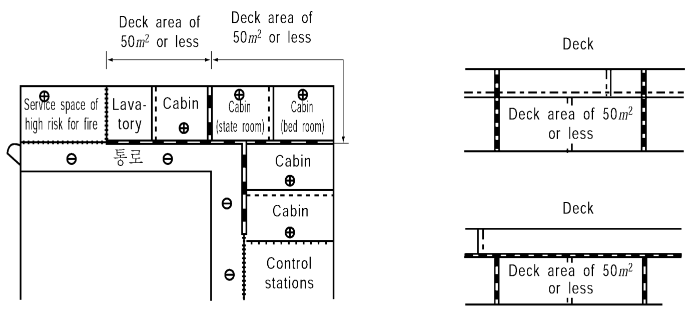
<tr><td>IIIC method</td><td>
</td></tr>
<tr><td colspan="2">NOTES:
"A-60" class divisions
"A-0" class divisions
"B-0" class divisions
"C" class divisions
Bulkheads of the approved fire retardant base materials
Sprinker (containing fire detection and fire alarm systems)
Fixed fire detection and alarm systems
Smoke detector</td></tr>
</table>

Fig 8.3.1 Method of division and protection for accommodation spaces and service spaces

108. Protection of cabin balconies on passenger ships

In applying **108.** of the Rules, fixed fire detection and fire alarm systems for cabin balconies shall be approved by the Society based on the Guidelines (MSC.1/Circ. 1242) developed by the IMO.

SECTION 2 Control of smoke speed

201. Protection of control stations outside machinery space

In applying **201.** of the Rules, the "practicable equipment" means that mechanical ventilation system is preferable, but natural ventilation system may also be accepted. And "where the local closing arrangements are equally effective" means that fire dampers or smoke dampers which are easily closed within the control stations are provided in the ventilation system so that smoke will not be drawn into such a control station in case of fire, and further, any openings, where provided, can be easily and securely closed.

203. Draft stops

In applying **203.** of the Rules,the draft stops, in general, are to coincide with the bulkheads where continuous ceilings are used. And any of the following methods of construction may be used to construct draft stops.

(1) The extension of the "B" class bulkhead, ceiling or lining
(2) The extension of the "C" class bulkhead, ceiling or lining
(3) 1 mm thick minimum steel sheet, stiffened where necessary, intermittently welded to the ship's structure and the top profile of the bulkhead, or fastened mechanically to the ceilings or linings
(4) Non-combustible board type material fasten mechanically to the ship's structure, bulkheads, ceilings or linings
(5) "A" class mineral wool insulation, not less than 20 mm in thickness, faced on each side with expanded metal mesh, the mesh on one side being attached to the ship's structure or expanded metal mesh may be fitted on one side and non-combustible cloth (glass-cloth) on the other side of mineral wool insulation.

SECTION 3 Containment of fire

301. Thermal and structural boundaries

1. In applying **301. 1** of the Rules, spaces of categories for the application of the standards of fire integrity are also to be complied with following ,

Control stations	Motor-generator rooms or inverter rooms for navigational or radio apparatus, storage rooms for fixed gas fire extinguishing system (where the system is stored outside the space to be protected)
Service spaces (low risk)	Shore connection box rooms, accommodation ladder winch machinery rooms, spaces where distribution panels and starters are located, ballast control rooms, main cargo control rooms
Other machinery spaces	Storage rooms for hydraulic units for deck machinery and cargo gears, steering gear room (see Note (1) below) foam tank rooms (those not capable of being remotely-controlled are regarded as the control stations), inert gas fan rooms
Service spaces (high risk)	Oxygen or acetylene bottle storage rooms (see Note (2) below), provision store rooms (see Note (3) below), jumper lockers (see Note (4) below)
Others	1. Passages under decks of container ships are to be regarded as void spaces. However, in case where they serve as escape route, they are to be regarded as corridors. 2. In this case, locker rooms, store rooms, lavatories for control stations, etc., in which someone may occupy temporarily, having no entrance to corridors but only entrance therefrom may be regarded as an integral part of such spaces. If a space is divided into two (or more) smaller spaces so that these new spaces form enclosed spaces (e.g. a cabinet built in a mess-room, a store room built in a mess-room), these new enclosed spaces are to be surrounded by fire-resistant bulkheads and decks in accordance with Rules. 3. Weather decks used to cargo stowage are to be considered as cargo spaces except for cargoes which constitute a low fire risk. 4. Ventilating fan rooms within refrigerated cargo spaces and cargo handling gear locker which can be accessible only from ro/ro spaces or vehicle spaces may be regarded as a part of Cargo spaces, ro-ro and vehicle spaces respectively. 5. Cable trunks are to apply to the requirements of the Rules **301. 3** (4) for lift trunks
Notes: (1) In case where an emergency fire pump is installed in the steering gear room or spaces which are only accessible directly therefrom, the fire integrity of boundaries between the space where the main fire pump is installed and the steering gear room is to be in accordance with **Fig 8.3.6** (2) In case where one side or more of the walls are open to exposed deck, such storage rooms may be regarded as those on open deck. (3) Refrigerated provision chambers are to be service spaces (high risk) if thermally insulated with combustible materials, or service spaces (low risk) if thermally insulated with non-combustible material. Provision chambers having areas of less than 4 m^2 may be considered as a service space with low risk of fire. (4) In case where jumper lockers are used as Oil skin lockers, they are regarded as high risk service spaces, except for Oil skin lockers, they are regarded as low risk service spaces	

2. In applying **301. 2** (1) (C) of the Rules, if a stairway serves two main vertical zones, the maximum length of any one main vertical zone need not be measured from the far side of the stairway enclosure. In this case all boundaries of the stairway enclosure are to be insulated as main vertical zone bulkhead and access doors leading into the stairway are to be provided from the two outside zones. The number of main vertical zone of 48 m is not limited as long as they comply with all the requirements.

3. In applying **301. 2** (2) (C) of the Rules, if an air gap between cabins results in an opening in the continuous class B-15 ceiling, the bulkheads on both sides of the air gap are to be of class B-15.

4. In applying **301. 2** (3) (A) of the Rules, distribution board may be located behind panels/linings within accommodation spaces including stairway enclosures, without the need to categorize the space, provided no provision is made for storage.

5. In applying **301. 3** (1) (A) (c) of the Rules, increasing area for public spaces is, in principle, to be limited to 75 m^2.

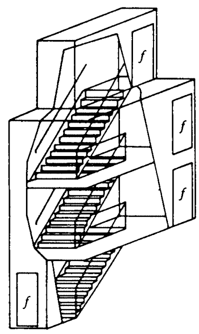
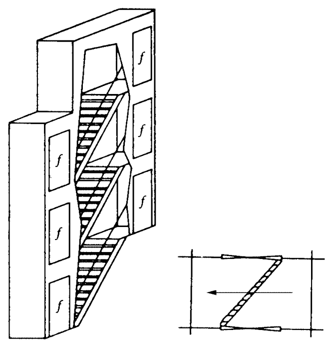
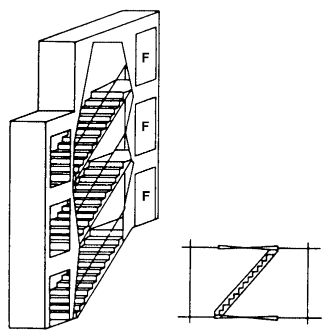
6. In applying **301. 3** (4) (A) of the Rules, stairway penetrating more than a single deck are to be protected in accordance with the following requirements:

(1) In case where stairways and passages are provided in stairway enclosures and access to other decks is possible through such stairway enclosures, self-closing "A" class fire doors are to be provided at each deck level (see **Fig 8.3.2** (a)).

(2) In case where only stairways are provided in stairway enclosures and access to other decks is made through outside the enclosures at each deck level, the following requirements are to be complied with:

(A) In case of stairways with open steps, they are to be protected by self-closing "A" class fire doors at each deck level and at each end of a stair (see **Fig 8.3.2** (b)).

(B) In case of stairways with closed steps, self-closing "B" class fire doors are to be provided at least at one end of each stair (see **Fig 8.3.2** (c)).

Structural configuration	Structural details
(a) Stairways accessible to other decks not going out of the stairway enclosures	
(b) Only stairways with open steps are surrounded by an enclosure and access to other decks is made through outside the enclosure at each deck level and each end a stair.	
(c) Only stairways with closed steps are surrounded by an enclousre and access to other decks is made through outside the enclosure at each deck level and one end of each stair.	

f : Self-closing "A" class fire door
F : Self-closing "B" class fire door

Fig 8.3.2 Protection of the stairway enclosures penetrating more than a single deck

7. In applying **301. 4** (2) (E) of the Rules, insulation of superstructures and deckhouses facing the cargo area are to be in accordance with the following requirements:

(1) "The outward sides for a distance of 3 m from the end boundary" refer to the **Fig 8.3.3** (a) of the Guidance.

(2) In the case of the arrangement as shown in **Fig 8.3.3** (b) of the Guidance, "A-60" class insulation is to be applied to the aft end bulkhead of deckhouse and side walls of accommodation spaces and service spaces of 3 m from the fore end thereof where they form the external boundaries of accommodation spaces and service spaces.

(3) "A-60" class Insulation requirements for the side walls for 3 m aft of the front bulkhead are to apply to all areas in the vertical direction up to the underside of the deck of the navigation bridge for superstructures and deckhouses.

(4) The side walls of a wheelhouse having the structural arrangement unlikely to be exposed to flames in case of fire in way of cargo area (e.g. structural arrangement of a wheelhouse provided on the sponson deck) may not be provided with the insulation.

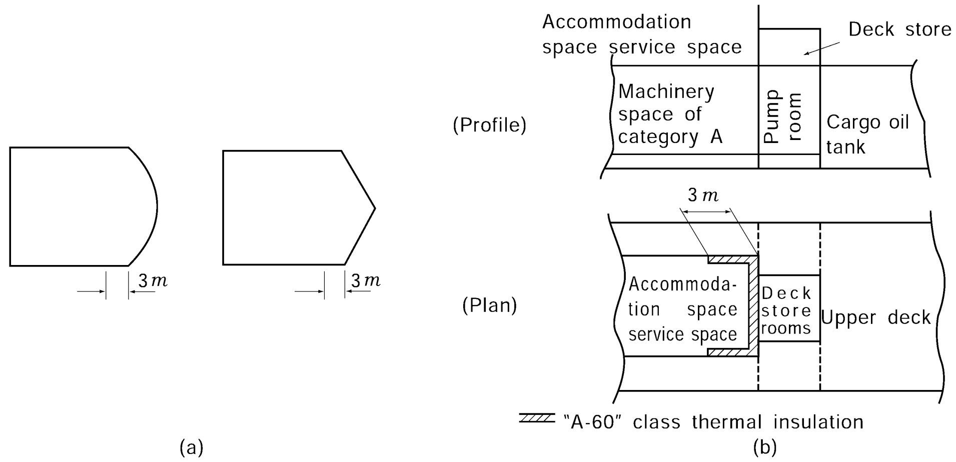


Fig 8.3.3 Insulation of superstructures and deckhouses facing the cargo area

8. In applying **301. 4** (2) Table Notes d. of the Rules, permanent approved gastight lighting enclosures for illumination with sufficient strength and maintaining the fire integrity and gas tightness of the bulkhead or deck are to have integrity and gas tightness equivalent to Grade A bronze side scuttles (fixed type) specified in **Pt 4, Ch 8, Sec 8** of the Rules and to be fitted with fire-resisting glass where illumination is made through a glazed window. The skylight, the bulkheads and decks bounding the cargo pump rooms required to have "A-60" class fire protection under the requirements of the Rules are not to be fitted with these glazed windows.

302. Penetration in fire-resisting divisions and prevention of heat transmission

1. In applying **302.** of the Rules, the structural arrangements penetrated through "A"or "B" class divisions are to be in accordance with **Annex 8-2** of the Guidance, and in addition electric cable penetrations are also to be complied with the requirement of **Pt 6, Ch1, 408.** of the Rules.

2. In applying **302. 4** of the Rules, treatment of terminal points and intersections of insulated bulkheads and decks" is to be in accordance with **Fig 8.3.4**.

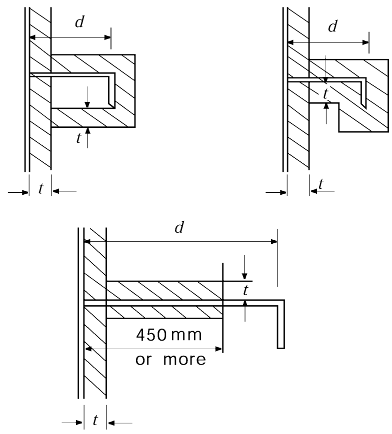
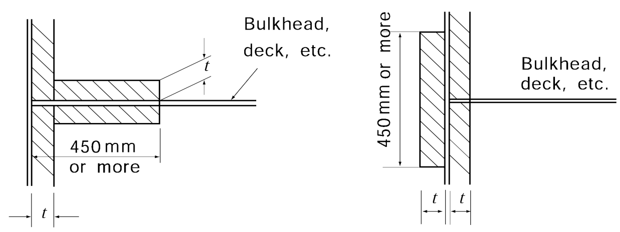
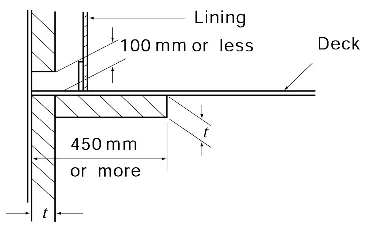
Treatment of terminal points and intersections	Structural details
(1) Insulation of stiffeners, girders, etc., in case where their depth is 450 mm or less, is to be applied to the whole structure including the flanges or face plates. Where the depth exceeds 450 mm, such insulation is to be applied to at least 450 mm in depth from bulkheads or decks. However, in case where the fire integrity has been verified by a standard fire test, this requirement may be dispensed with	Where $d \leq 450$ mm Where $d > 450$ mm 
(2) The structural extension of insulation at intersections between uninsulated bulkheads, decks or brackets is to be 450 mm or more	
(3) In case where the lower part of insulation has to be cut for drainage, the construction is to be inaccordance with the structural details.	
t : Thickness of thermal insulation d : Depth of stiffener or girder	

Fig 8.3.4 Treatment of terminal points and intersections of insulated bulkheads and decks

303. Protection of openings in fire resisting divisions

1. In applying **303. 1** of the Rules, balancing openings or ducts between two enclosed spaces are prohibited except for openings as permitted by **303. 1** (2) & **2** of the Rules.
2. In applying **303. 1** of the Rules, guidelines developed by the IMO referred in **303. 1** (3) (C) (c) of the Rules should be in accordance with the IMO Res. A.800(19).
3. In applying **303. 2** (1) of the Rules, where required divisions are replaced by divisions of a higher standard, the door need only conform to the required division.
4. In applying **303. 2** (2) of the Rules, "Remote release devices of fail-safe type" means the system which releases hooks or other equivalent devices by remote operation, and that the door is automatically closed even in case of failure of the system.

5. In applying **303. 2** (3) of the Rules, in case where ventilation openings are provided on corridor bulkheads, the following requirements are to be complied with

(1) For corridor bulkheads except stairway enclosures required to have "B" class fire integrity, "B" class fire door with louvres of approved type leading to lavatories, offices, pantries, lockers and store rooms may be provided. In this case, the louvres are to be capable of being closed from the corridor side.

(2) For duct trunks adjoining to corridor bulkheads, ventilation openings with manual closing appliances may be provided. In this case, grids made of non-combustible materials are to be fitted to the ventilation openings. Furthermore, in case where the sectional area of such a ventilation opening exceeds 0.075 m^2, self-closing type fire damper is to be provided in addition to the manual closing appliances.

305. Protection of cargo space boundaries

In applying **305. 5** of the Rules, when ships are designed to transport alternatively oil or dry cargoes, openings which may be used for cargo operations are not permitted in bulkheads and decks separating oil cargo spaces from other spaces not designed and equipped for the carriage of oil cargoes unless alternative approved means are provided to ensure equivalent integrity.

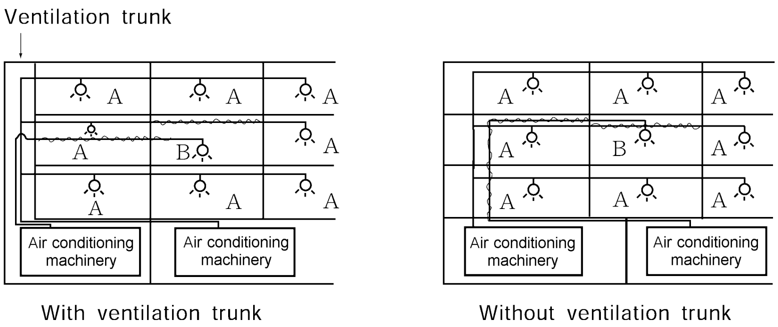
306. Ventilation systems

1. In applying **306.** of the Rules, exhaust ventilations of accommodation spaces, service spaces and control stations to be effected through the exhaust ventilation ducts except where ventilation openings are accepted under **303. 4**.

2. In applying **306. 1** (1) of the Rules, Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of an opening in an A class or B class division and in ducts required to be of A class construction. However, flexible bellows of combustible material may be used for the connecting fans to ducting in air conditioning rooms. And a free cross-sectional area means the area calculated on the basis of the inner diameter of the duct.

3. In applying **306. 1** (B) of the Rules and **306. 4** (3) (C) of the Rules, calorific value refers to ISO, in particular publication ISO 1716, Determination of calorific potential.

4. In applying **306. 2** of the Rules, "A-60" class insulation" is, as a standard, to be an insulation with rock-wool approved as non-combustible material, or insulation approved as "A-60" class standard and arrangement of ducts are to be in accordance with **Fig 8.3.5**.



A: Accommodation spaces, service spaces excluding galleys or control stations
B: Machinery spaces of category A, galleys, car deck spaces or ro-ro cargo spaces

Fig 8.3.5 Examples for arrangements of Ventilation system

5. In applying **306. 2** (1) of the Rules, the expression"in any case" means, in this context, "for any duct section" and this section actually applies to arrangements where a ventilation unit serves some spaces and a galley by a separate duct as permitted, as permitted for cargo ships of less than 4,000 gross tonnage and for passenger ships carrying not more than 36 passengers.

6. In applying **306. 3** (1) (B) of the Rules, "Fire dampers automatically" is to be the fuse type dampers or those considered to be equivalent by the Society. "Being closed manually" means closing by mechanical means of release or by remote operation of the fire damper by means of a fail-safe electrical switch or pneumatic release (spring-loaded, etc.) on both sides of the division. However, ducts or pipes with free sectional area of 0.075 m^3 or less need not be fitted with fire damper at their passage through Class"A" division.

7. In applying the requirements of **306. 5** of the Rules, the exhaust ducts from galley ranges are to be in accordance with the following requirements:

(1) The exhaust ducts from galley ranges are, in principle, to be independent from other ducts. In case where this is impracticable, self-closing type fire dampers which can be remotely operated are to be fitted to the other branch ducts in order to be capable of closing these dampers together with those for galley ranges simultaneously.
(2) Unless otherwise permitted by the Society, the term of "spaces containing combustible materials" will normally apply to all spaces in accommodation.
(3) "A" class divisions herein means that ducts are to be of steel with a thickness of 4.5 mm or more.
(4) The fire dampers located at the lower end of the ducts are to be such that they can be readily and safely closed in the galley in case of fire in way of range.
(5) In case where the carbon dioxide gas fire extinguishing system specified in **403.** of the Rules is provided as fixed means for extinguishing a fire within the exhaust duct, the quantity of fire extinguishing medium is to be 100 % or more of the volume of the duct spaces to be protected.
(6) The fire extinguishing system specified in **306. 5** (3) (D) of the Rules shall be operated automatically due to a fire within the duct.

8. In applying **306. 5** (1) of the Rules, the requirements to exhaust ducts from galley ranges in which grease or fat is likely to accumulate will apply to all exhaust ducts from galley ranges.

9. In applying **306. 5** (3) of the Rules, fire dampers do not need to pass the fire test in Res. A754(18), but should be of steel and capable of stopping the draught. The requirements to “A” class applies only to the part of the duct outside of the galley. And the term"spaces containing combustible materials will normally apply to all spaces in accommodation.

10. In applying **301. 2** (1), (2) & **301. 5** (2), (3) of the Rules for determining fire insulation for trunks and ducts which pass through an enclosed space, the term "pass through" means the part of the trunk/duct contiguous to the enclosed space. (see **Fig 8.3.6**)

11. In applying the requirements of **306. 3** (1) (B) of the Rules, fire-protection requirements of fan rooms serving engine-rooms are to be complied as follows.

(1) A fan room solely serving the engine-room or multiple spaces containing an engine-room, may be treated as machinery space having little or no fire risk.
In this case:
(A) Boundaries between the fan room and engine-room casing should be of “A-0” fire integrity;
(B) Duct penetrations should comply with **306. 3** (1) (B) of the Rules;
(C) Ducts serving the engine-room should be routed directly to the relevant fan(s) and from the fan to the louvers; and
(D) Closing of the ventilation duct to/from the engine-room should be possible from outside the engine-room. In this case, the controls for the closing of the engine-room ventilation duct (i.e., a fire damper installed in accordance with **306. 3** (1) (B) of the Rules) can be located inside the fan room.
(2) A fan room solely serving the engine-room may be considered as part of the engine-room. In this case:
(A) Requirements for fire integrity of the horizontal boundary between fan room and engine-room need not apply; and
(B) Closing the ventilation duct to/from engine-room should be possible from outside the engine-room. In this case, the controls for closing of the ventilation trunk (i.e., a fire damper installed as per **306. 3** (1) (B) of the Rules) should be located outside the fan room.
(3) For both of the cases described above:

(A) For any space(s) adjacent to the fan room superstructure, the fire integrity of the separating bulkhead(s) should meet the applicable fire integrity requirements contained in the table set out in **301. Table 8.3** of the Rules ;and

(B) Load Line Convention requirements relevant to the means of closing for downflooding protection should be applied, if necessary.

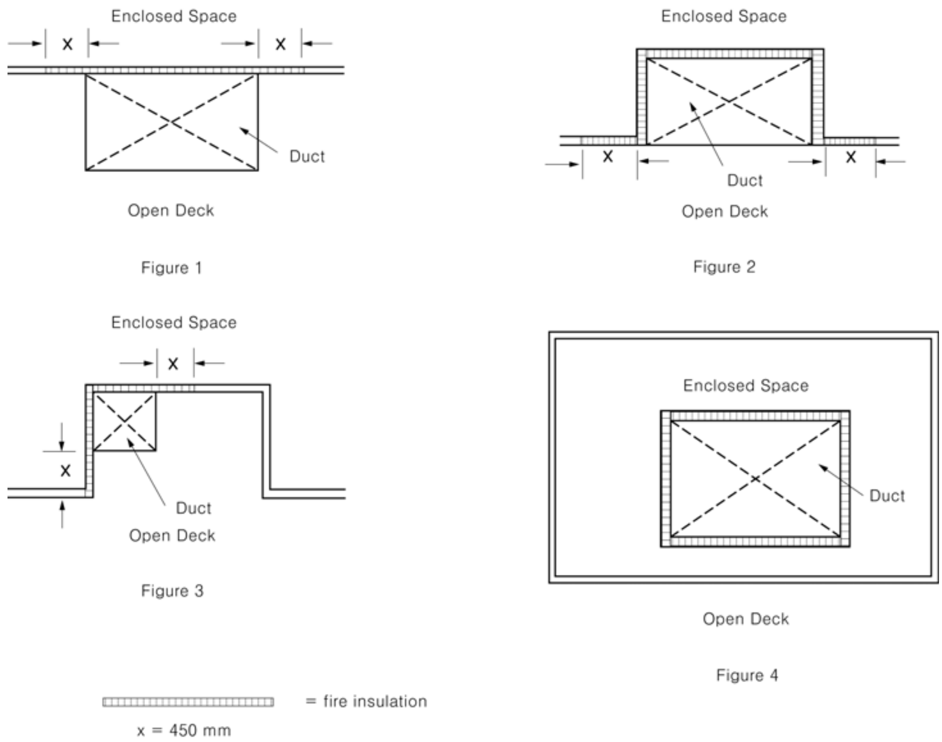


Fig 8.3.6 Examples of ducts contiguous to enclosed space

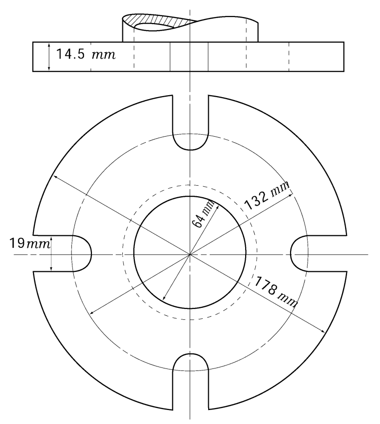
SECTION 4 Fire fighting

401. Water supply systems

1. In applying **401. 1** (4) (A) of the Rules, isolating valves are not applicable to the piping from fire pumps located in other spaces other than category A machinery spaces.

2. In applying **401. 1** (6) of the Rules, the minimum pressure is to be sufficient to produce a 12 m jet throw, through any adjacent hydrants, to any part of the ships referred to **401. 1** (5) of the Rules, on passenger and cargo ships under 1,000 tonnes gross tonnage.

3. In applying **401. 1** (7) of the Rules, Standard dimensions of flanges for the international shore connection shall be in accordance with the following table. And International shore connections shall be of steel or other equivalent material and shall be designed for 1.0 MPa services. The flange shall have a flat face on one side and, on the other side, it shall be permanently attached to a coupling that will fit the ship's hydrant and hose. The connection shall be kept aboard the ship together with a gasket of any material suitable for 1.0 MPa services.

Description	Dimension	
Outside diameter	178 mm	
Inside diameter	64 mm	
Bolt circle diameter	132 mm	
Slots in flange	4 holes 19 mm in diameter spaced equidistantly on a bolt circle of the above diameter, slotted to the flange periphery	
Flange thickness	14.5 mm minimum	
Bolts and nuts	4 ea, each of 16 mm diameter, 50 mm in length including eight(8) washers	

4. In applying **401. 2** (3) of the Rules, on ships for navigation in ice, on ships for navigation in polar water and on ships for navigation in polar and ice breaking service, sea inlet system is to be in accordance with the requirements in **Pt 3, Ch 20, 702.** of the Rules, the requirements in **Pt 3, Ch 21, 308.** of the Guidance and the requirements in **Pt 3, Ch 22, 903.** of the Guidance respectively.

5. In applying **401. 2** (3) (A) (b) of the Rules, the electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their sources of power and prime movers. They are to be of a fire resistant type approve by the Society, where they pass through other high fire risk areas. And unless the two main fire pumps, their sea suctions and the fuel supply or source of power for each pump are situated within compartments separated at least by A-0 divisions, so that a fire in any one compartment will not render both fire pumps inoperable, an emergency fire pump should be fitted. An arrangement in which one main fire pump is located in a compartment having more than one bulkhead adjacent to the compartment containing the other main fire pump should also require an emergency fire pump.

6. In applying **401. 2** (3) (B) of the Rules, emergency fire pumps is not applicable to passenger ships of l,000 gross tonnage and upwards and is also, in principle, to be complied with as follows,

(1) The emergency fire pump shall be of a fixed independently driven power-operated pump.

(2) Capacity of emergency fire pump

(A) The capacity of the pump shall not be less than 40 % of the total capacity of the fire pumps specified in **401. 2** (4) of the Rules and in any case not less than

(a) for passenger ships less than 1000 gross tonnage and for cargo ships of 2000 gross tonnage and upwards ; 25 cubic meters/h

(b) for cargo ships less than 2000 gross tonnage ; 15 cubic meters/h.

(B) In applying **403. 1** (1) of the Rules, where a fixed water-based fire extinguishing system installed for the protection of the machinery space of cargo ships is supplied by the emergency fire pump, the emergency fire pump capacity shall be adequate to supply the fixed fire extinguishing system at the required pressure plus two jets of water. The capacity of the two jets shall in any case be calculated by that emanating from the biggest nozzle size available onboard from the following table(When selecting the biggest nozzle size available onboard, the nozzles located in the space where the main fire pumps are located can be excluded), but shall not be less than 25 m^3/h

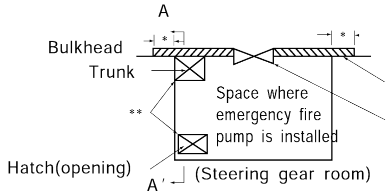
< Capacity of single jet >

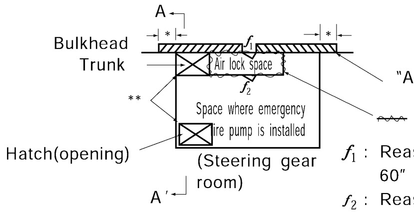
Pressure at Hydrant \ Nozzle size	16 mm	19 mm
0.27 N/mm^2	16 m^3/h	23.5 m^3/h

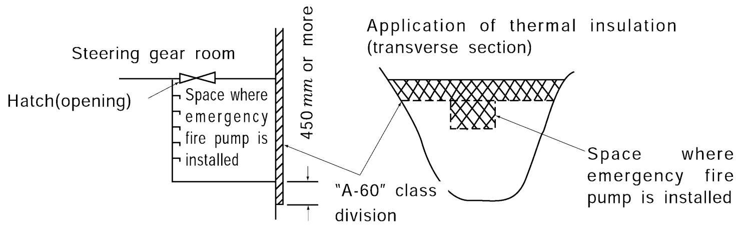
(3) When the pump is delivering the quantity of water required by paragraph (2) the pressure at any hydrants shall be not less than the minimum pressure specified in the Rules.
(4) The total suction head and the net positive suction head of the pump shall be determined having due regard to the requirements on the pump capacity and on the hydrant pressure under all conditions of list, trim, roll and pitch likely to be encountered in service. The ballast condition of a ship on entering or leaving a dry dock need not be considered a service condition. Upon completion of the emergency fire pump installation, a performance test confirming the capacity required in the Rules should be carried out. As far as practicable, the test should be carried out at lightest seagoing draught at the suction position.
(5) Any diesel driven power source for the pump shall be capable of being readily started in its cold condition down to the temperature of 0 ℃ by hand (manual) cranking. If this is impracticable, or if lower temperature are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangement, acceptable to the Society so that ready starting will be assured. If hand (manual) starting is impracticable, the Society may permit other means of starting. These means shall be such as to enable the diesel driven power source to be started at least six times within a period of 30 min and at least twice within the first 10 min.
(6) Any service fuel tank shall contain sufficient fuel to enable the pump to run on full load for at least three hours and sufficient reserves of fuel shall be available outside the machinery space of category A to enable the pump to be run on full load for an additional 15 h.
(7) The room where the pump and prime mover are installed is to have adequate space for maintenance work and inspections .
(8) Where necessary to ensure priming, the emergency fire pump should be of the self priming type.
(9) Where a power-operated emergency fire pump is fitted, its fuel or power supply is to be so arranged that it will not readily be affected by a fire in the compartment containing the main fire pumps. The room where the emergency fire pump prime mover is located is to be illuminated and well ventilated from the emergency source of supply.

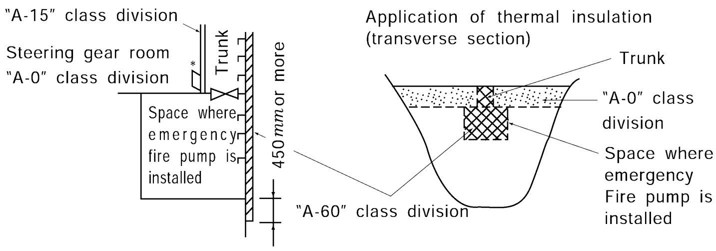
7. In applying **401. 2** (3) (B) (a) of the Rule, when a single access to the emergency fire pump room is through another spaces adjoining a machinery space of category A or the spaces containing the main fire pumps, class A-60 boundary is required between the other space and the machinery space of category A or the spaces containing the main fire pumps.

8. In applying **401. 2** (3) (B) (b) of the Rule, if a direct access between machinery spaces provided with the main fire pumps are installed and spaces provided with an emergency fire pump or the second means of access to the space provided with an emergency fire pump is inevitably provided, **Fig 8.3.7** is to be referred to as the standard arrangements.

<table>
<tr><th colspan="3">Construction</th><th>Structural details</th></tr>
<tr><td rowspan="4">In case where a direct acces is provided between machinery spaces and spaces provided with an emergency fire pump</td><td rowspan="2">1st corridors</td><td>In case where a watertight door is provided</td><td>

* : Extension of thermal insulation is to be 450 mm or more.
** : Either of these is to be provided.
"A-60" class division
Remotely operated watertight door(no thermal insulation is required.) which is also capable of being closed from a place near the door from the side of the space where an emergency fire pump is installed.</td></tr>
<tr><td>In case where an air lock is provided</td><td>

* : Extension of thermal insulation is to be 450 mm or more.
** : Either of these is to be provided.
"A-60" class division
(wavy line) : Bulkhead of steel or equivalent material
f_1 : Reasonably gastight self-closing door of "A-60" class without any hold back arrangement
f_2 : Reasonably gastight self-closing door of steel or other equivalent material without any hold back arrangement (Door packing is to be of non-combustible material.)</td></tr>
<tr><td rowspan="2">2nd corridors</td><td>In case where a hatch or an opening is provided</td><td>

(Section A-A' of figure of 1st corridors)</td></tr>
<tr><td>In case where a trunk is provided</td><td>

(Section A-A' of figure of 1st corridors)
*Self-closing door may be provided between the trunk and steering gear room.</td></tr>
</table>

Fig 8.3.7 Corridors in machinery spaces and spaces provided with emergency fire pumps

9. In applying **401. 2** (3) (C) of the Rules, this paragraph does not force designers to choose pumps with capacity and pressure characteristics other than that being optimal for the service intended, just to make their connection to the fire main possible, provided the required number and capacity of fire pumps are already fitted.

10. In applying **401. 3** of the Rules, Aluminium alloys may be used for fire hose couplings and nozzles, except in open deck areas of oil tankers and chemical tankers. And fire hose nozzles made of plastic type material, e.g. polycarbonate, are considered acceptable provided capacity and serviceability are documented and the nozzles are found suitable for the marine environment.

402. Portable fire extinguisher

1. In applying **402. 1** of the Rules, portable fire extinguisher is also to be complied with as follows.

(1) All fire extinguishers shall be of approved types and designs based on the guidelines **Res.A.602(15)** developed by the IMO.

(2) Each powder or carbon dioxide extinguisher shall have a capacity of at least 5 kg, and each foam extinguisher shall have a capacity of at least 9 L. The mass of all portable fire extinguishers shall not exceed 23 kg, and they shall have a fire-extinguishing capability at least equivalent to that of a 9 L fluid extinguisher.

(3) the Society shall determine the equivalent of fire extinguishers.

(4) Only refills approved for the fire extinguisher in question shall be used for recharging

(5) In applying **404. 1** (2) (A) & **404. 2** (2) (A) of the Rules, a portable foam applicator unit shall consist of a foam nozzle/branch pipe, either of a self-inducing type or in combination with a separate inductor, capable of being connected to the fire main by a fire hose, together with a portable tank containing at least 20 ℓ of foam concentrate and at least one spare tank of foam concentrate of the same capacity, and the System performance is as follows.

(A) The nozzle/branch pipe and inductor shall be capable of producing effective foam suitable for extinguishing an oil fire, at a foam solution flow rate of at least 200 ℓ/min at the nominal pressure in the fire main.

(B) The foam concentrate shall be approved by the Flag Administration in which the ship is registered or to be registered based on the guideline developed by the IMO.* However, in case where there is no expressly provided national regulations, the foam concentrate shall be approved by the Contracting Government of the SOLAS or the Society.

* Refer to the Guidelines for the performance and testing criteria and surveys of low-expansion foam concentrates for fixed fire-extinguishing systems (MSC/Circ.582/Corr.1).

(C) The values of the foam expansion and drainage time of the foam produced by the portable foam applicator unit shall not differ more than ± 10 % of that determined in (B).

(D) The portable foam applicator unit shall be designed to withstand clogging, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered on ships.

2. In applying **402. 2** of the Rules, number and arrangement of portable fire extinguishers are to be complied with as follows.

(1) If a space is locked when unmanned, portable fire extinguishers required for that space may be kept inside or outside the space.

(2) The selection of portable fire extinguishers should be appropriate to the fire hazard(s) in the space in accordance with the Guidelines for marine portable fire extinguishers, as adopted by Res.A.951(23). The classes of portable fire extinguishers in the table are only for reference.

(3) Unless expressly provided by the Unified Interpretations of SOLAS Ch II-2, the FSS Code, the FTP Code and related fire test procedures (MSC/Circ. 1120) or **404.** of the Rules, the number and arrangement of portable fire extinguishers in machinery spaces of category A are specified in the following table.

< Minimum numbers and distribution of portable fire extinguishers in the various types of spaces on board ships >

Type of spaces		Minimum number of extinguishers	Class(es) of extinguisher(s)(6)
Accommo. spaces	Public spaces	1 per 250 m² of deck area or fraction thereof	A
	Corridors	Travel distance to extinguishers should not exceed 25 m within each deck and main vertical zone	A
	Stairway	0	
	Lavatories, cabins, offices, pantries containing no cooking appliances	0	
	Hospital	1	A
Service spaces	Laundry drying rooms, pantries containing cooking appliances	1(2)	A or B
	Lockers and store rooms (having a deck area of 4 m² or more), mail and baggage rooms, specie rooms, workshops (not part of machinery spaces, galleys)	1(2)	B
	Galleys	1 class B and 1 additional class F or K for galleys with deep fat fryers	B, F or K
	Lockers and store rooms (deck area is less than 4 m²)	0	
	Other spaces in which flammable liquids are stowed	In accordance with **405. 3** of the Rules	
Control stations	Control stations (other than wheelhouse)	1	A or C
	Wheelhouse	2, if the wheelhouse is less than 50 m² only 1 extinguisher is required(3)	A or C
Machinery spaces of category A	Central control station for propulsion machinery	1, and 1 additional extinguisher suitable for electrical fires when main switchboards are arranged in central control station	A and/or C
	Vicinity of the main switchboards	2	C
	Workshops	1	A or B
	Enclosed space with oil-fired inert gas generators, incinerators and waste disposal units	2	B
	Separately enclosed room with fuel oil purifiers(7)	0	
	Periodically unattended Machinery spaces of category A	1 at each entrance(1)	B
Other spaces	Workshops forming part of machinery spaces and other machinery spaces (auxiliary spaces, electrical equipment spaces, auto - telephone exchange rooms, air conditioning spaces and other similar spaces)	1	B or C
	Weather deck	0(4)	B
	Ro-ro spaces and vehicle spaces	No point if space is more than 20 m walking distance from an extinguisher at each deck level(4),(5)	
	Cargo spaces	0(4)	B
	Cargo pump-room	2	B
	Helidecks	In accordance with **Ch 5, 104.** of the Rules	B

NOTES:
(1) A portable fire extinguisher required for a small space may be located outside and near the entrance to that space.
(2) For service spaces, a portable fire extinguisher required for that small space placed outside or near the entrance to that space may also be considered as part of the requirement for the space in which it is located.
(3) If the wheelhouse is adjacent with a chart room and has a door giving direct access to the chart room, no additional fire extinguisher is required in the chart room. The same applies to safety centres if they are within the boundaries of the wheelhouse in passenger ships.
(4) Two portable fire extinguishers, each having a capacity of not less than 6 kg of dry powder or equivalent, should be provided when dangerous goods are carried on the weather deck, in open ro-ro spaces and vehicle spaces, and in cargo spaces as appropriate. Two portable fire extinguishers, each having a suitable capacity, should be provided on weather deck for tankers.
(5) No portable fire extinguisher needs to be provided in cargo holds of containerships if motor vehicles with fuel in their tank for their own propulsion are carried in open or closed containers.
(6) Classes of extinguishers are as follows in accordance with Res.A 951(23)
(7) The separately enclosed room is to be enclosed by steel bulkheads extending from deck to deck and provided with self-closing steel doors. And, the room is to be provided with independent ventilation system, fire detecting system and fixed fire extinguishing installation.

< Class(es) of extinguisher(s) >

International Organization for Standardization (ISO standard 3941)	National Fire Protection Association (NEPA 10)
Class A: Fires involving solid materials, usually of an organic nature, in which combustion normally takes place with the formation of glowing embers.	Class A: Fires in ordinary combustible materials such as wood, cloth, paper, rubber and many plastics.
Class B: Fires involving liquids or liquefiable solids.	Class B: Fires in flammable liquids, oils, greases, tars, oil base paints, lacquers and flammable gases.
Class C: Fires involving gases.	Class C: Fires, which involve energized electrical equipment where the electrical non-conductivity of the extinguishing medium is of importance. (When electrical equipment is de-energized, extinguishers for class A or B fires may be used safely)
Class D: Fires involving metals.	Class D: Fires in combustible metals such as magnesium, titanium, zirconium, sodium, lithium and potassium.
Class F: Fires involving cooking oils.	Class K: Fires involving cooking grease, fats and oils.

3. In applying **402. 2** (2) of the Rules, it is recommended that the remaining portable fire extinguishers in the public spaces and workshops be located at or near the main entrances and exits.

403. Fixed fire-extinguishing systems

1. In applying **403. 1** (1) (A) of the Rules, fixed gas fire-extinguishing system is also to be complied with as follows.

(1) General

(A) Fire-extinguishing medium

(a) Where the quantity of the extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected. The system shall be fitted with normally closed control valves arranged to direct the agent into the appropriate space.

(b) The volume of starting air receivers, converted to free air volume, shall be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively, a discharge pipe from the safety valves may be fitted and led directly to the open air.

(c) Means shall be provided for the crew to safely check the quantity of medium in the containers.

(d) Containers for the storage of fire-extinguishing medium, piping and associated pressure components shall be designed according to the following pressure codes of practice to the satisfaction of the Society having regard to their locations and maximum ambient temperatures expected in service.

(i) ISO-9809/1 : Refillable seamless steel gas cylinders (design, construction and testing)

(ii) ISO-3500 : Seamless steel CO2 cylinders. For fixed fire-fighting installations on ships, specifying the principal external dimensions, accessories, filling ratio and marking for seamless steel CO2 cylinders used in fixed fire-fighting installations on ships, in order to facilitate their interchange ability

(iii) ISO-5923 : Fire protection - Fire-extinguishing media - Carbon dioxide

(iv) ISO-13769 : Gas cylinders - Stamp marking

(v) ISO-6406 : Periodic inspection and testing of seamless steel gas cylinders

(vi) ISO-9329, part 1 : Seamless steel tubes for pressure purposes - Technical delivery conditions. Part 1 : Unalloyed steels with specified room temperature properties

(vii) ISO-9329, part 2 : Seamless steel tubes for pressure purposes - Technical delivery conditions. Part 2 : Unalloyed and alloyed steels with specified elevated temperature properties

(viii) ISO-9330, part 1 : Welded steel tubes for pressure purposes - Technical delivery conditions - Part 1 : Unalloyed steels tubes with specified room temperature properties

(ix) ISO-9330, part 2 : Welded steel tubes for pressure purposes - Technical delivery conditions - Part 2 : Electric resistance and induction welded unalloyed and alloyed steel tubes with specified elevated temperature properties

(B) Installation requirements

(a) The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained. System flow calculations shall be performed using a calculation technique acceptable to the Society.

(b) Except as otherwise permitted by the Society, pressure containers required for the storage of fire-extinguishing medium, other than steam, shall be located outside protected spaces in accordance with **403. 3** of the Rules.

(c) Spare parts for the system shall be stored on board as below and be to the satisfaction of the Society.

(i) Rupture disc of all containers
(including for working rupture disc and packing)

(ii) Safety disc of 1/3 of all containers
(including for working safety disc and packing)

(iii) Necessary packing, o-ring and tools for maintenance, etc to recharge 1/10 of all containers

(d) In piping sections where valve arrangements introduce sections of closed piping, such sections shall be fitted with a pressure relief valve and the outlet of the valve shall be led to open deck

(e) All discharge piping, fittings and nozzles in the protected spaces shall be constructed of materials having a melting temperature which exceeds 925℃. The piping and associated equipment shall be adequately supported.

(f) A fitting shall be installed in the discharge piping to permit the air testing as required by (2) (C) (a) (i)

(C) System control requirements

(a) The necessary pipes for conveying fire-extinguishing medium into the protected spaces shall be provided with control valves so marked as to indicate clearly the spaces to which the pipes are led. Suitable provisions shall be made to prevent inadvertent release of the medium into the space. Where a cargo space fitted with a gas fire-extinguishing system is used as a passenger space, the gas connection shall be blanked during such use. The pipes may pass through accommodations providing that they are of substantial thickness and that their tightness is verified with a pressure test, after their installation, at a pressure head not less than 5 N/mm^2. In addition, pipes passing through accommodation areas shall be joined only by welding and shall not be fitted with drains or other openings within such spaces. The pipes shall not pass through refrigerated spaces.

(b) Means shall be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any ro-ro spaces and other spaces in which personnel normally work or to which they have access(spaces that doors or access manholes are installed at and personnel normally access during voyage, such as specific machinery spaces, vehicle deck spaces, roll-on, roll-off cargo spaces, refrigerated container storage spaces, etc except general cargo holds, small compressor rooms, paint lockers, flammable liquid lockers). The audible alarms shall be located so as to be audible throughout the protected space with all machinery operating, and the alarms should be distinguished from other audible alarms by adjustment of sound pressure or sound patterns. The pre-discharge alarm shall be automatically activated, e.g. by opening of the release cabinet door. The alarm shall operate for the length of time needed to evacuate the space, but in no case less than 20 seconds before the medium is released. Conventional cargo spaces and small spaces (such as compressor rooms, paint lockers, etc.) with only a local release need not be provided with such an alarm.

(c) The means of control of any fixed gas fire-extinguishing system shall be readily accessible, simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel.

(d) Automatic release of fire-extinguishing medium shall not be permitted, except as permitted by the Society.

(2) Carbon dioxide systems

(A) Quantity of fire-extinguishing medium

(a) For cargo spaces, the quantity of carbon dioxide available shall, unless otherwise provided, be sufficient to give a minimum volume of free gas equal to 30 % of the gross volume of the largest cargo space to be protected in the ship.

(b) For machinery spaces, the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

(i) forty percent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 % or less than of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing : or

(ii) thirty-five percent of the gross volume of the largest machinery space protected, including the casing;

(c) The percentages specified in paragraph (13) above may be reduced to 35 % and 30 %, respectively, for cargo ships of less than 2,000 tons gross tonnage where two or more machinery spaces, which are not entirely separate, are considered as forming one space.

(d) For the purpose of this paragraph the volume of free carbon dioxide shall be calculated at 0.56 m^3/kg.

(e) For machinery spaces the fixed piping system shall be such that 85 % of the gas can be discharged into the space within 2 min. And this may be checked by suitable calculations.

(B) Controls

(a) Carbon dioxide systems shall comply with the following requirements. And then these requirements only apply to systems protecting those spaces which are specified in (1) (C) (b).

(i) two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used for opening the valve of the piping which conveys the gas into the protected space and a second control shall be used to discharge the gas from its storage containers. Positive means shall be provided so they con only be operated in that order; and

(ii) the two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be in a break-glass-type enclosure conspicuously located adjacent to the box.

(C) Testing of the installation

(a) When the system has been installed, pressure -tested and inspected, the following shall be carried out;

(i) a test of the free air flow in all pipes and nozzles; and

(ii) a functional test of the alarm equipment

(D) Low-pressure CO_2 system

(a) Where a low pressure CO_2 system is fitted to comply with this regulation, the following applies.

(i) The system control devices and the refrigerating plants shall be located within the same room where the pressure vessels are stored.

(ii) The rated amount of liquid carbon dioxide shall be stored in vessels under the working pressure in the range of 1.8 N/mm^2 to 2.2 N/mm^2. The normal liquid charge in the container shall be limited to provide sufficient vapour space to allow for expansion of the liquid under the maximum storage temperatures than can be obtained corresponding to the setting of the pressure relief valves but shall not exceed 95% of the volumetric capacity of the container.

(iii) Provision shall be made for:

- pressure gauge;
- high pressure alarm: not more than setting of the relief valve;
- low pressure alarm: not less than 1.8 N/mm^2;
- branch pipes with stop valves for filling the vessel;
- discharge pipes;
- liquid CO_2 level indicator, fitted on the vessel(s);
- two safety valves.

(iv) The two safety relief valves shall be arranged so that either valve can be shut off while the other is connected to the vessel. The setting of the relief valves should not be less than 1,1 times working pressure. The capacity of each valve shall be such that the vapours generated under fire condition can be discharged with a pressure rise not more than 20 % above the setting pressure. The discharge from the safety valves should be led to the open.

(v) The vessel(s) and outgoing pipes permanently filled with carbon dioxide shall have thermal insulation preventing the operation of the safety valve in 24 hours after de-energizing the plant, at ambient temperature of 45 ℃ and an initial pressure equal to the starting pressure of the refrigeration unit.

(vi) The vessel(s) shall be serviced by two automated completely independent refrigerating units solely intended for this purpose, each comprising a compressor and the relevant prime mover, evaporator and condenser.

(vii) The refrigerating capacity and the automatic control of each unit shall be so as to maintain the required temperature under conditions of continuous operation during 24 hours at sea temperatures up to 32 ℃ and ambient air temperatures up to 45 ℃.

(viii) Each electric refrigerating unit shall be supplied from the main switchboard busbars by a separate feeder.

(ix) Cooling water supply to the refrigerating plant (where required) shall be provided from at least two circulating pumps one of which being used as a stand-by. The stand-by pump may be a pump used for other services so long as its use for cooling would not interfere with any other essential service of the ship. Cooling water shall be taken from not less than two sea connections, preferably one port and one starboard.

(x) Safety relief devices shall be provided in each section of pipe that may be isolated by block valves and in which there could be a build-up of pressure in excess of the design pressure of any of the components.

(xi) Audible and visual alarms shall be given in a central control station or, in accordance with regulation SOLAS Ⅱ-1/51, where a central control station is not provided, when:

- the pressure in the vessel(s) reaches the low and high values according to (C);
- any one of the refrigerating units fails to operate;
- the lowest permissible level of the liquid in the vessels is reached.

(xii) If the system serves more than one space, means for control of discharge quantities of CO2 should be provided, e.g automatic timer or accurate level indicators located at the control position(s).

(xiii) If a device is provided which automatically regulates the discharge of the rated quantity of carbon dioxide into the protected spaces, it should be also possible to regulate the discharge manually.

(3) Requirements of steam systems

The boiler or boilers available for supplying steam shall have an evaporation of at least 1.0 kg of steam per hour for each 0.75 cubic meters of the gross volume of the largest space so protected. In addition to complying with the foregoing requirements the systems in all respects shall be as determined by, and to the satisfaction of the Society.

(4) Systems using gaseous products of fuel combustion

(A) General

(a) In applying **403. 1** (4) of the Rules, where gas other than carbon dioxide or steam, as permitted by paragraph (3), is produced on the ship and is used as a fire-extinguishing medium, the system shall comply with the following requirements in (B).

(B) Requirements of the systems

(a) Gaseous products

Gas shall be a gaseous product of fuel combustion in which the oxygen content, the carbon monoxide content, the corrosive elements and any solid combustible elements in a gaseous product shall have been reduced to a permissible minimum.

(b) Capacity of fire-extinguishing systems

(i) Where such gas is used as the fire-extinguishing medium in a fixed fire-extinguishing system for the protection of machinery spaces, it shall afford protection equivalent to that provided by a fixed system using carbon dioxide as the medium.

(ii) Where such gas is used as the fire-extinguishing medium in a fixed fire-extinguishing system for the protection of cargo spaces, a sufficient quantity of such gas shall be available to supply hourly a volume of free gas at least equal to 25 % of the gross volume of the largest space protected in this way for a period of 72 hours.

(5) Equivalent fixed gas fire-extinguishing systems for machinery spaces and cargo pump-rooms

(A) Fixed gas fire-extinguishing systems equivalent to those specified in paragraphs (2) through (4) shall be approved by the Society based on the following guidelines developed by the IMO.

(a) Revised guidelines for the approval of equivalent fixed gas fire-extinguishing systems, as referred to in SOLAS, for machinery spaces and cargo pump rooms (MSC/Circ.848 & MSC.1/Circ.1267)

(b) Revised guidelines for the approval of fixed aerosol fire-extinguishing systems equivalent to fixed gas fire-extinguishing systems, as referred to in SOLAS, for machinery spaces (MSC/Circ.1007 & MSC.1/Circ.1270)

(B) Fixed gas fire-extinguishing systems referred to in the above (A) (a), whose agent containers are stored within the area it protects are to comply with the following (a) to (c).

(a) Agent containers stored in a protected space shall be distributed throughout the space with bottles or groups of bottles located in at least six separate locations except the below (c).

(b) Duplicate power release lines shall be arranged to release all bottles simultaneously. The release lines shall be so arranged that in the event of damage to any power release line, five sixths of the fire extinguishing gas can still be discharged. The bottle valves are to be considered to be part of the release lines and a single failure shall include also failure of the bottle valve.

(c) For systems that need less than six cylinders (using the smallest bottles available), agent containers need not to be distributed separately, provided that

(i) The total amount of extinguishing gas on the bottles shall be such that in the event of a single failure to one of the release lines (including bottle valve), five sixths of the fire extinguishing gas than required so that if one bottle is not discharging due to a single fault, the remaining bottles will discharge the minimum five sixths of the required amount of gas. This can be achieved with minimum two bottles.

(ii) NOAEL(no-observed-adverse-effect-level) valves calculated at the highest expected engine room temperature are not to be exceeded when discharging the total amount of extinguishing gas simultaneously. Systems that can not comply with the above, for instance systems using only one bottle located inside the protected space, can not be accepted. Such systems shall be designed with the bottles located outside the protected space, in a dedicated room in compliance with **403. 3** of the Rules.

2. In applying **403. 1** (1) (B) of the Rules, fixed high-expansion foam fire-extinguishing systems is also to be complied with as follows.

(1) Fixed high-expansion foam systems generating foam using outside air of the protected spaces(Refer to **Fig 8.3.8-1**) are to comply with the following (A) to (B)

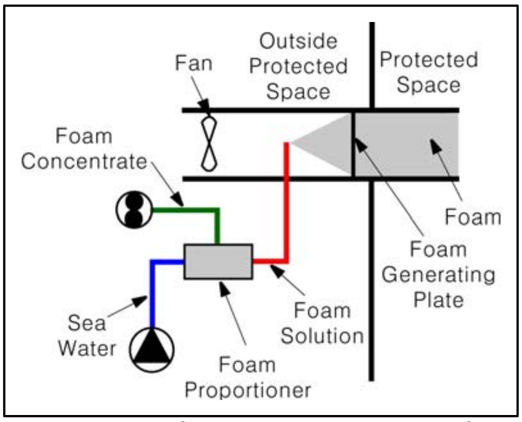


Fig 8.3.8-1(Outside air supply type)

(A) Quantity and performance of foam concentrates

(a) The foam concentrates of high-expansion foam fire-extinguishing systems shall be approved by the Flag Administration in which the ship is registered or to be registered based on the guideline developed by the IMO.* However, in case where there is no expressly provided national regulations, the foam concentrates of high-expansion foam fire-extinguishing systems shall be approved by the Contracting Government of the SOLAS or the Society.

* Refer to the Guidelines for performance and testing criteria and surveys of high expansion foam concentrates for fire-extinguishing systems (MSC/Circ.670).

(b) Any required fixed high-expansion foam system in machinery spaces shall be capable of rapidly discharging through fixed discharge outlets a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available shall be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected. The expansion ratio of the foam shall not exceed 1,000 to 1.

(c) The Society may permit alternative arrangements and discharge rates provided that it is satisfied that equivalent protection is achieved.

(B) Installation requirements

(a) Supply ducts for delivering foam, air intakes to the foam generator and the number of foam-producing units shall in the opinion of the Society be such as will provide effective foam production and distribution.

(b) The arrangement of the foam generator delivery ducting shall be such that a fire in the protected space will not affect the foam generating equipment. If the foam generators are located adjacent to the protected space, foam delivery ducts shall be installed to allow at least 450 mm of separation between the generators and the protected space. The foam delivery ducts shall be constructed of steel having a thickness of not less than 5 mm. In addition, stainless steel dampers (single or multi-bladed) with a thickness of not less than 3 mm shall be installed at the openings in the boundary bulkheads or decks between the foam generators and the protected space. The dampers shall be automatically operated (electrically, pneumatically or hydraulically) by means of remote control of the foam generator related to them.

(c) The foam generator, its sources of power supply, foam-forming liquid and means of controlling the system shall be readily accessible and simple to operate and shall be grouped in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

(2) Fixed high-expansion foam systems generating foam using inside air of the protected spaces(Refer to **Fig 8.3.8-2**) are to be approved by the Society based on the guidelines developed by the IMO(MSC.1/Circ.1271)

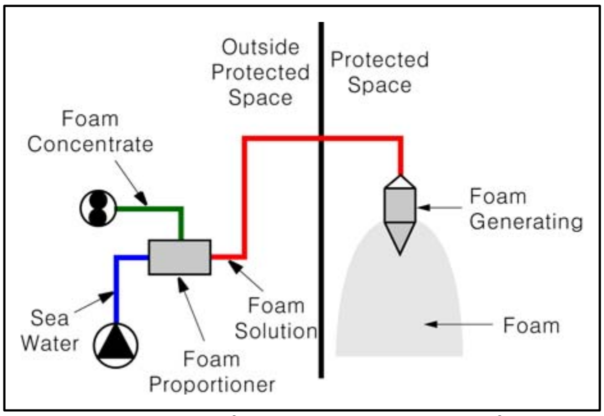


Fig 8.3.8-2(Inside air supply type)

(3) When such a system is to be fitted in any space than a machinery space, these requirements applies.

(4) In addition fixed low-expansion foam fire-extinguishing systems is also to be complied with as follows.

(A) Performance and Quantity of foam concentrates

(a) The foam concentrates of low-expansion foam fire-extinguishing systems shall be approved by the Flag Administration in which the ship is registered or to be registered based on the guidelines developed by the IMO* However, in case where there is no expressly provided national regulations, the foam concentrates of low-expansion foam fire-extinguishing systems shall be approved by the Contracting Government of the SOLAS or the Society.

* Refer to the Guidelines for performance and testing criteria and surveys of low expansion foam concentrates for fire-extinguishing systems (MSC/Circ.582 and Corr.1).

(b) The system shall be capable of discharging through fixed discharge outlets in no more than 5 min, a quantity of foam sufficient to produce an effective foam blanket over the largest single area over which oil fuel is liable to spread.

(B) Installation requirements

(a) Means shall be provided for the effective distribution of the foam through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the foam to be effectively directed by fixed sprayers on other main fire hazards in the protected space. The means for effective distribution of the foam shall be proven acceptable to the Society through calculation or by testing.

(b) The means of control of any such systems shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

3. In applying **403. 1** (1) (C) of the Rules, fixed pressure water-spraying and water-mist fire-extinguishing systems are also to be complied with as follows.

(1) Fixed-pressure water-spraying fire-extinguishing systems & equivalent water-mist fire-extinguishing systems for machinery spaces and cargo pump-rooms shall be approved by the Society based on the Guidelines (MSC/Circ.1165 & MSC.1/Circ.1269) developed by the IMO.

(2) Fixed-pressure water-spraying fire-extinguishing systems & equivalent water-mist fire-extinguishing systems for the cabin balconies of passenger ship shall be approved by the Society based on the Guidelines (MSC.1/Circ.1268) developed by the IMO.

4. In applying **403. 3** of the Rules, storage room of fire extinguishing medium is used for carbon dioxide fire extinguishing system, Fire-extinguishing media protecting the cargo holds may be stored in a room located forward the cargo holds, but aft of the collision bulkhead, provided that both the local manual release mechanism and remote controls for the release of the media are fitted, and the latter is of robust construction or so protected as to remain operable in case of fire in the protected spaces. The remote controls shall be placed in the accommodation area in order to facilitate their accessibility by the crew. The capability to release different quantities of fire-extinguishing media into different cargo holds so protected shall be included in the remote release arrangement.

404. Fire-extinguishing arrangements in machinery spaces

1. In applying **404. 1** and **2** of the Rules,Fire-extinguishing arrangements in boiler rooms and internal combustion machinery rooms are to be referred to the following Table. And herein oil fired machinery other than boilers such as fired inert gas generators, incinerators and waste disposal units are to be considered the same as boilers insofar as the required number and type of fire fighting appliances are concerned.

Machinery spaces of category A \ System, Appliances & extinguishers		Fixed fire-extinguishing system	(1)Portable foam applicator	portable foam extinguisher	Additional portable foam extinguisher	135 L foam extinguisher	(2)45L foam extinguisher	(3)sand box
Boiler room	oil-fired boilers	1	1	2N	NA	1(4)	-	N
	oil-fired boilers and oil fuel units	1	1	2N + 2	NA	1(4)	-	N
Engine room	oil fuel units only	1	-	2	NA	-	-	-
	Internal combustion machinery	1	1	x		-	y	-
	Internal combustion machinery and oil fuel units	1	1	x		-	y	-
Boiler room / Engine room	Internal combustion machinery, oil-fired boilers and oil fuel units	1	1	(2N+2) or x whichever is greater		1(4)	y(5)	N

\- Notes -
herein
N = Number of firing spaces. “2N” means that two extinguishers are to located in each firing space.
x = sufficient number, minimum two in each space, so located that there are at least one portable fire extinguisher within 10 m walking distance from any point.
y = sufficient number to enable foam to be directed onto any part of the fuel and lubricating oil pressure systems, gearing and other hazards.
(1) may be located at outside of the entrance to the room.
(2) may be arranged outside of the space concerned for smaller spaces of cargo ships.
(3) the amount of sand is to be at least 0.1 m^3. A shovel is to be provided.
Sand boxes may be substituted by approval portable fire extinguisher.
(4) not required for such spaces in cargo ships wherein all boilers contained therin are for domestic services and are less than 175 kW.
(5) in case of machinery spaces containing both boilers and internal combustion engines the requirements apply, with the exception that one of the foam fire-extinguishers of at least 45 L capacity or equivalent may be omitted on the condition that the 135 L extinguisher can protect efficiently and readily the area covered by the 45 L extinguisher.

2. In applying **404. 5** of the Rules, a water fog applicator might consist of a metal L-shaped pipe, the long limb being about 2 m in length capable of being fitted to a fire hose and the short limb being about 250 mm in length fitted with a fixed water fog nozzle or capable of being fitted with a water spray nozzle.

3. In applying **404. 6** of the Rules, fixed water-based local application fire extinguishing systems is also to be complied with as follows,

(1) the protected spaces are to apply as follows, (See also **Fig 8.3.9**)

(A) The protected hazards means the risk parts as defined in **404. 6** (3) of the Rules.

(B) The protected spaces means the spaces which the protected hazards are located.

(C) The protected areas means the effective areas of the system which is fitted to suppress the fire in the protected hazards. These areas are not to be less than the protected hazards in any case.

(D) The adjacent areas means areas other than protected areas exposed to direct spray and areas other than those defined above where water may extend.

(E) Boiler fronts should be interpreted as the boiler burner location irrespective of the boiler design.

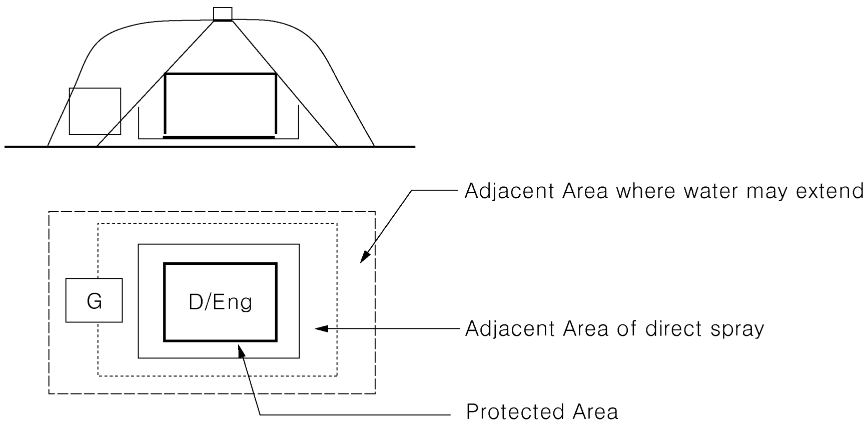


Fig 8.3.9 Protected spaces

(2) The system is to be capable of manual release. (except for periodically unattended machinery space)

(3) The fire extinguishing capability of the systems fitted on ships is to be approved by the Society in accordance with the requirements of MSC/Circ.913. As for fire nozzles they are to be approved by the Flag Administration in which the ship is registered or to be registered in accordance with the requirements of MSC/Circ. 668 and 728 of IMO respectively. However, in case where there is no expressly provided national regulations, the fire extinguishing capability of the system and nozzles fitted on ship approved by the Contracting Government of the SOLAS or the Society. Nozzle installations are to be determined as in the following (A) or (B) corresponding to the test results in accordance with MSC/Circ.913.

(A) For nozzles of a system that passed the fire tests referred to in 3.3.2.1 to 3.3.2.3 of Appendix of Annex to MSC/Cir.913 (Refer to the **Fig 8.3.10-7**)

(a) Nozzles installed in grid(3 x 3 nozzle) : See **Fig 8.3.10-1**

(b) Nozzles installed in a single row : See **Fig 8.3.10-2**

(c) Single Nozzle : See **Fig 8.3.10-3**

(B) For nozzles of a system that passed the fire tests referred to in 3.3.2.3 to 3.3.2.5 of Appendix of Annex to MSC/Circ.913 (Refer to the **Fig 8.3.10-8**)

(a) Nozzles installed in grid(2 x 2 nozzle) : See **Fig 8.3.10-4**

(b) Nozzles installed in grid(3 x 3 nozzle) : See **Fig 8.3.10-5**

(c) Nozzles installed in a single row : See **Fig 8.3.10-6**

(d) Single nozzle : See **Fig 8.3.10-3**

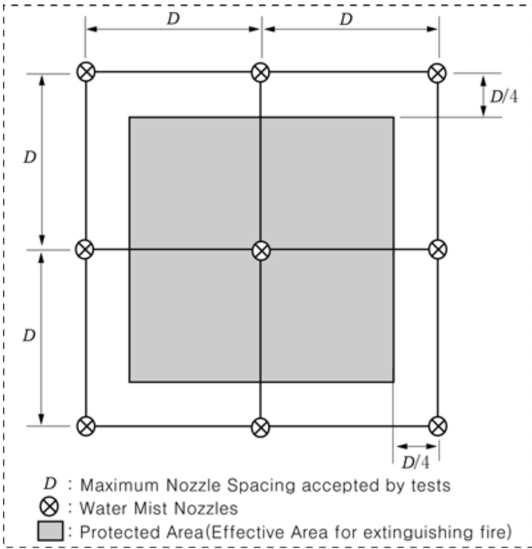


Fig 8.3.10-1

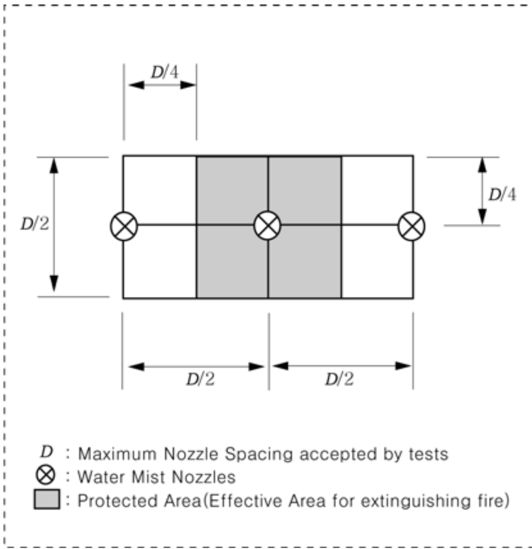


Fig 8.3.10-2

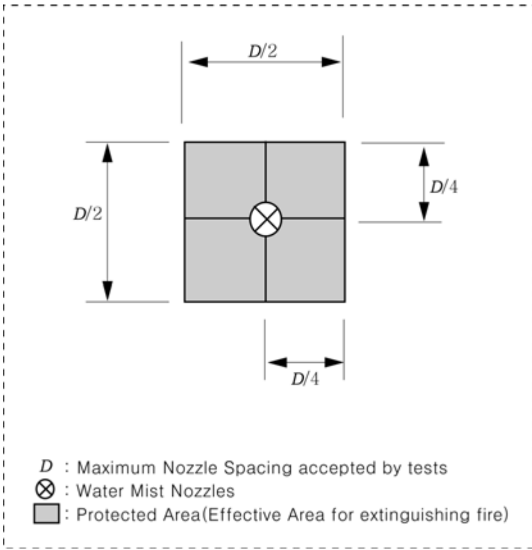


Fig 8.3.10-3

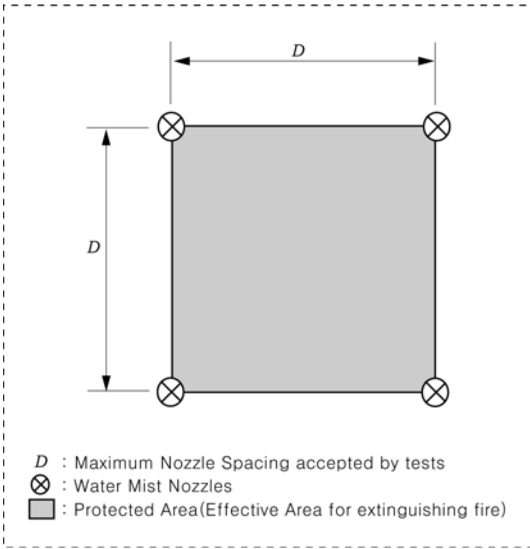


Fig 8.3.10-4

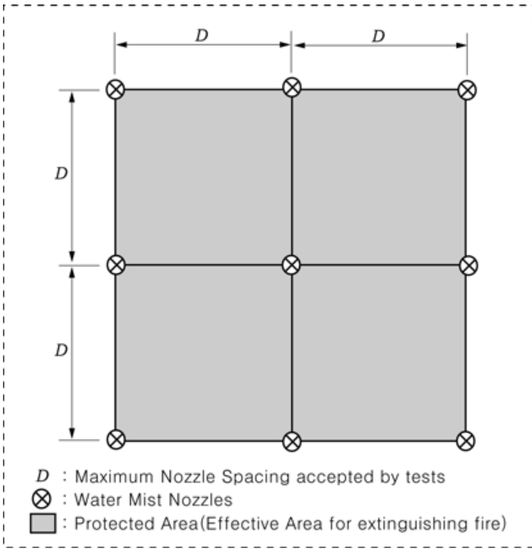


Fig 8.3.10-5

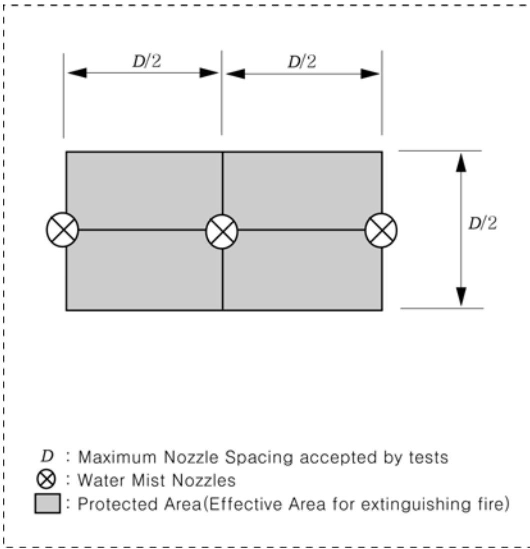


Fig 8.3.10-6

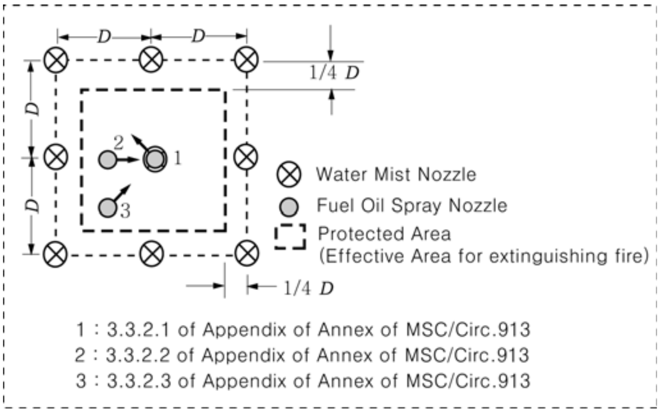


Fig 8.3.10-7

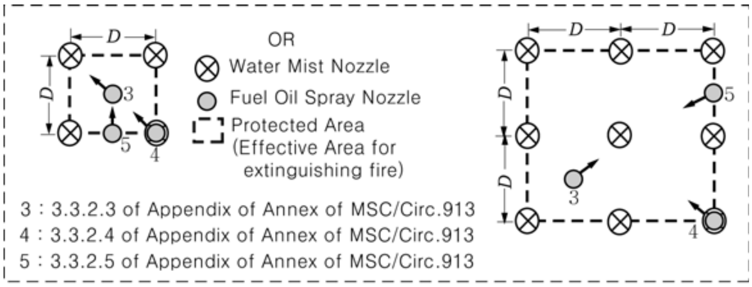


Fig 8.3.10-8

(4) The capacity and design of the system are to be based on the protected area demanding the greatest volume of water.
(5) The system is to be provided to suppress suitably and promptly against the fire which is occured in the protected hazard. However, the capacity of pumps is to be satisfied with the requirements of the flow and pressure which is required in each separate division.
(6) The activation of the fire-extinguishing system should not result in loss of electrical power or reduction of the maneuverability of the ship.(fixed water-based local application fire-fighting systems) Electrical and electronic equipment enclosures located within areas protected by FWBLAFFS and those within adjacent areas exposed to direct spray are to have a degree of protection not less than IP44, except where evidence of suitability is submitted to and approved by the Society. Electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection provided evidence of stability for use in those areas is submitted taking into account the design and equipment lay out, e.g. position of inlet ventilation openings, cooling airflow for the equipment are to be assured.
(7) The system is to be capable of fire suppression with forced ventilation fans running and supplying air to the protected area, or a method of automatically shutting air supply fans upon release of the system is to be provided to ensure that the fire-extinguishing medium is not dispersed.
(8) The system and its components are to be suitably designed to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in machinery spaces.
(9) Components within the protected spaces are to be designed to withstand the elevated temperatures which could occur during a fire.
(10) The location of each nozzle is to be considered so as not to obstruct spray of water.
(11) The electrical components of the pressure source for the system should have a minimum rating of IP 54. Systems requiring an external power source need only be supplied by the main power source.
(12) The manual releasing devices, fitted within the protected spaces, are to be arranged outside of the protected area and fitted to a readily accessible places. And, the devices are not to lose their availability by a fire in the protected areas.
(13) Pressure source components of the system are to be located outside of the protected areas.

(14) The system is to be ensured availability on size of pipings and capacity of pumps in accordance with a hydraulic calculation technique and arrangement of pipings.
(15) In case where the main fixed fire-extinguishing systems for machinery spaces are an water based system, the supply for the systems may be fed from the supply of main fire-extinguishing system. However, in this case, the adequate water quantity and pressure are available to operate both systems for the required period of time.
(16) The system is to be available for immediate use and capable of continuously supplying water-based medium for at least 20 minutes in order to suppress or extinguish the fire and to prepare for the discharge of the main fixed fire-extinguishing system within that period of time.
(17) In case of periodically unattended machinery spaces, the system is to have both automatic and manual release capabilities and the automatic release should be activated by a detection system capable of reliably identifying the local zone. Consideration should be given to prevent accidental release. However, in case of continuously manned machinery spaces, the system is only required to have manual release capability.
(18) Alarms against operation of the systems is to be complied with the following.
(A) In case where the system is activated at a space, a visual and distinct audible alarm is to be given in the protected spaces, engine control station, in the wheelhouse and at continuously manned stations.
(B) In case where the alarm is given as the above (A), the specific system activated is to be indicated. Audible alarms may use a single tone.
(C) The requirements on alarm devices for the systems are to be required in addition to, and not a substitute for, the detection and fire alarm system required elsewhere in this Chapter.
(19) In case where automatically operated fire-extinguishing systems are fitted, a warning notice is to be displayed outside each entry point stating the type of medium used and the possibility of automatic release.
(20) Operating instructions for the system are to be displayed at each operating position.
(21) The system is not to be located to prevent access to engine or machinery for routine maintenance or operation of overhead hoists and/or other moving equipment which are fitted in machinery space.
(22) Operating and maintenance instructions for the system are to be provided on each ship. And, the nozzles corresponding to 2 % of total number of each type and tools which are necessary to replace them (except for the standard tools) are to be provided on each ship.

4. In applying **404. 6** (3) (A) of the Rules, in the fire hazards portions of multi-internal combustion engines, at least two sections should be arranged.

405. Fire-extinguishing arrangements in control stations, accommodation and service spaces

1. In applying **405. 1** (1) of the Rules, heat detectors are acceptable in refrigerated chambers and in other spaces where steam and fumes are produced such as saunas and laundries. Refrigerated chambers may be fitted with dry pipe sprinkler systems. And then automatic sprinkler, fire detection systems and fire alarm systems is also to be complied with as follows,

(1) The automatic sprinkler systems shall be of the wet pipe type, but small exposed sections may be of the dry pipe type where in the opinion of the Society this is a necessary precaution. Saunas shall be fitted with a dry pipe system, with sprinkler heads having an operating temperature up to 140 ℃.
(2) Automatic sprinkler systems equivalent to those specified in paragraphs (3) to (9) shall be approved by the Administration based on the guidelines developed by the IMO.*
* Refer to the Revised Guidelines for approval of sprinkler systems equivalent to that referred to in SOLAS as adopted by the IMO by resolution A.800(19) & MSC265(84).
(3) Source of power supply is to be complied with the following requirements.
(A) In passenger ships, there shall be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where the sources of power for the pump are electrical, these shall be a main generator and an emergency source of power. One supply for the pump shall be taken from the main switchboard, and one from the emergency switchboard by separate feeders reserved solely for that purpose. The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards, and

shall be run to an automatic changeover switch situated near the sprinkler pump. This switch shall permit the supply of power from the main switchboard so long as a supply is available therefrom, and be so designed that upon failure of that supply it will automatically change over to the supply from the emergency switchboard. The switches on the main switchboard and the emergency switchboard shall be clearly labelled and normally kept closed. No other switch shall be permitted in the feeders concerned. One of the sources of power supply for the alarm and detection system shall be an emergency source. Where one of the sources of power for the pump is an internal combustion engine it shall, in addition to complying with the provisions of paragraph (9), be so situated that a fire in any protected space will not affect the air supply to the machinery.

(B) In cargo ships, there shall not be less than two sources of power supply for the sea water pump and automatic alarm and detection system. If the pump is electrically driven it shall be connected to the main source of electrical power, which shall be capable of being supplied by at least two generators. The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards. One of the sources of power supply for the alarm and detection system shall be an emergency source. Where one of the sources of power for the pump is an internal combustion engine it shall, in addition to complying with the provisions of paragraph (9), be so situated that a fire in any protected space will not affect the air supply to the machinery.

(4) Sprinkler requirements

The sprinklers shall be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers shall come into operation within the temperature range from 68 ℃ to 79 ℃ , except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30 ℃ above the maximum deckhead temperature.

A quantity of spare sprinkler heads shall be provided for all types and ratings installed on the ship as the following table, and then the number of spare sprinkler heads of any type need not exceed the total number of heads installed of that type.

Total number of heads	Required number of spares
〈 300	6
300 ~ 1000	12
〉 1000	24

(5) Pressure tanks

A pressure tank having a volume equal to at least twice that of the charge of water specified in this subparagraph shall be provided. The tank shall contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in paragraph (6) (B), and the arrangements shall provide for maintaining an air pressure in the tank such as to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank shall be provided. A glass gauge shall be provided to indicate the correct level of the water in the tank.

Means shall be provided to prevent the passage of sea water into the tank.

(6) Sprinkler pump is to be complied with the following requirements.

(A) An independent power pump shall be provided solely for the purpose of continuing automatically the discharge of water from the sprinklers. The pump shall be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

(B) The pump and the piping system shall be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of 280 square meters at the application rate specified in paragraph (10) (D). The hydraulic capability of the system shall be confirmed by the review of hydraulic calculations, followed by a test of the system, if deemed necessary by the Society.

(C) The pump shall have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe shall be adequate to permit the release of the required pump output while maintaining the pressure.

(7) Any parts of the system which may be subjected to freezing temperatures in service shall be suitably protected against freezing.

(8) Piping is to be complied with the following requirements.

(A) Sprinklers shall be grouped into separate sections, each of which shall contain not more than 200 sprinklers. In passenger ships any section of sprinklers shall not serve more than two decks and shall not be situated in more than one main vertical zone. However, the Society may permit such a section of sprinklers to serve more than two decks or be situated in more than one main vertical zone, if it is satisfied that the protection of the ship against fire will not thereby be reduced.

(B) Each section of sprinklers shall be capable of being isolated by one stop valve only. The stop valve in each section shall be readily accessible in a location outside of the associated section or in cabinets within stairway enclosures. The valve's location shall be clearly and permanently indicated. Means shall be provided to prevent the operation of the stop valves by any unauthorized person.

(C) A test valve shall be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section shall be situated near the stop valve for that section.

(D) The sprinkler system shall have a connection from the ship's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

(E) A gauge indicating the pressure in the system shall be provided at each section stop valve and at a central station.

(F) The sea inlet to the pump shall wherever possible be in the space containing the pump and shall be so arranged that when the ship is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

(9) The sprinkler pump and tank shall be situated in a position reasonably remote from any machinery space of category A and shall not be situated in any space required to be protected by the sprinkler system.

(10) System control is to be complied with the following requirements.

(A) Any required automatic sprinkler, fire detection and fire alarm system shall be capable of immediate operation at all times and no action by the crew shall be necessary to set it in operation.
The automatic sprinkler system shall be kept charged at the necessary pressure and shall have provision for a continuous supply of water as required in this chapter.

(B) Each section of sprinklers shall include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems shall be such as to indicate if any fault occurs in the system. Such units shall indicate in which section served by the system a fire has occurred and shall be centralized on the navigating bridge or in the continuously manned central control station and, in addition, visible and audible alarms from the unit shall also be placed in a position other than on the aforementioned spaces to ensure that the indication of fire is immediately received by the crew.

(C) Switches shall be provided at one of the indicating positions referred to in paragraph (B) which will enable the alarm and the indicators for each section of sprinklers to be tested.

(D) Sprinklers shall be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 L/m^2/min over the nominal horizontal projection area covered by the sprinklers. However, the Society may permit the use of sprinklers providing such an alternative amount of water suitably distributed as has been shown to the satisfaction of the Society to be not less effective.

(E) A list or plan shall be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance shall be available.

(11) Means shall be provided for testing the automatic operation of the pump on reduction of

pressure in the system.

2. In applying **405. 3** (2) & (3) of the Rules, these requirements given are not considered applicable for cargo service spaces intended for the stowage of cargo samples, when such spaces are positioned within cargo area onboard tankers.

406. Fire-extinguishing arrangements in cargo spaces

1. In applying **406. 1** of the Rules, the fire-fighting system for coal carriers is to comply with these requirements.

(1) Wiring and electrical equipment fitted in cargo holds, spaces having direct openings to cargo holds and zones within 3 m from ventilating openings of cargo holds are to comply with the requirements of electrical equipment for coal carriers in **Pt 7, Ch 3, Sec 16** of the Rules.

(2) Portable instruments to measure the atmosphere (densities of methane, oxygen and carbon monoxide) of upper parts in cargo holds are to be provided, and two restricted measuring holes (penetrating the walls and in use, permitting a small quantity of cargo vapour to be exposed to the atmosphere, but when not in use, completely closed) per hold, each both port and starboard sides of the hatch cover, are to be provided.

(3) Two self-contained breathing apparatuses required by **409.** of the Rules are to be provided, without no requirement of additional ones.

(4) Prohibition of arrangements adjacent to hot areas shall satisfy the following requirements.

(A) Hot areas of steam piping, exhaust gas piping, heaters, etc. in machinery spaces adjacent to cargo holds are to be separated as appropriate distances so as not to adjoin the cargo holds.

(B) In case where a bunker tank is provided in machinery spaces adjacent to cargo holds, heating coils are to be fitted so as not to adjoin the cargo holds as practicable, and appropriate measurements generally not exceeding 50 °C are to be taken.

(C) Heating coils in lubricating oil tanks adjacent to cargo holds are to be treated as same as the requirement of (B) above.

(D) In case where oil fuel systems of ships using oil fuel of low quality are fitted adjacent to cargo holds, their oil fuel tanks, in principle, are not to adjoin the cargo holds because of the higher normal operation temperature than limited temperature, but when avoidably fitted, appropriate measurements to prevent the temperature of bulkheads of cargo holds exceeding limited temperature are to be taken.

(E) In case where heating coils of tanks and their related equipment are provided so as not to exceed limited temperature, the Society may permit exemption from the requirements of (A), (B), (C) or (D) above in consideration of the data.

2. In applying **406. 1** (3) of the Rules, Ships of less than 2.000 tons gross tonnage carrying petroleum products having a flash point exceeding 60 °C (c.c. test) are not required to be fitted with a fixed fire extinguishing system. And the cargoes for which a fixed gas fire-extinguishing system is ineffective and for which a fire-extinguishing system giving equivalent protection should be available, are aluminium nitrate, ammonium nitrate, ammonium nitrate fertilizers, barium nitrate, calcium nitrate, lead nitrate, magnesium nitrate, potassium nitrate, sodium nitrate, Chilean natural nitrate, sodium nitrate and potassium nitrate mixture, and Chilean natural potassic nitrate.

3. In applying **406. 1** (4) of the Rules, “The non-combustible cargoes or cargoes which, in the opinion of the Society, constitute a low fire risk” means that all cargoes listed in appendices A, B and C of the Code of Safe Practice for Solid Bulk Cargoes (BC Code) are also specified in MSC/Circ.1146 and the updated version. And herein non-combustible cargoes such as in general products made only of glass, concrete, ceramic products, natural stone, masonry metals and metal alloys on the FTP code, need not be mentioned on exemption certificates.

4. In applying **406. 1** (4) of the Rules, all cargo sips, engaged in the carriage of dangerous goods, of 500 tons gross tonnage and above, shall be applied the requirement. And water supplies defined in **Ch 5, 202. 1** (2) of the Rules are considered as acceptable protection for cargoes listed in Table 2 of MSC/Circ.671.

407. Cargo tank protection

1. In applying **407. 1** of the Rules, fixed deck foam systems is also to be complied with as follows.

(1) The arrangements for providing foam shall be capable of delivering foam to the entire cargo

tanks deck area as well as into any cargo tank the deck of which has been ruptured.

(2) The deck foam system shall be capable of simple and rapid operation. And then the major equipment such as the foam concentrate tank and the pump may be located in the engine room.

(3) Operation of a deck foam system at its required output shall permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main. A common line for fire main and deck foam line can only be accepted provided it can be demonstrated that the hose nozzles can be effectively controlled by one person when supplied from the common line at a pressure needed for operation of the monitors. Additional foam concentrate is to be provided for operation of 2 hose nozzles for the same period of time required for the foam system. The simultaneous use of the minimum required jets of water should be possible on deck over the full length of the ship, in the accommodation, service spaces, control stations and machinery spaces.

(4) The rate of supply of foam solution shall be not less than the greatest of the following:

(A) 0.6 liter/minute per square metre of cargo tanks deck area, where cargo tanks deck area means the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces;

(B) 6 liter/minute per square metre of the horizontal sectional area of the single tank having the largest such area; or

(C) 3 liter/minute per square metre of the area protected by the largest monitor, such area being entirely forward of the monitor, but not less than 1,250 liter/minute.

(5) Sufficient foam concentrate shall be supplied to ensure at least 20 min of foam generation in tankers fitted with an inert gas installation or 30 min of foam generation in tankers not fitted with an inert gas installation when using solution rates stipulated in paragraph (4), as appropriate, whichever is the greatest. The foam expansion ratio (i.e., the ratio of the volume of foam produced to the volume of the mixture of water and foam-making concentrate supplied) shall not generally exceed 12 to 1. Where systems essentially produce low expansion foam but an expansion ratio slightly in excess of 12 to 1, the quantity of foam solution available shall be calculated as for 12 to 1 expansion ratio systems. When medium expansion ratio foam(between 50 to 1 and 150 to 1 expansion ratio) is employed, the application rate of the foam and the capacity of a monitor installation shall be to the satisfaction of the Society.

Refer to the Guidelines for the performance and testing criteria, and surveys of low-expansion foam concentrates for fixed fire-extinguishing systems (MSC/Circ.582 and Corr.1).

Refer to the Guidelines for the performance and testing criteria, and surveys of medium expansion foam concentrates for fixed fire-extinguishing systems (MSC/Circ.798).

(6) Monitors and foam applicators are also to be complied with the following requirements

(A) Foam from the fixed foam system shall be supplied by means of monitors and foam applicators. At least 50 % of the foam solution supply rate required in paragraphs (4) (A) and (4) (B) shall be delivered from each monitor. On tankers of less than 4,000 tons deadweight the Society may not require installation of monitors but only applicators. However, in such a case the capacity of each applicator shall be at least 25 % of the foam solution supply rate required in paragraphs (4) (A) or (4) (B).

(B) The capacity of any monitor shall be at least 3 litre/minute of foam solution per square metre of deck area protected by that monitor, such area being entirely forward of the monitor. Such capacity shall be not less than 1,250 L/min.

(C) The capacity of any applicator shall be not less than 400 L/min and the applicator throw in still air conditions shall be not less than 15 m.

(7) The main control station for the system shall be suitably located outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

(8) Monitors shall satisfy the following requirements.

(A) The number and position of monitors shall be such as to comply with paragraph (1)

(B) The distance from the monitor to the farthest extremity of the protected area forward of that monitor shall not be more than 75 % of the monitor throw in still air conditions.

(C) A monitor and hose connection for a foam applicator shall be situated both port and starboard at the front of the poop or accommodation spaces facing the cargo tanks deck. On tankers of less than 4,000 tons deadweight a hose connection for a foam applicator shall be situated both port and starboard at the front of the poop or accommodation spaces facing the cargo tanks deck. And port and starboard monitors required may be located in the cargo area, provided they are aft of cargo tanks and that they protect below and aft of each other.

(9) The number of foam applicators provided shall be not less than four. The number and disposition of foam main outlets shall be such that foam from at least two applicators can be directed on to any part of the cargo tanks deck area. Applicators shall be provided to ensure flexibility of action during fire-fighting operations and to cover areas screened from the monitors. And these foam applicators shall apply to all tankers regardless of size.

(10) Valves shall be provided in the foam main, and in the fire main when this is an integral part of the deck foam system, immediately forward of any monitor position to isolate damaged sections of those mains.

(11) Where an enclosed pipe trunk is situated within the cargo tanks deck area, the pipe trunk:

(A) should be protected by a fixed fire-extinguishing system in accordance with **408.** of the Rules. The extinguishing system should be operated from a readily accessible position outside the pipe trunk;

(B) is not considered part of the cargo tanks deck area;

(C) The area of the pipe trunk need not be included in the calculation of the foam solution rate of supply for the deck foam system required by **407.** of the Rules.;

(D) should be adequately ventilated and protected in accordance with **Ch 2, 104. 10** (2), (3) of the Rules.; and

(E) should contain no flammable gas sources other than pipes and flanges. If the pipe trunk contains any other source of flammable gas, i.e. valves and pumps, it should be regarded as a cargo pump-room.

408. Protection of cargo pump room

1. In applying **408. 1** of the Rules, in oil tankers carrying flammable high pressure gases, in addition, two portable carbon dioxide extinguishers or dry powder extinguishers are to be provided, one at the pumps and one at the pump room entrance. Instruments monitoring gas in any space where flammable high pressure gas is able to leak are to be fitted.

2. In applying **408. 1** (1) of the Rules, the audible alarms referred to in **403. 1** (9) of the Guidance are to be safe for use in a flammable cargo vapour/air mixture, and may be of the pneumatic type or electric type complying with the following requirements.

(1) In cases where the periodic testing of pneumatically operated alarms is required, CO_2 operated alarms are not to be used owing to the possibility of the generation of static electricity in the CO_2 cloud. Air operated alarms may be used, provided the air supply is clean and dry.

(2) When electrically operated alarms are used, the arrangements are to be such that the electric actuating mechanism is located outside the pump room except where the alarms are certified intrinsically safe.

409. Fire-fighter's outfit

1. In applying **409. 1** of the Rules, a fire-fighter's outfit shall consist of a set of personal equipment and a breathing apparatus and then also be complied with the following requirements.

(1) Personal equipment shall consist of the following:

(A) protective clothing of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam. The outer surface shall be water-resistant. (Reference is made to ISO standard 6942 - 1983 evaluation of thermal behavior of materials and material assemblies when exposed to source of radiant heat) ;

(B) boots of rubber or other electrically non-conducting material (Reference is made to (KS C) IEC standard 60903 - 1988 Specification for gloves and mitts of insulating material for live working) ;

(C) rigid helmet providing effective protection against impact;

(D) electric safety lamp (hand lantern) of an approved type with a minimum burning period of 3 hours. Electric safety lamps on tankers and those intended to be used in hazardous areas shall be of an explosion-proof type (Reference is made to (KS C) IEC Publication 60079) ; and

(E) axe with a handle provided with high-voltage insulation.

(2) Breathing apparatus shall be a self-contained compressed air-operated breathing apparatus for which the volume of air contained in the cylinders shall be at least 1,200 liters, or other self-contained breathing apparatus which shall be capable of functioning for at least 30 min. All

air cylinders for breathing apparatus shall be interchangeable.

(3) For each breathing apparatus a fireproof lifeline of at least 30 m in length shall be provided. The lifeline shall successfully pass an approval test by statical load of 3.5 kN for 5 min. without failure. The lifeline shall be capable of being attached by means of a snap-hook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the lifeline is operated.

SECTION 5 Structural Integrity

501. Material of hull, superstructures, structural bulkheads, decks and deckhouses

In applying **501.** of the Rules, deckhouses, boatswain's stores, etc. which are independently arranged away from a group of accommodation spaces may be regarded as independent service spaces respectively. Accordingly, internal divisions in these spaces may be of "C" class standard. Accordingly, access hatches to under deck spaces (for example, cargo space) from these spaces may be weathertight. Access hatches to the under deck spaces from other machinery spaces having little risk of fire which are independently arranged away from a group of accommodation spaces, may also be weathertight. And stairs in control stations, accommodation and service spaces are to be of steel or equivalent materials.

502. Structure of aluminium alloy

In applying **502. 1** (1) of the Rules, “structure which is non-load bearing" means, for example, partition walls, if an aluminium deck is tested with insulation installed below the deck, then the result will apply to decks which are bare on the top. And the use of aluminium coatings is prohibited in cargo tanks, cargo tank deck area, pump room, cofferdams or any other area where cargo vapour may accumulate. However, aluminized pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous area on open deck.

503. Machinery spaces of category A

In applying **503. 1** of the Rules, crowns and casings exposed to the open air need not be insulated.

504. Materials of overboard fittings

1. In applying **504.** of the Rules, the parts where the use of materials readily rendered ineffective by heat (PVC, FRP, aluminium alloys, lead, copper and copper alloys) is prohibited for overboard scuppers and sanitary discharges are to be in accordance with the following requirements:

(1) The parts of pipes for scuppers below the freeboard deck and sanitary discharges having open ends on the shell plating below the freeboard deck (see **Fig 8.3.11** (a)).

(2) In case where scuppers and sanitary discharges having open ends on the shell plating above the freeboard deck with their lower edges located at 150 mm or less above the load line, the parts of pipes in the spaces having such openings (see **Fig 8.3.11** (b)).

(3) In case (1) above, if the distance between the freeboard deck and the load line is 150 mm or less, the requirements are also to apply to the parts of pipes in the spaces directly above the freeboard deck (see **Fig 8.3.11** (c)).

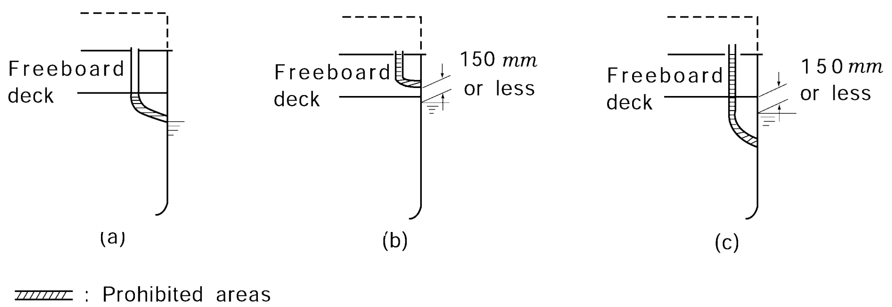


Fig 8.3.11 Areas prohibited from using materials readily rendered ineffective by heat

505. Protection of cargo tank structure against pressure or vacuum in tankers

1. In applying **505. 1** (1) of the Rules, the pressure setting, installation, tests and marking of "Pressure/Vacuum valve" are to be in accordance with following requirements. The Pressure/Vacuum valve is to be type approved by this Society.

(1) Pressure setting

(A) Pressure/Vacuum valves are to be set at a pressure within the range from 21 kPa to 14 kPa on the pressure side and 3 kPa to 7 kPa on the vacuum side. provided, however, that special reinforcements are made for the scantlings of cargo tanks, the set pressure on the pressure side may be of an appropriate value not exceeding 70 kPa.

(2) Installation

(A) In case where a Pressure/Vacuum valve is fitted on a vent branch pipe of the common venting system, the discharge outlet and the suction inlet are to be separated. The suction inlet is not to be fitted to the vent branch pipe to the cargo tanks.

(B) Means are to be provided for easy access to the valves.

(3) Tests and inspection

(A) The tests and inspection for the individual product are to be carried out in accordance with followings.

(a) Construction inspection

(b) Hydraulic test

(c) Confirmation of the pressure at which the valve opens and closes

(B) On board test

It is to be ascertained by a suitable method that the Pressure/Vacuum valves can be operable smoothly after installed on board.

(4) Test report

A test report for each finished device is to be prepared. This is to include followings.

(A) detailed drawings of the device and its components

(B) the types of test conducted and the results obtained, with all recorded data

(C) specific advice on approved attachments

(D) drawings of the test rig, to include a description of the inlet and outlet piping attached

(E) a record of all markings(refer to (6)) found on the device tested

(F) a report number

(5) Instruction manual

The manufacturer is to provide an instruction manual for each device. The instruction manual is to include the following items;

(A) Installation instructions

(B) Operating instructions, including information on the lowest MESG that the device is suitable for, if fitted with a flame screen or with a high-velocity vent. The instructions are to also include any service restrictions imposed for safe functioning of the device, including requirements imposed for the proper installation of the device

(C) Maintenance requirements, including information on maintenance of any corrosion protection system

(a) Instructions on how to determine when device cleaning is required and the method of cleaning. Where the manufacturer allows valve overhauls to be performed by the user, the manufacturer is to provide the necessary procedures, instructions and diagrams for the valve to restored to original, as-purchased condition with regard to set pressure and flow rate

(b) Instructions on the frequency of cleaning of the device to remove vapour condensate. The frequency of cleaning condensate residue from the valve will vary depending on the cargo

(c) Instruction clearly defining the method of setting the pressure, including information such as dismantling and reassembling the valve, numbering and ordering information, and diagrams for proper assembly of items

(d) Instructions to check valve lift by the user prior to each cargo loading and cargo unloading operation

(e) Instructions to conduct a complete inspection of the valve and the recommended frequency

(D) The test report described in **1** (4)

(E) Flow test data, including flow rates under both positive and negative pressures, operating

sensitivity, flow resistance, velocity and maximum pipe length on the inlet side
(F) The manufacturer's certification that the device has been constructed and tested in accordance with this International Standard

(6) Marking
Each device is to be permanently marked indicating followings.
(A) manufacturer's name or trademark
(B) style, type, model or other manufacturer's designation for the device, which is to form a unique identification of the device
(C) size of the inlet (and outlet, if applicable)
(D) serial number
(E) direction of flow through the device
(F) test laboratory and report number
(G) pressure and vacuum setting
(H) the reference number of this International Standard

(7) Combination type Pressure/Vacuum valve
In case where an exclusive automatic pressure valve and an exclusive automatic vacuum valve are provided in combination, such an arrangement may be regarded as to be provided with a Pressure/Vacuum valve. In this case, the exclusive automatic pressure valve and the exclusive automatic vacuum valve are to comply with the requirements for the discharge side or the suction side of the Pressure/Vacuum valves specified in (1) and (2) respectively.

2. In applying **505. 2** of the Rules, where area on open deck, or semi-enclosed spaces on open deck, within 3 m of cargo tank ventilation outlets which permit the flow of small volumes of vapour, air or inert gas mixtures caused by thermal variation are defined as Zone 1, electrical equipment shall be certified safe type equipments. And then areas within 2 m beyond zone 1 are defined as Zone 2 in which electrical equipment shall be of the following requirements.

(1) Certified safe type equipment for Zone 1,
(2) Equipment of a type, which ensure the absence of sparks, arcs and of "hot spots" during its normal operation,
(3) Equipment having an enclosure filled with a liquid dielectric, when required by the application, or encapsulated,
(4) Pressurized equipment,
(5) Equipment specifically designed for Zone 2(for example type "n" protection in accordance with (KS C) IEC 60079-15)

3. In applying **505. 3** (2) of the Rules, a P/V breaker fitted on the IG main may be utilized as the required as the required secondary means of venting. The height requirements of **Ch 2, 104. 3** (4) & **505. 2** of the Rules and the requirements for devices to prevent the passage of flame of **Ch 2, 104. 3** (3) are not applicable to the P/V breaker provided the settings are above those of the venting arrangements required by **505. 1** of the Rules. Where the venting arrangements are of the free flow type and the masthead isolation valve is closed for the unloading condition, the IG systems will serve as the primary underpressure protection with the P/V breaker serving as the secondary means. Inadvertent closure or mechanical failure of the isolation valves required by **Ch 2, 104. 3** (2) (B) of the Rules & **Annex 8-5, 7** (2) need not be considered in established the secondary means since the valves are operated under control of the responsible ships officer and a clear visual indication of the operational status of the valves, and the possibility of mechanical failure of the valves is remote to their simplicity.
And then pressure monitoring system as alternatives is to comply with the following requirements.

(1) The system is to be of a type approved by the Society.
(2) The pressure sensors are to be fitted in each tank.
(3) The following arrangements are to be provided in the ship's cargo control room or the position from which cargo operations are normally carried out.
(A) a monitoring system of the pressure within a tank
(B) an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

4. In applying **505. 4** of the Rules, together with IBC code and IGC code where areas on open deck, or semi-enclosed spaces on open deck, within a vertical cylinder of unlimited height and 6 m radius centred upon the center of the outlet, and within a hemisphere of 6 m radius below the outlet which permit the flow of large volume of vapour, air or inlet gas mixtures during loading/discharging/ballasting are defined Zone 1, electrical equipment shall be certified safe type equipments. And then areas within 4 m beyond zone 1 are defined as Zone 2 in which electrical equipment shall be of the following requirements.

(1) Certified safe type equipment for Zone 1,
(2) Equipment of a type, which ensure the absence of sparks, arcs and of "hot spots" during its normal operation,
(3) Equipment having an enclosure filled with a liquid dielectric, when required by the application, or encapsulated,
(4) Pressurized equipment,
(5) Equipment specifically designed for Zone 2(for example type "n" protection in accordance with (KS C) IEC 60079-15) ⚓

CHAPTER 4 ESCAPE

SECTION 2 Means of escape

202. Means of escape from control stations, accommodation and service spaces

1. In applying **202. 1** (4) of the Rules, two means of escape from the radio room are to be those which are separated each other and the escape routes are not common.

2. In applying **202. 2** (5) (C) of the Rules, guidelines developed by the IMO refer to MSC/Circ.1167(Functional requirements and performance standards for the assessment of evacuation guidance systems) and MSC/Circ.1168(Interim guidelines for the testing, approval and maintenance of evacuation guidance systems used as an alternative to low-location lighting systems.

3. In applying **202. 2** (4) (E) of the Rules, the requirements in the Fire Safety Systems Code for the means of escape shall be as follows.

(1) Stairways shall not be less than 900 mm in clear width. The minimum clear width of stairways shall be increased by 10 mm for every one person provided for in excess of 90 persons. The total number of persons to be evacuated by such stairways shall be assumed to be two thirds of the crew and the total number of passengers in the areas served by such stairways. The width of the stairways shall not be inferior to those determined by Calculation method of stairway width as follows.

(A) This calculation method determines the minimum stairway width at each deck level, taking into account the consecutive stairways leading into the stairway under consideration.

(B) It is the intention that the calculation method shall consider evacuation from enclosed spaces within each main vertical zone individually and take into account all of the persons using the stairway enclosures in each zone, even if they enter that stairway from another vertical zone.

(C) For each main vertical zone the calculation shall be completed for the night time (case 1) and day time (case 2) and the largest dimension from either case used for determining the stairway width for each deck under consideration.

(D) The calculation of stairway widths shall be based upon the crew and passenger load on each deck. Occupant loads shall be rated by the designer for passenger and crew accommodation spaces, service spaces, control spaces and machinery spaces. For the purpose of the calculation the maximum capacity of a public space shall be defined by either of the following two values: the number of seats or similar arrangements, or the number obtained by assigning 2 square meters of gross deck surface area to each person.

(E) For calculation method for minimum value, in considering the design of stairway widths for each individual case which allow for the timely flow of persons evacuating to the muster stations from adjacent decks above and below, the following calculation methods shall be used (see **Fig 8.4.1** and **Fig 8.4.2**):

when joining two decks: W=(N1+N2) 10 mm;
when joining three decks: W=(N1+N2+0.5N3) 10 mm;
when joining four decks: W=(N1+N2+0.5N3+0.25N4) 10 mm;
when joining five decks or more decks the width of the stairways shall be determined by applying the above formula for four decks to the deck under consideration and to the consecutive deck,

where:
W = the required tread width between handrails of the stairway.
The calculated value of W may be reduced where available landing area S is provided in stairways at the deck level defined by subtracting P from Z, such that:
P = S 3.0 person/sq.m ; Pmax = 0.25Z
where:
Z = the total number of persons expected to be evacuated on the deck being considered;

P = the number of persons taking temporary refuge on the stairway landing, which may be subtracted from Z to a maximum value of P = 0.25Z (to be rounded down to the nearest whole number) ;

S = the surface area of the landing, minus the surface area necessary for the opening of doors and minus the surface area necessary for accessing the flow on stairs (see **Fig 8.4.1**);

N = the total number of persons expected to use the stairway from each consecutive deck under consideration; N1 is for the deck with the largest number of persons using that stairway; N2 is taken for the deck with the next highest number of persons directly entering the stairway flow such that, when sizing the stairway width as each deck level, N1 > N2 > N3 > N4 (see **Fig 8.4.2**). These decks are assumed to be on or upstream (i.e. away from the embarkation deck) of the deck being considered.

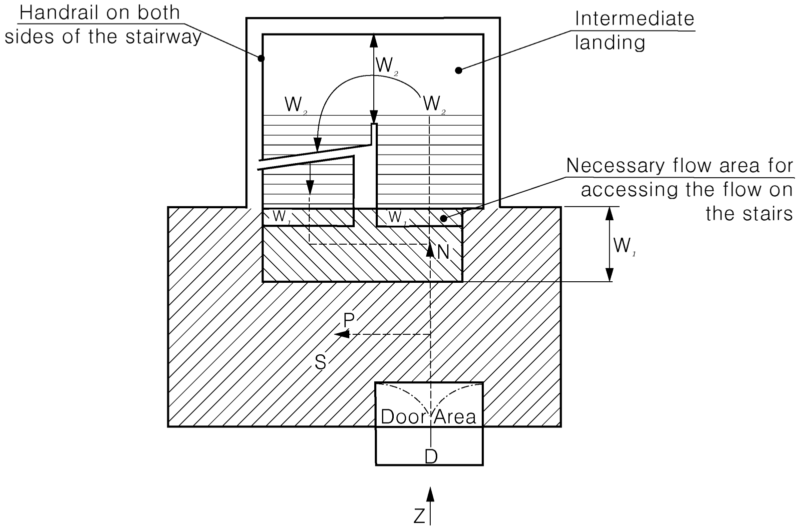


Fig 8.4.1 Landing calculation for stairway width reduction

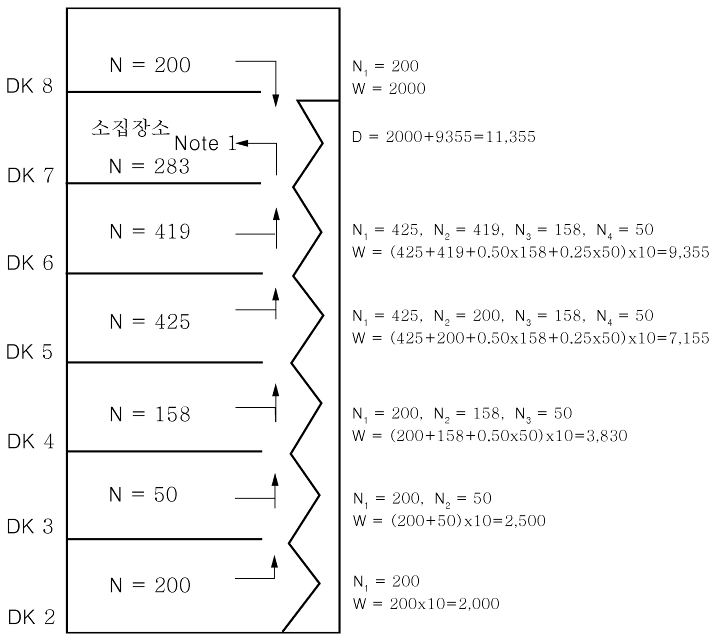


Fig 8.4.2 Minimum stair width (W) calculation example

Z (pers) = number of persons expected to evacuate through the stairway
N (pers) =number of persons directly entering the stairway flow from a given deck
W (mm) = $(N_1 + N_2 + 0.5 \times N_3 + 0.25 \times N_4) \times 10$ = calculated width of stairway

D (mm) = width of exit doors
$N_1 > N_2 > N_3 > N_4$ where:
N_1 (pers) = the deck with the largest number of persons N entering directly the stairway
N_2 (pers)= the deck with the next largest number of person N entering directly the stairway,etc.

(F) The dimension of the means of escape shall be calculated on the basis of the total number of persons expected to escape by the stairway and through doorways, corridors and landings (see **Fig 8.4.3**). Calculations shall be made separately for the two cases of occupancy of the spaces specified below. For each component part of the escape route, the dimension taken shall not be less than the largest dimension determined for each case:

(a) Case 1: Passengers in cabins with maximum berthing capacity fully occupied; members of the crew in cabins occupied to 2/3 of maximum berthing capacity; and service spaces occupied by 1/3 of the crew.

(b) Case 2: Passengers in public spaces occupied to 3/4 of maximum capacity; members of the crew in public spaces occupied to 1/3 of the maximum capacity; service spaces occupied by 1/3 of the crew; and crew accommodation occupied by 1/3 of the crew.

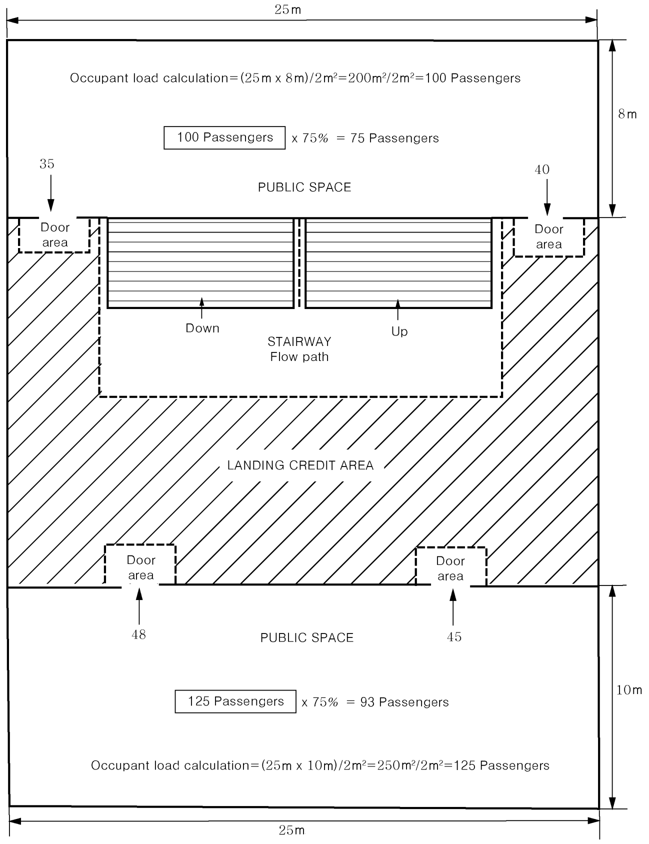


Fig 8.4.3 Occupant loading calculation example

(G) The maximum number of persons contained in a vertical zone, including persons entering stairways from another main vertical zone, shall not be assumed to be higher than the maximum number of persons authorized to be carried on board for the calculation of stairway width only.

(H) The stairway shall not decrease in width in the direction of evacuation to the assembly station, except in the case of several assembly stations in one main vertical zone the stairway width shall not decrease in the direction of the evacuation to the most distant assembly station.

(2) Details of stairways are also to be complied with the following requirements.

(A) Stairways shall be fitted with handrails on each side. The maximum clear width between handrails shall be 1800 mm.

(B) All stairways sized for more than 90 persons shall be aligned fore and aft.
(C) Stairways shall not exceed 3.5 m in vertical rise without the provision of a landing and shall not have an angle of inclination greater than 45 degrees.
(D) Landings at each deck level shall be not less than 2 m^2 in area and shall increase by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings servicing public spaces having direct access onto the stairway enclosure.

(3) Doorways and corridors shall satisfy the following requirements.
(A) Doorways and corridors and intermediate landings included in means of escape shall be sized in the same manner as stairways.
(B) The aggregate width of stairway exit doors to the assembly station * shall not be less than the aggregate width of stairways serving this deck.
* Refer to the Indication of the Assembly stations” in passenger ships (MSC/Circ.777).

(4) Evacuation routes to the embarkation deck shall satisfy the following requirements.
(A) It shall be recognized that the evacuation routes to the embarkation deck may include an assembly station. In this case consideration shall be given to the fire-protection requirements and sizing of corridors and doors from the stairway enclosure to the assembly station and from the muster station to the embarkation deck, noting that evacuation of persons from assembly stations to embarkation positions will be carried out in small control groups.
(B) Where the passengers and crew are held at an assembly station which is not at the survival craft embarkation position, the dimension of stairway width and doors from the assembly station to this position shall not be based on the number of persons in the controlled group. The width of these stairways and doors need not exceed 1,500 mm unless larger dimensions are required for evacuation of these spaces under normal conditions.

(5) Means of escape plans shall be provided indicating the following:
(A) the number of the crew and passengers in all normally occupied spaces;
(B) the number of crew and passengers expected to escape by stairway and through doorways, corridors and landings;
(C) assembly stations and survival craft embarkation positions;
(D) primary and secondary means of escape; and
(E) width of stairways, doors, corridors and landing areas.
(F) Means of escape plans shall be accompanied by detailed calculation for determining the width of escape stairways, doors, corridors and landing areas.

4. In applying **202. 2** (5) (A) of the Rules, the escape route or low location lighting(LLL) where satisfied by electric illumination should comply with the following requirements, having cognizance with IMO resolution A.752(18).

(1) The LLL system is to be connected to the emergency switchboard and capable of being powered either by the main source of electrical power, or by the emergency source of electrical power for a minimum period of 60 minutes after energizing in an emergency.
(2) The power supply arrangements to the LLL are to be arranged such that a single fault does not result in the complete loss of the lighting in any fire zone or deck and such that a fire in a fire zone or deck does not result in loss of the lighting in any other fire zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire resistant cables complying with (KS C) IEC Publication 60331: Fire Characteristics of electric cables, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes.
(3) Single lights and lighting assemblies are to be designed or arranged so that any single fault or failure in a light or lighting assembly, other than a short circuit, will not result in a break in visible delineation exceeding 1 metre.
(4) Lighting fixtures and assemblies are to be flame retardant as a minimum, have an ingress protection of at least IP55 and are to meet the type test requirements as specified in UR E10.
(5) The LLL system is to be capable of being manually activated by a single action from the continuously manned central control station. It may, additionally, be continuously operating or be switched on automatically, e.g. by the presence of smoke within the space(s) being served.
(6) When powered the systems are to achieve the following minimum luminance. And then: spacing between sources is not to exceed 300 mm.
(A) for any planar source:- 10 cd/m^2 from the active parts in a continuous line of 15 mm minimum width.
(B) for any point source:- 35 mcd in the typical track directions of approach and viewing which

is to be considered:

(a) for sources which are required to be viewed from a horizontal position, i.e. deck mounted or horizontally bulkhead mounted fittings, within a 60° cone having its centre located 30´ from the horizontal mounting surface of the point source and in line with the track direction, see **Fig 8.4.4** (a).

(b) for sources which are required to be viewed vertically, i.e. the vertical LLL marking up to the door handles, within a 30° cone having its centre located perpendicular to the mounting service of the point source, see **Fig 8.4.4** (b).

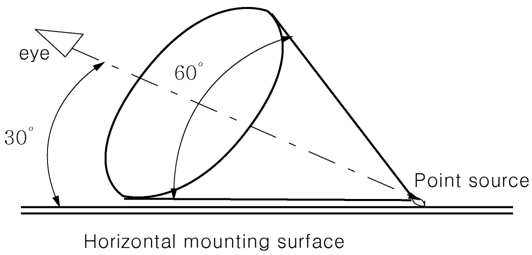
(7) The lights or lighting assemblies are to be continuous except as interrupted by constructional constraints, such as corridors or cabin doors etc. and are to provide a visible delineation along the escape route and, where applicable, are to lead to the exit door handles. Interruption of the LLL system, due to constructional constraints is not to exceed 2 meters.

(8) The lighting is to be provided on at least one side of the corridor or stairway. In corridors and stairways, in excess of 2 metre width, lighting is to be provided on both sides.

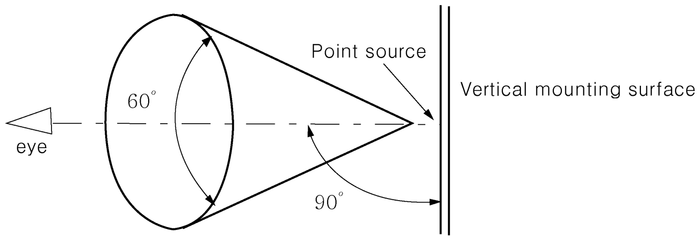
(9) In corridors the lighting is to be installed either on the bulkhead within 300 mm of the deck or alternatively, on the deck within 150 mm of the bulkhead.

(10) In stairways the lighting is to be installed within 300 mm above the steps such that each step may be readily identified from either above or below that step.

(11) The condition of the LLL system and its power source(s) is to be verified every 5 years.



(a)



(b)

Fig 8.4.4

5. In applying **202. 3.** of the Rules, the means of escape is, in principle, to be not less than those given below :

Positions	Dimensions
Manhole (including window)	600 mm× 400 mm
Small hatch	600 mm × 600 mm in square , 600 mm in dia.

The embarkation deck is to be accessible from the open decks to which escape routes lead. The means of escape may be accepted even where lifeboats and liferafts area can not directly be reached, provided that such area can be reached through corridors and stairways in normal ways. Such arrangement as to reach the area only by passing through the cabins or using vertical ladders is not to be accepted.

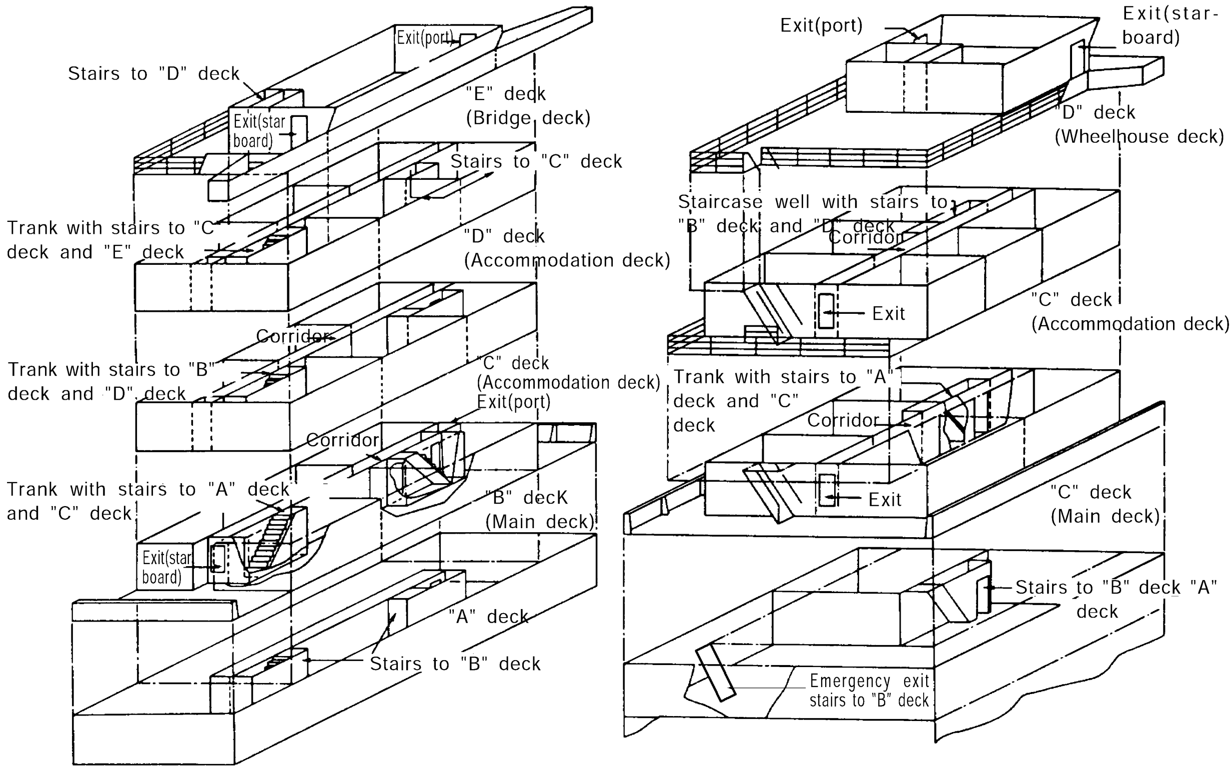
Stairways and corridors used as means of escape shall be not less than 700 mm in clear width and shall have a handrail on one side. Stairways and corridors with a clear width of 1,800 mm and over shall have handrails on both sides. "Clear width"” is considered the distance between the handrail and the bulkhead on the other side or between the handrails. The angle of inclination of stairways should be, in general, 45° but not greater than 50° and in machinery spaces and small spaces not more than 60° Doorways which give access to a stairway shall be of the same size as the stairway.

6. In applying **202. 3** (2) of the Rules, the means of second escape is to be either stairway which directly leads to open deck from the place concerned or hatch capable of being operated from both sides.

7. In applying **202. 3** (3) of the Rules, the following requirements shall be complied with :

(1) In case where two stairways protected by the divisions are provided, doors allowing to escape directly from at least two decks from where the lifeboats and liferafts area can be easily reached are to be provided on both sides (see **Fig 8.4.5** (a)).

(2) In case where only one stairway protected by the divisions is provided, at least one door through which direct escape to the open deck is possible, is to be provided on each deck (see **Fig 8.4.5** (b)).



(a) In case where two stairways protected by trunk (b) In case where one stairway protected by trunk

Fig 8.4.5 Means of Escape

8. In applying **202. 3** (4) of the Rules, dead-end corridors, which they can not be avoided, are to be so designed that persons do not easily enter such corridors in cases of emergency.

9. In applying **202. 4** (1) of the Rules, Emergency escape breathing devices (EEBD) shall satisfy the following requirements.

(1) An EEBD is a supplied-air or oxygen device only used for escape from a compartment that has a hazardous atmosphere and shall be of an approved type.

(2) EEBDs shall not be used for fighting fires, entering oxygen deficient voids or tanks, or worn by fire-fighters. In these events, a self-contained breathing apparatus, which is specifically suited for such applications, shall be used.

(3) Face piece means a face covering that is designed to form a complete seal around the eyes, nose and mouth which is secured in position by a suitable means.

(4) Hood means a head covering which completely covers the head, neck, and may cover portions of the shoulders.

(5) Hazardous atmosphere means any atmosphere that is immediately dangerous to life or health.

(6) The EEBD shall have a service duration at least 10 minutes.

(7) The EEBD shall include a hood or full face piece, as appropriate, to protect the eyes, nose and mouth during escape. Hoods and face pieces shall be constructed of flame resistant materials and include a clear window for viewing.

(8) An inactivated EEBD shall be capable of being carried hands-free.

(9) An EEBD, when stored, shall be suitably protected from the environment.

(10) Brief instructions or diagrams clearly illustrating their use shall be clearly printed on the EEBD. The donning procedures shall be quick and easy to allow for situations where there is little time to seek safety from a hazardous atmosphere.
(11) Maintenance requirements, manufacturer's trademark and serial number, shelf life with accompanying manufacture date and name of approving authority shall be printed on each EEBD. All EEBD training units shall be clearly marked.

203. Means of escape from machinery spaces

1. In applying **203. 1** and **2** of the Rules, the means of escape to the open deck from machinery spaces of category A shall satisfy the following requirements.

(1) One of the means of escape required by the Rules is to be arranged as follows:
  (A) It is to be enclosed and insulated as required for spaces of the Rules against the space it serves. Ladders are to be fixed in such a way that heat cannot, in case of a fire in the machinery space, be transferred to the ladder through non-insulated fixing points;
  (B) The self-closing door is to have the fire integrity of the bulkhead in which it is fitted. If there are other exits to this trunk they are also to be provided with such doors;
(2) It is not desirable to use ro-ro spaces or vehicle spaces as a part of the escape routes from machinery space of category A to the open deck. In case where such arrangement is unavoidable, the following requirements shall be satisfied:
  (A) The escape route through ro-ro spaces or vehicle spaces is to be restricted to one, and other routes are to be arranged either through spaces other than the above route or through enclosed escape trunks. The trunks are to be applied with insulation in accordance with the requirements of the Rules, as corridors.
  (B) The escape route through ro-ro spaces and vehicle spaces is to be as short as possible, and a corridor is to be secured by the permanent and strong construction so that passage may not be hampered by cargo.
(3) Insulation of the shelter is to be taken as equivalent to that of the passage way or lobby and be in compliance with **Table 8** of the Rules.
(4) In case where only one set of means of escape other than the shelter for machinery spaces of category A is provided, self-closing doors required at the lower part of the shelter are to be provided at each deck level.
(5) "Ladder" means stairways and ladders. Ladders having strings of flexible steel wire ropes are not acceptable in such escape routes.
(6) In case where machinery spaces of category A are recessed in toward the stern, one set of escape routes from the machinery space of category A, in addition to those required, is to be provided aft of the recess However, in case where the length of the recessed part (portion with asterisk in this **Fig 8.4.6**) is 7 m or less, this escape route is not required. (see **Fig 8.4.6**).

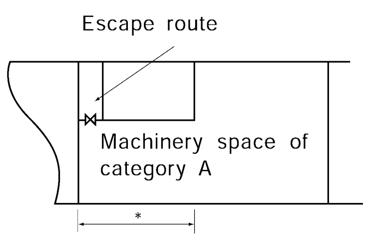


Fig 8.4.6 Escape of recessed category A

2. In applying **203. 2** (3) of the Rules, for machinery spaces which are regarded as those having little or no fire risk, machinery spaces in which the crew is not normally employed, or small spaces, only one set of means of escape may be provided. In this case, however, the escape route is not to pass through machinery spaces of category A. Where shaft tunnel is provided, an escape route is to be provided aft of the shaft tunnel (see **Fig 8.4.7**).

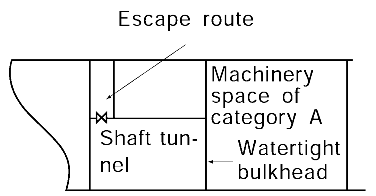


Fig 8.4.7 Escape of small spaces

3. In applying **203. 3** of the Rules, the minimum quantity of emergency escape breathing devices is to be as follows: one (1) in engine control room, one (1) at the workshop and two (2) in escape route of which one is to be provided at the lowest through the escape route. If there is no the engine control room and the workshop, at least three (3) of emergency escape breathing devices shall be provided.

4. In applying **203. 3** (3) of the Rules, emergency escape breathing devices (EEBD) are to be complied with **202. 8** requirements of the Guidance.

205. Means of escape from ro-ro spaces

1. In applying **205.** of the Rules, the escape (and access) routes are to be so arranged that there are adequate escape routes also during loading and unloading. ⚓

CHAPTER 5 SPECIAL REQUIREMENTS

SECTION 1 Helicopter facilities

101. Application

1. In applying **101. 3** of the Rules, "the relevant regulation of the Convention" means as follows.

(1) All ro-ro passenger ships shall be provided with a helicopter pick-up area approved by the Society having regard to Res. A229(VII) of the recommendation adapted by the IMO.

(2) Ro-ro passenger ships of 130 m in length and upwards, constructed on or after 1 July 1999, shall be fitted with a helicopter landing area approved by the Society having regard to MSC/Cic.895 of the recommendation adapted by the IMO.

SECTION 2 Carriage of dangerous goods

201. General requirements

1. In applying **201. 2** (2) of the Rules, A purpose built container space is a cargo spaces fitted with cell guides for stowage securing of containers;

2. In applying **201. 2** (3) of the Rules, Ro-ro spaces include special category spaces and vehicle deck spaces;

202. Special requirements

1. In applying **202. 1** of the Rules, for Open-Top Container Ships of dangerous goods the following requirements may comply with in lieu of the water spray system.

(1) Open top container holds are to be protected by a fixed water spray system. The system is to be capable of spraying water into the cargo hold from deck level downward. The system is to be designed and arranged to take account of the specific hold and container configuration. If found necessary, the Society may require a full-scale test.

(2) The water spray system is to be able to effectively contain a fire in the container bay of origin. The spray system is to be subdivided, with each subdivision to consist of a ring-line at deck in an open cargo hold around a container bay.

(3) The water spray system is to be capable of spraying the outer vertical boundaries of each container bay in an open cargo hold and of cooling the adjacent structure. The uniform application density is to be not less than 1.1 ℓ/m^2. At least one dedicated fire-extinguishing pump for the hold water spray system with a capacity to serve all container bays in any one open top container hold simultaneously is to be provided. The pump(s) is to be installed outside the open top area. The availability of water to the water spray system is to be at least 50 % of the total capacity, with adequate spray patterns in the open top container hold, and with any one dedicated pump inoperable. For the case of a single dedicated water spray pump this may be accomplished by an interconnection to an alternative source of water. The extinguishing system is to be supplemented by hose supply from the weather deck.

(4) The amount of water required for fire-fighting purposes in the largest hold is to allow simultaneous use of the water spray system plus four jets of water from hose nozzles.

2. In applying **202. 1** (2) of the Rules, the number and position of hydrants should be such that at least two of the required four jets of water, when supplied by single lengths of hose, may reach any part of the cargo space when empty; and all four jets of water, each supplied by single lengths of hose may reach any part of ro-ro cargo spaces. And the mount of water required for fire fighting purposes in the largest hold is to satisfy simultaneous use from the water spray systems plus 4 jets of water from hose nozzles.

3. In applying **202. 1** (4) of the Rules, a high expansion foam system is acceptable except if cargoes dangerously react with water.

4. In applying **202. 2** of the Rules, the electrical equipment are to be complied with the following requirements.

(1) The electrical equipment provided in the enclosed cargo spaces or vehicle spaces which are regarded as hazardous environment are to be of those approved by the Society taking into account the requirements of IMDG Code. However, even electrical equipment not approved by the Society may be provided in the above-mentioned spaces if they are of IP55 or equivalent, provided that they are not used while dangerous goods are loaded in such spaces.

(2) In case where electric cables, which are used while dangerous substances are loaded likely to evolve explosive mixture gases, are arranged in cargo spaces, the following requirements are to apply:

(A) Cables are to be mineral-insulated copper sheathed cables, lead sheathed and armoured cables or non-metal sheathed and armoured cables.

(B) Through runs of cables and those led to electrical equipment installed in cargo spaces are to be protected by metal coverings or the like.

(3) For electrical equipment other than specified in (A) and (B) above, refer to (KS C) IEC 60092-506.

(4) the following requirements are to be regarded as sources of ignition, and they are not to be installed in the proximity of the openings of ventilation for cargo spaces:
(A) Electrical equipment other than those of safe type approved for use in hazardous environment
(B) Windlasses and openings for chain lockers
(5) Reference is to be made to (KS C) IEC 60092-506 standard, Special features-Ships carrying specific dangerous goods and materials hazardous only in bulk.
(6) For pipes having open ends (e.g., ventilation and bilge pipes, etc.) in hazardous area, the pipe itself is to be classified as hazardous area. See (KS C) IEC 60092-506 table B1, item B)
(7) For the cargoes specified in (A) and (B) below, Enclosed spaces (e.g., pipe tunnels, bilge pumps, etc.) containing such pipes with equipment such as flanges, valves, pumps, etc. are to be regarded s extended hazardous area, unless provided with overpressure in accordance with (KS C) IEC 60092-506 clause 7.
(A) Class 2.1, and Class 3, Class 6.1, Class 8 having a flash point less than 23 ℃ in packaged form
(B) Class 4.3 in bulk

5. In applying **202. 4** of the Rules, mechanical ventilation systems provided in enclosed cargo spaces are to be of exhaust type. If the space has access from another enclosed space, the door shall be self-closing.

6. In applying **202. 4** (1) of the Rules, the following ventilation requirements for individual cargoes and open top container cargo holds are to be complied with.
(1) If adjacent spaces are not separated from cargo spaces by gastight bulkheads or decks, ventilation requirements are to apply as for the cargo space itself, required under **202. 4** (2) of the Rules.
(2) Individual cargoes are also to be complied with the following requirements.
(A) Cargoes liable to give off vapours or gases which can form an explosive mixture with air (refer to the BC Code, Appendix B, e.g. IMO Class 4.3 materials ; aluminium ferrosilicon, aluminium silicon, ferrosilicon, zinc ashes):
Two separate fans are to be permanently fitted or being of a portable type adopted for being permanently fitted prior to loading and during voyage. The fans are to be either explosion proof or arranged such that the escaping gas flow is separated from electrical cables and components. Ventilation is to be such that any escaping gases cannot reach living spaces on or under deck.
(B) Cargoes liable to spontaneous combustion (refer to the BC Code, Appendix B, only applicable to seed cake (b) and (c)) :
The requirements in (A) above are to be complied with.
(3) For open top container ships, power ventilation is to required only for the lower part of the cargo hold for which purpose ducting is required. The ventilation capacity is to be at least 2 air changes per hour, based on the empty hold volume below weather deck.

7. In applying **202. 4** (2) of the Rules, in case where electric motor driven ventilating fans are installed, the following requirements are to be complied with:
(1) Where a ventilating fan of internal motor-driven type is installed, the motor is to be of the one approved by the Society for use in hazardous environment taking into account the requirements of the IMDG Code (see **Fig. 8.5.1** (a)).
(2) Where a ventilating fan of external motor-driven type is installed on exposed deck, the motor is to be of the covering equivalent to IP55 or upward (see **Fig. 8.5.1** (b)).
(3) Even in the case of (2) above, where the motor is installed in the proximity of the exhaust opening, the motor is to comply with the requirements of (1) above (see **Fig. 8.5.1** (c)).
(4) Ventilating fans are to be of non-sparking type in accordance with **Pt 7, Ch 1, 1006.** of the Guidance, and "suitable wire mesh guards" are to be of the standard wire mesh guards having a size 13 mm × 13 mm.

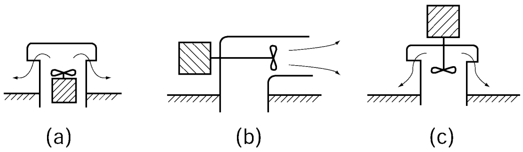


Fig 8.5.1 Ventilating fans of motor-driven type

8. In applying **202. 5** of the Rules, bilge systems for open top container holds should be independent of the machinery space bilge system and be located outside of the machinery space.

9. In applying **202. 5** (2) of the Rules, if a single drainage system completely independent of the machinery space is provided, the system is to comply with the Rules requirement to redundancy and capacity based on the size of the space or space which it services.

10. In applying **202. 5** (3) of the Rules, in case where bilge pipes are led to machinery spaces, the following requirements are to be complied with :

(1) Caution plate stating that the bilge pipes are to be blocked while dangerous goods are loaded on board are to be posted in the vicinity of the above-mentioned stop valves and blank flanges.

(2) Eductors are to be provided as the means of bilge discharging for cargo spaces so that bilges can be discharged overboard without passing through machinery spaces.

11. In applying **202. 6** (1) of the Rules, for solid bulk cargoes the protective clothing is to satisfy the equipment requirements specified in the respective schedules of the IMSBC Code for the individual substances. For packaged goods the protective clothing is to satisfy the equipment requirements specified in emergency procedures (EmS) of the Supplement to IMDG Code for the individual substances.

12. In applying **202. 6** (2) of the Rules, These spare bottles are to be in addition to the spare bottles required for fireman's outfit.

13. In applying **202. 8** of the Rules, In the case that a closed or semi-closed cargo space is located partly above a machinery space and the deck above the machinery space is not insulated, dangerous goods are prohibited in the whole of that cargo space. If the uninsulated deck above the machinery space is a weather deck, dangerous goods are prohibited only for the portion of the deck located above the machinery space.

In a case where dangerous goods are carried, no direct access is, in principle, to be provided between machinery spaces and cargo spaces. However, the access may be acceptable provided that air lock space with double self-closing steel doors of reasonably gastight is provided between those spaces. However, when dangerous goods without involving the hazard of generating noxious gas (including the case of fire) are carried, this requirement may be dispensed with.

In a case where explosives are stowed at least 3 m horizontally away from the machinery space boundaries, refer to **Fig 8.5.2**.

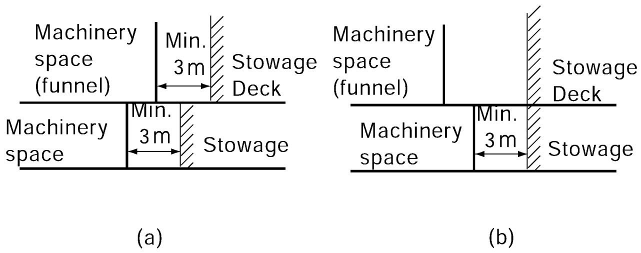


Fig 8.5.2 Areas acceptable to stowage of explosives

14. In applying **203. Table 8.5.1** of the Rules, a ro-ro space fully open above and with full openings in both ends may be treated as a weather deck.

SECTION 3 Protection of vehicle, special category and ro-ro spaces

301. General requirements

In applying **301. 2** (1) of the Rules, the "Total overall clear height for vehicles" is the sum of distances between deck and web frames of the decks forming one horizontal zone.

302. Precaution against ignition of flammable vapours in closed vehicle spaces, closed ro-ro spaces and special category spaces

1. In applying **302. 1** (3) of the Rules, the requirements to indicate any loss of ventilation capacity is considered complied with by an alarm on the bridge, initiated by fall-out of starter relay of fan motor.

2. In applying **302. 1** (4) (A) of the Rules, rapid shutdown of ventilation system is to be provided with dampers which can be isolated by a single action or closing appliances capable of isolation at equivalent closing speed. And ro-ro spaces capable of being sealed are to be capable of being sealed from a location outside of such cargo spaces, if they are protected with a fixed gas fire-extinguishing system.

3. In applying **302. 1** (5) of the Rules, "permanent openings" are to be arranged at the outside of the areas within the survival craft length plus 2 m from its ends in vertical direction on the shell plating under conditions of trim of up to 10 degrees and heel of list of up to 20 degrees. (Refer to **Fig 8.5.3**).

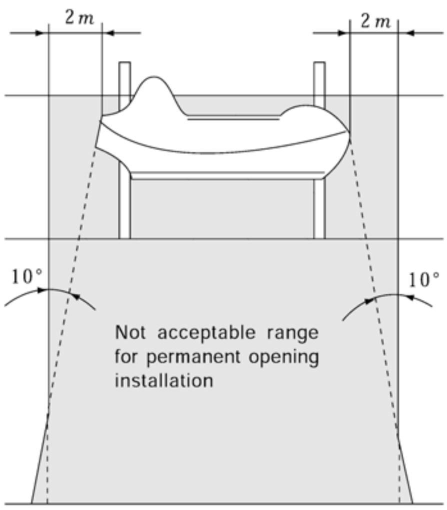


Fig 8.5.3 Not acceptable range for permanent opening installation

4. In applying **302. 2** (1) of the Rules, the electrical equipment "a type suitable for use in explosive petrol and air mixture" is to be of certified safe type and wiring, if fitted, and is to be suitable for use in Zone 1 areas as defined in (KS C) IEC 60079(Gas Group IIA, and Temperature Class T3), and exhaust fans are to be of non-sparking type in accordance with **Pt 7, Ch 1, 1006.** of the Guidance. The windlass and opening for chain lockers are to be regarded as sources of ignition.

5. In applying **302. 2** (2) of the Rules, "electrical equipment of a type so enclosed and protected as to prevent the escape of sparks" means a certified safe equipment with an enclosure of at least IP55 or suitable for use in Zone 2 areas as defined in (KS C) IEC 60079.

6. In applying **302. 3** of the Rules, air ventilation of ro-ro spaces is to be of the exhaust type. However, in the following cases, the ventilation may be of the suction type:

(1) In case where there are no openings except to exposed spaces.

(2) In case where machinery spaces of category A or accommodation spaces contiguous thereto are provided, and an air-locked corridor is available when access opening for the spaces is provided

(see **Fig 8.5.4**).

(3) In case where spaces other than those shown in (2) above are adjoining with the spaces and access opening thereto is provided, self-closing door of reasonable gas-tightness is to be provided.

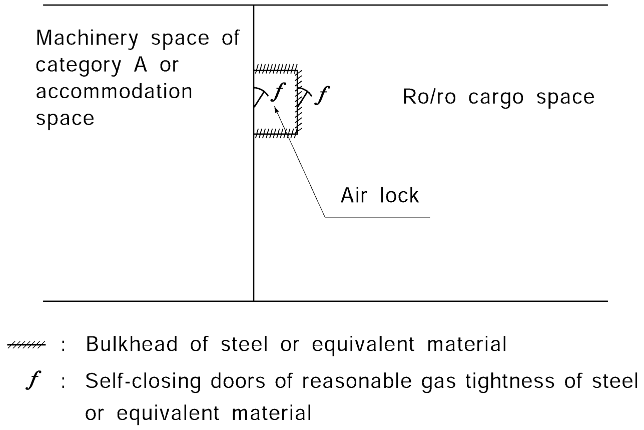


Fig 8.5.4 Air lock

305. Fire extinction

1. In applying **305. 1** (1) (A) of the Rules, these requirements may be checked by suitable calculations.

2. In applying **305. 1** (4) (A) of the Rules, (a), (b), (c) are to be applied above the bulkhead deck and (d) is to be applied below the bulkhead deck.

3. In applying **303. and 305** of the Rules, the regulations for a fixed fire extinguishing system, fire detection, foam applicators and portable extinguishers need not apply to weather decks used for the carriage of vehicle with fuel in their tanks.

4. In applying **305. 2** (2) of the Rules, cargo holds loaded with vehicles with fuel in their tanks which are stowed in open or closed containers need not to be provided with portable fire extinguishers, water-fog applicators and foam applicator units. ⚓

ANNEX

Annex 8-1 Fire Protection Materials

1. Fire protection materials for Method IC

Kinds of Components \ Requirements for components / **Pt 8, Ch 2** of the Rules		Noncombustible material **202. 1.(3)(A)**	Noncombustible material **202. 1.(1)**	Low flame spread **202. 2.(5)**	Equivalent volume **202. 2.(4).(A)**	Calorific value **202. 2.(3)**	Smoke production **301**	Not readily ignite **302**
1	Moulding				○			
2	Panel	○						
3	Painted surface, veneer, fabric or foils			○	○	○	○	
4	Painted surface, veneer, fabric or foils			○	○	○	○	
5	Decorative panel				○		○(2)	
6	Painted surface, veneer, fabric or foils				○	○	○(2)	
7	Skirting board				○			
8	Insulation		○(1)					
9	Surfaces and paints in concealed or inaccessible spaces			○				
10	Draught stop	○						
11	Grounds and supports	○		○				
12	Lining	○						
13	Primary deck covering 1st layer						○	○
14	Floor finishing			○(3)			○(3)	
15	Window box	○						
16	Window box surface			○(3)	○	○	○(3)	
17	Window box surface in concealed or inaccessible spaces			○				
18	Ceiling panel	○						

NOTES:

1. Wherever "○" appears it means that the requirements are applicable.
2. The superscripts to "○" are as follows:
   (1) Vapour barriers and adhesives used in conjunction with insulations, as well as the insulation of pipe fittings, for cold service systems, need not be of non-combustible materials, but their exposed surfaces are to have low flame-spread characteristics.
   (2) Applicable to paints, varnishes and other finishes.
   (3) Only in corridors and stairway enclosures.
   - Paints, varnishes and other finishes only applies to accommodation spaces, service spaces and control stations as well as stairway enclosures.
   - As far as window boxes construction is concerned, reference is also to be made MSC/Circ.917 and MSC/Circ.917 Add.1.
3. The number of components is referred to the following drawing. (see **Fig Annex 8-1**)

2. Fire protection materials for Method IIC and IIIC

Kinds of Components / Requirements for components / **Pt 8, Ch 2** of the Rules		Noncombustible material **202. 1.(3)(A)**	Noncombustible material **202. 1.(1)**	Low flame spread **202. 2.(5)**	Equivalent volume **202. 2.(4).(A)**	Calorific value **202. 2.(3)**	Smoke production **301**	Not readily ignite **302**
1	Moulding				○			
2	Panel	○(4)						
3	Painted surface, veneer, fabric or foils			○	○	○	○	
4	Painted surface, veneer, fabric or foils			○	○(3)	○(2)	○	
5	Decorative panel				○(3)		○(5)	
6	Painted surface, veneer, fabric or foils				○(3)	○(2)	○(5)	
7	Skirting board				○(3)			
8	Insulation		○(1)					
9	Surfaces and paints in concealed or inaccessible spaces			○				
10	Draught stop	○(4)						
11	Grounds and supports	○(4)		○				
12	Lining	○(4)						
13	Primary deck covering 1st layer						○	○
14	Floor finishing			○(6)			○(4)	
15	Window box	○(4)						
16	Window box surface			○(3)	○(3)	○(2)	○(4)	
17	Window box surface in concealed or inaccessible spaces			○				
18	Ceiling panel	○(4)						

NOTES:
1. Wherever "○" appears it means that the requirements are applicable.
2. The superscripts to "○" are as follows:
   (1) Vapour barriers and adhesives used in conjunction with insulations, as well as the insulation of pipe fittings, for cold service systems, need not be of non-combustible materials, but their exposed surfaces are to have low flame-spread characteristics.
   (2) Where the material is fitted on non-combustible bulkheads, ceiling and lining in accommodation and service spaces.
   (3) To be applied to those accommodation and service spaces bounded by non-combustible bulkheads, ceiling and linings.
   (4) Only in corridors and stairway enclosures serving accommodation and service spaces and control stations.
   (5) Applicable to paints, varnishes and other finishes.
   (6) Only in corridors and stairway enclosures.
   - Paints, varnishes and other finishes only applies to accommodation spaces, service spaces and control stations as well as stairway enclosures.
   - As far as window boxes construction is concerned, reference is also to be made MSC/Circ.917 and MSC/Circ.917 Add.1.
3. The number of components is referred to the following drawing. (see **Fig Annex 8-1**)

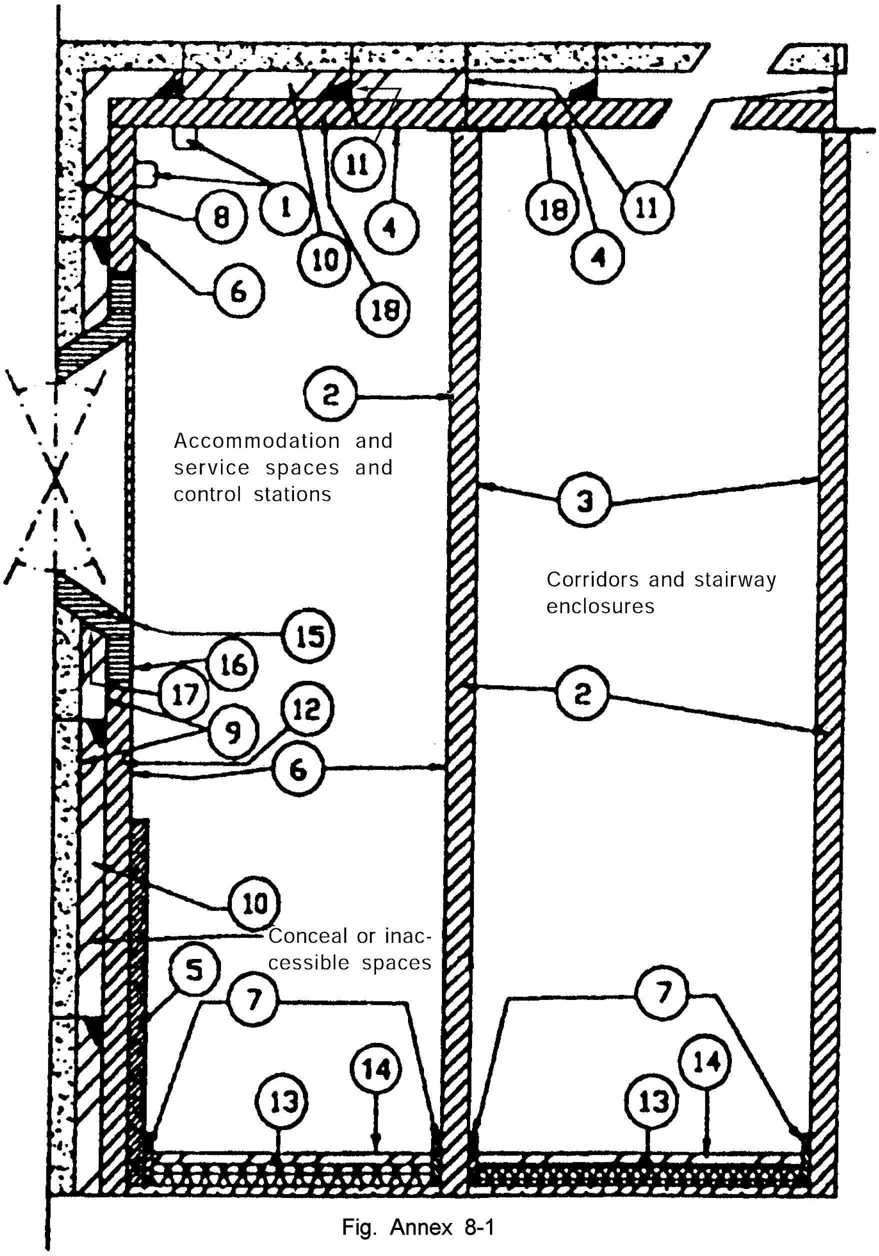
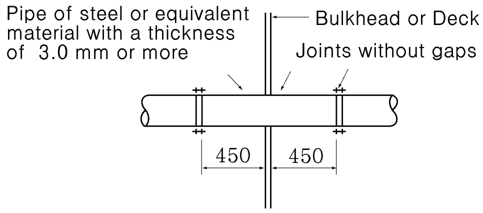

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Accommodation and service spaces and control stations
Corridors and stairway enclosures
Conceal or inaccessible spaces

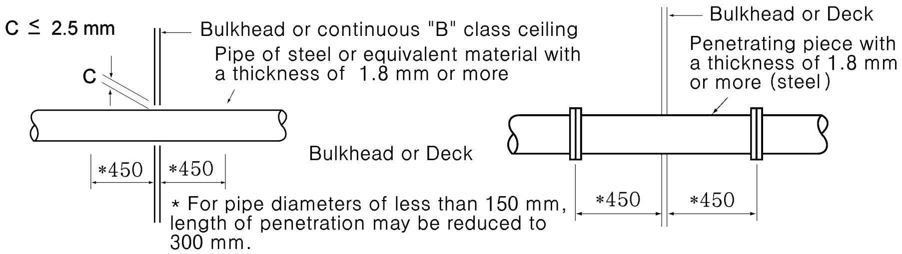
Fig. Annex 8-1

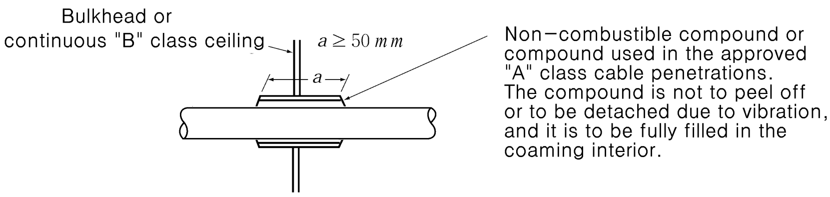
Annex 8-2 Penetrations through Divisions

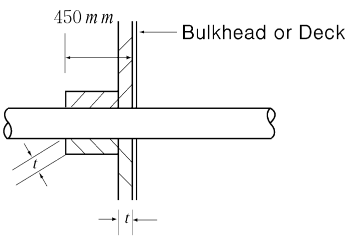
1. Penetrations of Pipes or Trunks

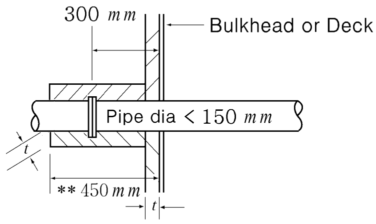
1.1 Penetrations through “A” and “B” class divisions (steel or equivalent material)

<table>
<tr><th>Divition</th><th>Details of penetrations</th></tr>
<tr><td>"A" class division</td><td>


</td></tr>
<tr><td>"B" class division</td><td>


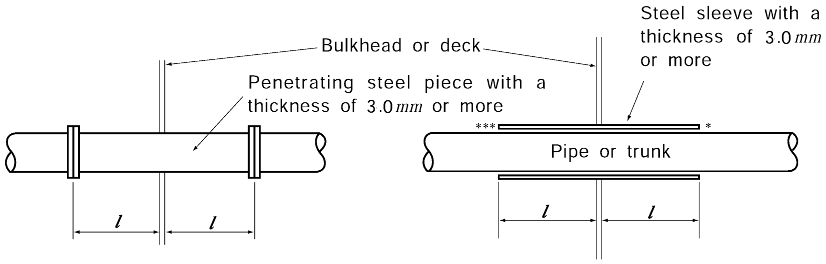
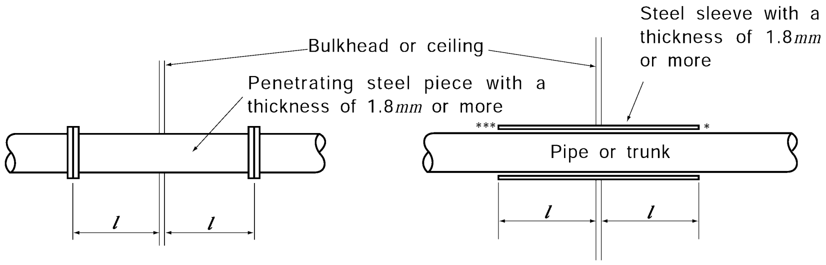


</td></tr>
<tr><td>Prevention of heat transmission</td><td>




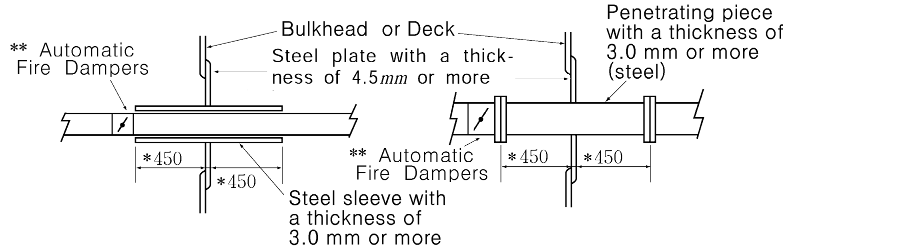
** In case the penetrations passes the FTP code test(In case of having the equal fire integrity with 450 mm) or In case penetration piece and duct connection part have a structure that heat can not be transferred, 300 mm is admitted.
</td></tr>
</table>

1.2 Pipes and trunks made of materials readily rendered ineffective by heat (PVC, FRP, aluminium alloy, lead, etc)

Division	Details of penetrations
"A" class division	 The thickness of penetrating pieces or steel sleeves may be that of the carbon steel pipes for ordinary piping of national standard according to their nominal diameter.
"B" class division	 Pipes or trunks with nominal diameter of 30 mm or less need not comply with this requirement.

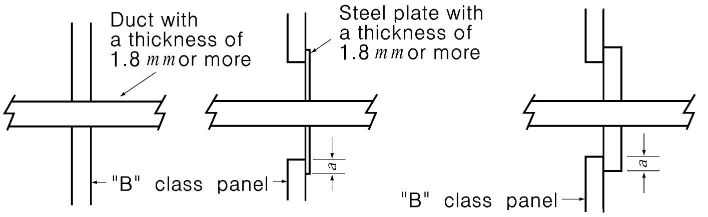
NOTES:
1. l is the distance from the divisions to the end of sleeve or joint which is to be 450 mm or more, but in case of where in "B" class division, l is to be not less than 300 mm for pipe diameters of less than 150 mm. However, the shorter length may be permitted when the equivalent fire integrity is obtained by a standard fire test for division with a shorter steel sleeve or penetrating piece.
2. The steel penetrating piece or steel sleeve provided on the pipe or trunk on the side of the open end in case where the open end is located within l from the divisions, may be up to the open end.
3. Thermal insulation is to be applied to 150 mm or more of the length on one side of the penetrating pieces or steel sleeves according to the fire integrity of the divisions. The steel penetrating piece or steel sleeve provided on the pipe or trunk on the side of the open end in case where the open end is located within 50 mm from the divisions, may be up to the open end.
4. The pipe is to be connected to the ends of the sleeve by flanges or couplings; or the clearance (with mark ***) between the sleeve and the pipe is not to exceed 2.5 mm; or any clearance between pipe and sleeve is to be made tight by means of non-combustible or other suitable material.
5. Uninsulated metallic pipes penetrating "A-0" or "B-0" class divisions are to be of a suitable material, the melting temperature of which exceeds 950 ℃ for "A-0" and 850 ℃ for "B-0" class divisions.
6. For penetrations in "A" or "B" class divisions, a fire-tested penetration device other than that mentioned above, suitable for the fire resistance of the division pierced and the type of pipe used, may be accepted (reference is made to IMO Res. A.753 (18) and the Fire Test Procedures Code.).

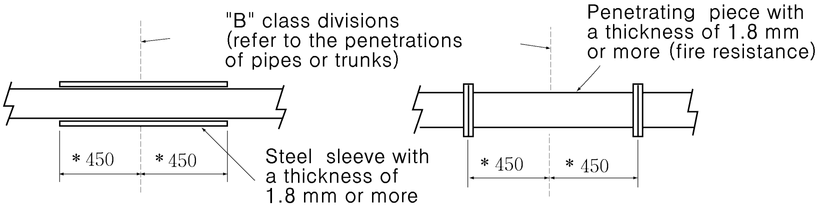
2. Penetrations of Ventilation Ducts

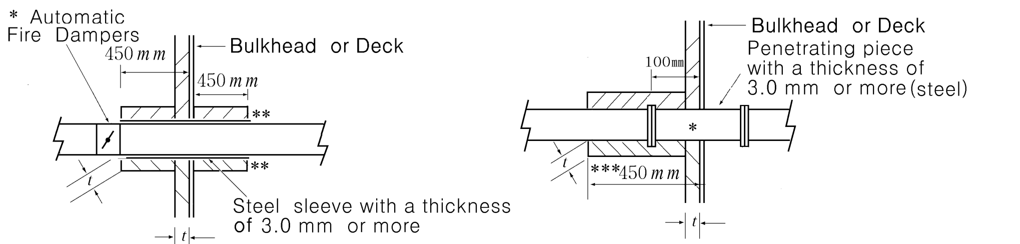
<table>
<tr><th>Division</th><th>Penetrations of ventilation ducts</th></tr>
<tr><td>"A" class</td><td>


* When free cross-sectional Duct area ≤ 0.02 m², it may be reduced to 100 mm

(Only, in the case of the deck, wholly laid on the lower side of the decks pierced)

** When free cross-sectional Duct area > 0.075 m²
</td></tr>
<tr><td>"B" class</td><td>


a ≥ T where T is thickness of panel excluding finishes


* When free cross-sectional Duct area ≤ 0.02 m², it may be reduced to 100 mm
</td></tr>
<tr><td>Prevention of heat treatment</td><td>


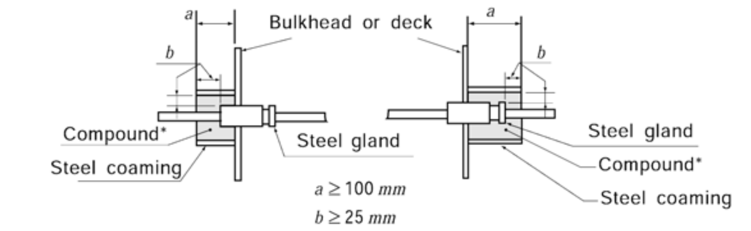
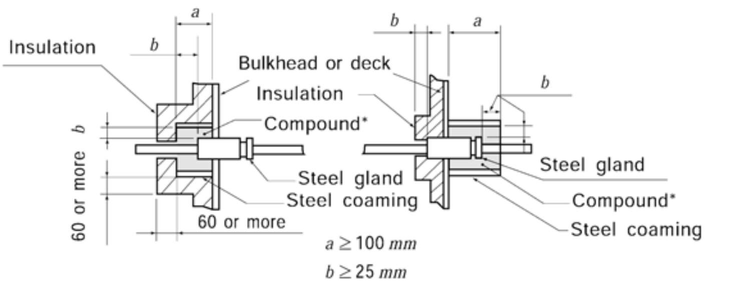
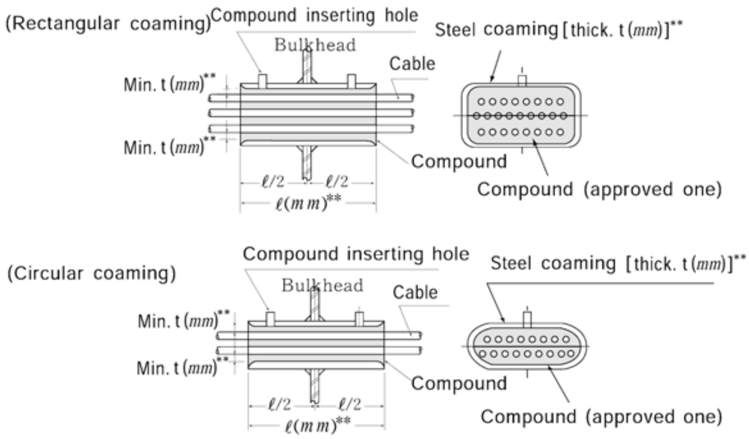
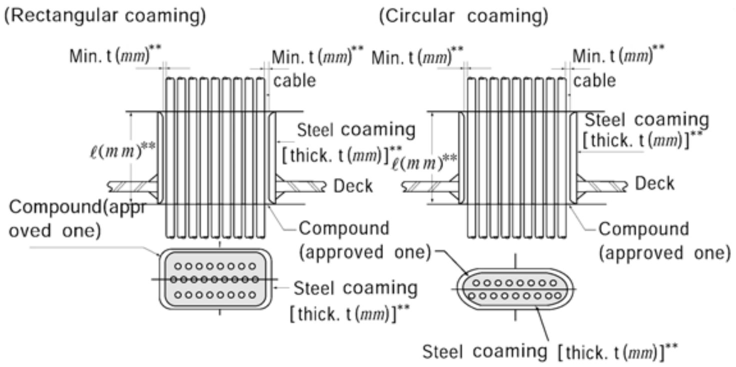
* (If needed)

** May be omitted except in cases where fire damper

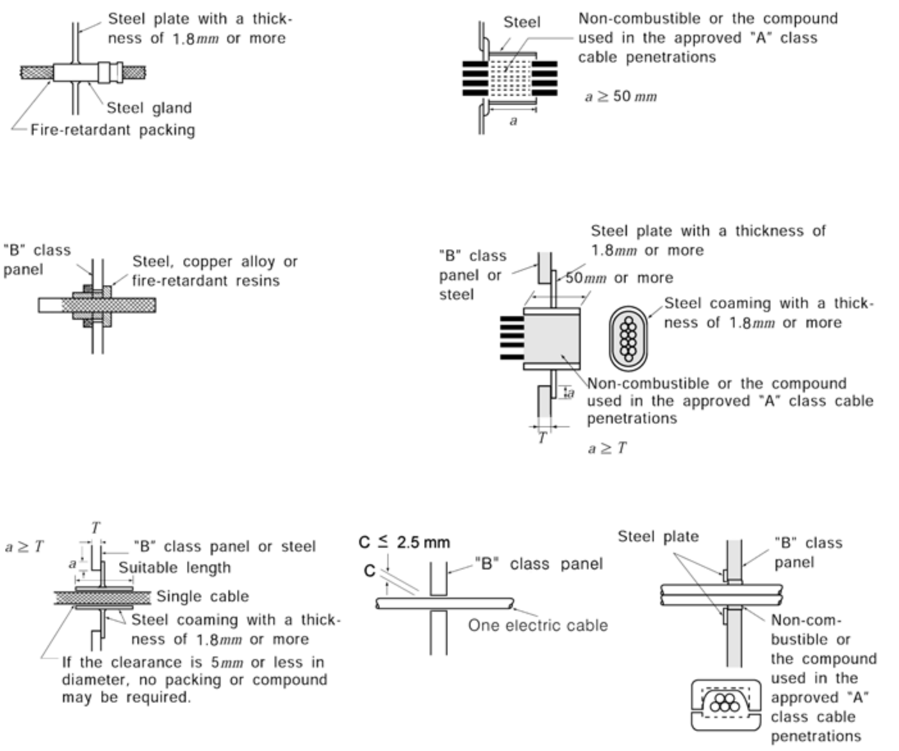
* Free cross-sectional area ≤ 0.02 m²

*** In case the penetrations passes the FTP code test(In case of having the equal fire integrity with 450mm) or In case penetration piece and duct connection part have a structure that heat can not be transferred, 100mm is admitted.
</td></tr>
</table>

3. Penetrations of Electric Cables

Division		Details of electrical cable penetrations
Single cable penetration	"A-0" class division	
	Division other than "A-0" class	
Multi-cable penetration	"A-0" class bulkhead	
	"A-0" class deck	

NOTES:
1. * Compound means non-combustible compound or compound used in the approved "A" class penetration for cables.
2. Cable penetrations in "A" class divisions are to be tested and approved in accordance with **Ch 3.** of "Guidance for Approval of Manufacturing Process and Type Approval. Etc."
3. ** The thickness(t) & length(ℓ) should be used with the same dimensions passed in the type approval test in accordance with FTP code.

Division	Details of cable penetrations
"B" class	

Annex 8-3 Special Requirements for Ships which are not engaged in international voyage or Ships of less than 500 gross tonnage (Fire-fighting system of ships which are subject to Ships Safety Law of the Korean Government, but not SOLAS, shall follow the relevant requirements)

1. Fire pumps, etc may be also loosened as follows.

(1) In case ships of less than 300 gross tonnage, not engaged in international voyage and for restricted service, the requirements of fire fighting and fire detection are not sufficiently complied with.

(2) In case ships of 300 gross tonnage and over, not engaged in international voyage and for restricted service, one independent fire pump driven by power may be permitted.

(3) In case ships of less than 150 gross tonnage, instead of one independent fire pump driven by power one power driven pump may be used.

(4) For ships less than 500 gross tonnage, and ships of less than 1,000 gross tonnage, not engaged in international voyage, and ships of 1,000 gross tonnage and over, not engaged in international voyage and for restricted service, the requirements of emergency fire pump need not apply.

(5) In case ships of 300 gross tonnage and over but less than 500 gross tonnage, and 500 gross tonnage and over, not engaged in international voyage and for restricted service, the number and position of the hydrants are to be such that at least one jet of water from a single length of hose may reach any part of the ship normally accessible to the crew while the ship is being navigated and any part of any cargo space when empty (except ro/ro space).

(6) In case ships of 300 gross tonnage and over but less than 1,000 gross tonnage and for restricted service, and ships of 1,000 gross tonnage and over, not engaged in international voyage and for restricted service, the requirements for the number of fire hoses in machinery space or boiler space need not apply. And then spare fire hoses may be omitted.

(7) In case ships less than 300 gross tonnage, fire hoses may be omitted.

2. The quantity or mass of spare extinguishing medium is to be able to charge extinguishers not less than required numbers of extinguishers multiplied by 0.1.

3. Fire-extinguishing systems in accommodation and service spaces and control stations may be also loosened as follows.

(1) At least five portable fire extinguishers for ships of 1,000 gross tonnage and over, not engaged in international voyage and for restricted service, at least four extinguishers for ships of 500 gross tonnage and over but less than 1,000 gross tonnage, at least three extinguishers for ships of 100 gross tonnage and over but less than 500 gross tonnage, at least two extinguishers for ships of 50 gross tonnage and over but less than 100 gross tonnage, and at least one extinguisher for ships of less than 50 gross tonnage, are to be provided in accommodation and service spaces as appropriate.

(2) For ships for restricted service, fire-extinguishing systems, smoke detection systems, fixed fire detection and fire alarm systems and automatic sprinkler may be omitted.

4. Fire-extinguishing arrangements in machinery spaces may be also loosened as follows.

(1) For ships of less than 500 gross tonnage, fire-extinguishing foam system as a fixed fire-extinguishing system may be permitted to the satisfaction of the Society.

(2) Fixed fire-extinguishing systems for spaces containing oil fuel units (except oil-fired boilers) may be omitted.

(3) A portable fire extinguisher may be omitted for spaces containing parts of boiler firing places and oil fuel units, provided with foam fire extinguishers of not less than 135 ℓ and receptacles containing sand and so on. And herein portable foam applicator units may be omitted.

(4) For ships of less than 500 gross tonnage, smoke detection systems, fixed fire-extinguishing system may be omitted. However, in ships of less than 500 gross tonnage and having cargo spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion (except ships registered with the notation "S"), this requirement is not to apply for places containing internal combustion engines (only those of their total output of not less than 750 kW for main propulsion).

(5) In ships of less than 500 gross tonnage and ships of 500 gross tonnage and over but less than 1,000 gross tonnage, not engaged in international voyage and for restricted service, foam fire extinguishers of not less than 45 ℓ may be omitted.

5. Fireman''s outfits may be also loosened as follows.

(1) Ships for restricted service, fireman"s outfits may be omitted. However, for ships intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, this requirement is not to apply. Nevertheless for tankers of 500 gross tonnage and over but less than 2,000 gross tonnage which are not engaged in international voyage, one set of fireman's outfits may be omitted.
(2) For ships of less than 100 gross tonnage, for restricted service, fireman's outfits may be of an axe and a lifeline.

6. The international shore connection may be omitted.

7. The fire control plans and booklets may be omitted.

8. Fire detection systems for periodically unattended machinery space may be also loosened as follows.

(1) In cargo ships with machinery spaces watched by one person, for restricted service, the requirement of the immediate water delivery from fire main need not apply.
(2) Auto-spreading liquid fire extinguishers of sufficient capacity may be provided to the satisfaction of the Society, instead of a fixed fire detection and fire alarm system.
(3) The requirement of fire detection and alarm system need not apply for machinery spaces.

9. Fire-extinguishing arrangements for tankers may be also loosened as follows.

(1) In tankers of less than 500 gross tonnage, fire-extinguishing arrangements and deck foam systems in pump rooms may be omitted. And visual/audible alarm and temperature measuring devices given in **Ch 2, 104. 10** (1) of the Rules may be omitted.
(2) For ships of less than 2,000 gross tonnage, not engaged in international voyage and for restricted service, foam concentrate of the quantity capable of giving foam for at least 20 minutes may be provided.
(3) In ships of 500 gross tonnage and over but less than 2,000 gross tonnage, not engaged in international voyage and for restricted service, two foam applicator units may be omitted.
(4) For ships of less than 2,000 gross tonnage, not engaged in international voyage and for restricted service, the capacity of a foam applicator may be at least 250 ℓ/minute when the greater supply rate of foam solution between (A) and (B) is not more than 500 ℓ/minute.
  (A) 0.6 ℓ/minute per square metre of cargo tanks deck area, where cargo tanks deck area means the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces;
  (B) 6 ℓ/minute per square metre of the horizontal sectional area of the single tank having the largest such area;

10. In ships having closed ro/ro spaces and for restricted service, the flammable gas detector may be omitted.

11. In tankers for restricted service, the requirements of fixed gas detector may be replaced with portable gas detector.

12. Machinery spaces are to be complied with the following requirements,

(1) Means are to be provided in machinery spaces, capable of effectively ventilating to ensure prevention of accumulation of flammable vapours under normal service condition and releasing smoke in the event of fire.
(2) The number of skylights, doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces is to be reduced to a minimum consistent with the needs of ventilation.
(3) The openings given in (2) above are to be provided with the closing arrangement which is capable of being operated from a place outside machinery spaces in the event of fire.
(4) In addition to the requirements given in (1), (2) and (3) above, the periodically unattended machinery spaces are to be provided with the fire protection arrangement as considered appropriately in consideration of the risk of fire where deemed necessary by the Society.

13. For unmanned barges not propelled by mechanical means, the requirements specified in **para 12** above need not to apply. For manned barges provided with machinery spaces, the requirements specified in **para 12** above are, in principle, to apply. However, the extent and degree of application of the requirements may be modified to a reasonable extent depending on the construction, purpose, etc. of the barges.

14. The cargo ships (cargo ferries, etc.) provided with spaces to carry motor vehicles with fuel in their tanks for their own propulsion (hereinafter referred as "car spaces"), are to comply with the Guidance **Pt 7, Annex 7-3 10** (2)

15. Where ships for restricted service comply with **para 12, 13** & **14** above. they may be registered with the notation "n·f " of the Register,

16. Where ship is not engaged in international voyage or Ships of less than 500 gross tonnage, the machinery system may be dispensed with as follows:

(1) Where the capacity of fuel oil tank (including fuel valve cooling oil tank, light oil tank, fuel oil additive tank) or lubricating oil tank is not more than 1 m^3, it is to be omitted for the valves or cocks having remote closing means.

(2) In case of passenger ships, it is to be omitted for the requirement of oil level gauges given in **Ch 2, 101. 2** (3) (E) (b) (i) of the Rules.

(3) In application to **Ch 2, 101. 2** (5) (B) of the Rules, the requirements specified in **Ch 2, 101. 2** (5) (B) of the Rules may not be applied except for the following.

(A) Internal combustion engines having a cylinder bore exceeding 300 mm

(B) Internal combustion engines having a cylinder bore not exceeding 300 mm and corresponding to the following.

(a) Where provided for UMA ships and used for main engines or driving generators

(b) Where provided for FRP ships with costal service(passenger ship only) and used for main engines having total output of 375 kW or over.

(4) It is to be omitted for the requirement of means of isolating fuel supply and spill piping given in **Ch 2, 101. 2** (5) (E) of the Rules.

(5) In application to **Ch 2, 101. 2** (3) (E) (b) of the Rules, where the glass level gauges comply with the following, tanks having 1 m or less in its full capacity may be provided with round glass level gauges. For small oil tanks other than fuel oil tanks, level gauges made of synthetic resin instead of glass may be used.

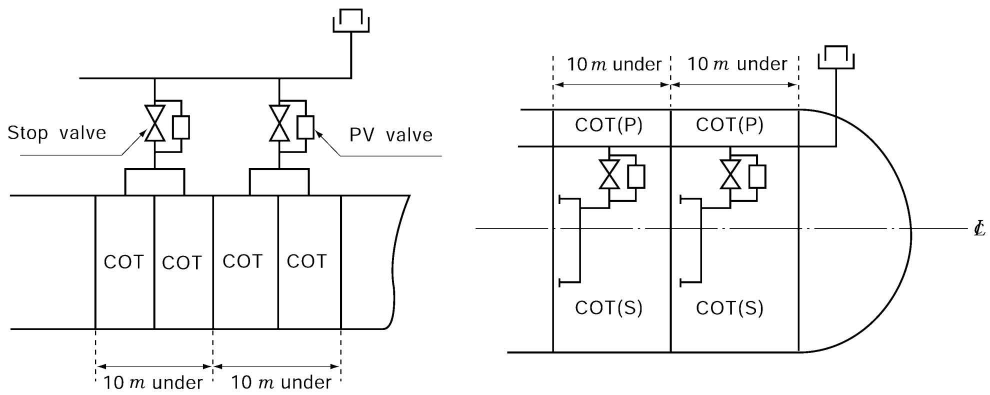
(A) Those are to be approved by the Society or to comply with "*KS V* 7222 (Glass Level Gauges with Self-closing Valve for Vessels)".

(B) Where connection pipe of glass level gauge is located under overflow pipe, valve or cock is to be provided on upper part of level gauge.

(C) Those are to be provided with *K* or *L* type protection according to *KS V* 7222.

17. In applying **104. 3** (2) (B) of the Rules, the alleviation provision for isolation requirement of cargo oil tank for tankers of less than 500 ton gross tonnage as follows ;

Where the arrangements are the plural cargo oil tank and each cargo oil tank of less than 10 mm length, these plural cargo oil tank may be regarded as one cargo oil tank.
(See **Fig Annex 8-3**)



(a) Longitudinal direction (b) Transverse direction

Fig. Annex 8-3 **Isolation of cargo oil tank for tankers of less than 500 ton gross tonnage.**

Annex 8-4 Alleviation Requirements for Fishing Vessels

1. Fire pumps may be also loosened as follows.

(1) In fishing vessels less than 80 gross tonnage, the requirement of fire pump may be omitted.
(2) For fishing vessels of 80 gross tonnage and over but less than 1,000 gross tonnage, one (1) of independently driven power fire pump may be provided.

2. The requirements of Emergency fire pumps may be not apply to fishing vessels.

3. The fire main may not be connected to the other pumps such as general service, bilge and ballast, etc., that are fitted in a machinery space.

4. Hydrants may be also loosened as follows.

(1) In fishing vessels of less than 80 gross tonnage. the requirements of hydrants may not be applied to.
(2) For fishing vessels of 80 gross tonnage and over but less than 500 gross tonnage, the number and position of the hydrants are to be such that at least one jet of water from a single length of hose may reach any part of the ship normally accessible to the crew while the ship is being navigated.
(3) The requirements of isolating valve, which is installed in machinery space to separate the section of the fire main within the machinery space containing the main fire pump from the rest of fire main, may not be applied to.

5. Fire hoses and nozzles may be loosened as follows.

(1) In fishing vessels less than 80 gross tonnage, the requirement of fire hose and nozzle may be omitted.
(2) For fishing vessels of 80 gross tonnage and over but less than 1,000 gross tonnage, the number of fire hoses may not be applied to.

6. Fixed fire detection and fire alarm systems need not apply to fishing vessels.

7. Fire-extinguishing systems in accommodation and service spaces and control stations may be loosened as follows.

(1) For fishing vessels of 80 gross tonnage and over but less than 500 gross tonnage, at least three portable fire extinguishers may be provided in accommodation and service spaces.
(2) In fishing vessels, two simple extinguishers may be provided instead of a portable fire extinguisher provided to in accommodation and service spaces.
(3) For fishing vessels less than 1,000 gross tonnage, the requirements of fixed extinguishing system for exhaust ducts from galley ranges may be omitted.

8. Fire-extinguishing arrangement in machinery spaces may be also loosened as follows.

(1) For fishing vessels less than 500 gross tonnage,the fixed low-expansion foam fire-extinguishing systems may be permitted in category "A" machinery space containing oil-fired boilers or oil fuel units.
(2) For fishing vessels less than 1,000 gross tonnage, fixed fire-extinguishing systems may be omitted in category "A" machinery spaces of not containing oil-fired boilers.
(3) For fishing vessels less than 500 gross tonnage, the portable foam applicator may be omitted in oil-fired boiler rooms.
(4) For fishing vessels less than 500 gross tonnage, a portable fire extinguisher or equivalent thereto, or such two simple extinguishers may be permitted instead of fire extinguishers provided in spaces containing boiler furnaces or parts of oil fuel units. However, for fishing vessels of 500 gross tons and over, a portable foam extinguisher or equivalent may be provided or alternative two simple extinguishers.
(5) The requirements of receptacle containing 0.1 m^3 of sand, sawdust and suitable shovel may be omitted in boiler furnaces.
(6) The requirements of category "A" machinery spaces, which is applied to main engines or internal combustion engines (except main engines) of a total power output of 375 kW and over, may be omitted. as follows.
(A) At least two portable foam fire extinguishers, carbon dioxide gas fire extinguishers or powder fire extinguishers for fishing vessels of not less than 80 but less than 500 gross tonnage, and at least one of such fire extinguishers for fishing vessels of less than 80 gross

tonnage are to be provided.

(B) In addition at least a portable foam fire extinguisher per output of 750 kW of internal combustion engines or each engine is to be provided.

(C) Two simple extinguishers may be permitted instead of one of fire extinguishers specified in (A) and (B).

(7) For machinery spaces containing steam turbines or enclosed steam engines and other machinery spaces, the requirements of fire fighting may be omitted.

9. For fishing vessels less than 1,000 gross tonnage, the requirements of fireman's outfits may be omitted.

10. The requirements of International shore connection may be omitted.

11. The requirements of Fire control plans may be omitted.

12. The requirements of Fire-extinguishing arrangements in cargo spaces may be omitted.

13. Besides the above paragraphs, the fishing vessel which is not engaged in international voyage and Ships of less than 500 gross tonnage shall be complied with the requirements of **Annex 8-3**.

Annex 8-5 Inert Gas Systems

1. The general requirements shall comply with as follows :

(1) Hereafter the term cargo tank includes also slop tanks.

(2) The inert gas system shall be designed, constructed and tested to the satisfaction of the Society. It shall be so designed and operated as to render and maintain the atmosphere of the cargo tanks non-flammable at all times, except when such tanks are required to be gas-free. In the event that the inert gas system is unable to meet the operational requirement set out above and it has been assessed that it is impracticable to effect a repair, then cargo discharge, deballasting and necessary tank cleaning shall only be resumed when the "emergency conditions" laid down in the Guidelines on Inert Gas Systems are complied with. (MSC/Circ.677.MSC/Circ.450/Rev.1, MSC/Circ.485), MSC/Circ.387)

(3) Inerting empty cargo tanks by reducing the oxygen content of the atmosphere in each tank to a level at which combustion cannot be supported;

(4) Maintaining the atmosphere in any part of any cargo tank with an oxygen content not exceeding 8 % by volume and at a positive pressure at all times in port and at aea except when it is necessary for such a tank to be gas-free.

(5) Eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas-free; and

(6) Purging empty cargo tanks of a hydrocarbon gas, so that subsequent gas-freeing operations will at no time create a flammable atmosphere within the tank.

(7) Inert gas system using stored carbon dioxide will not be permitted unless the Society is satisfied that there is no risk of ignition from generation of static electricity by the system itself.

(8) When two blowers are provided, the total required capacity of the inert gas system is preferably to be divided equally between the two blowers, and in no case is one blower to have a capacity less than 1/3 of the total capacity required.

(9) The compartment in which any oil fired inert gas generator is situated is to be treated as machinery space of Category A with respect to fire protection.

2. The inert gas supply shall be complied with the following requirements.

(1) The inert gas supply may be treated flue gas from main or auxiliary boilers. The Society may accept systems using flue gases from one or more separate gas generators or other sources or any combination thereof, provided that an equivalent standard of safety is achieved. Such systems shall, as far as practicable, comply with the requirements of this chapter. Systems using stored carbon dioxide shall not be permitted unless the Society is satisfied that the risk of ignition from generation of static electricity by the system itself is minimized.

(2) The system shall be capable of delivering inert gas to the cargo tanks at a rate of at least 125 % of the maximum rate of discharge capacity of the ship expressed as a volume.

(3) The system shall be capable of delivering inert gas with an oxygen content of not more than 5 % by volume in the inert gas supply main to the cargo tanks at any required rate of flow.

(4) Two fuel oil pumps shall be fitted to the inert gas generator. The Society may permit only one fuel oil pump on condition that sufficient spares for the fuel oil pump and its prime mover are carried on board to enable any failure of the fuel oil pump and its prime mover to be rectified by the ship's crew.

3. A flue gas scrubber shall be complied with the following requirements.

(1) A flue gas scrubber shall be fitted which will effectively cool the volume of gas specified in paragraphs **2** (1) and **2** (2) above and remove solids and sulphur combustion products. The cooling water arrangements shall be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision shall also be made for an alternative supply of cooling water.

(2) Filters or equivalent devices shall be fitted to minimize the amount of water carried over to the inert gas blowers.

(3) The scrubber shall be located aft of all cargo tanks, cargo pump-rooms and cofferdams separating these spaces from machinery spaces of category A.

4. Blowers shall be complied with the following requirements.

(1) At least two blowers shall be fitted and be capable of delivering to the cargo tanks at least the volume of gas required by paragraphs **2** (1) and **2** (2). For systems with gas generators the

Administration may permit only one blower if that system is capable of delivering the total volume of gas required by paragraphs **2** (1) and **2** (2) to the protected cargo tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the ship's crew.

(2) The inert gas system shall be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank. Suitable shutoff arrangements shall be provided on the suction and discharge connections of each blower. Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge. If the blowers are to be used for gas-freeing, their air inlets shall be provided with blanking arrangements.

(3) The blowers shall be located aft of all cargo tanks, cargo pump-rooms and cofferdams separating these spaces from machinery spaces of category A.

(4) In particular those parts of scrubbers, blowers, non-return devices, scrubber effluent and other drain pipes which may be subjected to corrosive action of the gases and/or liquids are to be either constructed of corrosion resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.

5. The water seal shall be complied with the following requirements.

(1) The water seal referred to in paragraph **6** (6) shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times.

(2) The arrangement of the seal and its associated fittings shall be such that it will prevent backflow of hydrocarbon vapours and will ensure the proper functioning of the seal under operating conditions.

(3) Provision shall be made to ensure that the water seal is protected against freezing, in such a way that the integrity of seal is not impaired by overheating.

(4) A water loop or other approved arrangement shall also be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas-safe spaces. Means shall be provided to prevent such loops from being emptied by vacuum.

(5) The deck water seal and loop arrangements shall be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks.

(6) In respect of paragraph **8** (7) (G), the Administration shall be satisfied as to the maintenance of an adequate reserve of water at all times and the integrity of the arrangements to permit the automatic formation of the water seal when the gas flow ceases. The audible and visual alarm on the low level of water in the water seal shall operate when the inert gas is not being supplied.

6. Safety measures in the system shall be complied with the following requirements.

(1) Flue gas isolating valves shall be fitted in the inert gas supply mains between the boiler uptakes and the flue gas scrubber. These valves shall be provided with indicators to show whether they are open or shut, and precautions shall be taken to maintain them gas-tight and keep the seatings clear of soot. Arrangements shall be made to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

(2) Special consideration shall be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.

(3) To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage shall be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.

(4) A gas regulating valve shall be fitted in the inert gas supply main. This valve shall be automatically controlled to close as required in paragraphs (10). It shall also be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the speed of the inert gas blowers required in paragraph **4**.

(5) The valve referred to in paragraph (4) shall be located at the forward bulkhead of the forward most gas-safe space through which the inert gas supply main passes. Herein a gas-safe space is a space in which the entry of hydrocarbon gases would produce hazards with regard to flammability or toxicity.

(6) At least two non-return devices, one of which shall be a water seal, shall be fitted in the inert gas supply main, in order to prevent the return of hydrocarbon vapour to the machinery space uptakes or to any gas-safe spaces under all normal conditions of trim, list and motion of the ship. They shall be located between the automatic valve required by paragraph (4) and the after most connection to any cargo tank or cargo pipeline.

(7) The devices referred to in paragraph (6) shall be located in the cargo area on deck.

(8) The second device shall be a non-return valve or equivalent capable of preventing the return of vapours or liquids and fitted forward of the deck water seal required in paragraph (6). It shall be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided forward of the non-return valve to isolate the deck water seal from the inert gas main to the cargo tanks.

(9) As an additional safeguard against the possible leakage of hydrocarbon liquids or vapours back from the deck main, means shall be provided to permit this section of the line between the valve having positive means of closure referred to in paragraph (8) and the valve referred to in paragraph (4), (5) to be vented in a safe manner when the first of these valves is closed.

(10) Automatic shutdown of the inert gas blowers and gas regulating valve shall be arranged on predetermined limits being reached in respect of paragraphs **8** (7) (A), (B) and **8** (7) (C) And Automatic shutdown of the gas regulating valve shall be arranged in respect of paragraph **8** (7) (D).

(11) In respect of paragraph **8** (7) (E), when the oxygen content of the inert gas exceeds 8 % by volume, immediate action shall be taken to improve the gas quality. Unless the quality of the gas improves, all cargo tank operations shall be suspended so as to avoid air being drawn into the tanks and the isolation valve referred to in paragraph (8) shall be closed.

7. Inert gas lines shall be complied with the following requirements.

(1) The inert gas main may be divided into two or more branches forward of the non-return devices required by paragraphs **5** and **6** (6) (7) (8) (9).

(2) The inert gas supply main shall be fitted with branch piping leading to each cargo tank. Branch piping for inert gas shall be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they shall be provided with locking arrangements, which shall be under the control of a responsible ship's officer. The control system operated shall provide unambiguous information of the operational status of such valves.

(3) In combination carriers, the arrangement to isolate the slop tanks containing oil or oil residues from other tanks shall consist of blank flanges which will remain in position at all times when cargoes other than oil are being carried except as provided for in the relevant section of the Guidelines on Inert Gas Systems (MSC/Circ.353 and MSC/Circ.387).

(4) Means shall be provided to protect cargo tanks against the effect of overpressure or vacuum caused by thermal variations when the cargo tanks are isolated from the inert gas mains.

(5) Piping systems shall be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

(6) Arrangements shall be provided to enable the inert gas main to be connected to an external supply of inert gas. The arrangements shall consist of a 250 mm nominal pipe size bolted flange, isolated from the inert gas main by a valve and located forward of the non-return valve referred to in paragraph **6** (8). The design of the flange should conform to the appropriate class in the standards adopted for the design of other external connections in the ship's cargo piping system.

(7) If a connection is fitted between the inert gas supply main and the cargo piping system, arrangements shall be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. This shall consist of two shutoff valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks. (see **Fig Annex 8-5**)

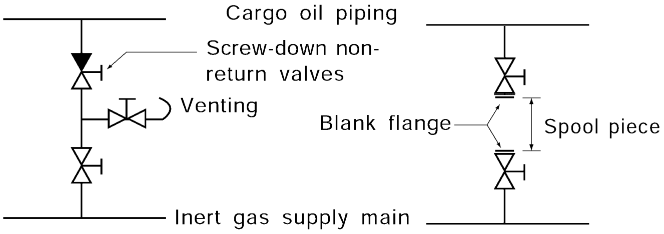


Fig. Annex 8-5

(8) The valve separating the inert gas supply main from the cargo main and which is on the cargo main side shall be a non-return valve with a positive means of closure. However, if only the spool piece is installed, stop valve also can be regarded as attached **Fig 8-5.**

8. Operation and control requirements shall comply with as follows.

(1) Means shall be provided for continuously indicating the temperature and pressure of the inert gas at the discharge side of the gas blowers, whenever the gas blowers are operating.

(2) Instrumentation shall be fitted for continuously indicating and permanently recording, when inert gas is being supplied:

(A) the pressure of the inert gas supply mains forward of the non-return devices required by paragraph **6** (6); and

(B) the oxygen content of the inert gas in the inert gas supply mains on the discharge side of the gas blowers.

(3) The devices referred to in paragraph (2) shall be placed in the cargo control room where provided. But where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.

(4) In addition, meters shall be fitted:

(A) in the navigating bridge to indicate at all times the pressure referred to in paragraph (2) (A) and the pressure in the slop tanks of combination carriers, whenever those tanks are isolated from the inert gas supply main; and

(B) in the machinery control room or in the machinery space to indicate the oxygen content referred to in paragraph (2) (B).

(5) Portable instruments for measuring oxygen and flammable vapour concentration shall be provided. In addition, suitable arrangement shall be made on each cargo tank such that the condition of the tank atmosphere can be determined using these portable instruments.

(6) Suitable means shall be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments, referred to in paragraphs (2) (3) (4) (5).

(7) For inert gas systems of both the flue, gas type and the inert gas generator type, audible and visual alarms shall be provided to indicate:

(A) low water pressure or low water flow rate to the flue gas scrubber as referred to in paragraph **3** (1);

(B) high water level in the flue gas scrubber as referred to in paragraph **3** (1);

(C) high gas temperature as referred to in paragraph (1);

(D) failure of the inert gas blowers referred to in paragraph **4**;

(E) oxygen content in excess of 8 by volume as referred to on para (2) (B).

(F) failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices as referred to in paragraphs **6** (4) (5) and (2) (A);

(G) low water level in the water seal as referred to in paragraph **6** (6);

(H) gas pressure less than 100 mm water gauge as referred to in paragraph (2) (A). The alarm arrangement shall be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times; and

(I) high gas pressure as referred to in paragraph (2) (A).

(8) For inert gas systems of the inert gas generator type, additional audible and visual alarms shall be provided to indicate:

(A) insufficient fuel oil supply;

(B) failure of the power supply to the generator; and

(C) failure of the power supply to the automatic control system for the generator.

(9) The alarms required in paragraphs (7) (E) (F) and (7) (H) shall be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

(10) An audible alarm system independent of that required in paragraph (7) (H) or automatic shut-down of cargo pumps shall be provided to operate on predetermined limits of low pressure in the inert gas main being reached.

(11) Detailed instruction manuals shall be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system. The manuals shall include guidance on procedures to be followed in the event of a fault or failure of the inert gas system. (MSC/Circ.353 and MSC/Circ.387)

9. If nitrogen generator system is provided, the follows requirements shall be complied with;

(1) The following requirements are specific only to the gas generator system and apply where inert gas is produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or absorber materials.
(2) A nitrogen generator consists of a feed air treatment system and any number of membrane or absorber modules in parallel necessary to meet the required capacity which is to be at least 125 % of the maximum discharge capacity of the ship expressed as a volume.
(3) The air compressor and the nitrogen generator may be installed in the engine room or in a separate compartment. A separate compartment is to be treated as one of "other machinery spaces" with respect to fire protection.
(4) Where a separate compartment is provided, it is to be positioned outside the cargo area and is to be fitted with an independent mechanical extraction ventilation system providing 6 air changes per hour. A low oxygen alarm is to be fitted as well. The compartment is to have no direct access to accommodation spaces, service spaces and control stations.
(5) The nitrogen generator is to be capable of delivering high purity nitrogen with O_2 content not exceeding 5 % by volume. The system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.
(6) The system is to be provided with two air compressors. The total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required. Only one air compressor may be accepted provided that sufficient spares for the air compressor and its prime mover are carried on board to enable their failure to be rectified by the ship's crew.
(7) A feed air treatment system is to be fitted to remove free water, particles and traces of oil from the compressed air, and to preserve the specification temperature.
(8) Where fitted, a nitrogen receiver/buffer tank may be installed in a dedicated compartment or in the separate compartment containing the air compressor and the generator or may be located in the cargo area. Where the nitrogen receiver/buffer tank is installed in an enclosed space, the access is to be arranged only from the open deck and the access door is to open outwards. Permanent ventilation and alarm are to be fitted as required by (4).
(9) The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck.
(10) In order to permit maintenance, means of isolation is to be fitted between the generator and the receiver.
(11) At least two non-return devices are to be fitted in the inert gas supply main, one of which is to be of the double block and bleed arrangement. The second non-return device is to be equipped with positive means of closure.
(12) Instrumentation is to be provided for continuously indicating the temperature and pressure of air, at the discharge side of the compressor and at the entrance side of the nitrogen generator.
(13) Instrumentation is to be fitted for continuously indicating and permanently recording the oxygen content of the inert gas downstream of the nitrogen generator when inert gas is being supplied.
(14) The instrumentation specified in (13) above is to be placed in the cargo control room where provided. But where no cargo control room is provided, they shall be placed in a position easily accessible to the officer of cargo operations.
(15) Audible and visual alarms are to be provided to indicate :
(A) Low feed-air pressure from compressor specified in (12) above.
(B) High air temperature specified in (12) above.
(C) High condensate level at automatic drain of water separator specified in (7) above.
(D) Failure of electrical heater, if fitted.
(E) Oxygen content in excess of that required in (5) above.
(F) Failure of power supply to the instrumentation specified in (13) above.
(16) Automatic shut-down of the system is to be arranged upon alarm conditions as required by (15) (A) to (E) above.
(17) The alarms required by (15) above are to be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

10. If nitrogen/inert gas systems are fitted for purpose other than inerting of the above 1 on oil tankers of less than 20,000 DWT, gas tankers or chemical tankers, the following requirements shall be complied with;

(1) The requirements apply except prescribed (1), (2) and (6) above.
(2) Where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices specified in (11) above may be substituted by two non-return valves.

11. In case where glass-fibre reinforced plastic pipes are used for the drainage piping from the scrubber and blower fan casing, the following requirements are to be complied with:

(1) The materials, design requirements, piping arrangements, connections of pipes, markings, tests and inspections are to be as specified in **Pt 5, Annex 5-6** of the Guidance.
(2) In case where glass-fibre reinforced plastic pipes are provided inside the machinery space, the following requirements are to be complied with:
(A) A valve operable from both inside and outside the machinery space either by pneumatic or hydraulic pressure led through steel piping is to be provided on a distance piece fitted to the shell plating. This valve is to be of automatic closing type in case of failure of the operating system.
(B) The valve specified in (A) above is to be provided with an indicator showing the opening/closing condition.
(C) The valve specified in (A) above is to be closed at all time when the inert gas system is not in operation as well as in the event of a fire in the machinery space.
(D) For the valve specified in (A) above, a short piece of steel pipe or spool piece is to be fitted. Further, a swing type non-return valve is to be attached to the piece. The piece is to be provided with a drain pipe of an inside diameter of approximately 12.5 mm and a drain valve.
(E) On the inboard side of the non-return valve specified in (D) above, a short piece of steel pipe or spool piece provided with a drain pipe with an inside diameter of approximately 12.5 mm and a drain valve is to be fitted.
(F) The distance piece and valve specified in (A) above, and short piece of steel pipe or spool piece and swing type non-return valve specified in (D) and (E) above are to be of corrosion resisting materials or are to be protected internally by rubber, glass fibers, epoxy resins or equivalent coating materials.
(G) Means for stopping the scrubber pump is to be provided outside the machinery space.

12. Installation inspection of inert gas system shall be complied with the following requirements:

(1) After installation inboard, inert gas system is to be tested at the working condition in accordance with **Annex 8-5** table as to airtight test and operation test, control device, safety system and warning device.
(2) The airtight test pressure for pipes and joints in the inert gas supply line is, in principle, to be 0.024 MPa. Note, however, that in case where the set pressure of the pressure/vacuum valve is 0.024 MPa or more, the test pressure is to be the set pressure of the pressure/vacuum valve.
(3) It is to be verified through the use of inert gas or fresh air that the capacity of the inert gas blower is equal to or greater than 1.25 times the maximum design discharge capacity of the ship. In case where fresh air is used in the test, such fresh air is to be taken in from the area in the proximity of the flue gas isolating valve. However, when a ship including its inert gas system is of the same design as a ship which has already tested, this test may be omitted.

Annex 8-5 table effectiveness test item

Item	Audible and visual alarm	Safety device	Note
(1) Supplied water pressure of scrubber and discharge drop	○	Inert gas control valve closing Inert gas blower stop	-
(2) A rising of the water level in the scrubber	○	Inert gas control valve closing Inert gas blower stop Stop of cooling water supply pump for scrubber	
(3) Inert gas high temperature of an outlet of inert gas blower	○	Inert gas control valve closing Inert gas blower stop	
(4) An obstacle of inert gas blower	○	Inert gas control valve closing	
(5) Oxygen content of inert gas blower outlet in excess of 8 % by volume	○	-	Closing passively to non-return device in addition to improvement of gas quality and water seal Alarm is to be given to machinery room and cargo control room
(6) Failure of the power supply to the automatic control system for the inert gas regulation valve	○	-	Alarm is to be given to machinery room and cargo control room
(7) Failure of the power the pressure of the inert gas supply mains afward of the non-return device	○		
(8) Failure of the power supply to the oxygen content of the inert gas blower outlet	○		
(9) Low water level in the water seal	○	-	-
(10) Gas pressure less than 100 mm water gause forward of non-return device	○	-	Alarm to machinery room and cargo control room
(11) Overpressure in inert gas supply main forward of non-return device	○	-	-
(12) Supply stop of inert gas	○	-	Low water level alarm is to be operated in the water seal Watertight is to be formed in the water seal
(13) Predetermined limits of low pressure in the inert gas mains being reached	○	-	Automation stop of cargo oil pump should be avaliable
(14) The automatic control system for the inert gas regulation valve	-	-	Provided where the automatic control system for the inert gas blower are not be provided
(15) Indicating device, recording device, measuring device	-	-	Operation and effectiveness test are to be accomplished

Annex 8-6 Other Operation Requirements, etc.

1. At all times while the ship is in service, the requirements that fire protection systems and fire-fighting systems and appliances are to be maintained ready for use shall be complied with. A ship is not in service when:
(1) it is in for repairs or lay-up (either at anchor or in port) or in dry-dock;
(2) it is declared not in service by the owner or the owner's representative; and
(3) in the case of passenger ships, there are no passengers on board.

2. The following fire protection systems shall be kept in good order so as to ensure their required performance if a fire occurs:
(1) structural fire protection including fire resisting divisions, and protection of openings and penetrations in these divisions;
(2) fire detection and fire alarm systems; and
(3) means of escape systems and appliances.

3. Fire-fighting systems and appliances shall be kept in good working order and readily available for immediate use. Portable extinguishers which have been discharged shall be immediately recharged or replaced with an equivalent unit.

4. Maintenance, testing and inspections shall be carried out based on the guidelines developed by the IMO Organization and in a manner having due regard to ensuring the reliability of fire-fighting systems and appliances.

5. The maintenance plan shall be kept on board the ship and shall be available for inspection whenever required by the Society.

6. The maintenance plan shall include at least the following fire protection systems and fire-fighting systems and appliances, where installed:
(1) fire mains, fire pumps and hydrants including hoses, nozzles and international shore connections;
(2) fixed fire detection and fire alarm systems;
(3) fixed fire-extinguishing systems and other fire extinguishing appliances;
(4) automatic sprinkler, fire detection and fire alarm systems;
(5) ventilation systems including fire and smoke dampers, fans and their controls;
(6) emergency shut down of fuel supply;
(7) fire doors including their controls;
(8) general emergency alarm systems;
(9) emergency escape breathing devices;
(10) portable fire extinguishers including space charges; and
(11) fire-fighter's outfits.

7. The maintenance programme may be computer-based.

8. In addition to the fire protection systems and appliances listed in paragraph **102. 3** ships carrying more than 36 passengers shall develop a maintenance plan for low-location lighting and public address systems.

9. In addition to the fire protection systems and appliances listed in paragraph **102. 3** tankers shall develop a maintenance plan for:
(1) inert gas systems;
(2) deck foam systems;
(3) fire safety arrangements in cargo pump rooms; and
(4) flammable gas detectors.

10. A training manual shall be provided in each crew mess room and recreation room or in each crew cabin.

11. The training manual shall be written in the working language of the ship.

12. The training manual, which may comprise several volumes, shall contain the instructions and information required in paragraph **4** in easily understood terms and illustrated wherever possible. Any part of such information may be provided in the form of audio-visual aides in lieu of the manual.

13. The training manual shall explain the following in detail:

(1) general fire safety practice and precautions related to the dangers of smoking, electrical hazards, flammable liquids and similar common shipboard hazards;
(2) general instructions on fire-fighting activities and fire-fighting procedures including procedures for notification of a fire and use of manually operated call points;
(3) meanings of the ship's alarms;
(4) operation and use of fire-fighting systems and appliances;
(5) operation and use of fire doors;
(6) operation and use of fire and smoke dampers; and
(7) escape systems

14. Fire Control Plans shall be permanently exhibited for the guidance of the ship's officers. Alternatively, at the discretion of the Society, the aforementioned details may be set out in a booklet, a copy of which shall be supplied to each officer, and one copy shall at all times be available on board in an accessible position. Plans and booklets shall be kept up to date; any alterations thereto shall be recorded as soon as practicable. Description in such plans and booklets shall be in the language or languages required by the Society. If the language is neither English nor French, a translation into one of those languages shall be included.

15. A duplicate set of fire control plans or a booklet containing such plans shall be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shore-side fire-fighting personnel.

16. In ships carrying more than 36 passengers, plans and booklets required by this regulation shall provide information regarding fire protection, fire detection and fire extinction based on the guidelines issued by the IMO Organization.

17. The required fire safety operational booklet shall contain the necessary information and instructions for the safe operation of the ship and cargo handling operations in relation to fire safety. The booklet shall include information concerning the crew's responsibilities for the general fire safety of the ship while loading and discharging cargo and while underway. Necessary fire safety precautions for handling general cargoes shall be explained. For ships carrying dangerous goods and flammable bulk cargoes, the fire safety operational booklet shall also provide reference to the pertinent fire-fighting and emergency cargo handling instructions contained in the International Maritime Solid Bulk Cargoes Code, the International Bulk Chemical Code, the International Gas Carrier Code and the International Maritime Dangerous Goods Code, as appropriate.

18. The fire safety operational booklet shall be provided in each crew mess room and recreation room or in each crew cabin.

19. The fire safety operational booklet shall be written in the working language of the ship.

20. The fire safety operational booklet may be combined with the training manuals.

21. For Tankers, the fire safety operational booklet referred to in paragraph **1** shall include provisions for preventing fire spread to the cargo area due to ignition of flammable vapours and include procedures of cargo tank gas-purging and/or gas-freeing taking into account the provisions as follows,

Procedures for cargo tank purging and/or gas-freeing

(1) When the ship is provided with an inert gas system, the cargo tanks shall first be purged in accordance with **Ch 2, 104. 6** of the Rules until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than 2 % by volume. Thereafter, gas-freeing may take place at the cargo tank deck level.
(2) When the ship is not provided with an inert gas system, the operation shall be such that the flammable vapour is discharged initially through:
  (A) the vent outlets as specified in **Ch 2, 104. 3** (4) of the Rules**;**
  (B) outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas-freeing operation; or
  (C) outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/s and which are protected by suitable devices to prevent the passage of flame.
(3) The above outlets shall be located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard.
(4) When the flammable vapour concentration at the outlet has been reduced to 30% of the lower

flammable limit, gas-freeing may e continued at cargo tank deck level.

Annex 8-7 Qualitative Failure Analysis for Propulsion and Steering on Passenger Ships

1. The scope is to be as specified in the followings.

A qualitative failure analysis for propulsion and steering for new passenger ships including those having of 120 m or more or having three or more main vertical zones.

2. The objectives are to be as specified in the followings.

(1) For ships having at least two independent means of propulsion and steering to comply with SOLAS requirements for a safe return to port, the following requirements are applicable.

(A) Provide knowledge of the effects of failure in all the equipment and systems due to fire in any space, or flooding of any watertight compartment that could affect the availability of the propulsion and steering.

(B) Provide solutions to ensure the availability of propulsion and steering upon such failures in item (a).

(2) Ships not required to satisfy the safe return to port concept will require the analysis of failure in single equipment and fire in any space to provide knowledge and possible solutions for enhancing availability of propulsion and steering.

3. The systems shall consider the following requirements and the analysis is to address the location and layout of equipment and systems to consider the effects of fire or flooding in a single compartment.

(1) The qualitative failure analysis is to consider the propulsion and steering equipment and all its associated systems which might impair the availability of propulsion and steering.

(2) The qualitative failure analysis should include:

(A) Propulsion and electrical power prime movers, e.g.,
- (a) Diesel engines
- (b) Electric motors

(B) Power transmission systems, e.g.,
- (a) Shafting
- (b) Bearings
- (c) Power converters
- (d) Transformers
- (e) Slip ring systems

(C) Steering gear, e.g,
- (a) Rudder actuator or equivalent for azimuthing propulsor
- (b) Rudder stock with bearings and seals
- (c) Rudder
- (d) Power unit and control gear
- (e) Local control systems and indicators
- (f) Remote control systems and indicators
- (g) Communication equipment

(D) Propulsors, e.g.,
- (a) Propeller
- (b) Azimuthing thruster
- (c) Water jet

(E) Main power supply systems, e.g.,
- (a) Electrical generators and distribution systems
- (b) Cable runs
- (c) Hydraulic
- (d) Pneumatic

(F) Essential auxiliary systems, e.g.,
- (a) Compressed air
- (b) Oil fuel
- (c) Lubricating oil
- (d) Cooling water
- (e) Ventilation
- (f) Fuel storage and supply systems

(G) Control and monitoring systems, e.g.,

(a) Electrical auxiliary circuits
(b) Power supplies
(c) Protective safety systems
(d) Power management systems
(e) Automation and control systems

(H) Support systems, e.g.,
(a) Lighting
(b) Ventilation

4. The failure criteria is to be as specified in the followings.

(1) Failures are deviations from normal operating conditions such as loss or malfunction of a component or system such that it cannot perform an intended or required function.
(2) The qualitative failure analysis should be based on single failure criteria, (not two independent failures occurring simultaneously).
(3) Where a single failure cause results in failure of more than one component in a system (common cause failure), all the resulting failures are to be considered together.
(4) Where the occurrence of a failure leads directly to further failures, all those failures are to be considered together.

5. The verification of Solutions is to be as specified in the followings.

(1) The shipyard is to submit a report to the Societies that identifies how the objectives have been addressed. The report is to include the following information:
(A) Identify the standards used for analysis of the design.
(B) Identify the objectives of the analysis.
(C) Identify any assumptions made in the analysis.
(D) Identify the equipment, system or sub-system, mode of operation of the equipment.
(E) Identify probable failure modes and acceptable deviations from the intended or required function.
(F) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode as applicable.
(G) Identify trials and testing necessary to prove conclusions.
(2) The report is to be submitted prior to approval of detail design plans. The report may be submitted in two parts:
(A) A preliminary analysis as soon as the initial arrangements of different compartments and propulsion plant are known which can form the basis of discussion. This is to include a structured assessment of all essential systems supporting the propulsion plant after a failure in equipment, fire or flooding in any compartment casualty.
(B) A final report detailing the final design with a detailed assessment of any critical system identified in the preliminary report.
(3) Verification of the report findings are to be agreed between the Society and the shipyard. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 8 FIRE PROTECTION AND FIRE EXTINCTION

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2011

Rules for the Classification of Steel Ships

Part 9 Additional Installations

Rules

2011

Guidance Relating to the Rules for the Classification of Steel ships

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KOREAN REGISTER

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KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 9 "ADDITIONAL INSTALLATIONS"

1. Unless expressly specified otherwise, the requirements in the Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date : 20 August 2010 (based on the application date for classification survey)

CHAPTER 3 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 3 Centralized Monitoring and Control Systems for Main Propulsion and Essential Auxiliary Machinery

- 310. 1 has been amended.

Effective Date 1 July 2011

CHAPTER 3 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 5 Automatic Equipment

- 503. 1 and 6 have been amended.

CHAPTER 4 DYNAMIC POSITIONING SYSTEMS

Section 1 General

- 102. (3) and (6) have been amended.

Section 2 Requirements of Dynamic Positioning Systems

- 202. 2 (3) has been amended.
- 202. 3 Table 9.4.1, (4) and (5) have been amended.
- 203. 1 (1) and 2 (3) have been amended.
- 203. 2 (6) has been newly added.
- 203. 3 (2) has been amended.

CHAPTER 5 NAVIGATION BRIDGE SYSTEMS

Section 2 Surveys of Navigation Bridge Systems

- 202. 3 (2) has been amended.

Section 5 Accident Prevention Systems

- 502. 2 has been amended.

CONTENTS

CHAPTER 1 CARGO REFRIGERATING INSTALLATIONS

Section 1 General

101. General

1. Application

(1) The Rules for Cargo Refrigerating Installations apply to the surveys and constructions of cargo refrigerating installations (hereinafter referred to as "refrigerating installations") of ships classed or to be classed with the requirements of **Pt 1, Ch 1** intended to be assigned and registered the class notations in accordance with **Pt 1, Ch 1, Sec 2.**

(2) For the refrigerating machinery within the refrigerating installations specified in above (1), the requirements in the Rules apply to the refrigerating machinery using the primary refrigerants listed below. The surveys and constructions of the refrigerating machinery using primary refrigerants other than those listed below are to be as deemed appropriate by the Society.

$R\ 22$: $CHClF_2$

$R\ 134a$: CH_2FCF_3

$R\ 404A$: $R\ 125/R\ 143a/R\ 134a$ (44/52/4 wt%)
$CHF_2CF_3/CH_3CF_3/CH_2FCF_3$

$R\ 407C$: $R\ 32/R\ 125/R\ 134a$ (23/25/52 wt%)
$CH_2F_2/CHF_2CF_3/CH_2FCF_3$

$R\ 410A$: $R\ 32/R\ 125$ (50/50 wt%)
CH_2F_2/CHF_2CF_3

$R\ 507A$: $R\ 125/R\ 143a$ (50/50 wt%)
CHF_2CF_3/CH_3CF_3

$R\ 717$: NH_3

(3) For refrigerating installations of ships with restricted area of service or those of small capacity, some of the requirements in the Rules may be modified appropriately provided that the Society considered it acceptable.

(4) At the request of the shipowner or his representative, the Surveyor may carry out Loading Port Surveys on registered refrigerating installations at the loading port in accordance with the requirements in **Ch 7.** On completion of the survey to the satisfaction of the Surveyor a Certificate on Loading Port Survey will be issued.

(5) The relevant requirements in the Rules for the Classification of Steel Ships apply to the materials, equipment, installation and workmanship of the systems, unless otherwise specified in the Rules.

2. Special installations

The surveys and constructions of refrigerating installations to which the requirements in this chapter can not be directly applied for a special reason are to be deemed appropriate at the discretion of the Society.

3. Equivalency

Refrigerating installations, which do not comply with requirements of the Rules may be accepted, provided that they are deemed by the Society to be equivalent to those specified in the Rules.

102. Definitions

The definitions of terms which appear in the Rules are to be as specified in the following **Par 1** to **5**, unless otherwise specified elsewhere.

1. **Refrigerating installations** means refrigerating machinery, insulation for refrigerated chambers and other related appliances in refrigerated chambers

2. **Refrigerating machinery** means a set of refrigerating units which compose refrigerating cycle, consisting of compressors, condensers, receivers, evaporators, coolers, piping and fittings, driving motors for the compressors and refrigerant pumps, automatic controllers, and electrical equipments.

3. **Refrigerating units** means in general such machinery as compressors, motors, condensers, evapo-

rators, pumps, etc., necessary to operate refrigerating cycles among the refrigerating machinery.

4. Brine is a general term for the secondary refrigerants which is cooled by the primary refrigerants and which is a thermal medium to cool the cargo.

5. Design pressures means the maximum working pressure. However, design pressures are not to be less than the values specified in **Table 9.1.1.**

Table 9.1.1 The Lowest Design Pressure

Refrigerants	High Pressure Side[1] (MPa)	Low Pressure Side[2] (MPa)
R 22	1.9	1.5
R 134*a*	1.4	1.1
R 404*A*	2.5	2.0
R 407*C*	2.4	1.9
R 410*A*	3.3	2.6
R 507*A*	2.5	2.0
R 717	2.3	1.8

(NOTES)
(1) High Pressure Side : The pressure part from the compressor delivery side to the expansion valve.
(2) Low Pressure Side : The pressure part from the expansion valve to the compressor suction valve. In case where a multistage compression system is adopted, the pressure part from the lower-stage delivery side to the higher-stage suction side is to be included.

Section 2 Surveys

201. General

1. Kinds of surveys

Kinds of surveys are as follows:
(1) Surveys for Classification (hereinafter referred to as "Classification Surveys")
 (A) Classification Surveys during Construction
 (B) Classification Surveys after Construction
(2) Surveys for Classification Maintenance
 (A) Annual Surveys
 (B) Special Surveys
 (C) Occasional Surveys

2. Classification Surveys and intervals of Classification Maintenance Surveys

(1) Classification Surveys
 (A) Classification Surveys during Construction
 For refrigerating installations intended to be constructed and registered with the Society, the construction, materials, scantlings and workmanship of the hull, equipment and machinery are to be undergo the Classification Survey during Construction. The presence of the Surveyor is required at the following stages of the work. However, the requirements may be modified having regard to the actual status of facilities, technical abilities and quality control at the works.
 (a) When the tests of materials in accordance with the requirements in **Pt 2** of the Rules and other tests necessary for the approval or acceptance described in **301. 3** (4), **502. 1** (1) and **502. 5** of the Rules are carried out.

(b) When the tests specified in **Ch 6** are carried out.
(c) When considered necessary by the Surveyor
(B) Classification Surveys after Construction
Refrigerating installations intended to be registered in a way other than that described in above (A) are to undergo the Classification Survey after Construction
(2) Classification Maintenance Surveys
Refrigerating installations which have been registered are to undergo surveys in accordance with the following intervals to maintain their Classification.
(A) Annual Surveys are to be carried out at intervals specified in **Pt 1, Ch 2, 201.**
(B) Special Surveys are to be carried out at intervals specified in **Pt 1, Ch 2, 401.**
(C) Occasional Surveys are to be carried out at a time falling on any of (a) to (c) mentioned below, independently of Special Surveys and Annual Surveys.
(a) When main parts of the installations have been damaged, repaired or renewed.
(b) When the installations are modified or altered.
(c) When a survey is needed for a reason other than the above.
(D) Continuous Surveys
(a) At the request of the Owner, and upon approval of the proposed arrangements by this Society, a system of Continuous Survey may be undertaken for all the items of machinery installations to be surveyed at the Special Survey. When such a system is adopted, all the requirements of the Special Survey are to be surveyed in regular rotation, as far as practicable, with uniform annual share within 5 year period and to be completed.
(b) The survey in such way as specified in above (a) is referred to as a Continuous Survey.

3. Preparation for surveys and others

(1) All such preparations as required for the Survey to be carried out as well as those which may be required by the Surveyor as necessary in accordance with the requirements in the Rules are to be made by the applicant of the survey. The preparations are to include provisions of an easy and safe access, necessary facilities, certificates and records for the execution of the survey, opening up of equipment, removal of obstacle and cleaning. Inspection, measuring and test equipment, which Surveyors rely on to make decisions affecting classification are to be individually identified and calibrated to a standard deemed appropriate by the Society. However, the Surveyor may accept simple measuring equipment(e.g. rulers, measuring tapes, micrometers, etc.) and gauge fitted on machinery(e.g. pressure gauges, temperature gauges, rpm gauges, etc.) without individual identification or confirmation of calibration, provided they are properly maintained and periodically compared with other similar equipment.
(2) The applicant for survey is to arrange a supervisor who is well conversant with the survey items intended for the preparation of the survey to provide the necessary assistance to the Surveyor according to his requests during the survey.
(3) The survey may be suspended where necessary preparations have not been made, any appropriate attendant mentioned in the previous (2) is not present, or the Surveyor considers that the safety for execution of the survey is not ensured.
(4) Where repairs are deemed necessary as a result of the survey, the Surveyor will notify his recommendations to the applicant of survey. Upon this notification, the repair is to be made to the satisfaction of the Surveyor.

202. Classification Surveys

1. Classification Surveys during Construction

(1) In a Classification Survey during construction, the construction, materials, scantlings and workmanship of the refrigerating installations are to be examined in detail in order to ascertain that they meet the full requirements of each chapter concerned of the Rules.
(2) For the refrigerating installations intended to undergo a Classification Survey during construction, the following plans and information in triplicate are to be submitted to the Society before the work is commenced.
(A) Specifications of the refrigerating installations(including particulars of refrigerating units)
(B) General arrangements of the refrigerating units(including detailed ventilating arrangements of the relevant compartment)
(C) Sectional assembly of refrigerant compressors for each type

(D) Detailed plans of pressure vessels subject to the primary refrigerant pressure
(E) Piping arrangements of primary refrigerants, brine and cooling water(materials, diameter and thickness of pipes are to be indicated)
(F) Arrangements of refrigerated chambers(including details of ductings for air circulation and ventilation)
(G) Wiring diagram for the refrigerating installations and arrangements of electric appliances
(H) Wiring diagram for detail construction of penetration of the insulation in refrigerated chambers
(I) Kind of insulation on all surfaces, physical properties, thickness and methods of attachment of the insulation and linings(including detailed construction and insulating methods of hatch covers, access doors, ventilating ducts, scupper and bilges)
(J) Drainage arrangements and defrosting arrangements in refrigerated chambers and spaces in which the air coolers are installed
(K) Arrangements of thermometers or sensors in refrigerated chambers and air coolers, and the name of manufacturer and the type of the sensors
(L) Explanatory documents to show the function of automatic temperature controls

2. Classification Surveys after Construction

(1) General
In an Classification Survey after Construction, the refrigerating installations are to be examined on their construction, materials, workmanship and actual conditions as required for the Special Survey corresponding to their age, in order to ascertain their effectiveness.
(2) Tests
(A) In the Classification Survey after Construction, operation tests and other various tests are to be carried out as required for the Special Survey.
(B) Where deemed necessary by the Surveyor, the tests and examination items may be added or omitted according to their age, service career and actual condition.
(3) Plans and documents for submission
When the refrigerating installations are intended to undergo the Classification Survey after Construction, plans and documents are to be submitted as may be required by the requirements in **202. 1** (2).

203. Classification Maintenance Surveys

1. Annual Surveys

At an Annual Survey, an external examination is to be carried out on the following items. Examination may also be made on the items which are prepared to be examined in detail or which are opened up by the Owners' option. If any defects are observed at such examinations, the Surveyor may require open-up examination of the suspected items.
(1) At examination of the refrigerating installation, log book is to be made to trace the operating condition of the installation during navigation.
(2) Insulation linings of refrigerated chambers and their fastening are to be examined. Any indication of dampness or deterioration of the insulation is to be investigated.
(3) Air circulation ducts, hatch covers and their seal, access doors in refrigerated chambers and their fastening, ventilating system and their closing means are to be examined. Care is to be given to the condition of penetrating parts where ducting or ventilating pipes pass through the deck plating.
(4) Bilge ways, bilge wells, strainers, non-return valves and water sealed traps of scupper pipes, suction and sounding pipes are to be cleaned and examined. The drainage arrangements of refrigerated chambers and the defrosting arrangements of air coolers are also to be examined.
(5) Condition of the cooling coils of air coolers and the cooling grids(including brine) in refrigerated chambers is to be examined.
(6) Shells of condensers, receivers, evaporators, separators, dryers, filters and other pressure vessels and their connections and piping are to be examined externally as far as possible.
(7) Insulation on the surfaces of pressure vessels, pipe connections and piping is to be examined for any indication of dampness or deterioration.

(8) Randomly selected thermometers and apparatus used for measuring the temperature in the suction and delivery side of cooling air in refrigerated chambers and air coolers are to be checked for their accuracy. However, the Surveyor may at the discretion accept the checking records made by some reliable persons.
(9) Condition of compressors, condenser cooling water pumps, primary refrigerant pumps, brine pumps, air circulation fans and their driving motors is to be examined externally.
(10) Water end covers of condenser selected by Surveyor are to be examined externally for their corrosion through inspection holes or other suitable openings.
(11) Tests for insulation resistance are to be made on the motors and controls of compressors, pumps, fans, etc. and their wiring, and the resistance is to be not less than 1 MΩ between insulated circuits and earth. However, when correct records are maintained, the above tests may be omitted at the discretion of the Surveyor.
(12) All automatic controls, safety devices and alarms are to be tested for their satisfactory function.

2. Special Surveys

At a Special Survey, items specified in **203. 1** (1) to (8) are to be examined. In addition, the examinations required by the followings are to be carried out.
(1) Compressors and their lubricating systems are to be opened up and examined. In the case of screwed-type compressors or compressors deemed appropriate by the Society, the interval of opened-up may be modified by the Society, provided their working condition is found satisfactory.
(2) Condenser cooling water pumps, primary refrigerant pumps and brine pumps are to be opened up and examined.
(3) Insulated pipes carrying the refrigerant are to be examined both outside and inside the insulated chambers, removing the insulation to the extent necessary for checking their condition, especially the locations which pipes are connected by butt welding in place.
(4) All pressure relief valves throughout the refrigerating plant are to be adjusted on their relieving pressure.
(5) All automatic controls, safety devices and alarms are to be tested for their satisfactory function.
(6) The insulation in refrigerated chambers is to be carefully examined, and bored where considered necessary in order to determine the integrity and dryness. These test holes are subsequently filled carefully.
(7) Brine pipe system is to be tested to the pressure of 1.5 times the design pressure or 0.4 MPa whichever is the greater.
(8) Pressure vessels are to be opened up for examination, and afterward pressure tested in accordance with the following procedures :
 (A) The coils of gas condensers of the coil-in-casing type are to be examined and tested to the pressure of 1.5 times the high pressure side design pressure. Where it is impracticable to remove the coils, they may be examined through inspection holes.
 (B) The coils of evaporators of the coil-in-casing type are to be examined and tested to the pressure of 1.5 times the low pressure side design pressure. Where it is impracticable to remove the coils, they may be examined through inspection holes.
 (C) The water end covers of the shell-and-tube type condensers and the shell-and-tube type evaporators in which the primary refrigerant is in the shell are to be removed and the tube plates, tube ends and inside the end covers are to be examined. Afterwards, the shells are to be tested to the pressure equal to the high pressure side design pressure.
 (D) The primary refrigerant end covers of the shell-and-tube type evaporators in which the brine is in the shell are to be removed and the tube ends and inside the end covers are to be examined. The shells are to be tested to the pressure of 1.5 times the design pressure or 0.4 MPa whichever is the greater. After refitting the end covers, the primary refrigerant side is to be tested to the pressure equal to the low pressure side design pressure.
 (E) Receivers are to be hydrostatically tested to the design pressure. However, when the receivers are designed to use such primary refrigerant as *R* 22, *R* 134*a*, *R* 404*A*, *R* 407*C*, *R* 410*A* or *R* 507*A*, or when they are proved to have no harmful defects such as erosions or cracks on the inner surface of the vessels by means of ultrasonic test or other effective non-destructive examinations, the above mentioned pressure test may be omitted.

(F) For pressure vessels for the refrigerant of *R* 22, *R* 134*a*, *R* 404*A*, *R* 407*C*, *R* 410*A* or *R* 507*A*, pressure tests specified in through above may be omitted at the first Special Survey provided that the vessels are found to be in good order.

(9) Current condition of the electrical equipment and electric cables are to be examined. It is to be ascertained that their insulation resistance is not less than 1 MΩ between all insulated circuits and earth. When correct records are maintained, the above examination may be omitted at the discretion of the Surveyor.

(10) Operation tests of the refrigerating installation are to be carried out.

3. Occasional Surveys

At an Occasional Survey, examinations or tests on items required are to be carried out in accordance with the requirements in **201. 2** (2) (C) to the satisfaction of the Surveyor.

Section 3 Refrigerating Machinery

301. General

1. General requirements

(1) Refrigerating machinery are to be designed taking into account their purpose and service conditions, etc.

(2) All components of the refrigerating machinery are to be so constructed and arranged that they can be easily maintained and readily opened up for repair or renewal.

(3) Where *R* 717 is used as refrigerant, the refrigerating machinery are to comply with the requirements in this section and in addition, they are to comply with the requirements in **Sec 4**.

(4) Primary refrigerant pipes for *R* 22, *R* 134*a*, *R* 404*A*, *R* 407*C*, *R* 410*A* or *R* 507*A* are to be classified into Class III specified in **Pt 5, Ch 6, 101. 4.**

(5) Pressure vessels for the refrigerant of *R* 22, *R* 134*a*, *R* 404*A*, *R* 407*C*, *R* 410*A* or *R* 507A are to be classified in accordance with the requirements in **Pt 5, Ch 5, 302.** according to the design pressure specified in **102. 5**.

(6) Refrigerating machinery are to be provided with the following equipment.
(A) Standard thermometer : 2 sets
(B) Hydrometer : 1 set (in the case of brine-cooling)
(C) Refrigerant leakage detector : 1 set

2. Capacity and number of refrigerating machinery

(1) At least two refrigerating units are to be provided and so arranged as to be readily interchanged with each other.

(2) The refrigerating capacity of the installation is to be sufficient to maintain the temperatures of the refrigerated chambers even though any one unit suspended.

3. Materials and welding

(1) Materials used for the refrigerating machinery are to be suitable for refrigerant, the design pressure, the minimum working temperature, etc.

(2) Materials used for the primary refrigerant pipes, valves and their fittings are to comply with the requirements in **301. 1** (4) and **402. 1** (1), according to the classes of pipes specified in **Pt 5, Ch 6, 102.**

(3) Materials used for the pressure vessels exposed to the refrigerant pressure (condensers, receivers and other pressure vessels)are to comply with the requirements in **301. 1** (5) and **402. 1** (1), according to the classes of pressure vessels specified in **Pt 5, Ch 5, 303.**

(4) Materials listed below are not to be used:
(A) For parts exposed to fluorine-substituted hydrocarbons:
aluminium alloys containing more than 2% of magnesium
(B) For parts always exposed to water:
aluminium of which purity is less than 99.7% (except corrosion protection treated materials)

(5) The use of cast-iron valves is to be in accordance with the requirements in **Table 9.1.2**. Even when the use of cast-iron valves is allowed in **Table 9.1.2**, such valves are not to be used where the design temperature is lower than 0℃ or higher than 220℃. In this case, such valves may be used at temperatures down to -50℃ even if the design temperature is lower than 0℃, provided that they are used under a pressure up to 1/2.5 of the design pressure.
(6) Refrigerating machinery using specific materials such as rubber hoses, plastic tubes, vinyl pipes or aluminium alloys, etc. is to be approved or accepted by the Society, considering the refrigerant used or service conditions.

Table 9.1.2 Service limitation of valves made of iron casting

Kind of valves	Materials	Application
Stop valves	*GC 100*, *GC 150* and *GC 200* in *KS D 4301* or equivalent thereto	Not to be used
	GC 250, *GC 300* and *GC 350* in *KS D 4301*, *KS D 4302* or equivalent thereto	1) May be used for design pressure not exceeding 1.6 MPa
Relief valves	*KS D 4301*, *KS D 4302* or equivalent thereto	Not to be used
Automatic control valves	*GC 100*, *GC 150* and *GC 200* in *KS D 4301* or equivalent thereto	Not to be used
	GC 250, *GC 300* and *GC 350* in *KS D 4301* or equivalent thereto	1) May be used for design pressure not exceeding 1.6 MPa 2) May be used for design pressure exceeding 1.6 MPa but not exceeding 2.6 MPa, provided nominal diameter does not exceed 100 mm and design temperature is 150℃ or below.
	KS D 4302 or equivalent thereto	Not to be used for design pressure exceeding 3.2 MPa

302. Construction, etc. of refrigerating machinery

1. Refrigerant compressors

(1) Compressor components subject to the refrigerant pressure(including crankcases in the case of reciprocating compressors) are to be so designed to withstand the design pressure for HP side. However, when a relief valve is fitted to the crankcase integral with compressor cylinder, the components mentioned above may be designed for the design pressure for the relief valve.
(2) Where the compressor is lubricated by pressure oil, the compressor is to be stopped automatically when the oil pressure falls below a preset value.
(3) The compressor is to be provided with an alarm or automatic cut off device which operates where condenser cooling water pressure falls below a predetermined value.

2. Driving machines and gearing

Prime movers and step-up gearing for compressors are to be in accordance with the relevant requirements in **Pt 5**.

3. Pressure vessels exposed to the refrigerant pressure

Design, construction and strength of pressure vessels exposed to the refrigerant pressure(condensers, receivers, and other pressure vessels) are to be in accordance with the requirements in **304.** to **316.** of **Pt 5, Ch 5, Sec 3**.

4. Oil separators

Suitable oil separators with drainage are to be provided to the discharge side of the compressor, except when a unit integrated with evaporator is provided to ensure oil recovery.

5. Filters

Suitable filters are to be provided in the refrigerant gas lines to the compressors and in the liquid lines to the automatic regulators. Filters may be omitted provided oil separators fitted have filtrating capability.

6. Refrigerating dryers

Dryers are to be provided to the refrigerant pipes for R 22, R 134a, R 404A, R 407C, R 410A or R 507A. Driers are to be so arranged that they can be by-passed or changed over to a stand-by unit without interrupting the operation of the plant in case of failure. However, such arrangement is not required when the change over to the stand-by unit is ensured by a unit integrated with the evaporator.

7. Refrigerant pumps

Where the primary and/or secondary refrigerants are circulated round the system by pumps, a stand-by pump so arranged as to be easily interchangeable with pumps for normal operation is to be provided. Its capacity is not to be less than that of the largest pump for normal operation.

8. Condenser cooling water pumps

(1) At least two separate condenser cooling water pumps are to be provided and so arranged as to be interchangeable with each other. In this case, one of the pumps may be used for other purposes, provided that it is of adequate capacity and its use on other services does not interfere with the supply of cooling water to the condenser.
(2) Condenser cooling water is to be taken from at least two sea connections(suctions). One of the sea connections is to be provided on the port side and the other on the starboard side.

9. Piping systems

Design, construction, strength, fabrication and outfitting of piping systems are to be in accordance with the requirements in **Pt 5, Ch 6, 102.** to **107.**

10. Safety devices against excessive pressure

(1) A high pressure cut out switch and a relief valve are to be fitted between each compressor (except turbo compressors) and its delivery stop valve. The gas discharged from the relief valve is to be led to the open air or the low pressure side of the refrigerant system.
(2) The refrigerant side of the condenser, the receiver and parts containing liquid refrigerant, which may be isolated and exposed to a pressure exceeding their design pressure, are to be provided with relief valves or other suitable pressure relieving devices.
(3) Pressure vessels used for low pressure side containing liquid refrigerants(including brine coolers and closed type brine tanks) and isolated by stop valves are to be provided with pressure relief valves or other suitable pressure relieving devices.
(4) All pumps and piping systems which may be exposed to a pressure exceeding their design pressure are to be provided with relief valves or other suitable pressure relieving devices.
(5) Where gas discharged from the relief valve on the high pressure side of the primary refrigerant is led to the low pressure side, the arrangement is to be made so that the operation of the relief valve is not affected by back pressure accumulation.
(6) Where gas discharged from relief valves or other pressure relieving devices are led to the open air, the openings are to be located at safe places above the weather deck.
(7) Pressure relieving devices are to be capable of preventing the pressure accumulation exceeding 1.1 times the design pressure of the parts to which the devices are fitted.

11. Automatic control

Automatic control is to be in accordance with the requirements in **Pt 6, Ch 2, 102.**

12. Electrical equipment

(1) The electric power supply to the refrigerating installation is to be fed by at least two sets of generating units.
(2) The capacity of the generating units mentioned above (1) is to be such that in the event of any one generating unit being stopped the remaining generating units are capable of maintaining the temperature of the refrigerated chambers.
(3) The construction of electrical equipment arranged in the refrigerating installation is to comply with the requirements in **Pt 6, Ch 1.**

303. Cooling appliances in refrigerated chambers

1. Cooling grids

Brine cooling grids or direct expansion cooling grids in each refrigerated chamber are to be divided in at least two sections so arranged that each section can be shut off, where necessary.

2. Air cooler

Cooling coils of each air cooler are to be arranged in not less than two sections, each of which can be shut off where necessary. Alternatively, at least two independent air coolers are to be provided.

3. Refrigerated air circulating fans

Where circulation of air is dependent on a single fan and motor, access arrangements are to be such that the fan and motor can be readily removed for repair or renewal even when the chamber is loaded with refrigerated cargo. Where the chamber temperature can be maintained in an allowable range even if one unit is out of use, the above requirement is not applied.

4. Automatic temperature regulating devices

Where automatic regulating devices for controlling the temperatures in the refrigerated chambers are provided, a manually operated regulating valve or system is to be provided as stand-by service. Alternatively, two sets of automatic regulating systems so arranged that each system can be readily operated by changing over may be provided.

5. Temperature difference

The temperature difference between the refrigerated chamber and the refrigerant is to be controlled so that the dehydration of cargo and frosting of the cooling appliances in each chamber can be minimized.

6. Galvanizing of brine tanks and pipes

Internal surfaces(brine side) of brine tanks and pipes exposed to brine are not to be galvanized. However, this requirement is not applied where brine tanks are closed type and they are provided with a ventilating pipe or pipes led to the open air in a location where no damage will arise from the gas discharged and their open ends are fitted with non corrosive metalic wire gauze diaphragms, or where the tanks are open type and the compartments in which they are situated are efficiently ventilated.

7. Corrosion protection of refrigerant pipes in refrigerated chambers

External surfaces of primary refrigerant or brine pipes of steel within refrigerated chambers or embedded in insulation thereof are to be suitably protected from corrosion by galvanizing, coating of any corrosion protective paint or other methods. Where pipes are connected by screwed couplings or by welding, ungalvanized or uncoated portions of the pipes are to be coated with an efficient corrosion resisting material after pressure testing.

304. Other arrangements in refrigerated chambers

1. Defrosting arrangements

Where refrigerated chambers are operated below 0℃, means for effectively defrosting air cooler coils in refrigerated chambers are to be provided.

2. Ventilating arrangements in refrigerated chambers

Where chambers are intended for the carriage of refrigerated cargoes requiring controlled ventilation, air refreshing arrangements are to be provided. In this case, each chamber is to be provided with its own separate inlet and exhaust vent, and each vent is to be provided with an airtight closing appliance. The positions of the air inlet and exhaust vent are to be selected to minimize the possibility of contaminated air entering into the chambers.

3. Heating arrangements for fruit cargoes

Where it is intended to carry fruit cargoes which may be adversely affected by low temperatures into areas where the ambient temperature may become below the carrying temperature, arrangements for heating the chambers are to be provided.

305. Refrigerating machinery compartments

Refrigerating machinery compartments are to be provided with efficient arrangements of drainage and ventilation, and separated by gastight bulkheads from the adjacent refrigerated chambers.

Section 4 Special Requirements for Refrigerating Machinery Using Ammonia as Refrigerant

401. General

1. General requirements

Refrigerating machinery using ammonia as refrigerant is to be of an indirect refrigerating system using brine, and to use *R* 717 refrigerant as the primary refrigerant only.

2. Definition

The definitions of terms which appear in this chapter are to be as specified in the following (1) to (4), unless otherwise specified specially in other chapter.
(1) **Gas** means ammonia gas used as the refrigerant.
(2) **Gas purging** means the discharge of non-condensing gases from the condenser.
(3) **Storage container** means a vessel used for storing gas for replenishment.
(4) **Gas expulsion system** means the system for excluding gas quickly from a compartment, and consists of ventilation system, gas absorption system, water screening system, gas absorption water tanks, etc.

3. Drawings and data

Drawings and data to be submitted in addition to those specified in other chapters, are generally as follows:
(1) Gas Detector Arrangement
(2) General Arrangement of Refrigerating Machinery Compartment

402. Design

1. General requirements

(1) Pressure vessels used in the refrigerating machinery are to be in accordance with the requirements of Class I specified in **Pt 5, Ch 5**, and the primary refrigerant pipes(hereinafter referred to as "refrigerant pipes".) are to be classified into Class I piping specified in **Pt 5, Ch 6**.
(2) Refrigerating machinery is to be provided with auxiliary receivers of adequate capacity so that repairs and maintenance may be carried out without discharging the gas to the atmosphere. However, the auxiliary receivers can be dispensed with, if at least the refrigerant in the receiver with the largest capacity can be stored in some other receiver.

2. Materials

(1) Materials capable of highly corrosion(copper, zinc, cadmium, or their alloys) and materials containing mercury are to be not used at locations where ammonia comes in contact.
(2) Nickel steel is not to be used in pressure vessels and piping systems.
(3) Cast-iron valves are not to be used in the refrigerant piping system.
(4) Material for sea-water cooled condensers is to be selected considering the corrosion due to sea water.

403. Refrigerating machinery

1. Refrigerant compressors

Refrigerant compressors are to be provided with means for automatically stopping the compressor when the pressure on the high pressure side of the refrigerant piping system becomes excessively high. Also, an alarm system which generates visible and audible alarms when this means are in operation is to be installed in the refrigerating machinery compartment and monitoring position.

2. Piping joints

Piping joints for the refrigerant piping system are to be butt welded as far as practicable.

3. Pressure relieving devices

The refrigerant gas discharged from a pressure relief valve is to be absorbed in water, except when leading the gas to the low pressure side.

4. Liquid level gauge

If liquid level gauges made of glass are used at locations where pressure exists permanently, they are to comply with the requirements given below.

(1) Flat type glass is to be used in the liquid level gauge, and the construction is to be such that the gauge is adequately protected against external impacts.

(2) The construction of the stop valve for the liquid level gauge is to be such that the flow of liquid is automatically cut off if the glass breaks.

5. Gas purging

Gas discharged from the purging valve is to be not discharged directly to the atmosphere, but absorbed in water.

6. Condenser

Independent piping for discharge of cooling sea water for the condenser is to be used. The piping is to be led directly overboard without passing through accommodation spaces.

404. Refrigerating machinery compartment

1. Construction and arrangement

(1) The compartment where the refrigerating machinery and storage vessels are installed(hereinafter referred to as "refrigerating machinery compartment".) is to be a special compartment isolated by gastight bulkheads and decks from all other compartments so that leaked ammonia does not enter other compartments. The refrigerating machinery compartment is to be provided with access doors which comply with the following requirements:

(A) At least two access doors are to be provided in the refrigerating machinery compartment as far apart as possible from each other. At least one access door is to lead directly to the weather deck. However, if it is not possible to provide access door directly to the weather deck, then at least one access is to have airlock type doors.

(B) Access doors not leading to weather deck are to be of high tightly and self-closing type.

(C) Access doors are to be capable of being operated easily and are to open outward.

(2) The refrigerating machinery compartment is to be not adjacent to accommodation spaces, hospital room or control room.

(3) Passages leading to the refrigerating machinery compartment are to comply with the following requirements:

(A) If a passage is adjacent to accommodation spaces, hospital room or control room, it is to be isolated by gastight bulkheads and decks.

(B) The passage is to be isolated from passages to accommodation spaces, and led directly to the weather deck.

(4) Penetrations on gastight bulkheads and decks where cables and piping from the refrigerating machinery compartment pass through, are to be of gastight construction.

(5) Drain pans of adequate size are to be provided at a position which is lower than the refrigerating machinery and storage vessels in the refrigerating machinery compartment so that liquid ammonia does not leak outside the compartment.

(6) An independent drainage system is to be provided in the refrigerating machinery compartment so that the drainage of this compartment is not discharged into open bilge wells or bilge ways of other compartments.

405. Gas expulsion system

1. General

A gas expulsion system consisting of ventilation system, gas absorption system, water screening system, and gas absorption water tanks is to be installed in the refrigerating machinery compartment so that the gas leaked out accidentally can be expelled quickly from the refrigerating machinery compartment.

2. Ventilation system

(1) A mechanical ventilation system, which complies with the following requirements as a rule, is to be installed in the refrigerating machinery compartment so that this space can be ventilated all the time.

(A) The ventilation system is to have adequate capacity to ensure at least 30 air changes per hour in the refrigerating machinery compartment.

(B) The ventilation system is to be independent of other ventilation systems on board the ship, and is to be capable of being operated from outside the refrigerating machinery compartment.

(C) Exhaust outlets are to be installed at a horizontal distance of more than 10 m from the nearest air intake opening, openings of accommodation spaces, service spaces and control stations, and at a vertical distance of more than 4 m from the weather decks.

(D) The air intake opening is to be provided at a low position and the exhaust opening is to be provided at a high position in the refrigerating machinery compartment so that the gas does not accumulate in the compartment and the exhaust ducts.

(E) Exhaust fans and the exhaust ducts in which the fans are installed, are to be of a construction such that sparks are not generated according to any of the (a) to (c) mentioned below.

(a) Either the impeller or the casing, or both, are made of non-electrostatic, non-metallic materials.

(b) Non-ferrous metallic material is used in the impeller and the casing.

(c) In case where ferrous material is used in the impeller and the casing, the tip clearance is greater than 13 mm. However, use of a combination of aluminium or magnesium alloy with ferrous materials has possibilities of generating sparks regardless of the tip clearance, therefore, such materials are not to be used in the refrigerating machinery compartment. As a rule, motors for driving the fans are to be of the exterior mount type.

(2) Independent ventilation systems are to be installed in passages leading to the refrigerating machinery compartment. However, if the ventilation system specified in above (1) is provided with ducts so that it can be used for exhausting air in the passages, then an independent ventilation system need not be installed.

3. Gas absorption system

A gas absorption system satisfying any of the requirements given below, capable of excluding leaked gases quickly from the refrigerating machinery compartment, and capable of being operated from outside the compartment, is to be installed.

(1) Scrubber

(A) The scrubber is to be designed with an adequate processing capacity which restricts the gas concentration at the exhaust fan to well below 25 ppm, and absorbs ammonia in the largest receiver within 30 minutes.

(B) The pump for the scrubber is to start automatically when the gas concentration in the refrigerating machinery compartment exceeds 300 ppm.

(2) Water sprinkler system

(A) The quantity of sprinkled water is to be such that the leaked gas can be satisfactorily absorbed.

(B) Nozzles are to be of type approved by the Society. As a rule, nozzles are to be positioned so that their range covers all the refrigerating machinery in the compartment.

(C) When the gas concentration in the refrigerating machinery compartment exceeds 300 ppm, the pump for sprinkling water is to start automatically.

4. Water screening system

All doors of the refrigerating machinery compartment are to be provided with water screening system which can be operated from outside the compartment.

5. Gas absorption water tanks

Gas absorption water tanks complying with the requirements given below, are to be installed at a position lower than the refrigerating machinery compartment so that the leaked liquid ammonia can be recovered quickly.

(1) The tank is to have such a capacity that the water which can absorb the refrigerant filled in at least one refrigerating machinery can be fully recovered.
(2) An automatic water supply system is to be installed in the tank so that the fully-filled condition of the tank is always maintained.
(3) Overflow from the tank is to be diluted or neutralized and then discharged overboard directly, without leading the discharge pipes through accommodation spaces.
(4) Means are to be provided in the tank to recover the drain of the liquid ammonia generated in the refrigerating machinery compartment. An appropriate drain trap is to be provided to prevent reverse flow of the gas from the tank.
(5) All the vent pipe of the tank is to be connected to the exhaust pipe of the ventilation system of **405. 2.**

406. Gas detection and alarm system

1. Installation requirements

(1) Gas detection and alarm systems are to be provided in the refrigerating machinery compartment complying with the following requirements:
  (A) At least one gas detector complying with the requirements given below, is to be installed above each refrigerating machinery.
    (a) The detectors are to activate an alarm when the gas concentration exceeds 25 ppm.
    (b) When the gas concentration exceeds 300 ppm, the detector is to automatically stop the refrigerating machinery, automatically activate the gas expulsion, and activate the alarm.
  (B) An adequate number of flammable gas detectors are to be provided so that when the gas concentration reaches up to 4.5%, the power supply to the electrical equipment in the refrigerating machinery compartment is cut off and the alarm systems are activated.
  (C) The alarm systems are to generate visible and audible alarms near the doors, within and outside the refrigerating machinery compartment and at monitoring locations.
  (D) A manually-operated transmitter for leakage warnings is to be provided, near the doors and outside the refrigerating machinery compartment.
(2) Gas detection and alarm system complying with the following requirements are to be provided in passages leading to the refrigerating machinery compartment:
  (A) The gas detectors are to activate the alarm system when the gas concentration exceeds 25 ppm
  (B) The alarm systems are to generate visible and audible alarms in the passage and near the doors of the refrigerating machinery compartment.
(3) Detectors are to be capable of continuous detection and considered to be appropriate by the Society.

407. Electrical equipment

1. General

(1) Electrical equipment in the refrigerating machinery compartment required to be operated in the event of leakage accidents, gas detection and alarm system, and emergency lights are to be of certified safety types for use in the flammable atmosphere concerned.
(2) Electrical equipment in the refrigerating machinery compartment other than mentioned in above (1), are required to switch off automatically, by means of circuit breakers installed outside the refrigerating machinery compartment when the flammable gas detector specified in **406. 1** (1) (B) activates.
(3) If a water sprinkler system is installed in the refrigerating machinery compartment as the gas absorption system, all electrical machinery and equipment in the refrigerating machinery compartment are to be of the waterproof type.

408. Safety and protective equipment

1. General

As a rule, safety and protective equipment as given below are to be provided, and are to be stored at locations outside the refrigerating machinery compartment so that they can be easily retrieved in the event of leakage of the refrigerant. Storage locations are to be marked with signs so that they can be identified easily.

(1) Protective clothing(helmet, safety boots, gloves, etc.) × 2
(2) Self-contained breathing apparatus(capable of functioning for at least 30 minutes) × 2
(3) Protective goggles × 2
(4) Eye washer × 1
(5) Boric acid
(6) Emergency electric torch × 2
(7) Electric insulation resistance meter × 1

Section 5 Refrigerated Chambers

501. Construction of refrigerated chambers

1. Materials used for refrigerated chambers

Decks, floors and boundary bulkheads of refrigerated chambers are to be constructed of materials confirmed to be airtight. However, divisional bulkheads between refrigerated chambers, where the chambers concerned are intended for cargo which will not taint or adversely affect the cargo in any other chamber, may be constructed of appropriate materials subject to the approval of the Society.

2. Airtightness of closing appliances

Closing appliances such as hatch covers, access doors, bilge and manhole covers forming part of the insulated envelope of independently refrigerated chambers, are to be made airtight. Where hatch covers or plugs are exposed to the ambient conditions, they are to be provided with a double seal.

3. Welding and materials of steelworks in refrigerated chambers

Special attention is to be paid to welding and materials of members which are directly welded to the main structural hull members, and structural discontinuities and/or defects in welded joint are to be avoided.

4. Coamings of manholes, etc.

Tank top insulation in way of manholes and bilge hats is to be provided with a liquidtight coaming with a suitable height to prevent seepage into the insulation.

5. Penetration of ventilation ducts and pipes through decks, bulkheads, etc.

(1) Ventilation ducts are not to pass through the collision bulkheads below the freeboard deck. Ducts passing through the other watertight bulkheads are to be provided with an efficient closing appliance which can be operated from a position above the freeboard deck accessible at all times. In the operating position, an indicator is to be provided to show whether the duct is opened or closed.
(2) Refrigerating pipes passing through bulkheads or decks of refrigerated chambers are not to be in direct contact with the steelwork. Airtightness of the bulkheads or decks is to be maintained. Where these pipes pass through deck plating or watertight bulkheads, the fittings and packing of the glands are to be both fireresisting and watertight.
(3) Ventilators, air ducts or pipes passing through refrigerated chambers to other compartments are to be made airtight in way of penetrating parts of insulation, and they are to be effectively insulated in the refrigerated chamber.
(4) Air pipes, sounding pipes, bilge suction pipes and other pipes led from the outside of refrigerated chambers and passing through refrigerated chambers are to be effectively insulated and special consideration is to be given to the arrangement of these pipe lines to prevent freezing of liquid in these pipes.

6. Insulating linings, etc.

Insulation linings, bilge limbers and their covers, hatch covers and access doors to refrigerated chambers are to be constructed of water-vapour-resisting material or covered with such material.

7. Cargo battens

Cargo battens are to be fitted and so arranged on all vertical walls of refrigerated chambers as to provide sufficient space for air circulation and prevent the cargo from coming to contact with the insulation or cooling grids. However, where the form of insulation lining, storage method of cargo, etc. are adequate, and need not provided battens, they may not be required.

8. Gratings

Gratings of suitable form and strength are to be provided on floors of refrigerated chambers so as to provide sufficient space between floors and cargo for free air circulation and prevent the floor insulation from mechanical damage by cargo handling. However, where the floor insulation lining meets the above requirements or cargoes to be loaded are supported on suitable pallets, gratings are not required.

502. Insulation and insulation materials

1. Insulation materials

(1) Insulation materials approved or accepted by the Society are to be used.
(2) If slab formed insulant is used, it is to have suitable strength. Where a binder is used to join slabs each other, it is to be odourless and not to absorb any of the odours from the cargo.

2. Protective coatings

(1) Steelworks to be insulated are to be thoroughly cleaned and coated with an anti-corrosive composition before they are insulated.
(2) All steel bolts, nuts and other fixtures which support or secure insulation materials, joints, coverings, etc. are to be galvanized or protected against corrosion with suitable means.

3. Insulation

(1) The thickness of insulation over all surfaces and the manner in which it is supported are to be in accordance with the approved specification and plans. The insulation is to be strongly fixed so as not to be loose. Where the insulation is of slab form, the joints are to be butted closely together and staggered so as not to be made a gap between the slab forms. Unavoidable crevices between insulations or insulation and structural member are to be filled with suitable insulating material.
(2) Structural members which extend into refrigerated chambers are to be effectively insulated over a sufficient length in the refrigerated chambers to prevent heat penetration into the chambers and supercooling of each member at the place of penetration.

4. Removal of insulation

(1) The insulation of such places that easy access to bilge hats, bilge ways and tank manhole lids is required is to be of plug type and removable.
(2) The insulation in way of bilge suction pipes, air and sounding pipes and other pipe lines is to be removable to the extent necessary for access for inspection.

5. Insulation of oil tank plating

Where the tank top and bulkhead of the oil storage tank form part of the refrigerated chamber walls, air space of sufficient width is to be provided between the tank plating and the insulation, or the surface of the tank plating is to be coated with an oil-proof and oil-tight composition of sufficient thickness approved by the Society, before the insulation is fitted. Where air space is provided between the tank plating and the insulation, free drainage of oil seepage to the gutter way and bilges is to be ensured. Furthermore, such air spaces are to be provided with ventilating pipes led to the open air, and corrosion resisting metalic wire gauze diaphragms are to be fitted at the outlet.

503. Temperature measuring arrangements

1. Number of thermometers and sensors

(1) Two sets of thermometers are to be provided in each refrigerated chamber. At least two sensors are to be connected to each set of thermometer for each chamber.
(2) Unless otherwise required, at least the following number of sensors are to be provided in each chamber, depending upon the volume of the chamber.
(A) Volume up to 300 m^3 : 4
(B) Volume up to 600 m^3 : 5
(C) Volume above 600 m^3 : 5 plus one for above 400 m^3 or fraction thereof.
(3) In addition to those specified in above (2), one sensor is to be fitted in each main stream of air in the suction and delivery sides of each air cooler.

2. Electric thermometers

(1) Electric power supply to each instrument in refrigerated chambers is to be fed by a separate final sub-circuit.
(2) Sensors connected to thermometers in refrigerated chambers are to be properly protected from mechanical damage.

504. Drainage arrangements

1. General

(1) Drainage arrangements are to be in accordance with the relevant requirements in **Pt 5, Ch 6, Sec 4** in addition to the requirements in this chapter.
(2) All refrigerated chambers and air coolers are to have ample continuous drainage.

2. Non-return valves and sealed traps in scupper pipes

(1) Scupper pipes led from refrigerated chambers and air cooler trays are to be provided with non-return valves and liquid sealed traps. However, the pipes led from between deck chambers and air cooler trays may be not provided with non-return valves.
(2) Where scupper pipes from refrigerated chambers and air cooler trays are connected to a common header, each branch pipe is to be provided with a liquid sealed trap, and those from lower hold spaces are to be fitted, in addition, with non-return valves.
(3) Where the chamber temperature contemplated is 0℃ or below, scupper pipes together with non-return valves and liquid sealed traps specified in above (1) and (2) are, if necessary, to be well insulated.
(4) Liquid sealed traps are to have an adequate depth and arranged so as to be accessible for cleaning and refilling with liquid.

Section 6 Tests

601. Tests at the manufacturers works

1. Pressure tests and leak Tests

(1) Machinery components, pressure vessels and pressure piping exposed to a primary refrigerant pressure are to be subjected to hydrostatic tests to the pressure of 1.5 times the design pressure. After hydrostatic tests, they are to be leak tested to a pressure equal to the design pressure.
(2) Machinery components, pressure vessels and pressure piping intended for use with brine are to be subjected to hydrostatic tests to a pressure of 1.5 times the design pressure or 0.4 MPa whichever is the greater.
(3) In general, pressure tests are to be carried out with water or oil and leak tests are to be carried out with air or suitable inert gases or any inert gas with a small amount of the refrigerant added to it.

2. Performance tests

(1) Compressors, fans, primary refrigerant or brine pumps and their prime movers are to be tested for their performance.
(2) Welded parts in pressure vessels and piping are to be tested in accordance with the relevant requirements in **Pt 5, Ch 5, Sec 4** and **Pt 5, Ch 6, Sec 13.**
(3) Electrical equipment is to be tested in accordance with the requirements in **Pt 6, Ch 1.**

602. Shop tests

1. Leak tests

(1) The primary refrigerant system is to be leak tested after the piping arrangement is completed on board the ship, generally with inert gases or inert gases with a small amount of refrigerant added, to a pressure of 90% of the respective design pressures.
(2) The brine system is to be leak tested after the piping arrangement is completed on board the ship to a pressure of 1.5 times the maximum working pressure of the brine pump or 0.4 MPa whichever is the greater.

2. Calibration of thermometers

Thermometers are to be checked for accuracy at the freezing point of water, after they are set up on board the ship, and their accuracy is to comply with the required specification. The records of checking are to be submitted to the Surveyor.

3. Air circulation tests

Where air circulating fans are provided in refrigerated chambers, it is to be ascertained that the velocity of circulating air and the state of air circulation are satisfactory.

4. Functional tests

Automatic control devices, safety devices and alarms are to be ascertained that they operate satisfactorily.

5. Tests after installation

All components of the refrigerating machinery are to be operated under full load condition as far as possible, and changing over to stand-by units is smooth.

6. Defrosting tests

The defrosting arrangement for air coolers are to be tested for satisfactory operation.

Section 7 Loading Port Surveys

701. General

1. General

(1) At the request of the shipowner or his representative, the Surveyor may carry out Loading Port Surveys on a registered refrigerating installation at a loading port in accordance with the requirements in **701. 2**. On completion of the survey to the satisfaction of the Surveyor, Certificate on Loading Port Survey will be issued.
(2) A Loading Port Survey may be carried out concurrently with other surveys of the refrigerating installations such as Annual Surveys.
(3) If there is no Surveyor available at the loading port, the Society may accept the report of a survey held at the loading port by a reliable competent person as considered appropriate by the Society, provided that all requirements of Loading Port Surveys are fulfilled.

2. Items to be Examined

At the Loading Port Survey, the following items are to be confirmed or examined.
(1) The refrigerating installation is to be examined under working condition to confirm that it operates in good order, and the temperatures at that time in the refrigerated chambers are to be noted.
(2) The Surveyor is to ascertain that there is ample generating capacity available for the ships essential services and maximum required power to the refrigerating installation, even when one generator is out of use. Where the electric power source is also used as the ships main power supply, it is to be ascertained that the chamber temperature can be maintained at the specified value with the remaining generators used.
(3) The refrigerated chambers are to be examined in an empty state to ascertain that:
(A) They are clean and free from odour which may adversely affect the cargo to be loaded.
(B) Brine or refrigerant pipe grids, coils of air coolers and connections are free from leakage.
(C) Cargo battens, where fitted to the vertical walls, are in good order.
(D) Cargo gratings or dunnages are available as necessary for the floors or decks.
(E) There is no damage sustained to the insulation or its linings in the refrigerated cargo holds.
(F) All scuppers and bilge suctions for draining the refrigerated cargo holds are in good working order, and water sealed traps are provided. ⚓

CHAPTER 2 CARGO HANDLING APPLIANCES

Section 1 General

101. General

1. Application

(1) The Rules apply to the cargo handling appliances which are installed on the ships classed with the Society, and which are intended to be registered under the Society.
(2) The relevant requirements in the Rules apply to the materials, equipment, installation and workmanship of the cargo handling appliances, unless otherwise specified in the Rules.

2. Equivalency

(1) Cargo gear, cargo ramps and loose gear which do not comply with the requirements of the Rules may be accepted, provided that they are considered by the Society to have the effectiveness equivalent to those complying with the Rules.
(2) Any existing cargo gear, cargo ramps and loose gear designed and manufactured not under the requirements of the Rules may be deemed by the Society to comply with the Rules, provided that they comply with any rules or standards recognized by the Society to be appropriate and have passed the tests and inspection required by the Society.

3. Precautions in Application

(1) As for the cargo gear, cargo ramps and loose gear, precautions are to be taken to any manners of their treatment different from the requirements of the Rules in the flag state of the ship or state of call.
(2) The Society may carry out inspection and issue necessary certificates for the cargo handling appliances according to the designated rules in the capacity of the government of the state concerned or other organization under the authorization by such state or organization.

102. Definitions

For the purpose of the Rules, the terms are defined as following below unless otherwise defined

1. Cargo handling appliances are lifting appliances and loose gear.

2. Lifting appliances are cargo gears and cargo ramps include their installations of driving systems and cargo fittings.

3. Cargo gears are derrick systems, cranes, cargo lifts and other machinery used for the loading and unloading of cargo and other articles except cargo ramps, and include their installations of driving systems and cargo fittings.

4. Structural members are those of cargo handling appliances carrying the safe working load, including cargo fittings and cargo blocks permanently incorporated in the cargo gear and the cargo ramps.

5. Cargo fittings are goose neck brackets, topping brackets, fittings at the derrick boom head, derrick heel lugs, guy cleats, eye fittings, etc. which are permanently fitted to the structural members or the hull structure for the purpose of cargo handling.

6. Loose gears are blocks, ropes, chains, rings, hooks, shackles, swivels, clamps, grabs, lifting magnets, spreaders, etc. which are removable parts used for transmitting the loads of cargo to the structural members.

7. Safe working load is the maximum allowable mass of cargoes specified by the Rules with which the cargo gear and the cargo ramp can be safely operated. It is abbreviated to "*SWL*" and expressed in tons (t).

8. Allowable minimum angle is the angle to horizontal of a derrick boom at which the derrick system is permitted to operate under the safe working load, and expressed in degrees (°).

9. Maximum slewing radius is the radius at which a jib crane is permitted to operate under the safe working load, and expressed in meters (m).

10. Safe working load, etc. are safe working load, allowable minimum angle and other restrictive conditions in case of the derrick systems, safe working load, maximum slewing radius and other restrictive conditions in case of the jib cranes, safe working load and other restrictive conditions deemed necessary by the Society in case of other machinery used for the loading and unloading of cargo, and safe working load and other restrictive conditions deemed necessary by the Society in case of the cargo ramps.

11. Safe working load of a loose gear is the maximum allowable mass of cargoes specified by the Rules with which the loose gear can be used safely. It is abbreviated to "*SWL*" and expressed in tons (t). For cargo blocks, the safe working load is defined according to (1) or (2) below:

(1) The safe working load of a single sheave block is the maximum mass of cargoes that can be safely lifted by that block when it is suspended by its head fitting and the mass is secured to a wire rope passing round its sheave.

(2) The safe working load of a multiple sheave block is the maximum mass of cargoes that may be applied to its head fitting of the block.

12. Derrick systems are installations for handling cargo by suspending the cargo from the top of the derrick boom fitted to derrick post or mast, including those specified in (1), (2) and (3) below:

(1) The end of topping lift being fixed, two guy ropes fitted at the top of the derrick boom are wound by independent winches respectively to swing the boom horizontally(hereinafter referred to as "swinging derrick system").

(2) Two derrick booms, on port and starboard sides, in pair are fixed at predetermined positions. The cargo falls of two derricks are connected to load or unload the cargo(hereinafter referred to as "union-purchase derrick system").

(3) The cargo fall can be paid out or heaved in and luffing and slewing of derrick boom can be carried out singly or simultaneously while the cargo is suspended(hereinafter referred to as "derrick crane system").

13. Cranes cover jib cranes, gantry cranes, overhead cranes and hoists, cargo davits, etc. and are capable of performing the works of cargo loading and unloading, slewing and/or horizontal movement simultaneously or separately.

14. Cargo lifts are the installations designed to contain the cargo in their structure to loading and unloading the cargo.

15. Cargo ramps are the installation mounted on the shell or provided in the ship, and arranged to permit passage of vehicles as cargo or vehicles loaded with cargo on themselves and having mechanism enabling its opening and closing or turning.

16. Lifting load is the sum of the safe working load defined as the maximum mass of cargoes themselves to be suspended and the mass of accessories such as hooks, cargo blocks, grabs, buckets, lifting beams, spreaders, etc. Unless otherwise deemed necessary by the Society, the mass of wire ropes used as cargo falls need not be taken into account except when the installation is designed for a lift of 50 m or more.

17. The acceleration of gravity is to be equal to 9.81 m/sec^2.

103. Arrangement, Construction, Materials and Welding

1. Arrangement

(1) The arrangement and dimensions of the cargo gear and the cargo ramps are to be determined with due consideration given to avoid interference with maneuvering lights, navigation lights and other functions of the ship.

(2) When same parts of the cargo gear are utilized commonly for other functions, such as ventilators, or important systems or equipment designed for other purposes, or further, when some systems or equipment for other purposes are mounted on them, due considerations are to be given to avoid undue interference with each other in relation to their functions and strength.

(3) When any parts of the cargo gear or the cargo ramps project beyond the ship’s side under the working condition, it is recommended that such parts are to be of retractable, foldable or removable type designed for stowing within the line of ship’s side when not in use.

(4) The cargo gear and the cargo ramps are to be provided with equipments for securing the movable parts when not in use.

2. General Construction

(1) The cargo gear and the cargo ramps other than those used ordinary trim and heel in calm weather and sea states, are to comply with, in addition to the requirements in the Rules, such additional requirements as considered appropriate by the Society for the actual working condition.
(2) The requirements in **Sec 3, 4** and **8** assume the use of hull structural rolled steels specified in **Pt 2, Ch 1, 301.** High tensile steels used in the structural members, if any, are to comply with requirements specially made up by the Society. The construction and dimensions of the structural members containing or made of materials other than those steel specified herebefore are to be specially considered by the Society.
(3) The structural members are to be designed to avoid structural discontinuities and abrupt change of sections as far as practicable. The welded joints are to be arranged to avoid the parts where concentration of stress is expected.
(4) Corners of openings in the structural members are to be appropriately rounded off.
(5) Openings causing dimensional anisotropy in the structural members are to be so arranged as their long sides or long axes may assume parallel to the direction of principal stresses.
(6) Where two members having remarkably different stiffness are directly connected with each other, proper reinforcement is to be made by means of brackets, etc. to maintain the continuity of stiffness. Special consideration is to be given to the connection to the hull structures.
(7) The cargo blocks of the structural members are to comply with the requirements in **602.**

3. Direct Calculation of Strength

The dimensions of the structural members are to be determined by the method of direct calculation of strength approved by the Society using the design loads and allowable stresses specified in respective Sections concerned, with the exception of those members for which calculation formulae are given in **Sec 3.**

4. Materials

(1) The hull structural rolled steel used in the structural members are to be as given in **Table 9.2.1** depending on their thickness, except in cases considered appropriate by the Society.
(2) For the cargo gear and the cargo ramps always used in especially cold zones or refrigerated hold chambers and for any other cases considered to be necessary by the Society, the Society may require the use of steel materials of higher notch toughness notwithstanding the requirement specified in (1) above.
(3) Steel casting and steel forgings used in the structural members are, as a rule, to comply with the requirements in **Pt 2, Ch 1, Sec 5** and **Sec 6** respectively or of equivalent qualities.
(4) The materials of bolts and nuts used for connection of components of the structural members are to be considered appropriate by the Society.
(5) Wire ropes used as components of the structural members are to be those specified in **Pt 4** for use as standing riggings or of an equivalent quality.
(6) The materials used in the main parts of the installations of driving systems are to comply with the requirements in **Pt 2, Ch 1** or any standards recongnized by the Society to be of equivalent qualities.

Table 9.2.1 Thickness and Grades of Steels

Thickness t (mm)	$t \leq 20$	$20 < t \leq 25$	$25 < t \leq 40$	$40 < t$
Grade	A/AH	B/AH	D/DH	E/EH

(NOTES)
AH, DH and EH in the Table correspond to the following material grades.
AH : AH 32, AH 36 and AH 40
DH : DH 32, DH 36 and DH 40
EH : EH 32, EH 36 and EH 40

5. Welding

(1) The Welding of the structural members is to comply with the requirements in **Pt 2, Ch 2** and the additional requirements considered necessary by the Society according to the types of construction.
(2) The arrangement of welded joints in the structural members is to be specially considered to avoid remarkable difficulties in welding work.

6. Prevention of Corrosion

(1) The structural members are to be protected against corrosion with coating of a good quality or using other proper means.
(2) Any parts liable to the accumulation of rainwater or dew condensation are to be provided with proper draining means.

Section 2 Surveys

201. General

1. Application

(1) The requirements in this Section apply to the tests and surveys for the cargo handling appliances.
(2) Where the structural members of the cargo handling appliances are permanently fitted to the hull structure or where they form an integral part thereof, the tests and surveys for these parts are to comply with the requirements in this Section and, in addition they are to comply with the relevant requirements of the other Part of the Rules.
(3) At the Periodical Surveys, the Surveyor may require surveys other than those specified in **202.** through **205.** in this Section where deemed necessary.
(4) At Annual Surveys, the Surveyor may reduce the extent and contents of the tests and surveys specified in **202.** through **205.** in this Section, where deemed appropriate, having regard to the purpose, construction, age, history, results of the previous surveys and the current condition of the cargo handling appliances.

2. Preparation for Surveys and Others

(1) All such preparations as required for the survey to be carried out as well as those which may be required by the Surveyor as necessary in accordance with the requirements in the Rules are to be made by the applicant of the survey. The preparations are to include provisions of an easy and safe access, necessary facilities and necessary records for the execution of the survey. Inspection, measuring and test equipment, which Surveyors rely on to make decisions affecting classification are to be individually identified and calibrated to a standard deemed appropriate by the Society. However, the Surveyor may accept simple measuring equipment(e.g. rulers, measuring tapes, weld gauges, micrometers) without individual identification or confirmation of calibration, provided they are of standard commercial design, properly maintained and periodically compared with other similar equipment or test pieces. The Surveyor may also accept equipment fitted on board a ship and used in examination of shipboard equipment(e.g. pressure, temperature or rpm gauges and meters) based either on calibration records or comparison of readings with multiple instruments.
(2) The applicant for the survey is to arrange a supervisor who is well conversant with the survey items intended for the preparation of the survey to provide the necessary assistance to the Surveyor according to his requests during the survey.
(3) The survey may be suspended where necessary preparations have not been made, any appropriate attendant mentioned in the previous (2) is not present, or the Surveyor considers that the safety for execution of the survey is not ensured.
(4) Where repairs are deemed necessary as a result of the survey, the Surveyor will notify his recommendations to the applicant of the survey. Upon this notification, the repair is to be made to the satisfaction of the Surveyor.

3. Presentation of Certificates

All of the certificates for cargo handling appliances issued by the Society are to be kept on board and presented to the Surveyor when requested at the tests and surveys.

4. Records of the Surveys

The "Register of Ship’s Lifting Appliances including Cargo Handling Gears" is to be made necessary entries on it and endorsed by the Surveyor at the completion of the Surveys.

5. Notification of Survey Results

(1) The Society is to notify the results of the Survey to the applicant in a form of Survey Report.
(2) In case where repairing is requested on the Survey Report, the repairs are to be made to the satisfaction of the Society.
(3) The Survey Report in (1) above is to be kept on board and presented to the Surveyor when requested at the subsequent Survey.

6. Re-Survey

In case where the applicant has any complaints in the Survey carried out in accordance with the Rules, he may request execution of re-survey in writing to the Society.

202. Surveys of Cargo Handling Appliances

1. Kinds of Surveys

The kinds of Surveys for cargo handling appliances are as follows:
(1) Registration Survey
(A) Registration Survey during Construction
(B) Registration Survey after Construction
(2) Periodical Survey for maintaining registration
(A) Annual Survey
(B) Load Test
(3) Occasional Survey

2. Due range

The timing of the Surveys of cargo handling appliances are to be in accordance with the followings:
(1) A Registration Surveys are to be carried out when the safety working load, etc. are assigned for the first time.
(2) Annual Survey is to be carried out within 3 months before or after each anniversary date.
(3) Load Test is to be carried out at the Registration Survey and at the dates not exceeding 5 years from the date of completion of the Registration Survey or the previous Load Test.
(A) When serious damage is caused on the structural members and the repair or conversion is made
(B) When major conversion is made in the cargo handling procedures, rigging arrangements, operation and control methods
(C) When the assignment and marking of safe working load, etc. is altered
(D) Other cases when considered necessary by the Society

3. Periodical Surveys carried out in Advance

Periodical Surveys may be carried out in advance of the due date of each Survey upon application by the Owner.

203. Registration Surveys

1. Drawings and Other Documents to be Submitted

(1) At a Registration Survey, it is to be ascertained that the strength and construction of the cargo handling appliances comply with the Rules based on the drawings and documents submitted to the Society. In this case, the applicant is to submit the relevant drawings and documents out of listed in (2), (3) and (4) below.
(2) The relevant drawings and documents listed in the following (A) through (K) are to be submitted for approval for cargo handling appliances to be newly constructed;
(A) General arrangement of cargo gears and cargo ramps
(B) Construction drawings of cargo gears and cargo ramps(including the dimensions of structural members, specifications of materials and joint details)
(C) Drawings of cargo fittings(including the dimensions, specifications of materials and the fixing methods of these fittings with structural members or hull structure)
(D) Arrangement of loose gears(including rigging arrangement)
(E) List of loose gears(showing the construction, dimensions, materials and locations. For those in compliance with the well-known code or standard, the type symbol may be used in place of dimensions and materials)
(F) Construction drawings of driving gears
(G) Power system diagram
(H) Drawings of operation and control mechanism
(I) Drawings of safety devices
(J) Drawings of protective devices
(K) Other drawings and documents as deemed necessary by the Society

(3) The relevant drawings and documents listed in the following (A) through (G) are to be submitted for reference for cargo handling appliances to be newly constructed;
 (A) Specifications for cargo gears and cargo ramps
 (B) Calculation sheets or check sheets relevant to drawings and documents for approval specified in (2) above
 (C) Operation manual for cargo gears and cargo ramps
 (D) Procedures of non-destructive testing
 (E) Procedures of Load tests
 (F) Where materials which contain asbestos are used, documents including the location and other detailed information.
 (G) Other drawings and documents as deemed necessary by the Society
(4) At a Registration Survey of cargo handling appliances not built under Survey, the drawings and data to be submitted for the cargo handling appliances are to be same as specified in (2) and (3) above. However, some of these drawings and documents may be omitted submitting the past survey records and certificates with respect to them subject to approval by the Society.

2. Examinations for Workmanship

(1) Workmanship of cargo handling appliances is to be examined and ascertained to be in good order when any of the following (A) through (E) is relevant;
 (A) When, in process of manufacturing and assembling of structural members, requested by the Society
 (B) When structural members are installed on board the ship
 (C) For driving gears, at the times when the finishing work on major parts is completed and when the Surveyor considers necessary during the process of manufacture
 (D) When the subcontracted materials, parts or equipment are incorporated to the cargo handling appliances
 (E) Other cases when considered necessary by the Society
(2) Cargo handling appliances are to be examined and ascertained to be in good order by the following tests and surveys;
 (A) Testing as specified in **Pt 2, Ch 1** where the materials need to be in compliance with the requirements in **Pt 2, Ch 1**
 (B) Testing as specified in **Pt 2, Ch 2** where the welding works need to be in compliance with the requirements in **Pt 2, Ch 2**
 (C) Non-destructive testing where requested by the Surveyor
 (D) Shop trial of the driving gears
 (E) Operation tests of the cargo handling appliances
 (F) Operation tests of the safety devices and protective devices(including braking tests and electric power source cut-off tests with a testing weight equal to the safe working load applied)
 (G) Other tests considered necessary by the Society

204. Annual Surveys

1. Derrick Systems

(1) At Annual Surveys, the following items in (A) are to be visually examined for derrick systems and ascertained to be in good order. Where considered necessary by the Surveyor, the items in (B) are to be examined.
 (A) Items to be examined
  (a) Structural members
  (b) Connection between the structural members and hull structure
  (c) Driving systems
  (d) Safety devices and protective devices
  (e) Markings of the safe working load, etc., and the effectiveness of the relevant certificates
  (f) Preservation of the instruction manuals on board the ship
 (B) Items to be examined where considered necessary by the Surveyor
  (a) Checking of plate thickness of the structural members, non-destructive testing and open-up examinations of the topping brackets, goose neck brackets and derrick heel lugs
  (b) Open-up examination of the driving systems
  (c) Operation tests of the safety devices and protective devices
(2) At the fifth Annual Survey from the date of completion of the Registration Survey or the previous open-up examination but not exceeding 5 years, the open-up examination of the topping brackets, goose neck brackets and derrick heel lugs is to be carried out.

2. Cranes

At Annual Surveys, the following items in (A) are to be visually examined for cranes and ascertained to be in good order. Where considered necessary by the Surveyor, the items in (B) are to be examined.

(A) Items to be examined
 (a) Structural members
 (b) For stationary cranes, the connection between the structural members and hull structure
 (c) For track-mounted cranes, rails, buffers and the connection between those members and hull structure
 (d) Installations of driving system
 (e) Safety devices and protective devices
 (f) Markings of the safe working load, etc., and the effectiveness of the relevant certificates
 (g) Preservation of instruction manuals on board the ship
(B) Items to be examined where considered necessary by the Surveyor
 (a) Checking of plate thickness of the structural members, non-destructive testing and open-up examinations of the bearings
 (b) Inside of the posts, their legs and stiffeners of cranes
 (c) Open-up examinations of the driving gears
 (d) Operation tests of the safety devices and protective devices

3. Cargo Ramps

At Annual Surveys, the items in (A) are to be visually examined for cargo ramps in detail and ascertained to be in good order. Where considered necessary by the Surveyor, the items in (B) are to be examined.

(A) Items to be examined
 (a) Structural members
 (b) Connection between the structural members and hull structure
 (c) Connection between the stoppers and hull structure
 (d) Water-tight or weather-tight arrangements of cargo ramps that are used as water-tight or weather-tight doors when closed
 (e) The driving gears
 (f) Safety devices and protective devices
 (g) Markings of the safe working load and the effectiveness of the relevant certificates
 (h) Preservation of the instruction manuals on board the ship
(B) Items to be examined where considered necessary by the Surveyor
 (a) Plate thickness measurements, open-up-inspection of lifting pins, nondestructive tests, etc.
 (b) Hose testing or airtight testing for cargo ramps that are used as water-tight or weather-tight doors when closed
 (c) Open-up examinations of the driving gears
 (d) Operation tests of safety devices and protective devices

4. Cargo Lifts, etc.

(1) At Annual Surveys, the items in (A) are to be visually examined for cargo lifts in detail and ascertained to be in good order. Where considered necessary by the Surveyor, the items in (B) are to be examined.
 (A) Items to be examined
  (a) Structural members
  (b) Connection between the holding parts of cargo lifts and hull structure
  (c) Connection between the lifting/lowering devices of cargo lifts and hull structure
  (d) Driving gears
  (e) Safety devices and protective devices
  (f) Markings of the safe working load and the effectiveness of the relevant certificates
  (g) Preservation of the instruction manuals on board the ship
 (B) Items to be examined where considered necessary by the Surveyor
  (a) Plate thickness measurements, open-up-inspection of lifting pins, nondestructive tests, etc.
  (b) Open-up examinations of the driving gears
  (c) Operation tests of the safety devices and protective devices
(2) At Annual Surveys for other cargo handling appliances used for loading and unloading of cargoes and other articles, they are to be visually examined and ascertained to be in good order. When considered necessary by the Surveyor, a further examination may be carried out.

5. Loose Gears

(1) At Annual Surveys, the following items in (A) through (C) of loose gears are to be visually examined and ascertained to be in good order. However, where considered necessary by the Surveyor, the items in (B) are to be opened up and examined.
(A) Wire ropes for their full length
(B) Cargo blocks, chains, rings, hooks, shackles, swivels, lifting beams, cramps, rigging screw grabs, lifting magnets, spreaders, etc.
(C) Markings of the safe working load and identification symbols, and the effectiveness of the relevant certificates

(2) In case where some of loose gears need to be repaired or renewed at times other than at the Periodical Surveys, the Society may accept an autonomous inspection carried out by ship's master or his representative. In this case, the personnel who carried out an autonomous inspection is to record the following (A) through (F) for the loose gears renewed in the Inspection Record Book of Loose Gear, and show this Inspection Record Book and the certificates of the loose gears concerned to the Surveyor for his approval at the next Periodical Survey or Occasional Survey.
(A) Names and identification symbols
(B) Locations in service
(C) Safe working loads
(D) Testing loads
(E) Dates of renewal or repairs and dates of commencement of use
(F) Reasons for renewal or repairs

205. Load Tests

(1) At Load Tests, cargo handling appliances are to be examined by applying movable weights or loads at least equal to the test loads as specified in (2) below and in the manners specified in (3) or (4) depending on the types of cargo handling appliances and ascertained that they are in good order. However, Load Tests of loose gears may be omitted provided that the certificates with testing records of them are examined.

(2) The test loads used for Load Tests are to comply with the requirements of the following (A) through (C) depending on the types of cargo handling appliances;
(A) The test loads for cargo gears and cargo ramps are to be as given in **Table 9.2.2**
(B) The test loads for loose gears except for ropes are to be as given in **Table 9.2.3**
(C) The test loads for ropes are to satisfy the following formula;

$$T \geq W \cdot f$$

where,

T : Test loads for ropes (t)

W : Safe working loads of ropes (t)

f : Safety factors specified in **603. 1** (E) or **603. 2** (C)

Table 9.2.2 Test Load for Cargo Gear and Cargo Ramps

Safe working load SWL (t)	Test load (t)
$SWL < 20$	$1.25 \times SWL$
$20 \leq SWL < 50$	$SWL + 5$
$50 \leq SWL < 100$	$1.1 \times SWL$
$100 \leq SWL$	Load as considered appropriate by the Society

Table 9.2.3 Test Loads for Loose Gears

Article of Gear		Safe Working Load SWL (t)	Test Load (t)
Pulley blocks	Single-sheave block without becket	-	$4 \times SWL$
	Single-sheave block with becket	-	$6 \times SWL$
	Multi-sheave block	$SWL \leq 25$	$2 \times SWL$
		$25 < SWL \leq 160$	$(0.933 \times SWL) + 27$
		$160 < SWL$	$1.1 \times SWL$
Chain hook, shackle, ring, link, swivel, clamp and similar gear		$SWL \leq 25$	$2 \times SWL$
		$25 < SWL$	$(1.22 \times SWL) + 20$
Lifting beam, Lifting magnet, spreader and similar gear		$SWL \leq 10$	$2 \times SWL$
		$10 < SWL \leq 160$	$(1.04 \times SWL) + 9.6$
		$160 < SWL$	$1.1 \times SWL$

(3) For cargo handling appliances of which the safe working loads, etc. are assigned for the first time, the methods of load tests are to comply with the following requirements in (A) through (E);

(A) Derrick systems

(a) In case of a swinging derrick system, the test weight is to be slewed throughout the working range at the allowable minimum angle and then lifted/lowered at some position of the working range.

(b) In case of a derrick crane, in addition to (a) above, the derrick boom is to be luffed with suspending the test weight at the position of outreach and ship's centre line.

(c) In case of a union-purchase derrick system, the test weight is to be maneuvered throughout the working range within the allowable lifting height or the maximum angle between two cargo falls specified in **902. 3.**

(B) Cranes

(a) In case of a jib crane, the test weight is to be slewed throughout the working range at the maximum slewing radius and then lifted/lowered at some position of the working range.

(b) In case of a track-mounted cranes, the crane with the test weight suspended is to be transveresed throughout the working range and test weight is to be lifted/lowered at some position. Further, jib is to be luffed at some position of the working range.

(c) In case of a track-mounted hoisting gear, the hoisting gear with suspending the test weight is to be traversed from one end of the bridge span to the other and the test weight is to be lifted/lowered at some position.

(C) Cargo lifts

In case of a cargo lift, the test weight is to be so spaced that the most severe working condition is available taking into account one side loading, and the cargo lift is to be moved between each stop position, and to be lifted/lowered within the entire stroke of motion.

(D) Cargo ramps

In case of a cargo ramp, the test weight is to be placed on the severest position of loading in the designed loading conditions, and the deflection is to be measured. As far as practicable, a vehicle with the mass corresponding to the safe working load is to run on the cargo ramp.

(E) In case of loose gear, the test load is to be loaded in the method considered as appropriate by the Society.

(4) For the cargo handling appliances other than described in (3) above, the methods of load tests are to comply with the following requirements in (A) or (B).

(A) The load test specified in (3) (A), (B), (C), or (D) above is to be carried out.

(B) The load test may be carried out using a spring or hydraulic weighing machine anchored suitably and safely in accordance with the method considered appropriate by the Society.

Section 3 Derrick Systems

301. General

1. Application

The requirements in this Section apply to the structural members of derrick systems.

302. Design Loads

1. Load Considerations

The loads to be taken into the calculations of dimensions of the structural members are to be as specified in (A) through (F) below:
(A) Safe working load of the derrick systems
(B) Self-weight of derrick boom and cargo fittings attached thereto
(C) Self-weight of loose gear
(D) Friction of cargo blocks
(E) Loads due to ship inclination
(F) Other loads considered to be necessary by the Society

2. Friction of Cargo Blocks

In calculating the load at the rope end, the following friction load coefficients are to be taken into account depending on the types of bearing:
Bush bearing : 0.05
Roller bearing : 0.02

3. Load due to Ship Inclination

The angles of inclination used for the calculation of the loads due to ship inclination are to be the angles expected to occur in service condition, but they are not to be taken as less than 5° in angle of heel and 2° in angle of trim. If data on the angles of inclination of the ship concerned are submitted and recognized as appropriate by the Society, however, these angles may be used in the calculations.

4. Load Combinations

(1) The load to be used in the strength analysis of the structural members is to be such a combined load that these members may be put in the most severe load condition considering the loads specified in **Par 1** above.
(2) The union-purchase derrick system is to be analyzed as a swinging derrick system and a union-purchase derrick system respectively using the combined load according to the requirement in (1) above.

303. Strength and Construction of Derrick Posts, Masts and Stays

1. Strength Analysis

(1) The strength of derrick posts, masts(hereinafter referred to as "posts") and stays are to be analyzed for the combined load specified in **302. 4** to determine the dimensions of their members in accordance with the requirement in **Par 2** and **Par 3** below.
(2) The Young's modulus of the wire ropes to be used in the analysis of strength of stayed posts is to be 30.4 kN/mm^2 and 45.1 kN/mm^2 for the case of determining the dimensions of posts and stays respectively.

2. Allowable Stress for Combined Loads

(1) The combined stress calculated by the following formula on the basis of the compressive stress due to bending moment, the compressive stress due to axial compression and the shearing stress due to twisting of the member is not to exceed the allowable stress σ_a given in **Table 9.2.4.**

$$\sqrt{(\sigma_b+\sigma_c)^2+3\tau^2} \quad (N/mm^2)$$

Where,

σ_b : Compressive stress due to bending moment (N/mm^2)

σ_c : Compressive stress due to axial compression (N/mm^2)

τ : Shearing stress due to twisting of member (N/mm^2)

Table 9.2.4 Allowable Stress σ_a

Safe working load W (t)	Allowable stress σ_a (N/mm^2)
$W < 10$	$0.50\sigma_y$
$10 \le W < 15$	$(0.016W+0.34)\sigma_y$
$15 \le W < 50$	$0.58\sigma_y$
$50 \le W < 60$	$(0.005W+0.33)\sigma_y$
$60 \le W$	$0.63\sigma_y$
(NOTES) σ_y : Specified yield stress or proof stress of material (N/mm^2)	

(2) The tension of the wire ropes used for stay is not to exceed the value obtained by dividing the value of breaking test loads specified in **Pt 4, Table 4.8.11** by the safety factor specified in **603. 1** (E).

3. Minimum Plate Thickness of Posts

The plate thickness of posts is not to be less than 6 mm.

4. Construction of Posts

(1) The lower part of the post is to be effectively connected to hull structures by any of the following methods (A), (B) or (C), or any other method approved as appropriate by the Society:
(A) To be supported by two or more superposed decks
(B) To be supported by deckhouse of an enough strength
(C) To be supported by bulkhead for an ample depth beneath the deck

(2) The post well below the base to well above the goose neck bracket is to be of the dimensions equivalent to that at the base as far as practicable.

(3) The post is to be locally reinforced by the use of thicker plating, doubling plates, additional reinforcing members, etc. in the connection of post body and portal beam, the parts where the goose neck brackets and topping brackets are fitted, etc. and the parts where stress concentration expected.

(4) At the ends of the upper portal, its depth and plate thickness are to be properly increased. When opening hole at the end of the upper portal is avoidable, properly reinforcement is to be provided around the opening hole.

304. Strength and Construction of Derrick Booms

1. General

The strength of derrick booms is to be analyzed for the load conditions specified in **302. 4** and their dimensions are to be determined according to the requirements in **Par 2** to **Par 5** below.

2. Strength for Combined Load

The combined stress calculated by the following formula on the basis of the compressive stress due to twisting of the member is not to exceed the allowable stress σ_a given in **Table 9.2.5.**

$$\sqrt{(\sigma_b + \sigma_c)^2 + 3\tau^2} \qquad (\mathrm{N/mm^2})$$

Where,

σ_b : Compressive stress due to bending moment $(\mathrm{N/mm^2})$

σ_c : Compressive stress due to axial compression $(\mathrm{N/mm^2})$

τ : Shearing stress due to twisting of member $(\mathrm{N/mm^2})$

Table 9.2.5 Allowable Stress σ_a

Safe working load W (t)	Allowable stress σ_a $(\mathrm{N/mm^2})$
$W < 10$ $10 \leq W < 15$ $15 \leq W$	$0.34\sigma_y$ $(0.018W + 0.16)\sigma_y$ $0.43\sigma_y$
(NOTES) σ_y : Specified yield stress or proof stress of material $(\mathrm{N/mm^2})$	

3. Buckling Strength

For member subjected to compression, the value obtained from the following formula is not to exceed the allowable stress σ_a given in **Table 9.2.5.**

$$1.15\omega\sigma_c \qquad (\mathrm{N/mm^2})$$

Where,

σ_c : Axial compressive stress $(\mathrm{N/mm^2})$

ω : Coefficient calculated by the formula in **Table 9.2.6** and **Table 9.2.7** for the slenderness ratio and type of the member concerned

4. Combined Compressive Stress

The compressive stress due to combination of the compressive stress due to axial compression and that due to bending moment is to meet the following formula:

$$\frac{\sigma_c}{\sigma_{ca}} + \frac{\sigma_b}{\sigma_a} \leq 1.0$$

where,

σ_a : Allowable bending stress given in **Table 9.2.5** $(\mathrm{N/mm^2})$

σ_{ca} : Allowable compressive stress to be taken as a quotient of σ_a divided 1.15 $(\mathrm{N/mm^2})$

σ_b : Compressive stress due to bending moment $(\mathrm{N/mm^2})$

σ_c : Compressive stress due to axial compression $(\mathrm{N/mm^2})$

Table 9.2.6 Formula for ω

Relation of λ and λ_0	Type of member	Formulae for ω
$\lambda \geq \lambda_0$	All members	$2.9\left(\frac{\lambda}{\lambda_0}\right)^2$
$\lambda < \lambda_0$	Plate members	$\frac{1+0.45(\lambda/\lambda_0)}{1-0.5(\lambda/\lambda_0)^2}$
	Cylindrical members	$\frac{0.87+0.46(\lambda/\lambda_0)+0.12(\lambda/\lambda_0)^2}{1-0.5(\lambda/\lambda_0)^2}$

(NOTES)
1. λ is the slenderness ratio of the member subjected to compression to be obtained from the following formula:

$$l_e\sqrt{\frac{A}{I}}$$

where,
A : Sectional area of the member (m^2)
I : Moment of inertia of section of member (m^4)
l_e : Effective length of the member to be determined as the product of the actual length of the member and coefficient K obtained from the following **Table 9.2.7** for respective end conditions (m):

2. λ_0 is the value obtained from the following formula:

$$\sqrt{\frac{2\pi^2 E}{\sigma_y}}$$

where,
π : The circular constant
E : Young's modulus (N/mm^2)
σ_y : Specified yield stress or proof stress of material (N/mm^2)

Table 9.2.7 Values of K

Another end	One end			
	R : con. D : con.	R : con. D : free	R : free D : con.	R : free D : free
R : con. D : con.	0.5	1.0	0.7	2.0
R : con. D : free	1.0	-	2.0	-
R : free D : con.	0.7	2.0	1.0	-
R : free D : free	2.0	-	-	-

(NOTES)
R : Rotation D : Displacement con. : constrained

5. Minimum Plate Thickness of Derrick Booms

The plate thickness used for the body of derrick booms is not to be less than 2 % of the outside diameter at middle of the effective length of the boom or 6 mm, whichever is the greater.

6. Reinforcement of Derrick Booms

(1) The plating at the head of the derricks booms to which fittings are attached is to be provided with doubling plates or reinforced by other suitable means.
(2) Where cargo fittings for whipped rigging are attached to the boom, proper reinforcement is to be made by doubling plates or other suitable means.

7. Derrick Boom Stopper for Dropping Out

Derrick booms are to be supported by a goose neck bracket and to be safeguarded against dropping out of their sockets or supports.

305. Simplified Calculation Method for Post and Stays of Swinging Derrick Systems

1. Application

Notwithstanding the provisions in **303. 1** through **3,** the dimensions of posts and stays of swinging derrick systems may be determined according to the requirements in **305.**

2. Diameter of Post at the Base

The outside diameter of post at the base is not to be less than the value obtained from the following formula. For elliptic or oval section, its minor diameter is to be regarded as the outside diameter, while the short side is to be regarded as the outside diameter for rectangular cross section.

$$5h \quad (\text{cm})$$

where,

h : Vertical distance from the base of post to the topping bracket (m)

3. Section Modulus of Post at the Base

(1) The section modulus of unstayed posts at the base is not to be less than the value obtained according to (A) through (C) below depending upon the arrangement of derrick booms.
(A) When a derrick boom is fitted on either of forward or afward side of the post, the section modulus is to be the value obtained from the following formula:

$$C_1 C_2 \rho W \quad (\text{cm}^3)$$

where,

W : Safe working load (t)

ρ : Slewing radius at the allowable minimum angle (m)

C_1 and C_2 : Coefficients obtained from **Table 9.2.8.** For intermediate values of W, the coefficients C_1 and C_2 are to be obtained by interpolation.

Table 9.2.8 Values of C_1 and C_2

W (t)	2 or less	3	4	5	6	7	8	9	10
C_1	1.35	1.25	1.20	1.17	1.15	1.14	1.13	1.12	1.10
C_2	125	120	117	115	114	113	112	111	110

(B) The section modulus about the axis parallel to the longitudinal direction of the ship is to be the value obtained from (A) above or the value obtained from the following formula, whichever is the greater, when two derrick booms are fitted on both the forward and aftward the post.

$$\sum C_2 W u \quad (\mathrm{cm}^3)$$

where,

$\sum C_2 W$: Sum of $C_2 W$ for derrick booms situated forward and aftward the post respectively Where C_2 and W are those obtained from (A) above

u : Distance from the center of the post to the side of the ship, plus the outreach (m)

(C) Where derrick booms are supported by an independent structure other than the post, the section modulus is not to be less than obtained from the formula in (A) and (B) above, multiplied by the value obtained from the following formula. In this case, the coefficient C_1 in the formula specified in (A) above is to be taken as 1.0.

$$\frac{h}{h-h'}$$

where,

h' : Vertical distance from the base of the post to the center of horizontal pin of the goose neck bracket (m)

h : As specified in **Par 2** above

(2) The section modulus of stayed posts at the base may be the value specified in (1) above reduced by the value obtained from the following formula:

$$10\frac{h^3}{d_m}\sum R \quad (\mathrm{cm}^3)$$

where,

h : As specified in **Par 2** above

d_m : Outside diameter of the post at the base in the direction in which R assumes minimum in the slewing range for the formula in (1) (A) above, or in the axis parallel to the athwartship direction of the ship for the formula in (1) (B) above (cm)

$\sum R$: Sum of the values obtained from the following formula for each effective stay:

$$\frac{d_s^2 a^2}{l_0 l_s^2}$$

where,

d_s : Diameter of the wire rope for stays (mm)

l_s : Length of stays between the upper and lower ends (m)

l_0 : Length equal to l_s reduced by the value obtained from the following formula: (m)

$0.045 d_s + 0.26$ (m)

a : Length of horizontal projection of the stays measured in the same direction as the measurement of d_m (m)

(3) Where the derrick booms are supported by a king post with a portal having uniform cross section, the section modulus of the post at the base is not to be less than the values obtained from (A), (B) and (C) below:

(A) The section modulus about the axis parallel to the athwartship direction of the ship is to be the value obtained by the formula in (1) (A) multiplied by the following coefficient C_P :

0.7 for $r \geq 0.6$
$1-0.5r$ for $r < 0.6$

where,

r : Ratio of the breadth of the cross section of the portal to the diameter of the post at the base in the longitudinal of the ship

(B) The section modulus about the axis parallel to the longitudinal direction of the ship is to be the values obtained from (1) (A) or (B) above, whichever is the greater, multiplied by the following coefficient:

0.35 for $r' \geq 0.3$
$0.5-1.67r'^2$ for $r' < 0.3$

where,

r' : Ratio of the depth of the cross section of the portal to the diameter of the post at the base in the athwarship direction

(C) Where the distance between posts on the port and starboard sides exceed 2/3 of the height of the post, the coefficients specified in (A) and (B) above are to be suitably increased.

(4) The section modulus of the stayed king post at the base is not to be less than the values obtained from (A) and (B) below:

(A) The section modulus about the axis parallel to the athwartship direction of the ship is to be the value obtained from the following formula:

$$C_P\left(C_1 C_2 \rho W - 10\frac{h^3}{d_m}\sum R\right) \quad (\text{cm}^3)$$

where,

C_P : As specified in (3) (A) above
C_1, C_2 and ρ : As specified in (1) (A) above
$10\frac{h^3}{d_m}\sum R$: Values obtained according to (2) above, provided that stays on one side only are to be taken into account

(B) The section modulus about the axis parallel to the longitudinal direction of the ship is to be the value given in (3) (B) above.

(5) The section modulus of the short side post at the base supporting the derrick boom is not to be less than the value obtained according to (A) or (B) below:

(A) When a derrick boom is fitted on either of the forward or aftward the side post, the section modulus is to be the value obtained from the following formula:

$$85\frac{h'}{h-h'}\rho W \quad (\mathrm{cm}^3)$$

where,

W and ρ : As specified in (1) (A) above

h' : As specified in (1) (C) above

h : As specified in **Par 2** above

(B) Where derrick booms are fitted on the forward and aftward the side post, the section modulus of the side post about the parallel to the longitudinal direction of the ship is to be the greater of the value obtained from (A) above or the value obtained from the formula in (A) above using, in place of ρW, the product of the sum of W values for the forward and aftward booms and the value u given in (1) (B) above, provided that u is to be measured from the center of the side post.

4. Dimensions of Post other than at the Base

(1) The post from well below the base to well above the goose neck bracket is to be of the dimensions equivalent to that at the base as far as practicable.

(2) The diameter and thickness of the post above the position specified in (1) above may be gradually reduced according to the following (A) and (B).

(A) The outside diameter where the outrigger or the topping bracket are fitted may be 85 % of the diameter at the base.

(B) The plate thickness at any arbitrary position of the post is not to be less than obtained from the following formula.

$$0.1d_m + 2.5 \quad (\mathrm{mm})$$

where,

d_m : Minimum outside diameter of the post at each position (cm)

5. Outriggers

Outriggers are to be properly constructed and of sufficient strength.

6. Portals

(1) The section modulus of the portal of uniform section fitted to the king post is not to be less than the values obtained from (A) to (C) below:

(A) The section modulus about the vertical axis is to the value obtained from the formula given in **Par 3** (1) (A) above multiplied by the coefficient obtained from the following formula. Where this coefficient exceeds 0.2, it may be taken as 0.2.

$$0.1 + 0.235\frac{r}{c}$$

where,

r : As specified in **Par 3** (3) (A) above

c : Ratio of the actual section modulus (cm^3) of the post at the base about the axis parallel to the athwarship direction of the ship to that obtained from the formula in **Par 3** (1) (A) above

(B) Notwithstanding the requirements in (A) above, the section modulus of the portal about the vertical axis may be reduced to a half of the value in (A) above where derrick boom is fitted only on one side of the forward of post.

(C) The section modulus about the horizontal axis is to be the value obtained from the formula in **Par 3** (1) (B) above multiplied by the coefficient obtained from the following formula. Where this coefficient exceeds 0.2, it may be taken as 0.2.

$$0.25\frac{r'}{c'}$$

where,

r' : As specified in **Par 3** (3) (B) above

c' : Ration of the actual section modulus (cm^3) of the post at the base about the axis parallel to the longitudinal direction of the ship to that obtained from the formula in **Par 3** (1) (B) above

(2) The portal is to be properly stiffened so as to prevent the deformation due to bending.

7. Stays

The tension in wire ropes used for stays is to be less than the value obtained from the following formula.

$$18\frac{d_s^2 a}{l_0 l_s}\delta \qquad (\mathrm{kN})$$

where,

a, d_s, l_0 and l_s : As specified in **Par 3** (2) above. In this case, a is to be measured in the same direction as in the calculation of the value of δ.

δ : Value obtained from the following formula:

$$C_s\frac{h}{h-h'} \cdot \frac{\rho W}{\frac{I}{h^2}+7.32h\sum R}$$

where,

I : Moment of inertia of section (cm^4) of the post at the base about the axis parallel to the athwarship direction of the ship. For the king posts, however, the value of I divided by the coefficient C_P given in **Par 3** (3) (A) above is to be used in place of I.

h : As specified in **Par 2** above

h', W and ρ : As specified in **Par 3** (1) (A) and (C)

$\sum R$: As specified in **Par 3** (2) above. In this case, a is to be measured in all directions in the slewing range of the derrick boom in calculating $\sum R$

C_s : Value given in **Table 9.2.9.** For intermediate values of W, the coefficient C_s is to be obtained by interpolation.

Table 9.2.9 Values of C_s

W (t)	2 or less	3	4	5	6	7	8	9	10	15 and above
C_s	2.64	2.52	2.46	2.41	2.38	2.35	2.33	2.31	2.29	2.22

306. Simplified Calculation Methods for Derrick Booms

1. General

Notwithstanding the requirements in **304. 1** through **5**, the dimensions of derrick booms may be determined in accordance with requirements in this **306.**

2. Derrick Booms without Whipped Rigging

(1) The dimensions of derrick booms of derrick system without whipped rigging are not to be less than obtained according to (A), (B) and (C) below:

(A) The moment of inertia of derrick boom at the middle post is not to be less than obtained from the following formula:

$$C_B P l^2 \qquad (\mathrm{cm}^4)$$

where,

C_B : Value obtained from **Table 9.2.10**

l : Effective length of derrick boom (m) (See **Fig 9.2.1**)

P : Axial compression of derrick boom to be determined according to (a) or (b) depending on the type of the derrick systems. When the self-weight of derrick boom and its fitting are accurately estimated, the value obtained from the force diagram may be used as P.

(a) Swinging Derrick Systems

$$P=\left(\alpha_1 \frac{l}{h-h'}+f\right) Wg \qquad (\mathrm{kN})$$

where,

W and h' : As specified in **305. 3** (1) (A) and (C)

h : As specified in **305. 2**

α_1 : Value obtained from **Table 9.2.11.** For intermediate values of W, α_1 is to be obtained by interpolation.

f : Coefficient obtained from **Table 9.2.12.** depending on the number of cargo block for cargo fall. Where the cargo fall is carried to the top of the post through the sheave fixed to the top of the boom, f may be taken as zero.

Table 9.2.10 Values of C_B

Safe working load W (t)	C_B
$W \leq 10$	0.28
$10 < W < 15$	$0.40-0.012W$
$15 \leq W \leq 50$	0.22
$50 < W$	Value as considered appropriate by the Society

Table 9.2.11 Values of α_1

W (t)	2 or less	3	4	5	6	7	8	9	10	above 10
α_1	1.28	1.23	1.20	1.18	1.16	1.15	1.14	1.13	1.13	Value as considered appropriate by the Society

Table 9.2.12 Values of f

n	1	2	3	4	5	6	7	8
f	1.102	0.570	0.392	0.304	0.251	0.216	0.192	0.172

(NOTES)
n : The sum of sheaves of cargo block for cargo fall.

(b) Derrick systems other than swinging derrick systems

$$P=\left(\alpha_1\frac{l}{h-h'}+f\right)Wg+\frac{Kn_1\alpha_1\alpha_2}{n_2\sqrt{b^2+l^2}}l\,Wg \quad \text{(kN)}$$

where,

α_1, l, h, h', f and W : As specified in (a) above
α_2 : As specified **502. 2**
b : Horizontal distance from the goose neck bracket to guy post (m)
n_1 : Number of guy ropes
n_2 : Number of topping ropes
K : Values given in **Table 9.2.13** depending on the type of rigging

Table 9.2.13 Values of K

Rigging system	K
Type A	0
Type B	1.2
Type C	2.0

(NOTES)
1. Type A is rigging system having two guy tackles on port and starboard sides of the top of the post so that these guy tackles may also serve as topping lifts.
2. Type B is a rigging system having a deltaplate connecting the end of topping lift and ends of port and starboard side guy ropes so that the tension of topping lift may absorb the slackening of guy ropes.
3. Type C is a rigging systems having a connecting block connecting the end of guy rope(s) of both sides (or of one side) and the topping lift led along the derrick post so that the slackening of guy rope(s) may be absorbed by the topping lift.

(B) In derrick booms with tapered end parts, the parallel part in the midlength is, as a standard, to be of a length equal to 1/3 of the effective length, and the diameter at the ends is not to be less than 60 % of the diameter of the parallel midlength part.
(C) The thickness of steel plate used for the body of derrick booms is not to be less than the value obtained from the following formula or 2 % of the outside diameter at the middle part whichever is the greater.

6 (mm) for $P < 75.5$ (kN)
$5+0.0133P$ (mm) for $P \geq 75.5$ (kN)

(2) The shape and dimensions of the derrick boom of swinging derrick system may be in accordance with any other standards recognized by the Society to be equivalent.

3. Derrick Booms with Whipped Rigging

The dimensions of derrick booms of derrick system with whipped rigging are not to be less than obtained according to (A) and (B).

(A) The moment of inertia of section at an arbitrary position at a distance of x (m) from the center of eye fitting at derrick heel is not to be less than obtained from the following formula. Where a doubling plate is fitted for a sufficient length, 70 % of the doubling plate may be added to $D(x)$ and $A(x)$ in the formula.

$$I(x) = C_B P l^2 \left\{ 1 - 3.136 \left(\frac{x}{l} - 0.5 \right)^2 \right\} + \frac{D(x) l_1 x}{2\left(\sigma_0 - \frac{P}{A(x)} \times 10 \right) l} \cdot \frac{Wg}{N} \cos\theta \times 10^3$$

where,

$I(x)$: Required moment of inertia of section at a distance of x (m) from the derrick heel (cm^4)

C_B : As specified in **Par 2** above

P : Axial compression of boom specified in **Par 2** (1) (A) (kN)

l : Effective length of boom (m)

W : Safe working load as specified in **305. 3** (1) (A) (t)

N : Sum of sheaves of cargo block for cargo fall(except cargo block for cargo relief)

θ : Allowable minimum angle of boom (degree)

l_1 : Distance between the eye fittings for whipped rigging (m) (See **Fig 9.2.1**)

$D(x)$: Outside diameter of derrick boom at a distance of x (m) from the boom heel minus plate thickness (cm)

$A(x)$: Sectional area of derrick boom at a distance of x (m) from the boom heel (cm^2)

σ_0 : Value given in **Table 9.2.14** (N/mm^2)

(B) The length of parallel part at the middle, the diameter at ends and the plate thickness of the boom body are to be as specified in **Par 2** (1) (B) and (C) above.

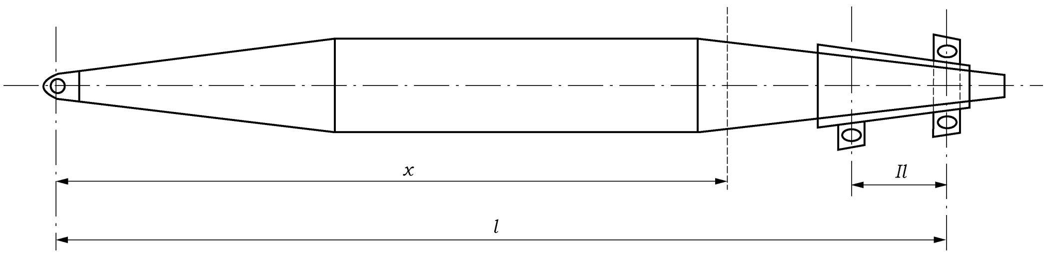


Fig 9.2.1 Derrick Boom with Whipped Rigging

Table 9.2.14 Values of σ_0

Safe working load W (t)	σ_0
$W \leq 10$	80.4
$10 < W < 15$	$4.04W + 40.0$
$15 \leq W \leq 50$	100.6
$50 < W$	Value as considered appropriate by the Society

Section 4 Cranes

401. General

1. Application

The requirements in this Section apply to the structural members of cranes.

402. Design Loads

1. Load Considerations

The loads to be taken into the calculation of dimensions of structural members are to be those related to the crane concerned among the items enumerated from (A) to (K) below:

(A) Safe working load of the cranes
(B) Additional impact loads
(C) Self-weight of crane system and cargo fittings attached thereto
(D) Self-weight of loose gear
(E) Friction of cargo blocks
(F) Horizontal forces
(G) Wind loading
(H) Buffer forces
(I) Loads due to ship inclination
(J) Loads due to ship motion
(K) Other loads considered necessary by the Society

2. Additional Impact Loads

(1) The additional impact load is to be the product of the lifting load and the impact load coefficient given in **Table 9.2.15** depending on the type of cranes. When the stress due to hoisting of cargo and the stress due to the self weight have different signs in a member, 50 % of additional impact load is to be taken into account in addition to the self-weight, considering the shock due to unloading.
(2) Notwithstanding the requirements specified in (1) above, additional impact load coefficient based on actual measurements taking into account the hoisting speed, deflections of girders, length of ropes, etc. may be used in place of the values given in **Table 9.2.15.**

Table 9.2.15 Additional Impact Load Coefficient

Types of cranes	Additional impact load coefficient
Provision handling crane, machinery handling crane, maintenance crane and hose handling crane	0.10
Jib crane and gantry crane for cargo handling	0.25
Jib crane and gantry crane occasionally used with hydraulically operated or rope-operated bucket, etc. for cargo handling	0.40
Jib crane and gantry crane always using grab, lifting magnet, etc. for cargo handling and offshore jib crane	0.60

3. Friction of Cargo Blocks

The friction of cargo blocks is to be as specified in **302. 2.**

4. Horizontal Forces

(1) In track-mounted cranes, the transverse forces due to travel motion is to be taken into consideration as a factor of horizontal force in addition to the inertial force and centrifugal force.

(2) The inertial force is to be obtained by multiplying the sum of the mass of the moving parts and the lifting load(in slewing motion, the load is assumed to be at the top of jib) by the following coefficient depending on the condition of motion. In the case of travelling by driven wheels, however, this inertial force need not exceed 15 % of the driving wheel load.

Level luffing motions : $0.01\sqrt{V}$
Traversing or travelling motions : $0.008\sqrt{V}$
Slewing motions : $0.006\sqrt{V}$

where,
V : Velocity of motion concerned to be determined by the designer (m/min)

(3) Notwithstanding the requirements in (2) above, the values of the actual acceleration deceleration characteristics, the actual braking time, etc. for the mode of motion concerned may be used as the inertial forces, if such values are known.

(4) For a system having structural members which will make slewing motions while supporting the safe working load, the centrifugal force determined from following formula is to be taken into consideration

$$\frac{Wv^2}{R} \quad (\mathrm{kN})$$

where,
W : Safe working load (t)
R : Slewing radius (m)
v : Circular speed (m/sec)

(5) The transverse force due to travel motions is to be calculated from the following formula:

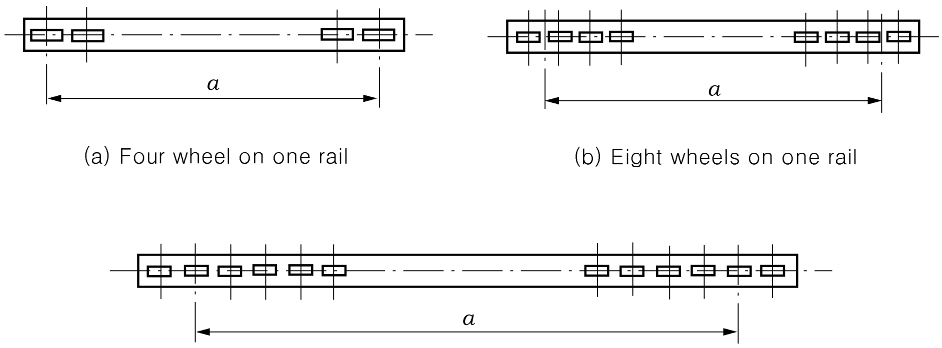
$$\lambda D \quad (\mathrm{kN})$$

where,
D : Wheel load (kN)
λ : Transverse force coefficient to be determined from the following formula depending on the value of l/a. However, λ need not exceed 0.15:

$$0.05 \qquad \text{for} \quad \frac{l}{a} \leq 2$$

$$\frac{1}{60}\left(\frac{l}{a}+1\right) \qquad \text{for} \quad \frac{l}{a} \leq 2$$

Where,
l : Span of rails (m)
a : Effective wheel base to be determined according to **Fig 9.2.2**



(a) Four wheel on one rail

(b) Eight wheels on one rail

(c) More than eight wheels on one rail

Fig 9.2.2 Measurement of Effective Wheel Base

5. Wind Loading

(1) The wind loading is to be calculated by the following formula:

$$F = PA \times 10^{-3} \quad (\mathrm{kN})$$

where,

F : Wind loading (kN)

A : Sum of structural members and cargo under wind pressure in projection in respective wind direction, corresponding to respective conditions of the cargo gear (m^2). When a girder is wholly or party protected from wind by another girder, the areas of the superposed portions may be multiplied by the reduction factor (η) obtained from **Fig 9.2.3.** The distance b between girders is to be as given in **Fig 9.2.4.**

P : Wind pressure calculated by the following formula (Pa)

$$\frac{1}{16} C_h C_s g V^2 \quad (\mathrm{Pa})$$

where,

V : Wind velocity according to (A) and (B) below (m/sec)

(A) The velocity of wind giving effect on the structural members and cargo in the service conditions is to be the design wind velocity specified by the applicant, but not be less than 16 m/sec.

(B) The velocity of wind giving effect on the structural members in the stowage conditions is to be the design wind velocity specified by the applicant. In no case is the design wind velocity to be less than 51.5 m/sec. In ships with restricted navigation areas, however, the design wind velocity may be decreased according to the degree of restriction as approved by the Society in the range down to 25.8 m/sec.

C_h : "Height factor" to be determined according to **Table 9.2.16** depending on the height of the position is question from the light weight waterline.

C_s : "Shape factor" to be determined according to **Table 9.2.17** depending on the shapes of various parts of the cargo gear and the cargo.

(2) Notwithstanding the requirements in (1), the data on wind loading obtained by wind tunnel tests for the structural members and cargo may be used for calculations.

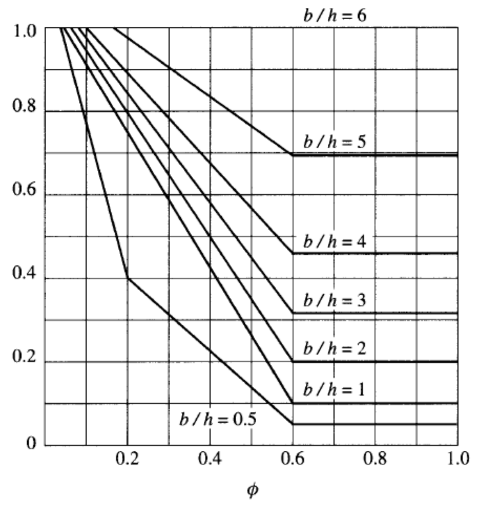


Fig 9.2.3 Repleteness Ratio, ϕ and versus Reduction Factor, η

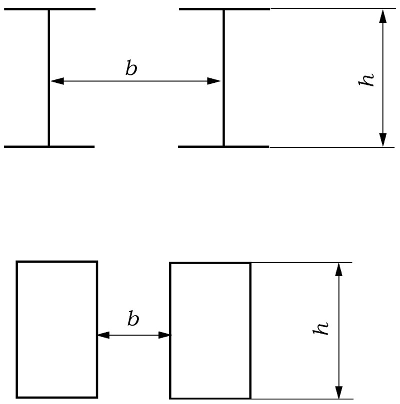
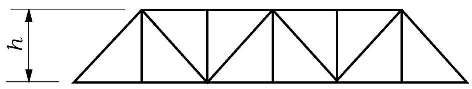
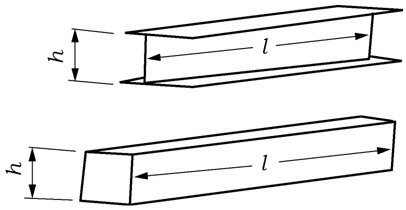
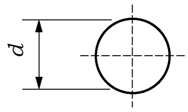


Fig 9.2.4 Distance between two neighbouring girders, b

Table 9.2.16 Height Factor C_h

Vertical height h (m)	C_h
$h < 15.3$	1.00
$15.3 \leq h < 30.5$	1.10
$30.5 \leq h < 46.0$	1.20
$46.0 \leq h < 61.0$	1.30
$61.0 \leq h < 76.0$	1.37
$76.0 \leq h$	Value as considered appropriate by the Society

Table 9.2.17 Shape Factor C_s

Type of area under wind pressure			C_s
Truss of angle		$\phi < 0.1$ $0.1 \le \phi < 0.3$ $0.3 \le \phi < 0.9$ $0.9 \le \phi$	2.0 1.8 1.6 2.0
Plate girder or Box girder		$\frac{l}{h} < 5$ $5 \le \frac{l}{h} < 10$ $10 \le \frac{l}{h} < 15$ $15 \le \frac{l}{h} < 25$	1.2 1.3 1.4 1.6
Cylindrical member or truss of cylindrical member		$d\sqrt{q} < 1.0$ $1.0 \le d\sqrt{q}$	1.2 0.7

(NOTES)
ϕ : Repleteness ratio equal to the ratio of projected area under wind pressure to the projected area surrounded by the outer contour of the area under wind pressure
l : Length of plate girder or box girder (m)
h : Height of plate girder or box girder looked at from windward (m)
d : Outer diameter of cylindrical member (m)
q : Value calculated by the following formula:
$$\frac{1}{16} C_h \cdot g V^2 \times 10^{-3} \quad (\text{kPa})$$

6. Buffer Forces

(1) The buffer forces are assumed to be the loads in the crane system originating from collision with buffer at a speed equal to 70% of the rated speed when no cargo is suspended from the crane. In a crane system having a rigid guide, etc. to limit the swinging of suspended cargo due to collision, the influence of the cargo weight is also to be taken into consideration.
(2) Notwithstanding the requirement in (1) above, in a crane system designed to be automatically decelerated before colliding the buffer, the speed after deceleration may be regarded as the rated speed in the requirement in (1) above.

7. Loads due to Ship Inclination

The angles of inclination used for the calculation of loads due to ship inclination are not to be less than the values specified below:

In service conditions : 5° in angle of heel and 2° in angle of trim occurring simultaneously
In stowage conditions : 30° in angle of heel

8. Loads due to Ship Motion

The accelerations used for the calculation of loads due to ship motion are the severest of the combinations (A) or (B) below for the stowage condition, and values recognized by the Society to be appropriate for the service condition. If data on the ship's motions are submitted and recognized by the Society to be appropriate, the values in such data may be used in the calculations.

(A) $\pm 1.0g$ in the direction normal to the deck and $\pm 0.5g$ in the longitudinal direction parallel to the deck
(B) $\pm 1.0g$ in the direction normal to the deck and $\pm 0.5g$ in the transverse direction parallel to the deck

9. Load Combinations

(1) The load to be used in the strength analysis of structural members is to be such a combined load that these members may be put in the severest loading condition considering the loads specified in (2) through (5) below.

(2) When the wind loading is not taken into account in service condition, the sum of loads from (A) to (I) below multiplied by a work coefficient given in **Table 9.2.18** according to the type of crane concerned is to be considered.

(A) Safe working load of the cranes
(B) Additional impact loads
(C) Self-weights of crane system and cargo fittings attached thereto
(D) Self-weights of loose gear
(E) Friction of cargo blocks
(F) Horizontal loads
(G) Loads due to ship inclination
(H) Loads due to ship motion(except those intended to cargo handling in harbours only)
(I) Other loads considered necessary by the Society

(3) When the wind loading are to be taken into consideration in the service conditions, the wind loading is to be added to the design load as specified in (2) above.

(4) The buffer forces as given in **Par 6** above are to be taken into consideration for the track-mounted cranes.

(5) In stowage condition, the loads from (A) to (E) below are to be considered

(A) Self-weights of crane system and cargo fittings attached thereto
(B) Wind Loading in the stowage conditions
(C) Loads due to ship inclination in the stowage conditions
(D) Loads due to ship motion stowage conditions
(E) Other loads considered necessary by the Society

Table 9.2.18 Work Coefficient of Crane Systems

Type of crane	Work coefficient
Provision handling crane, machinery handling crane, maintenance crane and hose handling crane	1.00
Jib crane and gantry crane for cargo handling	1.05
Jib crane and gantry crane occasionally used with hydraulically operated or rope-operated bucket, etc. for cargo handling	1.10
Jib crane and gantry crane always using grab, lifting magnet, etc. for cargo handling and offshore jib crane	1.20

403. Strength and Construction

1. General

(1) The strength of structural members is to be analyzed on the load conditions specified in **402. 9** to determine their dimensions according to requirements in **Par 2** through **Par 9** below.
(2) For structures connected by bolts and nuts, proper considerations are to be given to the decrease of effective sectional areas.
(3) When considered necessary the Society may require the confirmation of the appropriateness of strength analyses by examination of models or the things in question.

2. Allowable Stress for Combined Loads

The allowable stress given in **Table 9.2.19** are to be used for components subjected to combined loads.

3. Buckling Strength

For members subjected to compression, the values obtained from the following formula is not to exceed the allowable compressive stress given in **Table 9.2.19.**

$$\omega\sigma_c \quad (\mathrm{N/mm^2})$$

where,

ω and σ_c : As specified in **304. 3**

4. Combined Compressive Stress

When the compressive stress of a member is determined as a combination of compressive stress due to axial compression and that due to bending moment such a compressive stress is to comply with the following formula:

$$\frac{\sigma_c}{\sigma_{ca}} + \frac{\sigma_b}{\sigma_a} \leq 1.0$$

where,

σ_b : Compressive stress due to bending moment $(\mathrm{N/mm^2})$

σ_c : Compressive stress due to axial compression $(\mathrm{N/mm^2})$

σ_a : Allowable bending stress given in **Table 9.2.19** $(\mathrm{N/mm^2})$. For fixed posts at the base, however, the allowable stress σ_a in **Table 9.2.4** is to be used.

σ_{ca} : Allowable compressive stress given in **Table 9.2.19** $(\mathrm{N/mm^2})$. For fixed post at the base, however, the allowable stress $(\mathrm{N/mm^2})$ is to be taken equal to the allowable stress in **Table 9.2.4** divided by 1.15.

Table 9.2.19 Allowable Stress σ_a

Load Condition	Kind of stress					
	Tension	Bending	Shear	Compression	Bearing	Combined stress
Condition specified in **402. 9** (2)	$0.67\sigma_Y$	$0.67\sigma_Y$	$0.39\sigma_Y$	$0.58\sigma_Y$	$0.94\sigma_Y$	$0.77\sigma_Y$
Condition specified in **402. 9** (3)	$0.77\sigma_Y$	$0.77\sigma_Y$	$0.45\sigma_Y$	$0.67\sigma_Y$	$1.09\sigma_Y$	$0.89\sigma_Y$
Condition specified in **402. 9** (4) and (5)	$0.87\sigma_Y$	$0.87\sigma_Y$	$0.50\sigma_Y$	$0.76\sigma_Y$	$1.23\sigma_Y$	$1.00\sigma_Y$

(NOTES)
1. σ_Y : Specified yield stress or proof stress of material (N/mm^2)
2. The combined stress is to be the value obtained from the following formula:

$$\sqrt{\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y+3\tau_{xy}^2} \quad (N/mm^2)$$

where,

σ_x : Applied stress in x-direction at the middle of plate thickness (N/mm^2)
σ_y : Applied stress in y-direction at the middle of plate thickness (N/mm^2)
τ_{xy} : Applied shear stress in the $x-y$ plane (N/mm^2)

5. Fatigue Strength

Where the influence of repeated stress cannot be neglected, the member is to have an ample strength against fatigue with due consideration for the magnitude and frequency of repeated stress, the form of the member in question, etc.

6. Minimum Thickness

The thickness of structural members is not to be less than 6 mm.

7. Strength of Bolts, Nuts and Pins

Bolts, nuts and pins are to have sufficient strength for the magnitudes and directions of the loads they are subjected to.

8. Fixed Posts

(1) The fixed posts are to be effectively connected to the hull structure in accordance with the requirements in **303. 4** (1).
(2) The upper part of fixed post where the flange is attached is to be sufficiently reinforced by increasing the plate thickness or by providing of brackets.

9. Slewing-Ring Fixing Bolts

(1) Any material having a tensile strength exceeding 1.18 kN/mm^2 and yield stress exceeding 1.06 kN/mm^2 is not to be used for the bolts fixing the slewing-rings except when special considerations have given to the strength characteristics of the bolts.
(2) Special considerations are to be given to the tightening force of fixing bolts.
(3) The stress generated in fixing bolts is not to exceed the allowable stress given in **Table 9.2.20** according to the load conditions specified in **402. 9.** In this case, the stress in bolts is taken as the value of the axial compression determined by the following formula divided by the minimum sectional area of fixing bolts.

$$\frac{4M}{D \cdot N}-\frac{W}{N} \quad (N)$$

where,

M : Upsetting moment ($N \cdot mm$)
D : Pitch circle diameter of fixing bolts (mm)
N : Number of fixing bolts
W : Axial compression on the slewing-ring (N)

Table 9.2.20 Allowable Stress of Fixing Bolts σ_a

Load condition	σ_a
Condition specified in **402. 9** (2) and (3)	$0.4\,\sigma_y$
Condition specified in **402. 9** (5)	$0.54\,\sigma_y$
(NOTES) σ_y : Specified yield stress or proof stress of the material (N/mm^2)	

404. Special Requirements for Track-mounted Cranes

1. Stability

The track-mounted cranes are to have an sufficient stability under the load conditions specified in **402. 9.**

2. Prevention of Upsetting

The track-mounted cranes are to be designed with sufficient considerations for the stability to prevent upsetting even if the wheel shafts or wheels are damaged.

3. Deflection Criteria

When suspending the safe working load, deflection of the traveling girder of the track-mounted cranes is not to exceed 1/800 of the span between the supporting points.

4. Travel Gear

The travel gear is to be securely fixed to the main body of the track-mounted cranes by bolts, welding or pins. The inclinations of hull in service condition and stowage condition are to be taken into consideration.

5. Buffers

The track-mounted cranes are to be provided with buffers in accordance with (A) and (B) below, except when automatic system for prevention of collision is provided.

(A) At both ends of tracks or any other equivalent positions. These buffers may be replaced by stops of a height not less than 1/2 of the diameter of wheels.

(B) Where more than two track-mounted cranes are provided on one track, between these track-mounted cranes.

Section 5 Cargo Fittings

501. General

1. Application

The requirements in this Section apply to the cargo fittings.

502. Cargo Fittings

1. Goose Neck Brackets and Derrick Heel Lugs

(1) The sizes of goose neck pin, cross bolt and derrick heel lug shown in **Fig 9.2.5** are to be not less than the following values. The sizes of other parts are to be as deemed appropriate by the Society.

$$b = e_1 \sqrt{\frac{P}{g}} \quad (\mathrm{mm})$$

$$c = 0.55 e_1 \sqrt{\frac{P}{g}} \quad (\mathrm{mm})$$

$$d = e_1 \sqrt{\frac{P}{g}} \quad (\mathrm{mm})$$

where,

P : Design axial compressive force acting on derrick boo (kN)

e_1 : 15.6. However, in the swinging derrick system, the values given in **Table 9.2.21** may be used according to the safe working load.

(2) It is recommended that clearance at parts where the cross bolt penetrates through the derrick heel lug and the gooseneck pin of gooseneck bracket is to be less than 2 mm in diameter. The size of the outer parts of bolt holes for the gooseneck pin and derrick heel lug is to be of the same size at the cross bolt radius, as a standard.

(3) Notwithstanding the requirements in (1) above, the sizes of gooseneck bracket and derrick heel lug may be in accordance with any other standards recognized by the Society. However, for the cargo fittings used for other than the swinging derrick systems, consideration to the effect of increasing load caused by the guy ropes is to be given.

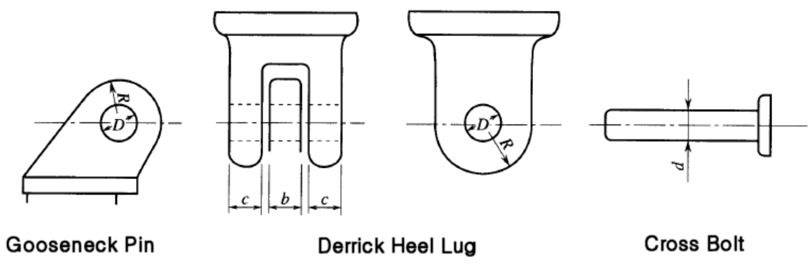


Fig 9.2.5 Gooseneck Pin, Derrick Heel Lug and Cross Bolt

Table 9.2.21 Values of e_1

Safe working load W (t)	e_1
$W \le 10$	15.6
$10 < W < 15$	$18.8 - 0.32W$
$15 \le W \le 50$	14.0
$50 < W$	Value as considered appropriate by the Society

2. Cargo Fittings attached to Head of Derrick Booms

(1) The sizes of cargo fittings attached to the head of derrick booms are not to be less than the values given in the following (A) to (C) according to the respective purpose and shapes of the fittings:

(A) Where the shape of cargo fittings attached to the head of derrick boom are as given in **Fig. 9.2.6**, the sizes of them are not to be less than the following values. The sizes of other parts are to be as deemed appropriate by the Society.

$$d = e_2\sqrt{\frac{T}{g}} \ (\mathrm{mm})$$

$$t = e_2\sqrt{\frac{T}{g}} \ (\mathrm{mm})$$

where,

e_2 : Value as given in **Table 9.2.22**

T : Maximum tension applied to cargo fitting at the head of derrick boom (kN). However, in the swinging derrick system, the following value may be used:

$\alpha_1\alpha_2 Wg$ for topping lift

λWg for cargo fall

where,

W : Safe working load (t)

α_1 : As specified in **306. 2**

α_2 : As given in **Table 9.2.23** depending on the value of $l/(h-h')$. However, for intermediate values of α_2, it is to be obtained by interpolation.

λ : Value given in **Table 9.2.24** depending on the number of sheaves of blocks for cargo fall. However, the value of λ may be taken as 1.0 where the cargo fall is led to the top of derrick post through the sheave incorporated in the head of the derrick boom.

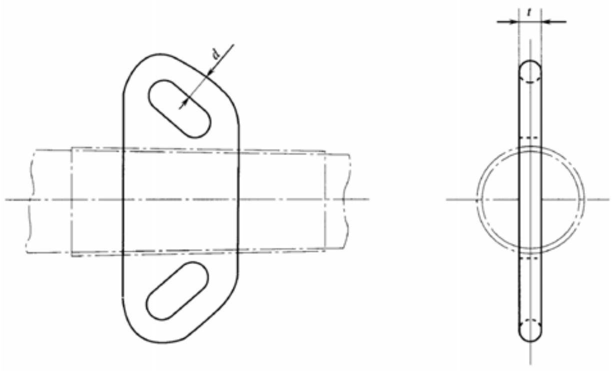


Fig 9.2.6 Cargo Fitting attached at Head of Derrick Boom

Table 9.2.22 Values of e_2

Safe working load W (t)	e_2
$W \leq 10$	12.5
$10 < W < 15$	$15.1 - 0.26W$
$15 \leq W \leq 50$	11.2
$50 < W$	Value as considered appropriate by the Society

Table 9.2.23 Values of α_2

$l/(h-h')$		2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2
α_2	$W < 10$	1.99	1.90	1.81	1.73	1.65	1.57	1.49	1.42	1.35
	$15 \leq W < 50$	1.82	1.73	1.65	1.57	1.49	1.41	1.33	1.26	1.19
(NOTES) l, h and h' : As specified in **306. 2.**										

Table 9.2.24 Values of λ

Sum of the number of sheaves of blocks for cargo fall	1	2	3	4	5	6	7	8
λ	2.10	1.58	1.40	1.31	1.26	1.23	1.20	1.18

(B) Where the shape of cargo fitting attached to the head of cargo derrick boom is as shown in **Fig 9.2.7**, the sizes of them are not to be less than the following values. The sizes of other parts are to be as deemed appropriate by the Society.

$$R \geq D$$

$$t = e_1 \sqrt{\frac{T}{g}} \quad \text{(mm)}$$

However, where the value of R is larger than $1.15D$, the value obtained from the following formula may be taken:

$$t = \frac{e_3}{\left(R - \frac{D}{2}\right)} \cdot \frac{T}{g} \quad \text{(mm)}$$

where,

e_1 : As specified in **Par 1** (1) above

T : As specified in (A) above

e_3 : As given in **Table 9.2.25**

(C) The sizes of guy fittings attached the head of derrick boom are to be enough against the design load.

(2) Notwithstanding the requirements in (1) above, the sizes of cargo fittings attached at the head of derrick boom may be in accordance with any other standards recognized by the Society to be equivalent. However, for the cargo fittings used for other than the swinging derrick systems, consideration to the effect of increasing load caused by the guy ropes is to be given.

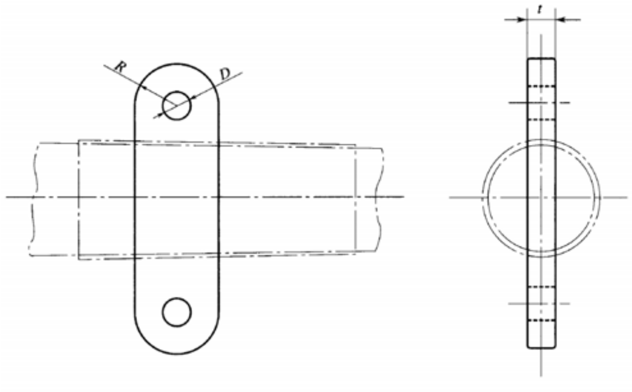


Fig 9.2.7 Fitting attached at Head of Derrick Boom

Table 9.2.25 Values of e_3

Safe working load W (t)	e_3
$W \le 10$	122
$10 < W < 15$	$170 - 4.8W$
$15 \le W \le 50$	98
$50 < W$	Value as considered appropriate by the Society

3. Other Cargo Fittings

The sizes of the other cargo fittings such as topping bracket, guy cleat, eye and so on, may be in accordance with any other standards recognized by the Society. However, for the topping bracket used for other than the swinging derrick systems, consideration to the effect of increasing load caused by the guy ropes is to be given.

Section 6 Loose Gear

601. General

1. Application

The requirements in this Section apply to the loose gear.

2. General Requirements

When the safe working load is applied to the cargo gear and cargo ramps, the load created in the important part of those loose gears and ropes is not to be exceed the respective specified safe working load.

602. Cargo Blocks

1. Cargo Blocks for Wire Ropes

The cargo blocks for wire ropes are to comply with the following requirements (A) through (D). However, in sheaves for equalizer sheaves or those for overload sensors, they are to be as deemed appropriate by the Society. (See **Fig 9.2.8**)

(A) The diameter of the sheave at the bottom of the rope groove is not to be less than 14 times the wire rope diameter.
(B) The depth of the groove of the sheave is not to be less than the wire rope diameter.
(C) The bottom of the groove of the sheave is to have a circular contour over a segment sustained by angle of not less than 120°
(D) The groove diameter of the sheave is to be 1.1 times the wire rope diameter, as a standard.

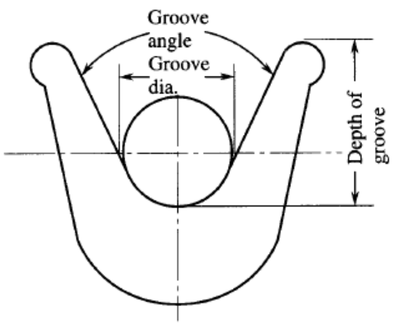


Fig 9.2.8 Sheave Groove

2. Cargo Blocks for Fibre Ropes

The cargo blocks for fibre ropes are to comply with the following requirements (A) through (C) below:

(A) The diameter of the bottom of the rope groove is not be less than 5.5 times the fibre rope diameter.
(B) The depth of the groove of the sheave is not be less than the fibre rope diameter.
(C) The groove diameter of the sheave is to be the fibre rope diameter plus 2 mm, as a standard.

603. Ropes

1. Wire Ropes

The wire ropes are to comply with the following requirements (A) through (E) below:

(A) The wire ropes are to be subjected to suitable corrosion prevention treatment.
(B) The wire ropes are to be suitable for the purpose of application, and in addition are to attach a certificate stating that they conform to the requirements of **Pt 4, Ch 8** of the Rules for the Survey and Construction of Steel Ships or the requirements of the standards as deemed appropriate by the Society.
(C) No splicing of the wire ropes is permitted.
(D) Terminal connection of wire ropes is to be made in a method approved by the Society to have sufficient strength.
(E) The safety factor of the wire ropes is not to be less than the following value according to their purpose and their safe working load. However, the safety factor of the wire ropes for running rigging may not exceed 5, and those for standing rigging, 4.

$$\frac{10^4}{8.85W+1910} \quad \text{for } W \leq 160$$

$$3 \quad \text{for } W > 160$$

where,

W : Safe working load (t)

2. Fibre Ropes

Fibre ropes are to comply with the following requirements (A) through (C) below:

(A) The fibre ropes are to comply with the recognized standards and to be provided with the certificate deemed appropriate by the Society.
(B) The diameter of the fibre ropes is not to be less than 12 mm.
(C) The safety factor of fibre ropes is not be less than the value given in **Table 9.2.26** depending on the rope diameter.

Table 9.2.26 Safety Factor of Fibre Ropes

Rope diameter D (mm)	Safety Factor
$12 \leq D < 14$	12
$14 \leq D < 18$	10
$18 \leq D < 24$	8
$24 \leq D < 40$	7
$40 \leq D$	6

604. Other Loose Gears

1. General

The design loads of loose gears such as chain, rings, hooks, shackles, swivels, clamps, grabs, lifting beams, lifting magnets, spreader, etc. are not to be more than the value obtained by dividing the breaking strength of each gears by the safety factor of 5.

605. Equivalent Requirements

1. General

Notwithstanding the requirements in **602.** through **604.** above, the constructions of loose gear may be in accordance with any other standards recognized by the Society.

Section 7 Machinery, Electrical Installations and Control Engineering Systems

701. General

1. Application

The requirement in this Section apply to the machinery, electrical installations and control engineering systems used in the cargo handling appliances. However, in applying the requirements in this Section to winches used for cargo ramps, they may be suitably modified.

702. Machinery

1. General

The driving systems of the cargo handling appliances are to be steadily operated in the rated speed under the safe working load.

2. Hoisting Machinery

(1) The construction of the hoisting machinery is to comply with the following requirements (A) through (F) below:

(A) The drum end flange diameter is to have an allowance corresponding to not less than 2.5 times the rope diameter as measured from the outer rim of the outermost layer of ropes in service condition. However, where rope disengagement prevention system is provided or in case of single layer winding on the drum, this requirement may be dispensed with.

(B) The pitch circle diameter of winch drum is to be not less than 18 times the rope diameter.

(C) Winches are to be installed on the winch foundation with foundation bolts having sufficient proof strength against the drum load(the maximum rope tension applied on the drum when the rope is wound under the single winding at a nominal rope hoisting speed) created when the safe working load is applied to the cargo handling appliances.

(D) Braking system complying with the following requirements (a) through (c) below is to be provided:

(a) The braking system is to be able to exert a breaking torque 50 % in excess of the torque required when the safe working load is applied to the cargo handling appliances.

(b) The power operated braking system is to operate automatically when the manoeuvring is returned to its neutral position.

(c) The power operated braking system is to operate automatically when there is any failure in the power supply. In this case, emergency retrieval for cargo lowering is to be provided.

(E) Clutchable drums are to be provided with effective locking system capable of restricting rotation of the drum. The locking system is be, as a rule, capable of resisting the torque not less than 1.5 times the torque required when the safe working load is applied to the cargo handling appliances.

(F) Rope guards or suitable other means of protection are to be provided.

(2) The rope at its end is to be secured to the drum in such a manner that will not damage any part of the rope and to have such a length that not less than 3 complete turns in case of an ungrooved drum, or 2 complete turns in case of a grooved drum are remaining on the drum when the complete working length of rope has been paid out.

703. Power Supply

1. General

(1) The equipment, piping and cables consisting of the electric, hydraulic, pneumatic or steam power supply system and their arrangements are, as a rule, to comply with the relevant requirements of the Rules for the Classification of Steel Ships.

(2) The construction, strength, materials, etc. of internal combustion engine used as the prime mover are to comply with the requirements in **Pt 5.**

704. Control Engineering Systems

1. General

(1) The electric, hydraulic or pneumatic equipments used for the control, alarm and safety systems are, as a rule, to comply with the relevant requirements of the Rules for the Classification of Steel Ships.
(2) The control, alarm and safety systems are to be designed on the basis of the principle of fail-safe.

2. Control System

(1) Control systems are to be so arranged as not interfere with the operator or qualified other personnel giving signals for operation.
(2) Control systems are, as a rule, to be of such design that controls automatically return to the neutral position when control operation by the operator is interrupted.
(3) For electric winches, local power disconnecting switch is to be provided at the position in the proximity of the place of operation.
(4) Cranes and cargo lifts are to be provided with emergency switch capable of stopping all the motions at the position readily accessible for the operator.
(5) Cargo lifts are to be provided with a suitable automatic speed control system that reduces the starting acceleration and stopping deceleration as far as practicable.
(6) Cargo lifts are to be provided with a suitable control system that stops the lift at the specified deck position.
(7) Where cargo lifts are secured by locking latches, suitable means is to be provided so as to prevent the impact load to be induced on the lift in case of withdrawal of the latches.

3. Safety System

(1) The cargo handling appliances are, as a rule, to be provided with an overload protection system.
(2) The cargo handling appliances are to be provided with suitable safety systems capable of preventing the abnormalities given in the following (A) through (F) according to kind of appliances and their motion:
(A) Over hoisting
(B) Over slewing
(C) Over luffing
(D) Excessive travelling speed
(E) Over run on the track
(F) Other items of abnormality recognized by the Society
(3) In cranes where the safe working load varies according to the operating radius, rating chart showing the relationship between the operating radius and safe working load are to be provided in the control cab and in addition, equipment satisfying the following (A) and (B) or (C) is, as a rule, to be provided:
(A) Operating radius indicator
(B) Lifting load indicator
(C) Overload preventer with respect to the safe working load according to the operating radius

4. Protection System

(1) For the rotating parts of the driving machinery, electrical installations and steam pipes, necessary means to protect the operator are to be provided.
(2) Steam winches are to be arranged not to interfere with the operator's field of vision by the steam.
(3) Cargo lifts are to be provided with the protection systems given in the following (A) through (D):
(A) Protective barriers of a height of not less than 1 m above deck level around the deck opening provided for lift platform.
(B) Interlocking system so that cargo lifts cannot be moved unless the barriers are all closed.
(C) Interlocking system that prevents opening of protective barriers unless cargo lifts are at the opening position of the barriers.
(D) Warning lights or suitable other warning signs at the boarding place of cargo lifts.

Section 8 Cargo Lifts and Cargo Ramps

801. General

1. Application

The provisions in this Section apply to the structural members of cargo lifts and cargo ramps.

802. Design Loads

1. Load Considerations

Consideration is to be given to the utilization and duty of the particular type of cargo lifts and cargo ramp in the "in service" and stowage conditions with respect to the following loads listed from (A) to (G) below.

(A) Safe working load
(B) Self-weight of the installation
(C) Wind loading
(D) Wave loading
(E) Loads due to ship inclination
(F) Loads due to ship motion
(G) Other loads considered necessary by the Society

2. Wind Loading

The wind loading is to be calculated according to **402. 5.**

3. Wave Loading

For the structural members forming parts of shell plating and subjected to the wave load, the head of water is not to be less than that obtained from the following formula:

$$\{d - 0.125D + 0.05L' + \Delta H_w(x)\}\frac{gD}{D+2h_s} \quad (\text{kPa})$$

where,

x : Distance from the forward face of stem on the designed maximum load line defined in **Pt 3, Ch 1, 110.** (m)

d : Designed maximum load draught defined in **Pt 3, Ch 1, 111.** (m)

D : Depth of ship defined in **Pt 3, Ch 1, 106.** (m)

L' : Length of ship defined in **Pt 3, Ch 1, 102.** (m). L' is to be taken as 230 m when the length exceeds 230 m.

$\Delta H_w(x)$: Value obtained from the following formula for respective value of x

$$(38 - 45C_b')\left(1 - \frac{x}{0.3L}\right)^2 \quad \text{for} \quad x \le 0.3L$$

$$0 \quad \text{for} \quad x > 0.3L$$

Where,

C_b' : Block coefficient defined in **Pt 3, Ch 1, 113.** C_b' is to be taken as 0.85 when the block coefficient exceeds 0.85.

L : Length of ship defined in **Pt 3, Ch 1, 102.** (m)

h_s : Value shown in **Table 9.2.27** depending on the length of ship

Table 9.2.27 Values of h_s

Length of ship L (m)	h_s
$L \leq 90$	1.95
$90 < L < 125$	$0.01L+1.05$
$125 \leq L$	2.30

4. Loads due to Ship Inclination

The loads due to ship inclination are to be as recognized by the Society to be appropriate.

5. Loads due to Ship Motion

The loads due to ship motion are to be as specified in **402. 8.**

6. Load Combinations

(1) The load combinations to be used in strength analysis of structural members is to be those causing the more severe loading condition of the structural members resulting from the load combinations specified in (2) to (5) below.
(2) The load combination of the following loads (A) to (E) are to be taken into consideration "in service" conditions:
(A) Safe working load
(B) Self-weight of slewing or moving parts of the cargo lifts and cargo ramps
(C) Self-weight of the fixed parts of the cargo lifts and cargo ramps
(D) Loads due to ship inclination
(E) Other loads considered necessary by the Society
(3) The loads (2) (A) and (B) above are to be multiplied by 1.2 for the installations designed to slew or move with cargo loaded thereon/therein and by 1.1 for the cargo ramps designed not to slew or move with cargo loaded thereon.
(4) The following loads (A) to (F) are to be taken into consideration for cargo lifts in stowage conditions.
(A) Loads in stowage conditions
(B) Self-weight of the cargo lifts
(C) Wind loading
(D) Loads due to ship inclinations in navigation
(E) Loads due to ship motions in navigation
(F) Other loads considered necessary by the Society
(5) The following loads (A) to (E) are to be taken into consideration for cargo ramps in stowage conditions.
(A) Self-weight of the cargo ramps
(B) Wind loading
(C) Loads due to ship inclinations in navigation
(D) Loads due to ship motions in navigation
(E) Other loads considered necessary by the Society

803. Strength and Construction

1. General

(1) The strength of structural members is to be analyzed for the load conditions specified in **802. 6** according to the requirements in **Par 2** to **Par 7** below.
(2) For the installations loaded with vehicles, the concentrated loads from wheels corresponding to their loading or running conditions are to be taken into account.
(3) The strength of structural members forming parts of shell plating is, in general, to be equivalent to that of the surrounding hull structure.
(4) The structural members are to have proper stiffeners and, in addition, suitable lashing devices for preventing their vertical and horizontal movements when stowed in position.

2. Allowable Stress for Combined Loads

The allowable stress prescribed in **Table 9.2.28** are to be used for components subjected to combined loads.

Table 9.2.28 Allowable Stress σ_a

Load Condition	Kind of stress					
	Tension	Bending	Shear	Compression	Bearing	Combined stress
Condition given in **802. 6** (2)	$0.67\sigma_Y$	$0.67\sigma_Y$	$0.39\sigma_Y$	$0.58\sigma_Y$	$0.94\sigma_Y$	$0.77\sigma_Y$
Condition given in **802. 6** (4) and (5)	$0.77\sigma_Y$	$0.77\sigma_Y$	$0.45\sigma_Y$	$0.67\sigma_Y$	$1.09\sigma_Y$	$0.89\sigma_Y$

(NOTES)
1. σ_Y : Specified yield stress or proof stress of material (N/mm^2)
2. The combined stress is to be the value obtained from the following formula:

$$\sqrt{\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y+3\tau_{xy}^2} \quad (N/mm^2)$$

where,

σ_x : Applied stress in x-direction at the middle of plate thickness (N/mm^2)
σ_y : Applied stress in y-direction at the middle of plate thickness (N/mm^2)
τ_{xy} : Applied shear stress in the $x-y$ plane (N/mm^2)

3. Lift Deck Plating and Ramp Plating Thickness

(1) The thickness of the plating forming a part of shell plating is not to be less than the thickness of shell plating at the position concerned to be determined regarding the actual stiffener spacing as the frame spacing.
(2) The plate thickness of the plating forming a part of bulkhead is not to be less than the thickness of bulkhead plating at the position concerned to be determined regarding the actual stiffener spacing as the bulkhead stiffener spacing.
(3) For the installations loaded with vehicles the thickness of lift deck plating or ramp plating is not to be less than required for deck plating of the car deck.

4. Minimum Thickness

The thickness of structural members is not to be less than 6 mm in the parts exposed to weather and 5 mm in the parts not exposed to weather.

5. Deflection Criteria

The deflection of the structural members due to the safe working load is to be limited, as a rule, to 1/400 of the span between supports in cargo lifts and 1/250 of the span between supports in cargo ramps.

6. Strength of Bolts, Nuts and Pins

Bolts, nuts and pins are to have ample strength for the magnitudes and directions of the loads they are subjected to.

7. Locking Devices of Cargo Ramps

(1) Stowage locks are to be provided to resist the load resulting from consideration of loads specified in **802. 6** (5).
(2) The hydraulic locking devices are to be designed to keep the ramp locked mechanically even in the event of failure of the hydraulic pressure.
(3) For a cargo ramp utilized commonly as a means for closing openings, the closing devices may be utilized as locking devices, if the area of opening is larger than half of the projected area of the stowed ramp. The design load of the closing devices is to include also the loads specified in **802. 6** (5) in addition to the loads in **Pt 4, Ch 3.**

Section 9 Certification, Marking and Documentation

901. General

1. Application

The requirements in this Section apply to the certification, marking and documentation of the cargo handling appliances.

902. Assignment of Safe Working Load, etc.

1. General

The Society assigns the safe working load, etc., for the cargo handling appliances that have passed the inspection and load tests specified in **Sec 2.**

2. Duplicated Assignment of Safe Working Load, etc.

The Society will assign, at the application of the shipowner, the following (A) or (B) in addition to the safe working load etc. in accordance with the requirements in **Par 1** above:

(A) The maximum load corresponding to an angle smaller than the assigned allowable minimum angle in case of derrick systems
(B) The maximum load corresponding to a radius exceeding the assigned maximum slewing radius in case of jib cranes

3. Assignment for Union-Purchase Derrick Systems

(1) The assignments of the safe working load, etc. for the union-purchase derrick systems are the safe working load and maximum angle between two cargo falls or the safe working load and allowable lifting height (the vertical distance between the highest position of the structure above the upper deck with hatch opening and the delta plate or ring attached to the cargo falls).
(2) The maximum angle between two cargo falls specified in (1) above is not to be assigned to exceed 120 °.

903. Marking of Safe Working Load, etc.

1. Marking for Cargo Gear and Cargo Ramps

(1) On the cargo gear and cargo ramps assigned by the requirements specified in **902.** above, the safe working load, allowable minimum angle, maximum slewing radius and other restrictive conditions are to be marked by using stamps in accordance with the following requirement in (A) through (C):
(A) Derrick systems
At the conspicuous place of the base of derrick boom, the stamp mark of the Society, the safe working load, the allowable minimum angle of the boom and other restrictive conditions are to be marked.
(B) Jib cranes
At the conspicuous place of the base of jib or the similar position, the stamp mark of the Society, the safe working load, the maximum slewing radius and other restrictive conditions are to be marked.
(C) Other cargo gear and cargo ramps
At the conspicuous place which is hardly fouled, the stamp mark of the Society, the safe working load and other restrictive conditions are to be marked.
(2) In the case of the duplicated assignment of safe working loads are assigned to derrick systems and jib cranes in accordance with the requirements of **902. 2**, the necessary markings for respective combinations are to be made correspondingly in according to the requirements of (1) above.
(3) For the cargo gear which is used with grabs, lifting beams, lifting magnets, spreaders and similar other loose gear and assigned the maximum cargo load excluding the self-weight of such loose gear to safe working load, the notation in this connection to be marked as other restrictive conditions correspondingly according to (1) above.
(4) The stamp marks are to be coated with anti-corrosive paint and framed with paint for easy recognition.

(5) In addition to the markings specified in (1), (2) and (3) above, the same markings (except the stamp mark of the Society) are to be made at the conspicuous places with paint, etc. In this case, the size of letters should not be less than 77 mm in height.

2. Marking for Loose Gear

(1) On the loose gear other than wire ropes and fibre ropes, the test load, the safe working load and the identification symbols are to be marked by using stamps at the conspicuous place and no adverse effects are to be caused for both their strength and service. On grabs, lifting beams, lifting magnets, spreaders and similar other loose gear, the self-weight of them are to be stamped additionally.
(2) The stamp marks are to be coated with anti-corrosive paint and framed with paint for easy recognition.
(3) In addition to the markings specified in (1) above, grabs, lifting beams, lifting magnets, spreaders and similar other loose gear are to be marked with the safe working load and the self-weight of them with paint, etc. In this case the size of letters should not be less than 77 mm in height.
(4) Notwithstanding the requirements in (1) and (3) above, where it is difficult to make direct stamp mark or marking with paint, other means may be taken when approved by the Society.

904. Documentation

1. Kinds of Documents

The kinds of the documents issued by the Society for cargo gears, cargo ramps and loose gear are to be as specified in the followings:

(A) Register of Ship’s Lifting Appliances including Cargo Handling Gears(Form CG1)
(B) Certificate of Test and Thorough Examination of Lifting Appliances(Form CG2)
(C) Certificate of Test and Thorough Examination of Lifting Appliances for Operation in Union Purchase(Form CG2(U))
(D) Certificate of Test and Thorough Examination of Loose Gear(Form CG3)
(E) Certificate of Test and Thorough Examination of Wire Rope(Form CG4)
(F) Certificate of Test and Thorough Examination of Fibre Rope(Form CG5)

2. Timing of Issuance of Documents

The timing of issuance of documents specified in **Par 1** above is to be as given in **Table 9.2.29** depending on the tests and survey.

3. Revocation of the Documents

(1) The whole or part of the certificates specified in **Par 1** above will be revoked when either of the following (A) through (I) is relevant:
(A) When application is made by the shipowner for cancellation or alteration of the assignment of the safe working load, etc.
(B) When the construction, arrangement or rigging of the cargo handling appliances are altered
(C) When the cargo handling appliances are removed
(D) When the surveys specified in **Sec 2** are not subjected to
(E) When the cargo handling appliances are considered to be unserviceable by the Surveyor
(F) When the contents in the certificates are intentionally altered
(G) When the contents in the certificates have become illegible due to foul or damage
(H) When the specified fee covering the survey is not paid
(I) In case where the Society has a doubt on the effectiveness of the certificates, etc.
(2) The certificates which become invalid in accordance with the provisions in (1) above are to be returned to the Society without delay.

4. Reissuance and Corrections of Documents

In case where the certificates, etc. become invalid in accordance with the provisions of the preceding **Par 3** (1) above or lost, the Society will reissue the certificates or make necessary corrections thereto depending on the circumstances involved.

905. Preservation of Documents

1. General

The Certificates issued depend on the requirements in **905.** by the Society and the instruction manual for cargo handling appliances are to be preserved aboard the ship or by shipowner's responsible person in case of towing boat not manned.

2. Instruction Manual

The instruction manual mentioned in **Par 1** above is to note essential items necessary for operation and maintenance of the cargo handling appliances among those given in the following (A) through (H):

(A) General arrangement of cargo gear and cargo ramps
(B) Arrangement drawing of loose gear(including rigging arrangement)
(C) List of loose gear
(D) Design conditions(including safe working load, wind speed, trim and heel of ship, etc.)
(E) List of materials
(F) Operation manual(including functions of safety systems and protective systems)
(G) Load testing procedure
(H) Maintenance and control procedures

Table 9.2.29 Timing of Issuance

<table>
<tr><th colspan="2">Kind of Documents</th><th>Timing of Issuance</th></tr>
<tr><td>A</td><td>Document in 904. 1 (A)</td><td>When the application for assignment is made and the ship passes the Registration Survey for the first time</td></tr>
<tr><td rowspan="2">B</td><td>Document in 904. 1 (B)</td><td rowspan="2">(1) When the application for assignment is made and the ship passes the Registration Survey for the first time
(2) When the cargo handling appliances that are installed additionally pass the Registration Survey
(3) When the safe working load, etc. is altered
(4) When the ship passes the load tests specified in 205. 4</td></tr>
<tr><td>Document in 904. 1 (C)</td></tr>
<tr><td rowspan="2">C</td><td>Document in 904. 1 (D)</td><td rowspan="2">(1) When the application for assignment is made and the ship passes the Registration Survey for the first time
(2) When the cargo handling appliances that are installed additionally pass the Registration Survey
(3) When loose gear is replaced or repair at time of the Periodical Surveys and the Occasional Survey, and when the contents of autonomous inspection is recognised appropriate by the Society</td></tr>
<tr><td>Document in 904. 1 (E) and (F)</td></tr>
</table>

CHAPTER 3 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 1 General

101. General

1. Scope

The Rules for the Automatic and Remote Control Systems (hereinafter referred to as "the Rules") apply to the survey and construction of centralized monitoring and control systems for main propulsion and essential auxiliary machinery, operating systems for periodically unattended machinery spaces and specific automation equipment (hereinafter referred to as "automatic and remote control systems") of ships classed or to be classed with the requirements of **Pt 1, Ch 1** intended to be assigned and registered the class notations in accordance with **Pt 1, Ch 1, Sec 2.**

2. Equivalency

Automatic and remote control systems which do not fully comply with the requirements of the Rules may be accepted provided that they are deemed by the Society to be equivalent to those specified in the Rules.

3. Modification of requirements

The Society may modify parts of the requirements specified in the Rules taking the national requirements of the ships nationality, purpose and service areas of the ship into consideration.

4. Automatic and remote control systems with novel design features

For automatic and remote control systems with novel design features the Society may impose appropriate requirements of the Rules to the extent practically applicable with additional requirements made on design and test procedures other than those specified in the Rules.

5. Definitions

The definitions of terms which appear in the Rules are specified as the following unless otherwise specified in other Sections.

(1) **Specific automation equipment** is a general term for Class 1 specific automation equipment, Class 2 specific automation equipment and Class 3 specific automation equipments detailed below:

(A) Class 1 specific automation equipment
Automatic or remote control equipment for remote controlled ballasting/deballasting arrangement, automatic steering system, remote-controlled handling system for liquid cargo in bulk, power-driven opening and closing devices, automatic recording devices for main engine, remote-controlled mooring arrangements and air-conditioning arrangements for control stations.

(B) Class 2 specific automation equipment
In addition to those in (A), Automatic or remote control equipment for remote-controlled fuel oil filling arrangements, centralized monitoring device for refrigerating containers, cargo hose handling winches, automatic deck washing arrangements, remote-controlled mooring arrangements at ship-sides, power-operated pilot ladder winding appliances and emergency towing rope winches

(C) Class 3 specific automation equipment
In addition to those in (B), Automatic or remote control equipment centralized monitoring systems for machinery, centralized control systems for machinery, remote control arrangements for main engines and steering gear at the outside of the navigating bridge, high level alarm devices for cargo hold bilge, independent remote-controlled mooring arrangements and towing rope winches

(2) An **CMA ship** is the ship of which centralized monitoring and control systems for main propulsion and essential auxiliary machinery comply with the requirements of **Sec 3** and is registered.

(3) An **UMA ship** is the ship of which operating systems for periodically unattended machinery spaces comply with the requirements of **Sec 4** and is registered.

(4) An **UMA1 ship** is the UMA ship of which Class 1 specific automation equipment complies with the requirements of **502.** and is registered.

(5) An **UMA2 ship** is the UMA ship of which Class 2 specific automation equipment complies with the requirements of **503.** and is registered.
(6) An **UMA3 ship** is the UMA ship of which Class 3 specific automation equipment complies with the requirements of **504.** and is registered.

6. Installations characters

(1) Character **CMA** is given in the Register for the centralized monitoring and control systems for main propulsion and essential auxiliary machinery of the CMA ship.
(2) Character **UMA** is given in the Register for the operating systems for periodically unattended machinery spaces of the UMA ship.
(3) Character **UMA1** is given in the Register for the Class 1 specific automation equipment of the UMA1 ship.
(4) Character **UMA2** is given in the Register for the Class 2 specific automation equipment of the UMA2 ship.
(5) Character **UMA3** is given in the Register for the Class 3 specific automation equipment of the UMA3 ship.

7. Terminology

Terms used in the Rules are defined as follows:

(1) **Monitoring station** (excluding control station) is a position where measuring instruments, indicators, alarms, etc. for the machinery and equipment are centralized and necessary information to grasp the operating condition of them can be obtained. Where, however, a monitoring station is provided with the ship in addition to a control station mentioned in (2) below, the requirements of the Rules relating to a monitoring station do not apply to the monitoring station concerned.
(2) **Control station** is a position which has a function as a monitoring station and from which the machinery and equipment can be controlled.
(3) **Main control station** is a control station provided with equipment necessary and sufficient to control the main propulsion machinery (this equipment will be referred to as "main control equipment" in this (3) and (4) and from which the main propulsion machinery is normally controlled, of the ship which provides the main control equipment at the outside of the navigation bridge.
(4) **Main control station on bridge** is a navigation bridge of the ship which provides main control equipment at the navigation bridge and that the main propulsion machinery is normally controlled there.
(5) **Sub-control station** is such a control station at which the main propulsion machinery is capable of being controlled, except for local control station for the main propulsion machinery, that is provided in the machinery room of the ship provided with a main control station on bridge.
(6) **Bridge control devices** are remote control devices for the main propulsion machinery or controllable pitch propellers provided on a navigation bridge or a main control station on bridge.
(7) **Sequential control** is a pattern of control that can be carried out automatically in the redetermined sequence.
(8) **Program control** is a pattern of control that desired values can be changed in the predetermined schedule.
(9) **Local control** is direct manual control of the machinery and equipment performed at or near their locations, receiving the necessary information from the measuring instruments, indicators and so on.
(10) **Safety system** is a system which operates automatically, in order to prevent damages to the machinery and equipment in case where serious impediments to functioning should occur on them during operation so that one of the following actions will take place.
(A) Starting of standby machinery or equipment.
(B) Reduction of outputs of the machinery or equipment.
(C) Shutting off the fuel or power supplies thereby stopping the machinery or equipment.
(11) **Override arrangements** are arrangements for stopping temporarily the functions of safety system in part or in whole.

(12) **Centralized control station** is one of the control stations of a ship which has necessary and sufficient systems to control main propulsion machinery, generating sets, auxiliary machinery essential for main propulsion of the ship(hereinafter referred to as "essential auxiliary machinery") and other auxiliaries considered necessary by the Society (hereinafter such are referred to as centralized monitoring and control systems for machinery in (12) and (13) outside the navigation bridge, and a room specially provided for the purpose of installing centralized monitoring and control systems for machinery, from which main propulsion machinery is normally controlled.

(13) **Centralized monitoring and control station on bridge** is a navigation bridge of a ship which has centralized monitoring and control systems for machinery on her bridge and from which main propulsion machinery is normally controlled.

(14) **Unattended machinery operation** is an operation of machinery and equipment specified as following (A) to (G) without watchkeeping personnel with the specific duty of the operation and surveillance during a predetermined period.
- (A) Main propulsion machinery (propulsion generating set in electric propulsion ships are excluded)
- (B) Controllable pitch propeller
- (C) Steam generating set
- (D) Electric generating set (propulsion generating set in electric propulsion ship are included)
- (E) Auxiliary machinery associated with machinery and equipment listed in (A) to (G)
- (F) Fuel oil systems
- (G) Bilge systems

(15) **Bridge** is an area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings.

(16) **Bridge wings** are parts of the bridge on both sides of the ships wheelhouse which extended to the ships side.

(17) **Wheelhouse** is an enclosed area of the bridge.

(18) **Computer-based system** is a system of one or more computers, associated software, peripherals and interfaces, and the computer network with its protocol.

(19) **Integrated system** is a system consisting of two or more subsystem having independent functions connected by a data transmission network and operated from one or more workstations.

(20) **Expert system** is an intelligent knowledge-based system that is designed to solve a problem with information that has been compiled using some form of human expertise.

(21) **Software** is the program, procedures and associated documentation pertaining to the operation of the computer system.

(22) **Basic software** is the minimum software, which includes firmware and middleware, required to support the application software.

(23) **Application software** is a software performing tasks specific to the actual configuration of the computer-based system and supported by the basic software.

(24) **Redundancy** is the existence of more than one means for performing a required function.

(25) **Interface** is a transfer point at which information is exchanged. (examples : interfaces including input/output interface; communications interface)

(26) **Peripheral** is a device performing an auxiliary function in the system. (examples : printer, data storage device)

(27) **Failure mode and effect analysis(FMEA)** is a failure analysis methodology used during design to postulate every failure mode and the corresponding effect or consequences.

Section 2 Surveys of Automatic and Remote Control Systems

201. General

1. Kinds of surveys

Kinds of surveys are as follows:
(1) Surveys for registration (hereinafter referred to as "Registration Surveys")
(2) Surveys for registration maintenance
  (A) Annual Surveys
  (B) Special Surveys
  (C) Occasional Surveys

2. Survey intervals

Surveys are to be carried out in accordance with the following requirements.
(1) A Classification Survey is to be carried out at the time when application for registration is made.
(2) Classification Maintenance Surveys are to be carried out at the times as prescribed below.
  (A) Annual Surveys are to be carried out at intervals specified in **Pt 1, Ch 2, 201.**
  (B) Special Surveys are to be carried out at intervals specified in **Pt 1, Ch 2, 401.**
  (C) An Occasional Survey: at a time falling on any of mentioned below, independently of Special Surveys and Annual Surveys.
    (a) When main parts of the systems have been damaged, repaired or renewed
    (b) When the systems are modified or altered
    (c) Whenever considered necessary by the Society

3. Preparation for surveys and others

(1) All such preparations as required for the survey to be carried out as well as those which may be required by the Surveyor as necessary in accordance with the requirements in the Rules are to be made by the applicant of the survey. The preparations are to include provisions of an easy and safe access, necessary facilities and necessary records for the execution of the survey. inspection, measuring and test equipment, which Surveyors rely on to make decisions affecting classification are to be individually identified and calibrated to a standard deemed appropriate by the Society. However, the Surveyor may accept simple measuring equipment (e.g. rulers, measuring tapes, weld gauges, micrometers) without individual identification or confirmation of calibration, provided they are of standard commercial design, properly maintained and periodically compared with other similar equipment or test pieces. The Surveyor may also accept equipment fitted on board a ship and used in examination of shipboard equipment (e.g. pressure, temperature or rpm gauges and meters) based either on calibration records or comparison of readings with multiple instruments.
(2) The applicant for the survey is to arrange a supervisor who is well conversant with the survey items intended for the preparation of the survey to provide the necessary assistance to the Surveyor according to his requests during the survey.
(3) The survey may be suspended where necessary preparations have not been made, any appropriate attendant is not present, or the Surveyor considers that the safety for execution of the survey is not ensured.
(4) Where repairs are deemed necessary as a result of the survey, the Surveyor will notify his recommendations to the applicant of the survey. Upon this notification, the repair is to be made to the satisfaction of the Surveyor.

202. Classification surveys

1. Drawings and data

(1) For centralized monitoring and control systems for main propulsion and essential auxiliary machinery or operating systems for periodically unattended machinery spaces intended to be registered, three copies of the following drawings and data are to be submitted.
- (A) Drawings and data concerning automation
  - (a) List of measuring points
  - (b) List of alarm points
  - (c) Control devices and safety devices
    - (i) List of controlled objects and controlled variables
    - (ii) Kinds of sources of control energy (self-actuated, pneumatic, electric, etc.)
    - (iii) List of conditions for emergency stopping, speed reduction (automatic or demand for reduction), etc.
- (B) Following drawings and data for the automatic control devices and remote control devices for main propulsion machinery or controllable pitch propellers:
  - (a) Operating instructions of main propulsion machinery such as starting and stopping, changeover of direction of revolution, increase and decreased of output, etc.
  - (b) Arrangements of safety devices (including those attached to the engines) and indicating lamps
  - (c) Controlling diagrams
- (C) Following drawings and data for the automatic control devices and remote control devices for boilers:
  - (a) Operating instructions of sequential control, feed water control, pressure control, combustion control and safety devices.
  - (b) Diagrams for automatic combustion control devices and automatic feed water control devices
- (D) Diagrams and operating instructions for automatic control devices for electric generating sets (automatic load sharing devices, preference tripping devices, automatic starting devices, automatic synchronous making devices, sequential starting devices, etc.)
- (E) Panel arrangements of monitoring panels, alarming panels and control stands at respective control stations
- (F) Schedules of on-board tests and sea trials

(2) For computer-based systems intended to be registered, three copies of following drawings and data are to be submitted.
- (A) Computer hardware
  The documentation to be submitted is to include:
  - (a) Hardware information of importance for the application and a list of documents that apply to the system
  - (b) The supply circuit diagram
  - (c) A description of hardware and software tools for equipment configuration
  - (d) The information to activate the system
  - (e) General information for trouble shooting and repair when the system is in operation
- (B) Computer software
  The documentation to be submitted is to include:
  - (a) A list of all main software modules installed per hardware unit with names and version numbers
  - (b) A description of all main software which is to include at least:
    - (i) A description of basic software installed per hardware unit, including communication software, when applicable
    - (ii) A description of application software
- (C) System reliability analysis
  The documentation to be submitted is to demonstrate the reliability of the system by means of appropriate analysis such as:
  - (a) A failure mode analysis describing the effects due to failures leading to the destruction of the automation system, In addition, this documentation is to show the consequences on other systems, if any.
  - (b) Mean time between failures (MTBF) calculation
  - (c) Any other documentation demonstrating the reliability of the system

(D) User interface description
The documentation is to contain:
(a) A description of the functions allocated to each operator interface(keyboard/screen or equivalent)
(b) A description of individual screen views (schematics, colour photos, etc.)
(c) A description of how menus are operated (tree presentation)
(d) An operator manual providing necessary information for installation and use.
(E) Test programs
The following test program are to be submitted:
(a) Software module/unit test
(b) Software integration test
(c) System validation test
(d) On-board test
Each test program is to include:
(i) A description of each test item
(ii) A description of the acceptance criteria for each tests.
(3) For specific automation equipment intended to be registered, three copies of the following drawings and data are to be submitted.
(A) Drawings showing the construction and layout of the specific automation equipment
(B) Drawings and data relative to the automatic and remote control systems of the specific automation equipment
(C) Particulars of the specific automation equipment
(D) Drawings and data other than above where deemed necessary by the Society

203. Shop tests

1. Type approval

Devices, units and sensors (hereinafter referred to as "automatic devices" in the Rules) and automatic equipment composed of automatic devices and basic software (if applicable) are to be type approved, in principle, according to the test methods approved by the Society before being taken into use.

2. Shop tests of automatic systems

The automatic devices which have passed through the type approval tests specified in **Par 1** are to be subjected to the following tests after completion of assembly as automatic system.
(1) Hardware
(A) External examination
(B) Operation tests and performance tests
(C) Insulation resistance tests and high voltage tests (to be applied to electric devices, electronic devices and so on)
(D) Pressure tests (to be applied to hydraulic devices, pneumatic devices and so on)
(E) Other tests considered necessary by the Society
(2) Software
Software acceptance tests of computer-based systems are to be carried out to verify their adaptation to their use on board, and concern mainly the application software
(A) The software modules of the application software are to be tested individually and subsequently subjected to an integration test. The test results are to be documented and to be part of the final file. The followings are to be checked.
(a) The development work has been carried out in accordance with the plan
(b) The documentation includes the proposed test, the acceptance criteria and the result.
Repetition tests may be required to verify the consistency of test results.
(B) Software acceptance will be granted subject followings.
(a) Examination of the avaliable documentation
(b) A function test of the whole system

204. On-board tests

The systems of automatic or remote control of the machinery and equipment are to be, after installed on board, confirmed that they operate effectively, respectively under as far practical condition as possible. Further, where deemed necessary by the Society, automatically or remotely controlled machinery and equipment are to be confirmed that they operate so as not to endanger the safety of the ship and machinery plant even in the case of failure of control systems as well. However, part of these tests may be carried out during sea trials. The proper documents, in which test procedures, set value for alarms and for operation of safety systems and so on are recorded, are to be kept on board.

205. Sea trials for the centralized monitoring and control systems for main propulsion and essential auxiliary machinery

1. Main propulsion machinery and controllable pitch propellers

The control systems for main propulsion machinery or controllable pitch propellers are to be subjected to the following tests and other tests considered necessary by the Society in accordance with the schedule of sea trials submitted in advance. After completion of the test on transfer of control specified in (3), it is to be shown that the main propulsion machinery or the controllable pitch propellers can be smoothly operated from the respective control stations.

(1) The main propulsion machinery or the controllable pitch propellers are to be subjected to starting tests, ahead-astern tests and running tests in the whole range of output, by means of the remote control devices from the main control station or the main control station on bridge.

(2) In addition to output increase and decrease tests, the operation tests of the main propulsion machinery or the controllable pitch propellers using the bridge control devices are to be carried out as deemed appropriate by the Society.

(3) In case where there are two or more control stations for main propulsion machinery or controllable pitch propellers, the test on transfer of control is to be carried out during ahead and astern operations of the main propulsion machinery or the controllable pitch propellers. In case where the transfer of control of the remote control devices for main propulsion machinery or controllable pitch propellers is carried out in accordance with **305. 2** (2) (C) (b), the above-mentioned test may be carried out during the stopping condition of the main propulsion machinery.

2. Boilers

The control systems for boilers are to be subjected to the following tests.

(1) With respect to main boilers, it is to be confirmed that the feed water control devices, combustion control devices and so on can operate stably in response to load variation of the main boilers, and the main boilers can supply steam stably to the main propulsion machinery, the electric generating sets and the auxiliary machinery essential for main propulsion of the ship without local manual operation.

(2) With respect to essential auxiliary boilers, it is to be confirmed that they can supply steam stably to the auxiliary machinery essential for main propulsion of the ship without manual operation.

(3) In case where an exhaust gas economizer is used as a source of steam supply to a turbine for driving a generator and steam is supplied from a boiler automatically in case of low power condition of the main propulsion machinery, operation tests of automatic control devices for this system are to be carried out.

3. Electric generating sets

In case where generators which supply electrical power to the loads necessary for propulsion of the ship and whose motive power is relying upon the propulsion systems, the systems of automatic or remote control of electric generating sets are to be subjected to operation tests.

206. Sea trials for the operating systems for periodically unattended machinery spaces

1. In sea trials, the tests specified in **205.** and this **206.** and other tests considered necessary by the Society are to be carried out in accordance with the schedule of sea trials submitted in advance.

2. The main propulsion machinery or the controllable pitch propellers are to show that they can be safely and surely operated in starting tests and ahead-astern tests and in the whole range of output, by means of the bridge control devices.

3. The electric generating sets are to be subjected to the following tests while the ship is navigating at normal sea going speed.

(1) In case where only one electric generating set is normally used, when stopping the main source of electrical power by tripping the circuit breaker, it is to be confirmed that automatic starting of the standby generator, automatic making of the air circuit breaker and sequential starting of important auxiliaries are performed.

(2) In case where two electric generating sets are normally used, when tripping the circuit breaker for one set, it is to be confirmed that preference tripping of non-important loads is performed, and propulsion and steering of the ship are maintained.

4. The auxiliary machinery is to be subjected to the following tests while controlling the main propulsion machinery or the controllable pitch propellers from the navigation bridge.

(1) Automatic starting tests of the standby pumps specified in **Table 9.3.1** to **9.3.6** and **Table 9.3.8** to **9.3.9.**

(2) For ships fitted with sea inlet scoops, automatic change over test to the circulating pumps.

(3) While the ship is navigating at normal sea going speed, it is to be confirmed that the exclusive air reservoirs for control use, if fitted, are capable of supplying air for at least five minutes after operation of a low pressure alarm for control air in a condition that the automatic starting function of control air compressor is stopped.

5. The exhaust gas economizer for supplying steam to turbine driving generator is to be subjected to the following tests.

(1) Operation tests such as steam supply from boilers and automatic starting of diesel engine driving generators, when putting back rapidly the handle of main propulsion machinery to the stop position while the ship is navigating at normal speed.

(2) When the main propulsion machinery is put into action expeditiously, it is to be confirmed that no critical condition occurs to water separator drums, piping, steam turbines and so on.

6. After completion of tests of automatic devices and automatic equipment, it is to be confirmed that the machinery can be safely and surely monitored and controlled under an unattended machinery operating condition as far similar to the normal sea going condition as practicable.

In this case, except where the operation mode is changed over, the running condition of the machinery is not to be adjusted by means of manual operation from any control station other than that on navigation bridge (including the centralized monitoring and control station on bridge).

207. Classification maintenance surveys

1. Annual surveys

(1) At each Annual Survey for the centralized monitoring and control systems for main propulsion and essential auxiliary machinery, the following performance tests are to be tested and placed in order. Where appropriate records of daily checks and periodical maintenances have been kept, some of the tests may be dispensed with at the Surveyors discretion.

(A) Safety devices for main propulsion machinery or controllable pitch propellers, and emergency stopping devices for main propulsion machinery fitted in the remote control station for the main propulsion machinery or controllable pitch propellers

(B) Safety devices for boilers

(C) Safety devices for electric generating sets

(2) At each Annual Survey for the operating systems for periodically unattended machinery spaces, the following performance tests are to be tested and placed in order. Where appropriate records of daily checks and periodical maintenances have been kept, some of the tests may be dispensed with at the Surveyors discretion.

(A) Safety devices for main propulsion machinery or controllable pitch propellers, and emergency stopping devices for main propulsion machinery fitted in the remote control station for the main propulsion machinery or controllable pitch propellers
(B) Safety devices for boilers
(C) Safety devices for electric generating sets
(D) Communication systems specified in **403. 3**

(3) At each Annual Survey for the specific automation equipment, general examination is to be carried out. Where considered necessary by the Surveyor, performance tests for the equipment may be required.

2. Special surveys

(1) At each special Survey for the centralized monitoring and control systems for main propulsion and essential auxiliary machinery, the followings are to be tested and placed in order. Where appropriate records of daily checks and periodical maintenances throughout the period since the last Periodical Survey have been kept, some of the tests may be abbreviated for the some parts which are in good condition.
(A) Main propulsion machinery and controllable pitch propellers
(a) Change-over devices of control positions between navigation bridge and centralized control station and between centralized control station and local control station; or between centralized monitoring and control station on bridge and local control station or sub-control station (where applicable to the ships which provide bridge control devices); and remote control systems installed in these positions
(b) Safety devices
(B) Boilers
(a) Automatic and remote control systems
(b) Safety devices
(C) Electric generating sets
(a) Automatic and remote control systems
(b) Safety devices
(D) Automatic change-over devices of essential pumps and automatic starting devices (or remote start/stop devices) of air compressors
(E) Alarm systems
(a) Function of alarm systems and indicator devices
(b) Confirmations of setting points of alarms
(F) Remote monitoring systems

(2) At each Special Survey for the operating systems for periodically unattended machinery spaces, the followings are to be tested and placed in order.
(A) Main propulsion machinery and controllable pitch propellers
(a) Change-over devices of control positions between navigation bridge and centralized control station and between centralized control station and local control station; or between centralized monitoring and control station on bridge and local control station or sub-control station; and remote control systems installed in these positions
(b) Safety devices
(B) Boilers
(a) Automatic and remote control systems
(b) Safety devices
(C) Electric generating sets
(a) Automatic and remote control systems
(b) Safety devices
(c) Automatic start of stand-by power supply unit after black-out
(d) Preferential trip systems
(D) Automatic change-over devices of essential pumps and automatic starting devices of air compressors
(E) Communication systems specified in **403. 3**
(F) Alarm systems

(3) At each Special Survey for the specific automation equipment, general examination and performance tests are to be carried out.

(4) Where considered necessary by the Surveyor, sea trials may be required after completion of the above mentioned tests in (1), (2) or (3).

Section 3 Centralized Monitoring and Control Systems for Main Propulsion and Essential Auxiliary Machinery

301. General

1. Scope

(1) The requirements in this Section apply to the centralized monitoring and control systems for main propulsion and essential auxiliary machinery of CMA ships.
(2) Automatic and remote control systems of CMA ships, which are specified in **Sec 4** or **Sec 5**, are to comply with the requirements in the Section concerned.

302. System design

1. System design

(1) Control systems, alarm systems and safety systems are to be so designed that one fault does not result in other faults as far as practicable and the extent of the damage could be kept to a minimum.
(2) Control systems, alarm systems and safety systems are to be designed on the fail-to-safe principle. The characteristic of fail-to-safe is to be evaluated on the basis not only of the respective systems themselves and associated machinery and equipment, but also the total safety of the ship.
(3) Systems of automatic or remote control are to be sufficiently reliable under service conditions.
(4) Cables for signals are to be installed in such a manner that harmful induced interference can be avoided.
(5) Constitution of systems is to comply with the following requirements:
(A) Control systems, alarm systems and safety systems are to be independent each other as far as practicable.
(B) Safety systems intended for the functions specified in **101. 7** (10) (C) are to be, in any case, independent of the other systems.
(C) Means are to be provided for the safety systems to investigate the cause of the action of the safety systems.

2. Supply of power

(1) Supply of electrical power
The supply of electrical power is to be in accordance with the following:
(A) Electrical supply circuits to control systems, alarm systems and safety systems are not to branch off from the power circuits and lighting circuits, except that the electrical power to the control systems, alarm systems and safety systems may be supplied from the power circuits to the machinery and equipment they serve.
(B) The electrical power to alarm systems and safety systems for electric generating sets is also to be supplied from an accumulator battery.
(2) Supply of oil pressure
The supply of control oil pressure is to be in accordance with the following:
(A) Sources of oil pressure are to be capable of supplying stably necessary pressure and quantity of purified oil.
(B) Overpressure preventive devices are to be provided on the delivery side of oil pressure pumps.
(C) Two or more sets of oil pressure pumps for the control of main propulsion machinery and main shaftings are to be provided and they are to be so arranged that in case where one of the pumps in operation becomes out of operation standby pump(s) may start automatically or may be readily remotely started. In this case, the oil pressure pumps are not to be used for the control of other machinery and equipment than main propulsion machinery and main shaftings.
(3) Supply of pneumatic pressure
The supply of control air is to be in accordance with the following:
(A) Control systems are to be provided with an air reservoir having a capacity capable of supplying air to control devices at least for 5 minutes in the event of failure of the control air compressor.

(B) Where starting air reservoirs for diesel engines used as main propulsion machinery are used as control air reservoirs, pressure reducing valves are to be duplicated.
(C) There are to be two or more sets of air compressors which may be used as a source of control air. Each air compressor is to have redundant capacity even in the event of failure of either one of them.
(D) Control air is to pass through a filter and, if necessary, a drier so that solid, oil and water may be removed to a minimum.
(E) Control air pipes are to be independent of general service air pipes and starting air pipes.

3. Environmental conditions

Systems of automatic or remote control are to be capable of withstanding the environmental conditions of the places where they are installed.

4. Control systems

(1) Independency of control systems
Control systems for main propulsion machinery or controllable pitch propellers, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are to be independent each other or designed such that failure of one system does not degrade the performance of other system.
(2) Interconnection devices
In case of plural main propulsion machinery or controllable pitch propellers, electric generating sets, or essential auxiliary machinery which are designed to be operated simultaneously in multiple under the same condition, interconnection devices may be provided between the control devices of these installations.
(3) Control characteristics
Remote control devices and automatic control devices are to have control characteristics in conformity with the dynamic properties of the machinery and equipment they serve and to be considered not to invite malfunction and hunting due to disturbance.
(4) Interlock
Control devices are to be provided with suitable interlocking arrangements in order to prevent damages to the machinery and equipment due to anticipated malfunction and maloperation of the machinery and equipment.
(5) Change-over to manual operating
Change-over to manual operating is to comply with the following requirements:
(A) Main propulsion machinery or controllable pitch propellers, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are to be so arranged as to be manually started, operated and controlled even in the event where automatic control devices become out of operation.
(B) Automatic control devices are generally to be provided with provisions to stop manually the automatic function of these devices.
(C) The provisions specified in (B) are to be capable of stopping the automatic function of the automatic control devices, even where any part of the automatic control devices become out of operation.
(6) Cancellation of remote control function
For remote control devices, the function of remote control is to be capable of being manually cancelled.
(7) Indication of control locations
In case where the machinery and equipment are capable of being operated from more than one station, the following requirements are to be complied with. However, this requirement need not be complied with in case the safety of the machinery and equipment and the safety at the time of maintenance work can be obtained by means of other measures considered appropriate by the Society.
(A) At each control station there is to be an indicator showing which station is in control of the machinery and equipment.
(B) Control of the machinery and equipment is to be possible only from one station at a time.

5. Alarm systems

(1) Function of alarm systems is to comply with the following requirements:
(A) In case where an abnormal condition is detected devices to issue a visual and audible alarm (hereinafter referred to as "alarm devices" in the Rules) are to operate.
(B) In case where arrangements are made to silence audible alarms they are not to extinguish visual alarms.
(C) Two or more faults are to be indicated at the same time.
(D) Audible alarms for machinery and equipment are to be clearly distinguishable from other audible alarms such as general alarm, fire alarm, CO_2 flooding alarm, etc.
(E) Alarm systems are to be designed with self-monitoring properties and alarms are to be given in the case of power and sensors failure.
(F) Alarm systems are to be capable of being tested during normal machinery operation.
(G) Where practicable, means are to be provided at convenient and accessible positions to permit the sensors to be tested without affecting the operation of the machinery.
(H) For the detection of transient faults which are subsequently self-correcting, a visual and audible alarm is required to lock in until accepted.
(2) Function of the alarm systems provided in the monitoring station for main propulsion machinery or controllable pitch propellers is to comply with the following requirements, in addition to the requirements in (1) :
(A) The visual indication of the alarm is to remain until the fault has been corrected.
(B) The acceptance of any alarm is not to inhibit another alarm.
(C) If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, alarm devices are again to operate.
(D) Manual stopping of each alarm system is to be clearly indicated.
(3) Visual alarms are to be so arranged that each abnormal condition of the machinery and equipment is readily distinguishable.

6. Safety systems

(1) Constitution of systems
Constitution of safety systems is to comply with the following requirements:
(A) Safety systems are to be, as far as practicable, provided independently of control systems and alarm systems.
(B) Safety systems for the main propulsion machinery, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are to be independent each other.
(2) Function of safety systems
Function of the safety systems is to comply with the following requirements:
(A) Alarm systems which have functions prescribed in **302. 5** are to operate when safety systems are put into action.
(B) In case where safety systems are put into action and the operation of the machinery or equipment is stopped, it is not to automatically restart before manual reset is made.
(3) Override arrangements
Override arrangements are to be complied with:
(A) A visual indication is to be given at the relevant control stations of the machinery and equipment when an override is operated.
(B) The override arrangements are to be such that inadvertent operation is prevented.

7. Computer-based Systems

(1) Application
(A) Computer-based systems where used for control, monitoring and safety systems are to comply with the provisons of this **Par**.
(B) Computerized control systems, alarm systems and safety systems are divided into three categories as shown in **Pt 6, Ch 2, Table 6.2.1** based on the impact a single failure has on human and vessel safety, and the environment.
(2) Systems requirements
(A) System security
Computer-based systems are to be protected against unintentional or unauthorized modification of software.
(a) The systems categorized in Categories Ⅱ and Ⅲ in **Pt 6, Ch 2, Table 6.2.1** are to be protected against program modification by end users.

(b) For the systems categorized in Categories Ⅲ in **Pt 6, Ch 2, Table 6.2.1** modifications of parameters by manufacturers are to be approved by the Society.
(c) Any modifications made after shipment are to be documented and traceable.

(B) Program and memory data
To preclude the possible loss or corruption of data as a result of power disruption, programs and associated memory data considered to be essential for the operation of the specific system are to be stored in non-volatile memory.

(C) Start-up after power failure
The system's software and hardware is to be designed so that upon restoration of power supply after power failure, automatic or remote control and monitoring capabilities can immediately be available after the pre-established computer control access (sign-in) procedure has been completed.

(D) Self monitoring
Computer-based systems are to be self-monitoring and any incorrect operation or abnormal condition is to be alarmed at the computer workstation.

(E) Power supply
The power supply is to be monitored for voltage failure and protected for short circuit. Where redundant computer systems are provided to satisfy (F), they are to be separately fed.

(F) System independence
Control, monitoring and safety systems are to be arranged such that a single failure or malfunction of the computer equipment will not affect more than one of these system functions.

(G) Response time
Computer system's memory is to be of sufficient capacity to handle the operation of all computer programs as configured in the computer system. The time response for processing and transmitting data is to be such that an undesirable chain of events may not arise as a result of unacceptable data delay or response time during the computer system's worst data overload operating condition. For propulsion related system applications, the time limit on response delays for safety and alarm displays is not to exceed two (2) seconds. The response delay is to be taken as the time between detection of an alarm or safety critical condition and the display of the alarm or actuation of the safety system.

(H) Fail-safe
Computer-based system is to be designed such that failure of any of the system's components will not cause unsafe operation of the process or the equipment it controls. FMEA is to be used to determine that any component failure will not result in the complete loss of control, the shutdown of the process or equipment, or other undesirable consequences.

(3) Additional requirements for integrated systems

(A) General
Common hardware in an integrated system serving many subsystems, e.g., monitor, keyboard, microprocessor, etc., is to be duplicated or otherwise provided with a means of backup.

(B) Component independence
Failure of one part (individual module, equipment or subsystem) of the integrated system is not to affect the functionality of other parts, except for those functions directly dependent upon information from the defective part.

(C) Data communication

(a) Data link
(i) Any detected abnormal condition is to be alarmed at the centralized control station and on the navigation bridge.
(ii) Safeguards are to be provided to prevent unacceptable data transmission delays (overloading of network).
(iii) Alarm is to be activated prior to a critical data overload condition.

(b) Duplicated data link
(i) When the same data link is used for two or more essential functions (e.g., propulsion control and generator control), this link is to be duplicated, and each is to be routed as far apart from the other as practical.
(ii) The duplicate link is for standby purpose only and not to be used to reduce traffic in the online link.

(iii)Duplicated data link is to be arranged so that upon the failure of the on-line link, the standby link is automatically connected to the system. Switching between duplicated links is not to disturb data communication or continuous functioning of the system.

(iv)The failure of one link is to be alarmed at the centralized control station and on the navigation bridge.

(c) Connection failure

A complete failure in connectivity between component systems and the data highway is not to affect individual functionality of the component systems.

(d) Transmission software

(i) The transmission software is to be so designed that alarm or control data have priority over any other data.

(ii) The transmission protocol is to be chosen among international standards.

(iii)A means of transmission control is to be provided and designed so as to verify the completion of the data transmitted (Cyclic Redundancy Check(CRC) or equivalent acceptable method).

(iv)When corrupted data is detected, th number of retries is to be limited so as to keep an acceptable global response time.

(4) Expert system

The expert system software is not to be implemented on a computer linked with essential functions and is not to be used for direct control or operation.

(5) Hardware

(A) Design for ease of maintenance

(a) The design and layout of the hardware is to ensure ease of access to interchangeable parts for repairs and maintenance.

(b) Each replaceable part is to be simple to replace and is to be constructed for easy and safe handling.

(c) All replaceable parts are to be so designed that it is not possible to connect them incorrectly or to use incorrect replacements. Where this is not practicable, the replaceable parts and their mounting location, including their means of electrical connection, are to be clearly marked.

(B) User interface and input devices

(a) General

Input devices are to have clearly marked functions and, as far as practicable, are to be arranged to avoid conceivable inadvertent errors in their operations.

(b) Security

Input devices, such as keyboard, which can be used to effect changes to equipment or processes under control, are to be provided with security arrangement, such as password, so as to limit access to authorized personnel only.

Where a single action of, for example, pressing of a key is able to cause dangerous operating conditions or malfunctions, measures such as use of two or more keys are to be taken to prevent execution by a single action.

(c) Control Status

Where control action can be effected from more than one station, conflicting control station actions are to be prevented by means of interlock or warning. Control status is to be indicated at all stations.

(C) Visual display unit

(a) General

The size, color and density of text and graphic information displayed on a visual display unit are to be such that it may be easily read from the normal operator position under all operational lighting conditions. The brightness and contrast are to be capable of being adjusted.

(b) Alarm display

Where alarms are displayed by means of visual display unit, they are to appear in the sequence as the incoming signals are received. Alarming of the incoming fault signals is to appear on the screen, regardless of the mode the computer or the visual display unit is in.

(c) Propulsion monitoring
Where visual display unit is used to display monitored parameters, unless other display means are provided capable of displaying the same information, the centralized control station is to be provided with at least two computer monitors.
(d) Color monitor
The failure of a primary color is not to prevent an alarm from being distinctly indicated.
(D) Graphical display
(a) General
Information is to be presented clearly and intelligibly, according to its functional relations. Display presentations are to be restricted to the data which is directly relevant for the user.
(b) Alarms
Alarms are to be clearly distinguishable from other information and are to be visually and audibly presented with priority over other information, regardless of the mode the computer or the visual display unit is in.
(6) Software
(A) General
(a) The basic software is to be developed in consistent and independent modules and a self checking function is to be provided to identify failure of software module. When hardware (e.g. input/output devices, communication links, memory, etc.) is arranged to limit the consequences of failures, the corresponding software is also to be separated in different software modules ensuring the same degree of independence.
(b) Loading of software, when necessary, is to be performed in the aided conversational mode.
(c) A clear warning is to be displayed when using functions such as alteration of control condition, or change of data or programs in the memory of the system.
(B) Software development quality
(a) Software development si to be carried out according to a quality plan defined by the builder and records are to be kept.
(b) The standard ISO/IEC 90003:2004 Software Engineering - Guidelines - Application of ISO 9001:2000 or equivalent international standards, is to be taken as guidance for the quality procedure.
(c) The quality plan is to include the test procedure for software and the results of the tests are to be documented.

303. Prevention of flooding and fire safety measures

1. Prevention of flooding

(1) Bilge wells in the spaces where main propulsion machinery, main shaftings, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are situated and other spaces considered necessary by the Society are to be large enough to accommodate easily the normal drainage during operation of the machinery installations and high liquid level alarm devices are to be provided at two or more places so that the increase of bilge can be detected at normal angles of heel and trim, except for such spaces that the Society appreciated that there is no fear of flooding.
(2) Where bilge pumps are capable of being started and stopped automatically, small bilge wells may be accepted in consideration of the operating frequency of the pump.
(3) Where bilge pumps are capable of being started and stopped automatically, alarm devices are to be provided to indicate either one of the following conditions:
(A) When the influx of liquid is greater than the pump capacity.
(B) When the pump is operating more frequently than would be normally expected.
(4) The controls of any valve serving a sea inlet, a discharge below the load water line or a bilge discharge system are to be so sited as to allow adequate time for operation in case of influx of water to the space with the ship in the fully loaded condition, having regard to the time likely to be required in order to reach and operate such controls.

2. Fire Safety Measures

(1) Fuel oil arrangements and lubricating oil arrangements installed in the spaces where main engines, boilers, electric generating sets and auxiliaries for propulsion of the ship are situated and other spaces which are considered necessary by the Society, are to comply with the following requirements, in addition to the requirements in **Pt 5, Ch 6, Sec 8** and **9**.

(A) Fuel oil piping system and lubricating oil piping system are, if necessary, to be shielded or appropriately protected in order to prevent, as far as practicable, scattering or leaking oil from touching the hot surfaces or from entering into the air inlets. The number of joints of piping systems is to be limited to a minimum.
(B) Where fuel oil service tanks are filled automatically or by remote control, means are to be provided to prevent overflow spillages.
(C) Equipment (except for tanks) which treats flammable liquids, e.g, fuel oil purifiers, which, whenever practicable, is to be installed in a special space reserved for purifiers and their heaters, is to have arrangements to prevent overflow spillages.
(D) In case where fuel oil service tanks or settling tanks are fitted with heating arrangements, a high temperature alarm device is to be provided, if the flash point of the fuel oil can be exceeded.

304. Centralized monitoring and control systems

1. General

Centralized control station or centralized monitoring and control station on bridge, designed and equipped to ensure the operation of the main propulsion and essential auxiliary machinery as safe as that under direct supervision under all sailing conditions including manoeuvring is to be provided.

2. Centralized monitoring and control systems for main propulsion and essential auxiliary machinery

Following devices are to be provided in the centralized control station or the centralized monitoring and control station on bridge:

(1) Remote control devices and monitoring devices for main propulsion machinery or controllable pitch propellers
(2) Remote control devices and monitoring devices for boilers
In this case, the remote control devices are to be in accordance with the following:
(A) Main boilers
Control devices for the control of the number of firing burners and combustion control devices, this does not include the ignition of the main boilers.
Where, however, the combustion and the number of the firing burners are automatically controlled, these control devices need not be fitted.
(B) Auxiliary boilers
Remote control devices for boilers which are required to be operated to supply steam to the turbines of exhaust gas turbo generator set in order to maintain stable electrical power in the case of low power condition of the main propulsion machinery.
However, where the boilers are arranged to operate automatically, the remote control devices may be dispensed with.
(3) Remote control devices and monitoring devices for electric generating sets
In case where the equipment specified in **403. 1** is provided, the remote control devices may be dispensed with.
(4) Remote starting and stopping devices and monitoring devices for pumps used as auxiliary machinery essential for main propulsion
In case where the standby pumps for these pumps are arranged to start automatically, the remote starting and stopping devices may be dispensed with.
(5) Remote starting and stopping devices and monitoring devices for air compressors for starting of main propulsion machinery and for controlling
In case where these air compressors are arranged to operate automatically, the remote starting and stopping devices may be dispensed with.

(6) Alarm devices to indicate the operation of the safety systems and the faults of the machinery specified in **305.** to **310.**
(7) Emergency stopping devices for main propulsion machinery specified in **305. 2** (3) (E).
(8) Communication means specified in **Pt 5, Ch 1, 106.** and engineers alarm specified in **Pt 5, Ch 1, 107.**
(9) Bilge alarm device specified in **303. 1** (1) and (3)
(10) Fire detectors
(11) Remote indications specified in **Table 9.3.1** to **9.3.9**
(12) Override arrangements

305. Automatic and remote control of main propulsion machinery or controllable pitch propellers

1. General

Devices for remote or automatic control by which the main propulsion machinery or the controllable pitch propellers are controlled are to comply with the requirements in this **305.**

2. Remote control devices for main propulsion machinery or controllable pitch propellers

(1) General
Remote control devices for main propulsion machinery or controllable pitch propellers are to be complied with the following requirements:
(A) Remote control devices for main propulsion machinery or controllable pitch propellers are to be capable of controlling the propeller speed and the direction of thrust (the blade angle of propellers in the case of controllable pitch propellers) by means of a simple operation.
(B) Remote control devices for main propulsion machinery or controllable pitch propellers are to be provided for each propeller. Where multiple propellers are designed to operate simultaneously, they may be control by one control device.
(C) In case where the speed of the diesel engines used as main propulsion machinery is controlled by governors, the governors are to be adjusted so that main propulsion machinery may not exceed 103 % of the maximum continuous revolutions. The governors are to be capable of maintaining the safe minimum speed.
(D) In case where a program control is adopted, the program for increase and decrease of output is to be so designed that undue mechanical stresses and thermal stresses do not occur in any parts of machinery.
(E) In the remote control stations or monitoring stations and at the maneuvering platform for the main propulsion machinery or controllable pitch propellers, the following instruments are to be provided.
(a) Indicators for propeller speed and direction of rotation in the case of solid propellers.
(b) Indicators for propeller speed and pitch position in the case of controllable pitch propeller.
(F) In the remote control stations for main engines or controllable pitch propellers, alarm devices necessary for the control of main engines are to be provided.
(2) Transfer of control
Remote control devices for main propulsion machinery or controllable pitch propellers are to comply with the following requirements with respect to transfer of control:
(A) Each control station for main propulsion machinery or controllable pitch propellers is to be provided with means to indicate which of them is in control.
(B) Remote control of main propulsion machinery or controllable pitch propellers is to be possible only from one location at a time.
(C) Transfer of control is to be possible only with order by the serving station and acknowledgement by the receiving station except for the following cases:
(a) Transfer of control between local control station for main propulsion machinery or controllable pitch propellers and main control station or subcontrol station; and
(b) Transfer of control during the stopping condition of the main propulsion machinery.
(D) While main propulsion machinery or controllable pitch propellers are controlled from the navigation bridge or the main control station on bridge, transfer of control is to be possible from the local control station for the main propulsion machinery or controllable pitch propellers, the main control station or the sub-control station with no order of the transfer of control from the navigation bridge or the main control station on bridge.

(E) Means are to be provided to prevent the propelling thrust from altering significantly when transferring control from one location to another except for the transfer of control described in (C) (a) and (D).

(3) Failure of remote control systems of main propulsion machinery or controllable pitch propellers
The following requirements are to be complied with in case of failure of remote control devices for main propulsion machinery or controllable pitch propellers:

(A) In the remote control stations for main propulsion machinery or controllable pitch propellers alarm devices which operate in the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers are to be provided.

(B) In the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers, the main propulsion machinery or the controllable pitch propellers are to be possible to control locally.

(C) In the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers, the preset speed and direction of the propeller thrust are to be maintained until the control is in operation at the main control station, the sub-control station or the local control station for main propulsion machinery or controllable pitch propellers, unless this is considered impracticable by the Society.

(D) In the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers, the transfer of control to the main control station, the sub-control station or the local control station for main propulsion machinery or controllable pitch propellers is to be possible by a simple operation.

(E) Remote control stations for main propulsion machinery or controllable pitch propellers are to be provided with independent emergency stopping devices for the main propulsion machinery, which are effective in the event of failure of the remote control devices for the main propulsion machinery or the controllable pitch propellers.

(4) Remote starting of main propulsion machinery in diesel ships
Starting by means of remote control devices for main propulsion machinery is to comply with the following:

(A) The number of starting of main propulsion machinery is to satisfy the number specified in **Pt 5, Ch 6, 1001.**

(B) Remote control devices for main propulsion machinery arranged to automatically start are to be so designed that the number of automatic consecutive attempts which fail to produce a start is limited to three times. In the event of failure of starting, a visual and audible alarm is to be issued at the relevant control station as well as the main control station on bridge, the main control station or the monitoring station (where the main control station on bridge and the main control station are not provided) for the main propulsion machinery or the controllable pitch propellers.

(C) Where compressed air is used for starting of the main propulsion machinery, alarm devices to indicate the low starting air pressure are to be provided at the remote control station and the monitoring station for the main propulsion machinery.

(D) The low starting air pressure mentioned in (C) for the operation of alarm devices is to be set at a level to permit further main propulsion machinery starting operations.

3. Bridge control devices

Bridge control devices are to comply with the following requirements as well as those in **305. 2.**

(1) Even when main propulsion machinery or controllable pitch propellers is controlled from the navigation bridge or the main control station on bridge, the telegraph orders at the navigation bridge or the main control station on bridge are to be indicated in the control stations and at the maneuvering platform which are capable of controlling main propulsion machinery or controllable pitch propellers.

(A) Sub-control station or local control station for main propulsion machinery or controllable pitch propellers for ships provided with main control station on bridge, or

(B) Main control station for ships not provided with main control station on bridge.

(2) Bridge control devices are to be provided with either one of the following devices in order to prevent prolonged running of main propulsion machinery in critical speed range:

(A) Devices to make to pass automatically and rapidly through the critical speed range.

(B) Alarm devices which operate in case where the main propulsion machinery operate exceeding a predetermined period in the critical speed range.

4. Safety measures

(1) Safety measures for main propulsion machinery or controllable pitch propellers
Safety measures for main propulsion machinery or controllable pitch propellers are to comply with the following requirements:
(A) The following safety measures are to be taken to remote control devices for main propulsion machinery or controllable pitch propellers:
(a) Necessary interlocking devices are to be provided to prevent serious damage due to mis-operation.
(b) Where the auxiliary machinery essential for main propulsion of the ship are driven by electric motors, the main propulsion machinery is to be so designed as to stop automatically in the event of failure of the main source of electrical power or to be capable of being stopped.
(c) The main propulsion machinery is to be so arranged as not to re-start automatically when electrical power is restored after the failure of the main source of electrical power whereas the main propulsion machinery was stopped.
(d) The remote control devices for main propulsion machinery or controllable pitch propellers are to be so designed that the engine may not be abnormally overloaded in the event of failure of them.
(B) Stopping devices for main propulsion machinery are to be provided at the monitoring station for main propulsion machinery or controllable pitch propellers.
(2) Safety systems of main propulsion machinery
Safety systems of main propulsion machinery are to comply with the following requirements:
(A) A device to shut off the fuel or steam supply (this device hereinafter being referred to as "safety device") for the main propulsion machinery is not to be automatically activated except in cases which could lead to complete breakdown, serious damage or explosion.
(B) The safety systems for the main propulsion machinery are to be so designed as not to lose their function or as to fail to safe, even in the event of failure of main electrical source or air source.
(3) Self-reversing diesel engines
At least the following safety measures are to be taken to the remote control devices for self-reversing diesel engines:
(A) Starting operation is to be possible only when the camshaft is surely at the position of "Ahead" or "Astern".
(B) During reversing operation, fuel is not to be injected.
(C) Reversing operation is to be conducted after "Ahead" revolution is reduced to a predetermined value.
(4) Main propulsion machinery of a multi-engines coupled to a single shaft ship
At least the following safety measures are to be taken to the remote control devices for multi-engines coupled to a single shaft:
(A) Each main propulsion machinery is to be provided with an overload preventive device.
(B) Each main propulsion machinery is not to be subjected to an abnormally unbalanced load.
(5) Main propulsion machinery with clutch
At least the following safety measures are to be taken to the remote control devices for engines with clutch:
(A) The clutch equipped to a main propulsion machinery in a multi-engines coupled to a single shaft is to be disengaged when the main propulsion machinery is stopped in an emergency. While multi-engines are operating in different directions of rotation their clutches are not to be engaged simultaneously.
(B) Engaging and disengaging of clutches are to be carried out below a predetermined revolutions of the main propulsion machinery.
(C) An overspeed protective devices specified in **Pt 5, Ch 2, 203. 1** and **2** or **Pt 5, Ch 2, 304. 1** of the Rules for the Survey and Construction of Steel Ships is to be provided.
(D) In case where there is fear that the speed of the propulsion motor would exceed 125 % of the rated revolution when the clutch is disengaged, an overspeed protective device as deemed appropriate by the Society it to be provided.
(6) Main propulsion machinery driving controllable pitch propellers
At least the following safety measures are to be taken to the remote control devices for engines driving controllable pitch propellers:

(A) In overload preventive device is to be provided.
(B) Starting of engines or engaging of clutches is to be performed while the propeller blades are in a neutral position.
(C) An overspeed protective device as specified in **Pt 5, Ch 2, 203. 1** or **Pt 5, Ch 2, 304. 1** is to be provided.
(D) In case where there is fear that the speed of the propulsion motor would exceed 125 % of the rated revolution when the propeller pitch is altered, an overspeed protective device as deemed appropriate by the Society is to be provided.

(7) Slow speed(crosshead) main diesel engines
For the slow speed main diesel engines, safety system specified in **Table 9.3.1** is to be provided.
(8) Medium and high speed(trunk piston) main diesel engines
For medium and high speed main diesel engines, safety system specified in **Table 9.3.2** is to be provided.
(9) Propulsion steam turbine
For propulsion steam turbines, safety system specified in **Table 9.3.3** is to be provided.
(10) Electric propulsion equipments
For electric propulsion equipments, safety system specified in **Table 9.3.4** is to be provided.
(11) Controllable pitch propellers
For controllable pitch propellers, safety system specified in **Table 9.3.5** is to be provided.

306. Automatic and remote control of boilers

1. General

(1) The systems of automatic control for both combustion and feed water of oil-fired boilers are to comply with the requirements in **Par 2** to **Par 4** respectively.
(2) The systems of automatic control for either combustion or feed water of oil-fired boilers are to comply with the relevant requirements in **Par 2** or **Par 3** as well as the requirements in **Par 4.**
(3) Automatic control of boilers other than oil-fired boilers or having a special feature is to be deemed appropriate by the Society.
(4) Remote water level indicators are to comply with the requirements in **Pt 5, Ch 5, 129.** for the Survey and Construction of Steel Ships.

2. Automatic combustion control systems

(1) General
Automatic combustion control systems are to comply with the following requirements:
(A) The automatic combustion control systems are to be able to control so as to obtain planned steam amount, steam pressure and steam temperature and to secure stable combustion.
(B) The devices to control the fuel supply to meet the load imposed are to be capable of ensuring stable combustion in the controllable range of fuel supply.
(C) Where combustion control is carried out according to the pressure of the boiler, the upper limit of this pressure is to be lower than the set pressure of the safety valves.

(2) Combustion control devices for intermittent operation
The combustion control devices for intermittent operation are to comply with the following requirements and they are to operate according to the planned sequence:
(A) Before ignition on the pilot burner or before ignition on the main burner if the pilot burner is not fitted, the combustion chamber and the flue are to be pre-purged by air of not less than 4 times the volume of the combustion chamber and the flue up to the boiler uptake. For small boilers with only one burner, pre-purge for not less than 30 seconds will be accepted.
(B) In case of direct ignition which is a method of ignition that the main burner is fired by ignition spark, opening of the fuel valve is not to precede the ignition spark.
(C) In case of indirect ignition which is a method of ignition that the main burner is fired by the pilot burner, opening of the fuel valve for the pilot burner (hereinafter referred to as " ignition fuel valve") is not to precede the ignition spark, and opening of the fuel valve for the main burner (hereinafter referred to as "main fuel valve") is not to precede opening of the ignition fuel valve.

(D) Firing is to be surely carried out within the planned period. Main fuel valve is to be so designed as to close after opening of the valve not exceeding 10 seconds in the case of direct ignition and 15 seconds in the case of indirect ignition if the firing on the main burner has failed.
(E) Firing on the main burners is to be carried out at their low firing position.
(F) After closure of the main fuel valve, post-purge is to be carried out for not less than 20 seconds to ensure adequate combustion air to completely burn all fuel oil remaining between the fuel oil valve and the burner nozzle. This requirements need not to be complied with in the case of auxiliary boilers as deemed appropriate by the Society.

(3) Combustion control devices for the control of the number of firing burners
The combustion control devices for the control of the number of firing burners are to comply with the following requirements:
(A) Each burner is to be fired and extinguished according to the planned sequence. However, the base burner may be fired by manual operation and other burners may be fired by flame of a burner(s) already fired.
(B) The remaining fuel in the extinguished burner is to be automatically burnt up in order not to interfere the restarting. However, while the pilot burner is not fired, the remaining fuel in the base burner is not to be removed by steam or air when it is in place.
(C) The burners for main boilers are to be capable of being fired and extinguished from the main control station or the main control station on bridge, except for the firing of base burner.

(4) Other combustion control devices
Other combustion control devices are to be deemed appropriate by the Society, as well as they are to comply with the relevant requirements in (2) and (3).

3. Automatic feed water control devices

(1) Automatic feed water control devices are to be capable of controlling automatically the feed water in order to maintain the water level in the boilers in a predetermined range.
(2) Main boilers are to be provided with not less than three water level detectors used for a feed water control device, a remote water level indicator, a low-water level safety device and a low-water level alarm device.

4. Safety measures

(1) Safety devices
Safety devices are to comply with the following requirements.
(A) A self-closing valve is to be provided in the feed water piping of the main boiler, and is to operate automatically in the event of abnormal rise of the water level in the main boiler.
(B) Safety devices for low water level in the main boilers are to be put into action by means of a signal from either one of the two low water level detectors which are independent each other. However, one of those detectors may be used for other purpose.

(2) For main boilers, safety system specified in **Table 9.3.6** is to be provided.
(3) For essential auxiliary boilers, safety system specified in **Table 9.3.7** is to be provided.

307. Automatic and remote control of electric generating sets

1. General

(1) Electric generating sets arranged to be automatically or remotely started are to be provided with interlocking devices necessary for safe operation.
(2) Electric generating sets arranged to be automatically started are to be so designed that the number of automatic consecutive attempts which fail to produce a start is limited to two times and to be provided with an alarm device which operate at the time of the failure of starting.
(3) In case where a diesel engine to drive a propulsion generator is remote started, the number of starting is to conform to the required number specified in **Pt 5, Ch 2, 202. 5.**
(4) Where automatic start of the standby generating set with automatic connection to the switchboard busbars is provided, automatic closure on to the busbars is to be limited to one attempt in the event of the original power failure being caused by short circuit.

(5) Automatic control and remote control systems for the electric generating set, whose generator is driven by the main propulsion machinery and supplies electrical power to the electrical installations relating to the services specified in **Pt 6, Ch 1, 201. 1** (1) and is operated while the main propulsion machinery is controlled by the bridge control devices are to comply with the requirement in **Pt 6, Ch 1, 201. 2** in addition to those in this **Sec 307.**

2. Safety measures

For auxiliary diesel engines and auxiliary steam turbines, safety system specified in **Table 9.3.8**. For main generators, safety system specified **Table 9.3.9** is to be provided.

308. Automatic and remote control of thermal oil installations

1. Control devices

Control devices are to comply with the requirements in **306. 2** (1) and (2) as well as those in **Pt 5, Ch 5, 202. 1** and **2.**

2. Safety measures

Safety devices are to comply with **Pt 5, Ch 5, 201.** and **Pt 5, Ch 5, 202. 5** and safety system specified in **Table 9.3.10**.

309. Automatic and remote control of other machinery

1. Air compressors

(1) Automatic operation of air compressors
In case where air compressors for starting and air compressors for controlling are automatically operated, alarm devices are to be provided to indicate pressure drop in air reservoirs.
(2) Safety devices
Air compressors are to be so arranged as to stop automatically in the event of drop of lubricating oil pressure.

2. Heat exchangers

The following heat exchangers used for main propulsion machinery, main boilers, important auxiliary boilers, generators and prime movers driving auxiliary machinery essential for main propulsion of ships are to be provided with temperature control devices in order to regulate the temperatures of lubricating oil, coolant and fuel oil in a predetermined range:
(1) Lubricating oil coolers
(2) Coolers for cylinder coolant water
(3) Coolers for piston coolant
(4) Coolers for fuel valve coolant
(5) Fuel oil heaters
(6) Heaters for fuel oil purifiers
(7) Heaters for lubricating oil purifiers

3. High temperature alarm for oil heaters

In case where a temperature for fuel oil and lubricating oil is automatically controlled, high temperature alarm devices are to be provided, except where oils are not heated above the flash point.

4. Opening and closing devices for sea valves

In case where sea valves fitted on the shell plating below the load water line are remotely or automatically controlled, other opening and closing devices which can be easily operated even in the event of failure of the automatic or remote control devices are to be provided.

5. Liquid level alarm systems for fuel oil tanks

In case where fuel transfer to fuel oil tanks is automatically controlled, the receiving tanks are to be provided with a high and low level alarm.

6. Mooring arrangements

In case where mooring arrangements are provided with remote control devices, the mooring arrangements are to be capable of being locally operated.

7. Fuel oil filling arrangements

In case where arrangements for filling fuel oil into respective fuel oil tanks from the outside of the ships (hereinafter referred to as "fuel oil filling arrangements") are provided with remote control devices, the fuel oil filling arrangements are to be such as not to interfere with filling of fuel even in the event of failure of the remote control devices.

8. Alarms

For other machinery alarm devices specified in **Table 9.3.11** are to be provided

310. Override arrangements

1. Application

(1) Automatic slowdowns and automatic shutdowns specified in **Table 9.3.1** to **Table 9.3.8** are to be provided with override arrangements, regardless of the mode of control(manual, remote or automatic). However, override arrangements do not need to be fitted in those cases where override may result in total failure of the engine and/or propulsion equipment within a short time. Automatic slowdowns and automatic shutdowns where provided in excess of those indicated in **Table 9.3.1** to **Table 9.3.8** are to be provided with override arrangements.

Table 9.3.1 Slow speed (Crosshead) diesel engines

Systems	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto slow down with alarm	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Sensors	Common or separate		c	c	c	s	s	c = common; s = separate
Fuel oil	Fuel oil after filter (engine inlet), pressure	L	●	●		●		
	Fuel oil before injection pumps, temp. (or viscosity L)	H	●					
	Fuel oil before injection pumps, temp. (or viscosity H)	L	●					
	Leakage from high pressure pipes	O	●					
	Fuel oil service tank, level	L	●					
	Common rail fuel oil pressure	L	●					
Lubricating oil	Lub. oil to main bearing and thrust bearing, pressure	L	●	●	●	●	●	
	Lub. oil to crosshead bearing, pressure	L	●	●	●	●	●	If of a different system.
	Lub. oil to camshaft, pressure	L	●			●	●	If of a different system.
	Lub. oil to camshaft, temp.	H	●					If of a different system.
	Lub. oil inlet, temp.	H	●					
	Thrust bearing pads temp. or bearing outlet temp.	H	●		●		●	
	Oil mist concentration in crankcase - H or Main, crank, crosshead bearing temp. (or bearing oil outlet temp).- H	H	●		●			For engines having power ≧ 2250 kW or cylinder bore > 300 mm (1)
	Each cylinder lubricator, flow rate	L	●		●			
	Lub. oil tanks, level	L	●					Where separate lubricating oil systems are installed (e.g. camshaft, rocker arms, etc.), individual level alarms are required for all the tanks.
	Common rail servo oil pressure	L	●					
Turbocharger	Lub. oil inlet, pressure	L	●					Unless provided with a self-contained lubricating oil system integrated with the turbocharger
	Lub. oil outlet (each bearing), temp.	H	●					(2)
	Speed			●				
Piston cooling	Coolant inlet, pressure	L	●		●	●		The slow down is not required if the coolant is oil taken from the main cooling system of the engine.
	Coolant outlet (each cylinder), temp.	H	●		●			
	Coolant outlet (each cylinder), flow	L	●		●			Where due to the design of the engine the flow of piston coolant outlet cannot be monitored, this item may be reconsidered.
	Coolant in expansion tank, level	L	●					

Table 9.3.1 Slow speed (Crosshead) diesel engines (continued)

Systems	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto slow down with alarm	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Sensors	Common or separate		c	c	c	s	s	c = common; s = separate
Sea water cooling	Sea water cooling, pressure	L	●			●		
Cylinder fresh water cooling	Water inlet, pressure	L	●		●	●		
	Water outlet from each cylinder, temp. (or *common water outlet, temp. H)	H	●		●			* Sensing at common water outlet is permitted for cylinder jackets fitted with common cooling space without intervening stop valves.
	Oily contamination of engine cooling water system.	O	●					Where engine cooling water is used in fuel and lubricating oil heat exchangers.
	Cooling water expansion tank, level	L	●					
Compre-ssed air	Starting air before main shut-off valve, pressure	L	●	●				
	Control air, pressure	L	●					
	Safety air, pressure	L	●					
Scavenge air	Scavenge air receiver, pressure			●				
	Scavenge air box, temp. (fire)	H	●		●			
	Scavenge air receiver water level	H	●					
Exhaust gas	Exhaust gas after each cylinder, temp.	H	●	●	●			
	Exhaust gas after each cylinder, deviation from average, temp.	H	●					
	Exhaust gas before each turbocharger, temp.	H	●	●				
	Exhaust gas after each turbocharger, temp.	H	●	●				
Fuel valve Coolant	Coolant, pressure	L	●			●		
	Coolant, temp.	H	●					
	Coolant expansion tank, level	L	●					
Engine	Speed/direction of rotation			●				
	Rotation-wrong way	O	●					
	Engine overspeed	O	●				●	
	Remote start failure	O	●					
Power	Control, alarm or safety system, power supply failure	O	●					

(NOTES)

(1) Oil mist detection system is to be of the approved type by the Society, tested by **Ch 3, Sec. 10 of the Guidance for Approval of Manufacturing Process and Type Approval, Etc.** and applied to **Pt 5, Ch 2, 203.**

(2) Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.

Table 9.3.2 Medium and high speed (trunk piston) diesel engines

Systems	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto slow down with alarm	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Sensors	Common or separate		c	c	c	s	s	c = common; s = separate
Fuel oil	Fuel oil after filter (engine inlet), pressure	L	●	●		●		
	Fuel oil before injection pumps, temp. (or viscosity L)	H	●					For heavy fuel oil burning engines only.
	Fuel oil before injection pumps, temp. (or viscosity H)	L	●					For heavy fuel oil burning engines only.
	Leakage from high pressure pipes	O	●					
	Fuel oil service tank, level	L	●					High level alarm is also required if without suitable overflow arrangements.
	Common rail fuel oil pressure	L	●					
Lubricating oil (Diesel engine)	Lub. oil to main bearing and thrust bearing, pressure	L	●	●		●	●	
	Lub. oil filter differential, pressure	H	●	●				
	Lub. oil inlet, temp.	H	●	●				
	Oil mist in crankcase, mist concentration(H) or main & connecting rod bearing temp. (or oil outlet temp.)(H) or an equivalent device	H	●				●	Only for medium speed engines having power ≧ 2250 kW or cylinder bore > 300 mm. Single sensor having two independent outputs for initiating alarm and for shutdown will satisfy independence of alarm and shutdown. (1) An equivalent device could be interpreted as measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.
	Each cylinder lubricator, flow rate	L	●		●			If necessary for the safe operation of the engine.
	Common rail servo oil pressure	L	●					
Reduction Gear	Reduction gear lub. oil inlet pressure	L	●	●	●	●	●	Shutdown is to affect all power input to gear
Turbo-charger	Turbo-charger lub. oil inlet pressure	L	●	●				Unless provided with a self-contained lubricating oil system integrated with the turbocharger
	Turbo-charger lub. oil temperature each bearing	H	●					(2)
Sea water cooling	Sea water cooling system pressure	L	●	●		●		
Cylinder fresh water cooling	Water inlet, pressure low or flow	L	●	●	●	●		
	Water outlet (general), temp.	H	●	●	●			Two separate sensors are required for alarm and slowdown.
	Cooling water expansion tank, level	L	●					

Table 9.3.2 Medium and high speed (trunk piston) diesel engines (continued)

Systems	Monitored parameters [H : High L : Low O : Abnormal status]		AA	RI	Auto slow down with alarm	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Sensors	Common or separate		c	c	c	s	s	c = common; s = separate
Compressed air	Starting air before shut-off valve, pressure	L	●	●				
	Control air pressure	L	●	●				
Scavenge air	Scavenge air receiver temp.	H	●					
Exhaust gas	Exhaust gas after each cylinder, temp.	H	●	●	●			For engine power > 500 kW /cylinder
	Exhaust gas after each cylinder, deviation from average, temp.	H	●					
Engine	Speed			●				
	Overspeed	O	●				●	
	Remote start failure	O	●					
Power	Control, alarm or safety system, power supply failure	O	●					

(NOTES)

(1) Oil mist detection system is to be of the approved type by the Society, tested by **Ch 3, Sec. 10 of the Guidance for Approval of Manufacturing Process and Type Approval, Etc.** and applied to **Pt 5, Ch 2, 203.**

(2) Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.

Table 9.3.3 Propulsion steam turbines

Systems	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto slow down with alarm	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Sensors	Common or separate		c	c	c	s	s	c = common; s = separate
Lubri-cating oil	Pressure at bearing inlets	L	●	●		●	●	For turbines, gears and thrust bearings.
	Temp. at bearing inlet	H	●	●				For turbines, gears and thrust bearings.
	Bearing temp. or bearing oil outlet temp.	H	●	●				For turbines, gears and thrust bearings.
	Filter differential pressure	H	●					
	Gravity tank and sump levels	L	●	●				
Lubri-cating oil Cooling medium	Pressure or flow	L	●	●		●		
	Temp. at outlet	H	●					
	Expansion tank level	L	●	●				
Sea wa-ter	Pressure or flow	L	●	●		●		
	Pump auto starting and running			●				For vessels fitted with sea inlet scoops
	Scoop valve open/close			●				For vessels fitted with sea inlet scoops.
Steam	Pressure at throttle	L	●				●	
	Pressure, ahead chest			●				
	Pressure, astern chest			●				
	Pressure, gland seal			●				
	Gland seal exhaust fan failure	O	●					
	Astern guardian valve position			●				
	Astern guardian valve fail to open	O	●					In response to throttle trip or maneu-vering signal.
Cond-ensate	Condenser level	H	●	●			●	
	Condenser level	L	●	●				
	Condensate pump pressure	L	●			●		
	Condenser vacuum	L	●	●			●	
	Salinity	H	●	●				
Turbine	Vibration Level	H	●		●			
	Axial Displacement large	O	●				●	
	Speed			●				
	Overspeed	O	●				●	
	Shaft rollover activated			●				
	Shaft stopped excess of set period	O	●					Shaft rollover to be activated man-ually or automatically
Power	Throttle control system power failure	O	●					

Table 9.3.4 Electric propulsion equipments

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Propulsion Generator	Bearing lub. oil inlet pressure	L	●	●	●	Prime mover automatic shutdown
	Voltage off-limits	O	●	●		To read all phases and at least one bus
	Frequency off-limits	O	●	●		
	Current			●		To read all phases
	Stationary windings temperature	H	●	●		To read all phases; for generators > 500 kW
	Main generator circuit breakers open/close			●		
	Generator running			●		
	Failure of on-line generator	O	●			
	Transfer of standby generator	O	●			
	Generator cooling medium temperature	H	●	●		If applicable
	Failure of generator cooling pump or fan motor	O	●			If applicable
	Field voltage and current			●		For DC generator
	Inter-pole winding temperature	H	●	●		For DC generator
Propulsion Motor - AC	Bearing, lub. oil inlet pressure	L	●	●	●	
	Armature voltage off-limits	O	●	●		To read all phases and at least one bus
	Field voltage			●		
	Frequency off-limits	O	●	●		
	Armature current			●		To read all phases
	Field current			●		For synchronous motors
	Ground lights or similar			●		
	Stationary windings temperature	H	●	●		To read all phases; for motors > 500 kW
	Motor circuit breakers open/close			●		
	Motor running			●		
	Failure of on-line motor	O	●			
	Transfer of standby motor	O	●			
	Motor cooling medium temperature	H	●	●		If applicable
	Failure of cooling pump or fan motor	O	●			If applicable

Table 9.3.4 Electric propulsion equipments (continued)

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Propulsion Motor - DC	Bearing lub. oil inlet pressure	L	●	●	●	
	Armature voltage off-limits	O	●	●		
	Field voltage			●		
	Armature current			●		
	Field current			●		
	Ground lights or similar			●		
	Motor circuit breakers open/close			●		
	Motor running			●		
	Motor overspeed	O	●		●	
	Failure of on-line motor	O	●			
	Transfer of standby motor	O	●			
	Motor cooling medium temperature	H	●	●		If applicable
	Failure of cooling pump or fan motor	O	●			If applicable
Propulsion SCR	Voltage			●		
	Current			●		
	Overload (high current)	O	●			Alarms before protective device is activated
	Open/close position for assignment switches			●		
	SCR cooling medium temperature	H	●	●		If applicable
	Failure of SCR cooling pump or fan motor	O	●			If applicable
Transformer	Transformer winding temperature high	O	●	●		For each phase

Table 9.3.5 Controllable pitch propellers

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	Auto start of Stand by pump with alarm	Notes [AA = Alarm Activation ●=apply]
Hydraulic oil	Delivery pressure or flow rate	L	●	●	
	Tank, level	L	●		

Table 9.3.6 Main boiler

System	Monitored parameters [H: High L: Low LL: Low-Low O: Abnormal status]		AA	RI	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Sensors	Common or separate		c	c	s	s	c = common sensor; s = separate sensor
Feed water	Atmospheric drain tank level	H L	●	●			
	Dearator level	H L	●	●			
	Dearator pressure	H L	●	●			
	Feed water pump pressure	L	●	●	●		
	Feed water temperature	H	●	●			
	Feed water outlet salinity	H	●	●			
Boiler Drum	Water level	H L	●	●			
	Water level	LL	●			●	
Steam	Pressure	H L	●	●			
	Superheater outlet temperature	H	●	●			
Air	Forced draft pressure failure	O	●			●	
	Rotating air heater motor failure	O	●				If provided
	Air register open/close			●			
	Fire in boiler casing	O	●	●			
Fuel oil	Pump pressure at outlet	L	●	●	●		
	Heavy fuel oil temperature (or viscosity L)	H	●	●			
	Heavy fuel oil temperature (or viscosity H)	L	●	●			
	Master fuel oil valve open/close			●			
Burner	Burner valve open/close			●			Individual
	Atomizing medium pressure off-limits	O	●	●			
	Ignition or flame of burners fails	O	●	●		●	For multiple burners, flame failure of a single burner is to shutdown the corresponding burner fuel valves.
	Flame scanner fails	O	●			●	For multiple burners fitted with individual flame scanner, failure of flame scanner is to shutdown the corresponding burner fuel valves.
	Uptake gas temperature	H	●				For fire detection
Power	Control system power supply fails	O	●	●		●	Automatic closing of fuel valve(s)

Table 9.3.7 Auxiliary boiler

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Feed water	Feed water outlet salinity	H	●	●		
Boiler drum	Water level	H	●			
	Water level	L	●	●	●	
Steam	Pressure	H L	●	●		
	Superheater outlet temperature	H	●	●		
Air	Supply air pressure failure	O	●		●	
	Fire in boiler casing	O	●			
Fuel oil	Pump outlet pressure	L	●	●		
	Temperature (or viscosity L and H)	H L	●	●		For heavy fuel oil only
Burner	Fuel oil valves open/close			●		Individual valves
	Ignition or flame fails	O	●	●	●	Individual
	Flame scanner fails	O	●		●	Individual
	Uptake gas temp.	H	●			
Power	Control system power supply fails	O	●		●	

Table 9.3.8 Auxiliary diesel engines and auxiliary turbines

Engine	System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Auto start of Stand by pump with alarm	Auto shut down with alarm	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Diesel Engine	Lubricating oil	Bearing oil inlet pressure	L	●	●		●	
		Bearing oil inlet temperature	H	●	●			
		Oil mist in crankcase, mist concentration(H) or main & connecting rod bearing temp. (or oil outlet temp.) (H) or an equivalent device.	H	●			●	Only for medium speed engines having power ≧ 2250 kW or cylinder bore > 300 mm. Single sensor having two independent outputs for initiating alarm and for shutdown will satisfy independence of alarm and shutdown.(1) An equivalent device could be interpreted as measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.
		Common rail servo oil pressure	L	●				
	Cooling medium	Pressure or flow	L	●	●	●		
		Temperature at outlet	H	●	●			
		Expansion tank level	L	●				
	Fuel oil	Fuel oil leakage from injection pipe	O	●				
		Fuel oil temp. (or viscosity L and H)	H L	●				For heavy fuel oil only
		Service tank level	L	●				
		Common rail fuel oil pressure	L	●				
	Starting medium	Energy level	L	●	●			
	Exhaust	Exhaust gas temperature after each cylinder	H	●				For engines having a power of more than 500 kW/cyl.
	Speed	Overspeed	O	●			●	
Steam Turbine	Lubricating oil	Bearing oil inlet pressure	L	●	●	●*	●	* : Back-up lubricating pump start
		Bearing oil inlet temperature	H	●	●			
		Bearing temperature or bearing oil outlet temperature	H	●	●			
	Lub. oil Cooling medium	Pressure or flow	L	●	●			
		Temperature at outlet	H	●				
		Expansion tank level	L	●				
	Sea water	Pressure or flow	L	●	●			
	Steam	Pressure at inlet	L	●	●			
	Condensate	Condenser vacuum	L	●	●		●	
		Condensate pump pressure	L	●	●			
	Rotor	Axial displacement large	O	●			●	
		Overspeed	O	●			●	

(NOTES)

(1) Oil mist detection system is to be of the approved type by the Society, tested by **Ch 3, Sec. 10 of the Guidance for Approval of Manufacturing Process and Type Approval, Etc.** and applied to **Pt 5, Ch 2, 203.**

Table 9.3.9 Main generators

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	RI	Notes [AA = Alarm Activation RI = Remote Indication ●=apply]
Electricity	Ampere	H	●	●	Sensors for controllers may be used
	Voltage	H L	●	●	
	Frequency or revolution of generator	H L	●	●	

Table 9.3.10 Thermal oil installations

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	Auto start of Stand by pump with alarm	Notes [AA = Alarm Activation ●=apply]
Thermal oil	Delivery pressure or flow rate	L	●	●*	* : Thermal oil circulating pump
	Flow or pressure difference between outlet and inlet of heater	L	●		
	Temperature	H	●		
	Level in expansion tank	L	●		
Fuel	Pressure, burner inlet	L	●	●**	** : Fuel oil supply pump
	Temperature, burner inlet	L	●		
Others	Flame failure	O	●		

Table 9.3.11 Other machinery

System	Monitored parameters [H: High L: Low O: Abnormal status]		AA	Notes [AA = Alarm Activation ●=apply]
Main shaftings	Stern tube aft bearing or bearing oil in bath	H	●	or stern tube outlet oil when forced circulation system is used. applied to oil lubrication system.
	Critical speed	O	●	
Auxiliaries	Distilling plant, salinity	H	●	
	Purifier, malfunction	O	●	
	F.O. or L.O. heater outlet, temperature	H	●	or heater outlet, flow L
	External desuperheater, steam temperature	H L	●	L is required when the steam is used for the aux. turbine relating to propulsion.
Fuel oil	Settling tank, level	H L	●	H is required in case of automatic filling only.
	Drain tank, level	H	●	
	Sludge tank, level	H	●	
Lub. oil and control oil	Drain tank, level	H	●	
	Sludge tank, level	H	●	
	Gravity tank, level	L	●	applied to oil bath type stern tube bearing, exhaust gas turbocharger and reduction gears for propulsion turbines
Water	Cooling water expansion (make-up) tank, level	L	●	
	Cascade tank, level	L	●	applied to diesel ship
	Atmospheric drain tank, level	H L	●	applied to steam turbine ship
	Distilled water tank, level	L	●	
Air	Starting air tank for propulsion engine, pressure	L	●	
	Staring air tank for generator diesel engine, pressure	L	●	applied to steam turbine ship
Control oil, control air and control power	Hydraulic control system, pressure	L	●	not required when they are integrated with engine's L.O. system
	Pneumatic control system, pressure	L	●	
	Control electric power, failure	O	●	

Section 4 Operating Systems for Periodically Unattended Machinery Spaces

401. General

1. Scope

(1) The requirements in this Section apply to the operating systems for periodically unattended machinery spaces of UMA ships.
(2) Automatic and remote control systems of UMA ships, which are specified in **Sec 5**, are to comply with the requirements in the Section.

2. General

(1) UMA ships are to be designed and arranged as to ensure that the safety of the ship is equivalent under all sailing conditions including maneuvering to that of a ship operated with watch keeping personnel at all times.
The design and arrangements are to be capable of performing unattended machinery operation for at least 24 consecutive hours.
(2) Operating systems for periodically unattended machinery spaces of UMA ships are to comply with the requirements in this Section as well as those in **Sec 3**. However, in **Sec 3**, standby pumps specified in **Table 3.1** to **Table 3.6** and in **Table 3.8** to **Table 3.9** are to be automatically started and those relevant alarms are to be activated.

402. Monitoring and control systems in navigation

1. Bridge control devices

The bridge control devices specified in **305. 3** are to be provided in the navigation bridge. The bridge control devices provided in the navigation bridge or at the bridge the centralized monitoring and control station are to include the following devices:
(1) Bypass devices to temporarily override the function of the program control devices or other devices considered appropriate by the Society which are provided according to the requirement in (2) and an indicator to show the activation of the bypass devices.
(2) The bridge control devices are to be provided with program control devices or other approved means to ensure that the main propulsion machinery will not suffer undue mechanical stress and thermal stress and speed of the main propulsion machinery is easily increased and decreased or easily increased. In case where, however, specially approved by the Society taking the kind of engines and so on into consideration, the program control devices or other means as may be dispensed with.

2. Navigation bridge

The alarm devices specified in the following are to be provided in the navigation bridge.
(1) Alarm devices for main propulsion machinery or controllable pitch propellers, electric generating sets and auxiliary machinery essential for main propulsion of the ship. The visual alarms may be displayed as group alarms. However, the visual alarms for automatic stoppage and for automatic reduction of speed of or load to the main propulsion machinery are to be displayed separately.
(2) Bilge alarm devices
(3) An alarm device for prolonged running in critical speed range

3. Bridge centralized monitoring and control station

(1) The alarm devices provided at the bridge centralized monitoring and control station are to comply with the following requirements.
(A) At least the following visual alarms of alarms required in **304. 2** (6) are to be equipped at confirmable positions from the place to control the operating handle of the main propulsion machinery.
(a) The alarms for automatic stoppage
(b) The alarms for automatic reduction of speed or load, or the alarms for demanding speed or load reduction
(c) The alarms for failure of remote control systems specified in **305. 2** (3) (A)
(d) The alarms for low starting air pressure specified in **305. 2** (4) (C)
(e) The alarms for failure of remote starting specified in **Table 3.1** and **Table 3.2**

(f) The alarms for prolonged running in critical speed range specified in **Table 3.11**

(B) The alarm devices required in **304. 2** (6) and (10), excluding those specified in (A), are to be so arranged that the working conditions of machinery are perceived at a glance from the place to control the operating handle of the main propulsion machinery. Where it is impracticable to comply with this requirement, additional visual alarms which may be of group indication are to be provided.

(2) The bridge centralized monitoring and control station are to comply with the following requirements in their shapes, sizes and arrangements.

(A) The bridge centralized monitoring and control station is to be situated within one deck floor and not to be provided with any partition walls (steel walls, wooden walls, glass walls, etc.) inside of the station except where it is considered inevitable by the Society.

(B) At the bridge centralized monitoring and control station any audible alarm and order issued from any position is to be capable of being heard clearly and directly at any other position.

403. Safety measures, means of communication, etc.

1. Continuity of electrical source

(1) Where the electrical power can normally be supplied by one generator, the main source of electrical power is to comply with the followings:

(A) Suitable load shedding arrangements are to be provided to ensure the integrity of supply to services required for propulsion and steering as well as safety of the ship in case where the generator is overloaded.

(B) In case of loss of electrical power of the generator in operation, adequate provision is to be made for automatic starting and connecting to the main switchboard of a standby generator of sufficient capacity to permit propulsion and steering and to ensure safety of the ship with automatic re-starting of the important auxiliaries including sequential operations.

(C) The standby generator specified in (B) is to be capable of supplying electrical power in not more than 30 seconds after the loss of electrical power.

(2) If the electrical power is normally supplied by more than one generator simultaneously in parallel operation, provision is to be made, for instance by load shedding, to ensure that, in case of loss of electrical power of one of these generating sets, the remaining ones are kept in operation without overload to permit propulsion and steering, and to ensure safety of the ship.

2. Air compressors

(1) Starting air compressors are to be capable of operating automatically so as to maintain the pressure in the starting air reservoirs in a predetermined range.

(2) Air compressors used for charging the control air reservoirs are to be capable of operating automatically so as to maintain the pressure in the control air reservoirs in a predetermined range.

3. Means of communication

A means of vocal communication which is operable even in the event of failure of the main electrical power supply is to be provided between the bridge centralized monitoring and control station the local control station of main propulsion machinery (when a sub-control station is provided, the station may be acceptable instead) and the engineers accommodation for the ship provided with a bridge centralized monitoring and control station and between the navigating bridge, the centralized control station, the local control station of main propulsion machinery and the engineers accommodation for the other ships.

4. Alarm systems

Alarm systems are to comply with the following requirements.

(1) Alarm systems are to be arranged with automatic change-over to an independent standby power supply in the event of loss of the normal power supply.

(2) Failure of the normal power supply and standby power supply specified in (1) is to be indicated by independent alarms.

(3) Alarm devices are to be provided on the engineers accommodation to indicate the fault of main propulsion machinery, electric generating sets, and auxiliary machinery essential for main propulsion. For this requirements, the visual alarms may be displayed as group alarms.

(4) Alarm devices provided on the engineers accommodation are to comply with the following requirements:
(A) Alarm devices are to be provided in engineers public rooms
(B) Alarm devices are to be provided in the respective private rooms for engineers and to have connection to each of the engineers cabins through a selector switch, to ensure connection to at least a cabin of an engineer on watch.
(C) Alarm devices are to be capable of activating the engineers alarm required by **Pt 5, Ch 1, 107.** of the Rules for the Survey and Construction of Steel Ships if an alarm function has not received attention locally within a limited time.
(5) Audible alarm devices which will provide warning of faults in machinery and equipment specified in **107. 7** (14) (A) to (G) are to be installed in the spaces where main propulsion machinery, boilers, electric generating sets, etc. are situated.
(6) For the ships provided with a bridge centralized monitoring and control station the local silencing of the audible alarms equipped in engineers accommodation is not to stop the audible alarm required in (5) and the audible and visual alarms equipped at the bridge centralized monitoring and control station. For the other ships than the foregoing, the local silencing of the audible alarms equipped in the navigation bridge and engineers accommodation is not to stop the audible alarm required in (5) and the audible and visual alarms equipped at the centralized control station.
(7) Where unattended machinery operation is adopted, alarm systems which will provide warning of faults in machinery and equipment specified in **101. 7** (14) (A) to (G) are to be such that the person on watch in the navigation bridge is made aware when:
(A) a fault has occurred,
(B) the fault is being attended to, and
(C) the fault has been rectified.
However, communication system specified in **403. 3** will be accepted as a substitute for the alarm for (C).

Section 5 Automatic Equipment

501. General

1. Scope

The requirements of this section is to apply specific automation equipments.

502. Class 1 specific automation equipment

The ships intended to be registered as ships provided with Class 1 automation equipment are to be provided with the automation equipment specified in following **Par 1** to **7.** However, the equipment which considered acceptable by the Society may be omitted in consideration of the purpose of the ship, the method of the cargo handling and so on.

1. Remote-controlled ballasting / deballasting arrangement

The remote-controlled ballasting/deballasting arrangements are to comply with the following requirements:

(1) Ballast pumps are to be provided with the following remote control devices, alarm devices, etc. at suitable positions and to be capable of being monitored and controlled in those positions:
  (A) Speed control devices or start/stop devices of ballast pumps.
  (B) Control devices necessary for ballasting and deballasting, such as opening and closing of valves.
  (C) Monitoring devices for ballast tank level.
  (D) Audible and visible alarm devices which operate in the following cases where ballast pumps or prime movers driving a ballast pump are located in dangerous spaces:
    (a) When the lubricating oil pressure of pumps or prime movers falls abnormally (only in the case of forced lubrication system).
    (b) When the temperature of the bearings or the lubrication oil of pumps or prime movers rises abnormally.
    (c) When the temperature of stuffing box provided at the penetration parts of the bulkhead between the engine room and the cargo pump room rises abnormally.

(2) Steam turbines driving ballast pumps are to be provided with the following devices:
  (A) An automatic shut-off device which operates in the overspeed of the turbine and its alarm device.
  (B) An alarm device which operates in the case of abnormal increase of exhaust pressure of the turbines.

2. Automatic steering system

When the steering gear is operated with automatic pilot, the automatic steering system is to comply with the following requirements:

(1) Running indication of the automatic pilot is to be provided.
(2) The function of compass and other equipment necessary to maintain the maneuverability of ship is not to be affected.
(3) Changing over from automatic to manual steering and vice versa is to be possible at the bridge.
(4) Except for the course setting control, the actuation of any other control is not to be significantly affect the course of the ship.
(5) Means are to be incorporated to prevent unnecessary activation of the rudder due to abnormal yaw motion.
(6) The automatic pilots are to enable automatically the ship to keep a preset course by interlocking with a magnetic compass or gyrocompass.
(7) When changing over from manual to automatic steering, the automatic pilot is to be capable of bringing the ship to the preset course.
(8) Means are to be incorporated to enable rudder angle limitation, and also to be available to indicate when the angle of limitation has been reached.
(9) Audible and visual alarms are to be issued on the navigating bridge when the heading direction of a ship is deviated exceeding the course deviation of a preset amount.
(10) Audible and visual alarms are to be issued on the navigating bridge in order to indicate the failure in the power supply to the automatic pilot and the alarm system specified in (9) above.
(11) Any other items considered necessary by the Society.

3. Remote-controlled handling system for liquid cargo in bulk

The remote-controlled handling system for liquid cargo in bulk is to comply with the following requirements:

(1) For ships carrying liquid cargoes in bulk, cargo-handling centralized control stations are to be provided.
(2) Steam turbines driving cargo pumps are to be provided with the following devices:
 (A) An automatic shut-off device which operates in the overspeed of the turbine and its alarm device.
 (B) An alarm device which operate in the case of abnormal increase of exhaust pressure of the turbine.
(3) At cargo-handling centralized control stations, the following remote control devices and alarm devices are to be provided:
 (A) Control devices for controlling the number of revolutions of cargo pumps.
 (B) Control devices necessary for loading and unloading of cargoes such as opening and closing of valves.
 (C) Monitoring devices for cargo tank level.
 (D) Audible and visible alarm devices which operate in the following cases in case where ballast pumps or their prime movers are located in dangerous spaces:
  (a) When the lubricating oil pressure of pumps or prime movers falls abnormally (only in the case of forced lubrication system).
  (b) When the temperature of bearings or lubricating oil of pumps or prime movers rises abnormally.
  (c) When the temperature of stuffing box at the penetrating part of pump room bulkheads (in case where pumps are driven by the prime movers installed in the engine room) has become high.
  (d) When the temperature of casings of cargo oil pumps has become high.
 (E) Other devices deemed necessary by the Society.

4. Power-driven opening and closing devices

Side ports, ramp ways and steel hatch covers of hatchways on weather decks (except for those of pontoon type) (hereinafter referred to as "side port, etc.") are to be provided with power-driven opening and closing devices in compliance with the following requirements:

(1) At the place where opening and closing operation is carried out, the operation necessary for opening and closing of the relevant side ports, etc. is to be easily executed.
(2) At the place where opening and closing operation is carried out, the open or closed condition of side ports, etc. is to be capable of being confirmed.
(3) In case where deemed necessary by the Society, appropriate measures to maintain the safety at the time of opening and closing operation are to be taken.

5. Automatic recording devices for main engine

Automatic recording devices for main engine are to be capable of recording the lubricating oil pressure, the cooling water temperature and other necessary information in order to ascertain the operating condition of main engine automatically.

6. Remote-controlled mooring arrangements

Remote-controlled mooring arrangements are to comply with the following requirements:

(1) Mooring winches are to be provided with the remote control devices to be capable of effectively controlling releasing and winding of mooring lines.
(2) The remote control devices specified in (1) above are to be capable of handling three or more mooring lines respectively at bow and stern on the positions where the devices are installed.

7. Air-conditioning arrangements for control stations

Air-conditioning arrangements for control stations are to have sufficient capacity to maintain a normal environmental condition in the control stations and are to be provided with alarm devices which give visual and audible alarms in the event of abnormal operation of the air-conditioning arrangements.

503. Class 2 automation equipment

The ships intended to be registered as ships provided with Class 2 automation equipment are to be provided with the automation equipment specified in the following **Par 1** to **7** in addition to those in **502.** However, the equipment which considered acceptable by the Society may be omitted in consideration of the purpose of the ship, the method of the cargo handling and so on.

1. Remote-controlled fuel oil filling arrangements

Remote-controlled fuel oil filling arrangements(limited to the case of filling fuel oil for main engines) are to be provided with the following remote control devices, alarm devices, etc. at suitable positions and to be capable of being monitored and controlled in those positions. However, the devices specified in (1) may be omitted when the Society considers acceptable in consideration of the valve arrangements and fuel oil tanks. In this case, the devices specified in (2) and (3) are not required.

(1) Remote control devices for opening and closing of valves.
(2) Level monitoring devices for fuel oil tanks (except for fuel oil tanks not built in as a part of hull in the engine room).
(3) High level alarm devices for the fuel oil tanks (except for fuel oil tanks not built in as a part of hull in the engine room).
(4) Speed control devices for the pumps when fuel oil is filled by pumps provided on board.

2. Centralized monitoring device for refrigerating containers

The centralized monitoring device for the refrigerating containers is to be capable of carrying out the following functions for carrying refrigerating containers loaded with refrigerated cargo:

(1) Monitoring of operating condition of the refrigerating machinery, working condition of the defrosting device and inside temperature of refrigerating containers are to be clearly indicated.
(2) An alarm device which gives visual and audible alarms in the event of the abnormal conditions of inside temperature of refrigerating containers is to be provided.

3. Cargo hose handling winches

For oil tanker, the cargo hose handling winch is to be easily operated in connecting and disconnecting the cargo hoses with manifolds.

4. Automatic deck washing arrangements

For ships carrying coals, ores or similar cargoes in bulk, the automatic deck washing arrangement are to be of fixed type and are to comply with the following requirements:

(1) The automatic deck washing arrangements are to be capable of washing decks and hatch covers.
(2) The deck washing machines are to have enough strength against its working pressure and enough corrosion resistance to sea water.
(3) The pipes for washing water are to be firmly fixed to the hull.

5. Remote-controlled mooring arrangements at ship-sides

Remote-controlled mooring arrangements at ship-sides are to be capable of effectively controlling three or more mooring lines both at the bow and at the stern of the ship. And they are to be located where leaving and berthing of the ship is visible by the operators.

6. Power-operated pilot ladder winding appliances

The power-operated pilot ladder winding appliances are to be capable of operating easily to wind the ladder for pilots at the control position. However, the power-operated pilot ladder winding appliances need not to be provided where one person can operate.

7. Emergency towing rope winches

For ships carrying dangerous goods exclusively, the emergency towing rope winches are to be easily operated in heaving and releasing the emergency towing ropes, which are arranged at the time of berthing.

504. Class 3 automation equipment

The ships intended to be registered as ships provided with Class 3 automation equipment are to be provided with the automation equipment specified in the following **Par 1** to **7** in addition to those in **502.** and **503.** However, the equipment which considered acceptable by the Society may be omitted in consideration of the purpose of the ship, the method of the cargo handling and so on.

1. Centralized monitoring systems for machinery

The centralized monitoring systems for machinery are to be capable of clearly indicating the lubricating oil pressure, the cooling water temperature and other necessary information in order to monitor the conditions of main engines, prime movers for driving generators (excluding emergency generators), main boilers, essential auxiliary boilers and other machinery which affects the propulsion of ships at the navigating bridge.

2. Centralized control systems for machinery

The centralized control systems for machinery are to be capable of effectively controlling main engines, prime movers for driving generators (excluding emergency generators), main boilers, essential auxiliary boilers and other machinery which are necessary in order to operate these machinery at the navigating bridge.

3. Remote control arrangement for main engines and steering gear at the outside of the navigating bridge

The remote control arrangements for main engines and steering gear are to be capable of effectively starting, stopping, reversing and speed controlling of main engines and effectively controlling the rudder angle at the control station outside of the navigating bridge.

4. High level alarm devices for cargo hold bilge

For ships deemed necessary by the Society, high level alarm devices which will operate in the event that the bilge reaches the pre-determined level, are to be provided.

5. Independent remote-controlled mooring arrangements

The independent remote-controlled mooring arrangements are to be capable of controlling each drum of mooring winches independently at the remote control position, in addition to the requirement in **502. 6.**

6. Towing rope winches

Towing rope winches are to be effectively operated by one man in heaving and releasing the towing ropes at the control position. ⚓

CHAPTER 4 DYNAMIC POSITIONING SYSTEMS

Section 1 General

101. General

1. **Application** The requirements in this Chapter apply to the ships intended to be registered as ships provided with dynamic positioning systems.

2. **Related requirements** In addition to complying with the requirements in this Chapter, those are to be applied respectively such as follows: For machinery installations, **Pt 5;** For electorial installations, **Pt 6, Ch 1;** For Automatic and remote control systems, **Pt 6, Ch 2.**

3. **Classes of dynamic positioning systems** Dynamic positioning systems are classed as follows:

(1) DPS(0)
(2) DPS(1)
(3) DPS(2)
(4) DPS(3)

102. Terminology

Terms used in this Chapter are defined as follows:

(1) **Dynamic positioning systems** comprise the following sub-systems, control panels, and back-up systems which are necessary to dynamically positioning the ship.
 (A) Thruster units
 (B) Electrical equipment
 (C) Control systems
  (a) Control system
   (i) Remote control system
   (ii) Automatic control system
  (b) Measuring system
  (c) Control panel

(2) **Thruster units** comprise the followings:
 (A) Thruster, power transmission gears driving thruster, thruster control hardware for control of thruster speed, pitch and heading
 (B) Main propellers and other propulsion units when these are included in dynamic positioning control mode.

(3) **Power system** comprise all units necessary to supply the dynamic positioning system with power and include the followings
 (A) Prime movers with necessary auxiliary systems including piping
 (B) Generators
 (C) Switchboards
 (D) Distributing system (cabling and cable routing)

(4) **Control system** comprises all central hardware and software necessary to dynamically position the vessel.

(5) **Remote control system** is a semi-automatic control system, which enables the operator to give a defined thrust (force and direction) and a turning moment to the vessel.

(6) **Measuring system** comprise all hardware and software for the following position reference system and environmental sensor to supply information and corrections necessary to give position and heading reference.
 (A) Position reference system
  (a) Position reference system
  Position reference system is to incorporate suitable position measurement techniques which may be by means of the followings.
  - Acoustic device
  - Radio
  - Radar
  - Inertial navigation
  - Satellite navigation

- Taut wire
- or, other acceptable means depending on the service conditions for which the ship is intended

(B) Environmental sensor
(a) Vertical reference sensor to measure the pitch and roll of the ship
(b) Means to ascertained the wind speed and direction acting on the ship
(c) Heading reference system
- Gyrocompass or equivalent means

(7) **Control panels** comprise centrally and locally situated panels for operating the dynamic positioning system.

(8) **Performance capability rating** is calculated by the data specified in **103. 2** and this rating indicates the percentage of time that a ship is capable of holding heading and position under a standard set of environmental conditions.

103. Drawings and data

1. General In the case of the ships intended to be registered as ships provided with dynamic positioning systems, the drawings and data to be submitted for approval before the commencement of work are generally as follows:

(1) Drawings
(A) Plans showing the construction and layout of the dynamic positioning system
(B) Plans with respect to the automatic and remote control of the dynamic positioning system
(a) Functional block diagrams of the control system
(b) Functional block diagrams of the measuring system
(c) Details of monitoring functions of the control system and measuring system together with a description of the monitoring functions
(d) Details of the overall alarm system
(e) Details of the control stations, e.g. control panels and consoles, including the location of the control stations
(C) Electrical diagrams for control system and measuring system

(2) Data
(A) Equipment list of dynamic positioning systems (Name of equipment, model, type, Manufacturer)
(B) Failure modes and effect analysis(FMEA) data (in the case of the ships intended to be registered as ships provided with DPS(2) or DPS(3))
(C) Operation manuals (including details of the dynamic positioning system operation, installation of equipment, maintenance and fault finding procedures together with a section on the procedure to be adopted in emergency)
(D) Test schedules including the methods of testing and the test facilities

2. Performance capability rating In addition to the requirements in **Par 1** above, the following data is to be submitted when the assignment of the supplementary notation PCR is required:

(1) Drawings
(A) Lines plan
(B) General arrangement
(C) Details of thruster arrangement

(2) Data
(A) Thruster power and thrusts
(B) Details of between thruster and thruster, between thruster and hull, and between thruster and current interaction
(C) Design maximum environmental conditions
(D) Details of sea current loads, wave drift forces and wind forces on ship
(E) Allocation logic

Section 2 Requirements of Dynamic Positioning Systems

201. General

The ships intended to be registered as ships provided with dynamic positioning systems are to be provided dynamic positioning systems specified in **202.** and **203.**

202. Requirements of dynamic positioning systems

1. Thruster

(1) Design and location of thruster
(A) Thrusters are to be designed to minimize potential interference with other thrusters, sensors, hull or other surfaces which could be encountered in the service for which the ship is intended.
(B) Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.
(2) Performance of thruster
The response and repeatability of thrusters to changes in propeller pitch, speed or direction of rotation are to be suitable for maintaining the area of operation and the heading deviation specified.
(3) Alarm for thruster
Each thruster unit is to be provided with a high power alarm. The setting of this alarm is to be adjustable and below the maximum thruster output.

2. Power system

(1) Electrical generating system
(A) Capacity of electrical generating system For electrically driven thruster, the total capacity of electrical generating system is to be not less than the maximum auxiliary load. This may be achieved by parallel operation of two or more generating sets provided that the requirements of **Pt 6, Ch 1, 201. 2** are complied with.
(B) Continuity of electric source
When the electrical power requirements are supplied by one generator set, on loss of power there is to be provision for automatic starting and connection to the switchboard of a stand-by set and automatic restarting of essential auxiliary services.
(2) Electrical supply for thruster auxiliaries, control computers and measuring system
Thruster auxiliaries, control computers and measuring systems are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practical and without the use of common feeders, transformers, converters, protective devices or control circuits.
(3) Electrical supply for actuating mechanism
(A) Steerable thrusters are to be provided with two or more independent supplies of motive power to the pitch and direction actuating mechanisms.
(B) Thrusters having variable pitch propellers are to be provided with two or more independent supplies of motive power to the pitch actuating mechanisms.
(4) Common source
Where the electrical auxiliary services necessary for maintaining the ship normally in operational and habitable conditions, and the electorial service necessary for operating e the dynamic positioning thrusters are supplied from a common source, the following requirements are to be complied with:
(A) The voltage regulation and current sharing requirements defined in **Pt 6, Ch 1, 205. 4** and **5** or **206. 2** and **4** are to be maintained over the full range of power factors that may occur in service.
(B) Where silicon controlled converters (inverter, cycloconverter, rectifier, etc.) are used to feed the thruster motor and the instantaneous value of the line-to-line voltage wave-form on the *a.c.* auxiliary system busbars deviates by more than 10 percent of the maximum value of the fundamental harmonic, the electrical auxiliary services necessary for maintaining the ship normally in operational and habitable conditions are to be capable of withstanding the additional temperature rise due to the harmonic distortion. Control systems, alarms and safety equipment are to operate satisfactorily with the maximum supply system waveform distortion,

or be provided with suitably filtered or converted supplies.

(C) When the control system incorporates volatile memory, it is to be supplied via uninterruptible power supply.

(5) Number and rating of transformers
The number and ratings of power transformers are to be sufficient to ensure full load operation of the dynamic positioning system even when one transformer is out of service.

(6) Alarm for electrical generating system
An alarm is to be initiated at the dynamic positioning control stations when the total electrical load of all operating thruster units exceeds a preset percentage of the running generators capacity. This alarm is to be adjustable between 50 and 100 percent of the full load capacity having regard to the number of electrical generators in service.

3. Control system

(1) General Minimum number of control system, position reference system and environmental sensor for dynamic positioning systems is to be in accordance with the **Table 9.4.1**:

Table 9.4.1 Minimum Number of Control System, Position reference System and Environmental Sensor

Class	Control system		Position reference system	Environmental sensor		
				Heading reference system	Vertical reference sensor	Means to ascertained the wind and direction
DPS(0)	Remote control system(1)	1 set	1 set	1 set	1 set	each 1 set
DPS(1)	Automatic control system(2) Remote control system(1)(2)	1 set 1 set	2 sets(3)	1 set	1 set	1 set
DPS(2)	Automatic control system(2)	2 sets	3 sets(3)(4)	3 sets(3)	3 sets(3)	each 3 sets(3)
DPS(3)	Automatic control system(2) Emergency automatic control system(2)	2 sets 1 set	3 sets(3)(4)	3 sets(3)	3 sets(3)	each 3 sets(3)

(NOTES)
(1) To be provided to maintain the desired heading of the ship.
(2) To be arranged to operate independently so that a failure in one control system will not render the other control system inoperative.
(3) To be arranged to operate independently so that a failure in on position reference system(or environmental sensor) will not render the other position reference system(or environmental sensor) inoperative.
(4) To be provided with at least two different measurement techniques.

(2) Control system
The control system for dynamic positioning operation is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

(3) Measuring system

(A) Measuring systems are to be provided to ensure the specified area of operation and heading deviation can be effectively maintained.

(B) Set point for the desired heading
The deviation from the desired heading is to be adjustable, but is not to exceed the specified limits. Arrangements are to be provided to fix and identify the set point for the desired heading.

(C) Validation for measuring system
Suitable processing and comparative techniques are to be provided to validate the. control system inputs from position reference systems and other environmental sensors, to ensure the optimum performance of the dynamic positioning system.

(4) Indicators
Indications of the following are to be provided at each station from which it is possible to control the dynamic positioning system.

(A) The heading and location of the vessel relative to the desired reference point or course

(B) Vectorial thrust output of thrusters, individual and total
(C) Operational status of position reference systems and environmental sensors
(D) Environmental conditions, e.g. wind strength and direction
(E) Available status of standby thruster units

(5) Alarms
Alarms are to be provided for the following fault conditions:
(A) Control computer system fault
(B) Automatic changeover to a standby control computer system
(C) Abnormal signal errors revealed by the validity checks required by (3) (C)
(D) When the ship deviates from its predetermined area of operation
(E) When the ship deviates from its predetermined heading limits
(F) Taut wire excursion limit
(G) Fault of position reference system
(H) Fault of environmental sensor
(I) Automatic changeover to a standby position reference system or environmental sensor

203. Additional requirements for dynamic positioning systems

1. DPS(1)

(1) In the event of a failure of a position reference system, the control systems are to continue operating on signals from the remaining position reference system without manual intervention.
(2) The area of operation is to be adjustable, but is not to exceed the specific limits which are to be based on a percentage of water depth, or if applicable a defined absolute surface movement. Arrangements are to be provided to fix and identify the set point for the area of operation.
(3) In the event of failure of the most effective thruster the ship is to be capable of maintaining its predetermined area of operation and desired heading in the environmental conditions for which the ship is designed and classed.
(4) A manually initiated emergency alarm, clearly distinguishable from all other alarms associated with the dynamic positioning system is to be provided at the dynamic positioning control station to warn all relevant personnel in the event of a total. loss of dynamic positioning capability. In this respect consideration is to be given to additional alarms being provided at locations such as the master's accommodation and operational control stations.
(5) For electrically driven thruster units, the following requirements are to be complied with:
(A) With one generating set out of action, the capacity of the remaining generating sets is to be not less than the maximum dynamic positioning load with the most effective thruster inoperative together with all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions.
(B) Where generating sets are arranged to operate in parallel, the supplies to, essential services are to be protected by the tripping of non-essential loads as required by **Pt 6, Ch 1, 305. 10** and additionally, on loss of a running generating set, a reduction in thrust demand may be accepted provided the, arrangements are such that a sufficient level of dynamic position capability is retained to permit the maneuverability of the ship.
(C) Indication of absorbed electrical power and available on-line generating capacity is to be provided at the main dynamic positioning control station.
(D) Means are to be provided to prevent starting of thruster motors until sufficient electrical generating capacity is available.

2. DPS(2)

(1) The requirements of **Par 1** above are to be complied with.
(2) In the event of a failure of the working system the standby control system is to be arranged to changeover automatically without manual intervention and without any adverse effect on the ship s station keeping performance.
(3) The power system should be divisible into two or more systems such that in the event of failure of one system at least one other system will provide enough power for essential services of the DP operation. The power system may be run as one system during operation, but should be arranged by bus-tie breakers to separate automatically upon failures which could be transferred from one system to another, including overloading and short-circuits.
(4) For electrically driven thruster units, the following requirements are to be complied with:
(A) The requirements as specified in **1** (5).

(B) To carter for operating conditions whereby all the generator sets required by (A) above are not being utilized, provision is to be made for automatic starting synchronization and load sharing of a non-running generator before the load reaches the alarm level required by **202. 2** (6).

(5) Control, alarm and safety systems are to incorporate a computer based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that position and heading deviation remain within acceptable limits. In the event of a possible hazardous condition being indicated from the consequence analysis an alarm is to be initiated.

(6) Power, control and thruster systems and other systems necessary for, or which could affect, the correct functioning of the DP system are to be provided and configured such that a fault in any active component or system will not result in a loss position. This is to be verified by means of a FMEA according to (KS A) IEC 60812 (Failure Mode and Effects Analysis) or equivalent. Active components may include, but are not restricted to, the following

(A) Prime movers (e.g. auxiliary engines)
(B) Generators and their excitation equipment
(C) Gearing
(D) Pumps
(E) Fans
(F) Switchgear and control gear, including their assemblies
(G) Thrusters
(H) Valves (where power actuated)

System which are not part of the DP System but which, in the event of a fault, could affect the correct functioning of the DP System (for example, fire suppression systems, engine ventilation systems, etc.) are to be included in the FMEA.

3. DPS(3)

(1) The requirements of **Par 2** above are to be complied with.

(2) The power system arrangement is to comply with the following requirements :

(A) The divided power system should be located in different spaces separated by A-60 class division.

(B) Where the power systems are located below the operational waterline, each power system is to be separated by independent watertight compartment.

(C) Bus-tie breakers should be open during DPS operations unless it can be accepted according to **203. 2** (3).

(3) The electrical power generating sets are to be arranged so that they are located in at least two separate machinery compartments.

(4) The switchboard supplying the dynamic positioning system is to be split into at least two equal sections each fitted in a separate compartment and capable of being connected by bus section switches.

(5) An emergency automatic control system is to be provided at an emergency control station, in a compartment separate from that for the main control station.

(6) Arrangements are to be provided such that in the event of a failure of the working and standby control systems a smooth transfer of control to the emergency control system may be effected from the emergency control station by manual means.

(7) The control and indication unit of one of the position reference systems required by the **Table 9.4.1** is to be located at the emergency control station. A repeater control and indication unit from this system is to be located at the main control station.

(8) An independent heading reference system among those required by **Table 9.4.1** is to be located at the emergency control station to provide heading reference to the emergency automatic control system.

(9) Signals from the environmental sensors required by **Table 9.4.1** are to supply the emergency automatic control system.

(10) The emergency automatic control system is to be supplied from its own independent uninterruptible power supplies.

Section 3 Testing and Inspection

301. Hydraulic Test

Thruster housing is to be tested at a hydraulic pressure of not less than 1.5 times the maximum service immersion head of water or 1.5 bar, whichever is greater.

302. On-board tests

After installation on board, the dynamic positioning system is to be tested under the condition as close to the actual operation as practicable and confirmed that each equipment functions appropriately. However, the tests may be carried out at the sea trial, when their testing items are considered impracticable to be conducted at occasions other than the sea trials.

303. Sea trials

In the sea trials, performance tests of the dynamic positioning system are to be carried out in accordance with the sea trial schedule including the followings approved by the Society.

(1) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power.
(2) Response of the system under a set of predetermined manoeuvres for changing of the followings:
- location of area of operation
- heading of the ship.

(3) Continuous operation of the system over a period of four to six hours.

304. Maintaining records and data regarding the performance capability of the dynamic positioning system

Records and data regarding the performance capability of the dynamic positioning system are to be maintained on board the ship and are to be made available at the time of the periodical survey.

305. Survey Assigned to Maintain Classification

Periodical survey interval and survey items of dynamic positioning systems(DPS) are to be applied as follows.

1. Annual survey

(1) System maintenance documentation, including information regarding hardware and software changes, shall be reviewed.
(2) The electrical installations comprising the DPS, such as controllers and operating stations for DP and independent joystick, references systems, sensors and mode change system, shall be visually inspected.
(3) The technical condition of the DPS shall be verified during the survey.
(4) If the survey is carried out when the vessel is undergoing regular operations, then tests that possibly can introduce unacceptable risks shall not be performed.
(5) Capacity of UPS and other battery systems serving the DP control system, including its peripherals, shall be verified. If the survey is carried out during regular operations, then the capacity of the batteries need not be proven by testing. Additionally, the alarm for loss of charging power shall be verified.
(6) For class notation DPS(3), normal working condition of the back-up DP control system shall be verified. If the survey is carried out during regular operations, then control need not be transferred to the back-up DP control system.
(7) Emergency stop of thrusters from the DP control centre shall be tested. If the survey is carried out when the vessel is undergoing regular operations, then testing shall not be performed if there is any possibility of introducing unacceptable risks.

2. Special survey

(1) With the vessel in DP mode, a sea trial shall be performed.
(2) The complete system shall be tested in all operational modes. The testing shall include simu-

lation of different failure conditions to verify switching of modes, back-up systems and the alarm system.

(3) The different modes of thruster control from the DP control centre shall be tested.
  (A) Manual control
  (B) Joystick control(independent joystick, if installed)
  (C) DP control
  (D) Transfer of control

(4) Manual override i.e. by thruster lever control and independent joystick control shall be demonstrated during normal operation and during failure conditions.

(5) Emergency stop of DP thrusters from DP control centre to be tested.

(6) All sensors, peripheral equipment and reference systems shall be tested.
  (A) Verify correct operation and adequate accuracy
  (B) Failure of sensors and reference systems shall be simulated to check the alarm system and the switching logic
  (C) Switch-over between reference systems as input to controller shall be carried out to assure that warnings, alarms and information to operator are satisfactory.

(7) Alarm for loss of position and heading out of limit shall be demonstrated.

(8) The electrical installations comprising the DPS, such as controllers and operating stations for DP and independent joystick, references systems, sensors and mode change system, shall be visually inspected.

(9) Single failures in thruster control systems including signal wire breaks of thruster command and feedback signals shall be tested in order to verify safe response on the thrust output. Equivalent testing may also be required for rudders controlled by the DP control system.

(10) Overload prevention shall be tested.

(11) Capacity of UPS and other battery systems serving the DP control system, including its peripherals, shall be verified by testing. Alarm for loss of charging power shall also be verified.

(12) For class notation DPS(2) & DPS(3), the required redundancy with respect to defined single failures modes shall be verified by redundancy testing.

(13) For class notation DPS(2) & DPS(3), the FMEA report and FMEA test program shall be verified to ensure that they have been updated when alterations have been done.

(14) For class notation DPS(2) & DPS(3), correct functioning of the Consequence Analysis facility shall be verified as far as possible.

(15) For class notation DPS(3), testing shall also be performed on the back-up DP control system. Switchover to back-up shall be tested, and monitoring of back-up control system status on the main control system shall be verified. ⚓

CHAPTER 5 NAVIGATION BRIDGE SYSTEMS

Section 1 General

101. General

1. Scope

The requirements in this Chapter apply to bridge layouts and bridge working environments, navigational equipment and accident prevention systems (hereinafter collectively referred to as "navigation bridge systems") of ships classed with the Society and intended to be registered.

2. Equivalency

Navigation bridge systems which do not fully comply with the requirements of this Chapter may be accepted provided that they are deemed by the Society to be equivalent to those specified in this Chapter.

3. Navigation bridge systems with novel design features

For navigation bridge systems with novel design features, the Society may apply the requirements of this Chapter so far as practicable and other requirements as considered appropriate by the Society.

4. Modification of requirements

The Society may modify parts of the requirements specified in this Chapter taking the national requirements of the ship's flag state, kind of the ship and intended service areas of the ship into consideration.

5. Installations Characters

(1) NBS : the ship of which bridge layout and bridge working environment and navigational equipment comply with the requirements of **Sec 3** and **Sec 4.**
(2) NBS1 : the ship of which bridge layout and bridge working environment, navigational equipment and accident prevention systems comply with the requirements of **Sec 3** to **Sec 5.**
(3) NBS2 : the ship of which bridge layout and bridge working environment, navigational equipment, accident prevention systems and bridge work assist systems comply with the requirements of **Sec 3** to **Sec 6.**

6. Definitions

Terms used in this Chapter are defined as follows:
(A) **Back-up navigator** is any individual, generally an officer, who has been designated by the ship master to be on call if assistance is needed on the bridge.
(B) **Bridge** is an area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings.
(C) **Bridge wings** are parts of the bridge on both sides of the ship's wheelhouse which extend to the ship's side.
(D) **Conning position** is a place on the bridge with a commanding view and which is used by navigators when commanding, maneuvering and controlling a ship.
(E) **Main conning position** is a conning position which is mainly used by navigators.
(F) **Field of vision** is an angular size of a scene that can be observed from a position on the ship's bridge.
(G) **Navigator** is a person navigating, operating bridge equipment and maneuvering the ship.
(H) **Wheelhouse** is an enclosed area of the bridge.
(I) **Workstation** is a position at which one or several tasks constituting a particular activity are carried out.
(J) **Centralized bridge workstation** is a workstation at which navigational equipment needed for navigation and maneuvering are arranged centrally, including the main conning position.
(K) **Ocean areas** are areas in which the freedom of course setting in any direction for a distance equivalent to at least 30 minutes sailing with the navigating speed of the ship is not restricted.

Section 2 Surveys of Navigation Bridge Systems

201. General

1. Kinds of surveys

Navigation bridge systems, which are registered or intended to be registered to the Society, are to be subjected to the following surveys:

(A) Survey for classification of navigation bridge systems (hereinafter referred to as "Classification Survey")
(B) Survey for maintaining classification of the navigation bridge systems (hereinafter referred to as "Survey Assigned to Maintain Classification"), which are:
  (a) Special Survey
  (b) Annual Survey
  (c) Occasional Survey

2. Time of classification survey and intervals of survey assigned to maintain classification

(1) Classification Survey is to be carried out when the application for classification is made.
(2) Survey Assigned to Maintain Classification is to be carried out at the periodical survey.

202. Classification Survey

1. Drawings and data

(1) For the classification survey of navigation bridge systems of a NBS ships, three copies of the following drawings and data are to be submitted for the approval by the Society.
  (A) General arrangement of the bridge (showing the main conning position, other conning positions, workstations, locations of control consoles and panels, and passage ways)
  (B) Particulars of the navigational equipment specified in **Sec 4, 402. 2.**
  (C) Electrical wiring diagrams for the navigational equipment specified in **Sec 4, 402.**
  (D) Schemes of on board tests and sea trials including methods of tests and test facilities provided
  (E) Other drawings and data deemed necessary by the Society
(2) For the classification survey of navigation bridge systems of a NBS1 ships, three copies of the following drawings and data are to be submitted for the approval by the Society.
  (A) The drawings and data specified in the preceding (1).
  (B) Particulars of the accident prevention systems specified in **Sec 5, 502.**
  (C) Electrical wiring diagrams for the accident prevention systems specified in **Sec 5, 502.**
(3) For the classification survey of navigation bridge systems of a NBS2 ships, three copies of the following drawings and data are to be submitted for the approval by the Society.
  (A) The drawings and data specified in the preceding (2).
  (B) Particulars of the bridge work assist systems specified in **Sec 6, 602.**
  (C) Electrical wiring diagrams for the bridge work assist systems specified in **Sec 6, 602.**
  (D) Detail arrangement of the centralized bridge workstation specified in **Sec 6, 601. 3.** (dimensions of control consoles, panel arrangement, etc., are to be shown)

2. Shop tests

The equipments listed below are to be approved by the Society. However, the equipment approved by the Government of State in which the ship is registered or to be registered, other Contracting Governments of the International Convention for The Safety of Life at Sea or the parties approved by the Governments mentioned above may be accepted provided that it is deemed appropriate by the Society.

(A) Automatic radar plotting aids (ARPA)
(B) Electronic position-fixing systems
(C) Radars
(D) Gyro compass systems
(E) Automatic steering systems
(F) Speed log systems
(G) Echo sounding systems
(H) Maritime safety information receivers

(I) VHF radio telephone installations
(J) Other equipment deemed necessary by the Society

3. Tests after installation on board

(1) Bridge layouts and bridge working environments, navigational equipment, and accident prevention systems are to be, after installation on board, tested and inspected in accordance with the scheme of on board tests approved by the Society to verify that they are constructed, installed and functioning properly under the normal working conditions, as far as practicable. A part of the verification may be carried out during sea trials.
(2) The following particulars are to be verified at the tests after installation on board.
(A) Bridge layouts and bridge working environments
The bridge layouts and bridge working environments are adequate to enable the navigator to perform navigational duties and other functions allocated to the bridge as well as to maintain a proper lookout from workstations on the bridge.
(B) Navigational equipment
(a) Gyro compass repeaters
Each repeater compass is installed parallel with a centre line of the ship.
(b) Echo sounding systems
A measuring error is within a permissible range.
(c) Steering pump selective control switches
The steering pumps are smoothly switched over.
(d) Electrical power supply
(i) When the main source of electrical power to the local distribution board for the navigational equipment is off, the audible and visual alarm is initiated, and the electrical power supply to the board is automatically switched over to the emergency source.
(ii) All primary functions of the navigational equipment are readily reinstated after 45 seconds interruption of the electrical power supply.
(C) Accident prevention systems (NBS1 ships and NBS2 ships)
(a) Bridge navigational watch alarm system
The bridge navigational watch alarm system is to initiate alarms that are able to be verified in the bridge and other places if the setting interval has elapsed.
(b) Alarm and warning transfer system
The alarm and warning transfer system automatically transfers an alarm and warning which requires the navigator response and which is not acknowledged on the bridge within 30 seconds to the master, to the selected back-up navigator and to the public rooms. The alarm of the bridge navigational watch alarm system is also transferred.
(c) System monitor
(i) The indicator lamps in the master room showing the bridge navigational watch alarm system, and the alarm and warning transfer system are functioning properly.
(ii) The audible and visual alarms are initiated on the bridge and in the master room when the bridge navigational watch alarm system, and the alarm and warning transfer system are malfunctioning.
(d) Electrical power supply
(i) When the main source of electrical power to the local distribution board for the accident prevention systems is off, the audible and visual alarm is given, and the electrical power supply to the board is automatically switched over to the emergency source.
(ii) All primary functions of the accident prevention systems are readily reinstated after 45 seconds interruption of the electrical power supply.
(D) Bridge work assist systems(NBS2 ships)
(a) Bridge information systems
The information display and alarm system deemed necessary for navigation and maneuvering are functioning properly.
(b) ECDIS
A chart, ship's position, planned route, radar and ARPA information are added to the display.

(c) System monitor
Audible and visual alarms for a malfunction of the bridge information systems, ECDIS and auto tracking system are given.

(d) Electrical power supply
(i) When the main source of electrical power to the local distribution board for the bridge work assist systems is off, the audible and visual alarm is given, and the electrical power supply to the board is automatically switched over to the emergency source.
(ii) All primary functions of the bridge work assist systems are readily reinstated after 45 seconds interruption of the electrical power supply.

4. Sea trials

(1) Bridge layouts and bridge working environments, navigational equipment, and accident prevention systems are to be tested and inspected in accordance with the scheme of sea trials approved by the Society to verify that they are constructed, installed and functioning properly.

(2) The following are to be verified during the sea trials.

(A) Bridge layouts and bridge working environments
(a) The bridge layouts and bridge working environments are adequate to enable the navigator to perform navigational duties and other functions allocated to the bridge as well as to maintain a proper lookout from workstations on the bridge under all navigating conditions day and night.
(b) The vibration level and the noise level satisfy the requirements of **Sec 3, 302. 2** and **3.**

(B) Navigational equipment
Among the tests of the navigational equipment verification of the prewarning required by **Ch 5, 501. 4** (1) (for NBS1 ships and NBS2 ships only) and the following are to be included.
(a) An automatic radar plotting aids (ARPA)
(i) Targets are acquired, and the course and speed information for acquired targets are displayed by both true and relative vectors.
(ii) The bearing and range of the acquired target are displayed.
(iii) The CPA and TCPA are displayed.
(iv) An audible and visual alarm is initiated when any acquired target approaches close to a range or transits a zone chosen by the navigator.
(b) Radars
(i) The bearing and range of at least two objects(one of them is to be an object on shore) which appear forward of the beam are displayed.
(ii) A measured error of the installed radar is not greater than the original error of the radar.
(c) Automatic steering systems
(i) The heading direction of the ship is automatically maintained at the preset course.
(ii) An audible and visual alarm is initiated when the rudder reaches a preset limit of angle.
(iii) An audible and visual alarm is initiated when the heading direction of the ship deviates beyond a preset amount of course deviation.
(d) Speed log systems
(i) The indicated speed is to be compared with the result of the speed trial.
(ii) The speed and distance are indicated during the speed trial.
(e) Echo sounding systems
The water depth is recorded while the ship is maneuvering.
(f) Whistle control systems
The fog signals are generated properly.
(g) Internal communication systems
(i) The internal communication system functions properly in the event of main electrical power failure.
(ii) The bridge has priority over the communication system.

(C) Accident prevention systems (NBS1 ships and NBS2 ships)
The system is in accordance with **3** (2) (C) (a) and (b).

(D) Bridge work assist systems (NBS2 ships)
(a) The system is in accordance with **3** (2) (D) (a) and (b).
(b) Auto tracking system
(i) The auto tracking system performs automatic steering of the ship along a planned route on an electronic chart.
(ii) Automatic course change occurs after acknowledgement by the navigator.
(iii) When there is no acknowledgement by the navigator at a waypoint, the course is maintained and the audible and visual alarm is given.
(iv) Change-over to manual steering mode is possible.

203. Survey Assigned to Maintain Classification

1. Special survey

(1) At each Special Survey for navigation bridge systems of NBS ships, the following tests and examination are to be carried out.
(A) General examination of the systems
(B) Function tests of navigational equipment specified in **Sec 4, 402. 2** (1) to (5), (7) to (11) and (13) to (16).
(C) Verification on the capability of navigational equipment to readily reinstate after 45 seconds interruption of the electrical power supply.
(2) At each Special Survey for navigation bridge systems of NBS1 ships, the following tests and examination are to be carried out.
(A) The tests and examination specified in the preceding (1).
(B) Function tests of accident prevention systems specified in **Sec 5, 502.**
(C) Verification on the capability of accident prevention systems to readily reinstate after 45 seconds interruption of the electrical power supply.
(3) At each Special Survey for navigation bridge systems of NBS2 ship, the following tests and examination are to be carried out;
(A) The tests and examination specified in the preceding (2).
(B) Function tests of bridge work assist systems specified in **Sec 6, 602.**
(C) Verification on the capability of bridge work assist systems to readily reinstate after 45 seconds interruption of the electrical power supply.

2. Annual survey

(1) At each Annul Survey for navigation bridge systems of NBS ships, the following tests and examination are to be carried out.
(A) General examination of the systems
(B) Function tests of the following equipment
(a) Automatic radar plotting aids (ARPA)
(b) Electronic position-fixing systems
(c) Radars
(d) VHF radio telephone installations
(e) Internal communication systems
(f) Other equipment deemed necessary by the Society
(2) At each Annual Survey for navigation bridge systems of NBS1 ships, the following tests and examination are to be carried out.
(A) The tests and examination specified in the preceding (1).
(B) Function tests of the following equipment
(a) Bridge navigational watch alarm systems
(b) Alarm and warning transfer systems
(3) At each Annual Survey for navigation bridge systems of NBS2 ships, the following tests and examination are to be carried out.
(A) The tests and examination specified in the preceding (2).
(B) Function tests of the following equipment
(a) Bridge information systems
(b) Electronic Chart Display Information System (ECDIS)
(c) Auto tracking system

Section 3 Bridge Layouts and Bridge Working Environments

101. General

1. Scope

The requirements in this Section apply to bridge layouts and bridge working environments for NBS ships, NBS1 ships and NBS2 ships.

2. General

(1) The bridge configuration, the arrangements of consoles, equipment location and the bridge working environments are to enable the navigator to perform navigational duties and other functions allocated to the bridge as well as to maintain a proper lookout from workstations on the bridge.
(2) Navigating and maneuvering workstations are to be so arranged to enable efficient operation under normal operating conditions. All relevant instrumentation and controls are to be easily visible, audible and accessible from the workstation.
(3) For the purpose of performing duties related to navigation and maneuvering, the field of vision from a navigating and maneuvering workstation and a conning position is to be such as to enable observation of all objects which may affect safety of the ship.
(4) The navigator is, as far as practicable, to be able to approach close to at least one bridge front window in order to watch the area immediately in front of the bridge superstructure from the wheelhouse.
(5) The bridge is, as far as practicable, to be placed above all other decked structures, not including funnels, which are on or above the freeboard deck.
(6) The navigation bridge visibility of the ship is to be as follows.
 (A) The view of the sea surface from the conning position is not to be obscured by more than two ship lengths or 500 m, whichever is less, forward of the bow to 10° on either side irrespective of the ship's draught, trim and deck cargo(e.g. containers). (See **Fig 9.5.1**)

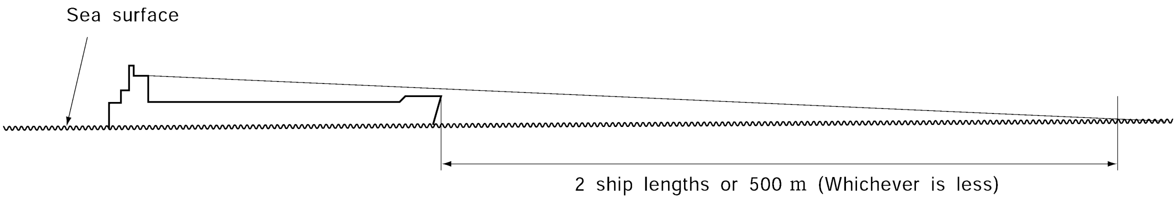


Fig 9.5.1 Forward view

 (B) The height of the lower edge of the front windows is to allow a forward view over the bow for person in a sitting position at the workstation.
 The height of the lower edge of front windows above the deck is to be kept as low as possible, and is not to, as far as practicable, be more than 1000 mm.
 (C) It is to be possible to observe all objects necessary for navigation, such as ships and lighthouses, in any direction from inside the wheelhouse.
  (a) There is to be a field of view around the vessel of 360° obtained by an observer moving within the confines of the wheelhouse. (See **Fig 9.5.2**)

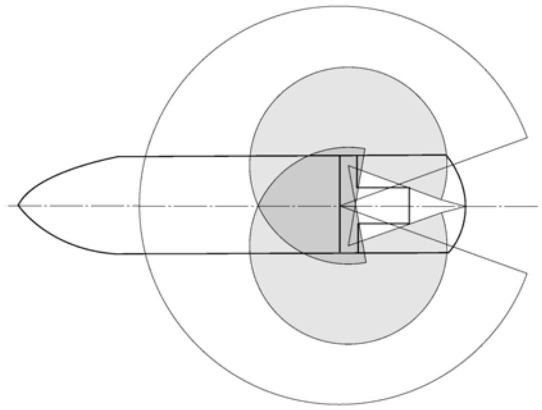


Fig 9.5.2 360° Field of vision

(D) At the navigating and maneuvering workstation and at the conning position, the navigator's field of view is to be sufficient to enable him to comply with the International Regulations for Preventing Collisions at Sea (COLREG 72).
   (a) The horizontal field of vision from the navigating and maneuvering workstation and from the conning position is to extend at least over an arc from 22.5° abaft the beam on one side, through forward, to 22.5° abaft beam on the other side. (See **Fig 9.5.3**)
   (b) From a monitoring workstation, the field of vision is to extend at least over an arc from 9° on the port bow, through forward, to 22.5° abaft the beam on starboard. (See **Fig 9.5.4**)
   (c) The field of vision from a workstation on the bridge wing is to extend over an arc from at least 45° on the opposite bow through dead ahead and then aft to 180° from dead ahead. (See **Fig 9.5.5**)

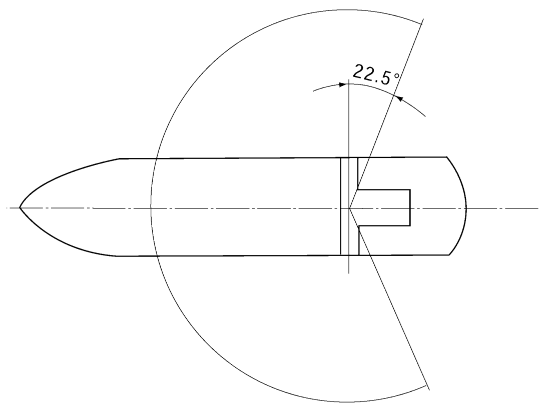


Fig 9.5.3 Navigating and maneuvering workstation and conning position

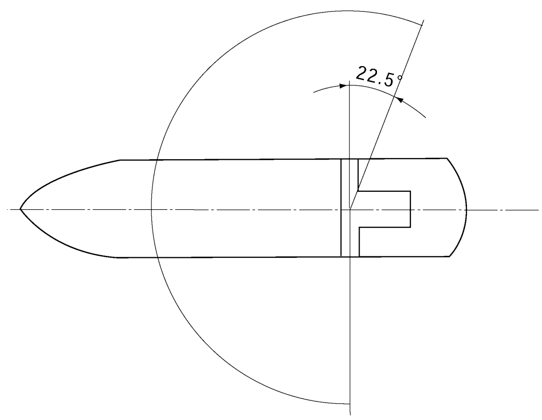


Fig 9.5.4 Monitoring workstation

(E) The helmsman's field of vision is to be sufficiently wide to enable him to carry out his functions safely.
   (a) The helmsman's field of vision from the workstation for manual steering is to extend over an arc from dead ahead to at least 60° on each side. (See **Fig 9.5.6**)
   (b) The workstation is not to be placed immediately abaft the front windows in order to obtain the required field of vision.

(F) Blind sectors caused by cargo, cargo gear and other obstructions are to be as few and as small as possible, and not in any way influence a safe look-out from the navigating and maneuvering workstation and from the conning position.
  (a) The total arc of blind sectors forward of the beam seen from the navigating and maneuvering workstation and from the conning position is not to exceed 20°. Each individual blind sector is not to exceed 10°.
  (b) Over an arc from dead ahead to at least 10° on each side, each individual blind sector is not to exceed 5°. The clear sector between two blind sectors is not to be less than 5°.

(G) The ship's side is always to be visible from the bridge wing especially where tugs or pilot boats come alongside and where the ship touches the jetty.
  (a) Bridge wings are to be provided out to the maximum beam of the ship. The view over the ship's side is not to be obstructed.

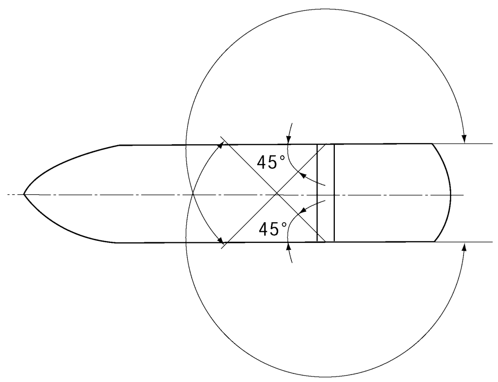


Fig 9.5.5 Bridge wing workstation

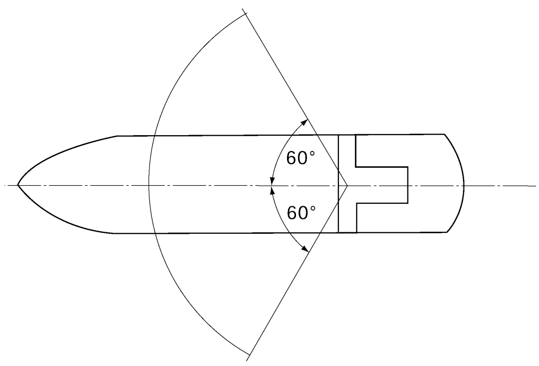


Fig 9.5.6 Helmsman's workstation

302. Bridge Working Environments

1. General

(1) Through the various stages of the design of a ship, care is to be taken to ensure a good working environment for bridge personnel.
(2) A ceiling and walls inside the wheelhouse are to be designed not to interfere with reading of the indication of instruments.
(3) Toilet facilities are to be provided on or adjacent to the bridge.

2. Vibration

The vibration level on the bridge is not to be uncomfortable to bridge personnel.

3. Noise

The noise level on the bridge is not to interfere with verbal communication, mask audible alarms or be uncomfortable to bridge personnel.

4. External sound signals

External sound signals such as fog signals that are audible on the bridge wings are also to be audible inside the wheelhouse.

5. Lighting

(1) The lighting required on the bridge is to be designed so as not to impair the night vision of the navigator.
(2) The lighting used in areas and at items of equipment requiring illumination whilst the ship is navigating is to be such that night vision adaptation is not impaired, e.g. red lighting. Such lighting is to be arranged so that it can not be mistaken for a navigation light by another ship. It is to be noted that red lighting is not to be fitted over chart tables so that possible confusion in colour discrimination is avoided.

6. Air conditioning system

The wheelhouse spaces are to be provided with an air conditioning system. System controls are to be readily available to the navigator.

7. Bridge personnel safety

(1) There are to be no sharp edges or protuberances on surfaces of the equipment and the instruments installed on the bridge which could cause injury to bridge personnel.
(2) Sufficient hand-rails or equivalent thereto are to be fitted inside of the wheelhouse or around equipment in the wheelhouse for safety in bad weather.
(3) Adequate means are to be made for anti-slip of the bridge floor whether it be dry or wet condition.
(4) Doors to the bridge wings are to be easy to open and close. Means are to be provided to hold the doors open at any position.
(5) Where provision for seating for the navigator is made in the wheelhouse, means for securing are to be provided having regard to storm conditions.

Section 4 Navigational Equipment

401. General

1. Scope

The requirements in this Section apply to navigational equipment for NBS ships, NBS1 ships and NBS2 ships.

2. General

(1) Navigational equipment is to be capable of continuous operation under the conditions of various sea states, vibration, humidity, temperature and electromagnetic interferences likely to be experienced in the ship which it is installed.
(2) Where computerized equipment is interconnected through a computer network, failure of the network is not to prevent individual equipment from performing their individual functions.

3. Electrical power supply

(1) Local distribution boards are to be arranged in the wheelhouse for all items of electrically operated navigational equipment. These boards are to be supplied by two exclusive circuits, one fed from the main source of electrical power and one fed from the emergency source of electrical power, and these circuits are to be separated throughout their length as widely as practicable. Each item of navigational equipment is to be individually connected to the distribution board. These boards may also be used for accident prevention systems specified in **Ch 5.**
(2) The power supplies to the distribution boards are to be arranged with automatic changeover facilities between the two sources.
(3) Failure of the main electrical power supply to the distribution board is to initiate an audible and visual alarm at the distribution board.
(4) Following a loss of electrical power supply which has lasted for 45 seconds or less, all primary functions of the navigational equipment are to be readily reinstated.

402. Navigational Equipment

1. General

(1) The instrumentation and controls at the navigating and maneuvering workstation are to be arranged to enable the navigator to;
(A) determine and plot the ship's position, course, track and speed,
(B) analyse the traffic situation,
(C) decide on collision avoidance manoeuvres,
(D) alter course,
(E) change speed,

(F) effect internal communication and external communication using a VHF radio telephone installation related navigation and maneuvering,
(G) give sound signals,
(H) hear sound signals,
(I) monitor navigational data such as course, speed, track, propeller revolutions (pitch), rudder angle, depth of water.
(J) record navigational data.
(2) Navigational equipment is to be arranged to avoid inadvertent operation.
(3) Navigational equipment is to be designed to permit easy and correct reading by day and by night.
(4) Each navigational equipment is to be placed with its face normal to the navigator's line of sight, or to the mean value if the navigator's line of sight varies through an angle.
(5) Navigational equipment is to be designed and fitted to minimize glare or reflection or being obscured by strong light.

2. Navigational equipment

Navigational equipment listed below are to be provided on the bridge.
(1) An automatic radar plotting aid (ARPA) independent or built into the radar equipment which complies with the following.
(A) A warning is to be given to the navigator at a time which is adjustable in the range of 6 to 30 minutes, having regard to the time to danger.
(B) True motion and relative motion modes are to be provided.
(C) Daylight visible display is to be provided.
(D) Capability of automatic acquisition and tracking of 20 radar targets or more is to be provided.
(E) Guard zone system, featuring adjustable parameters, notable warning and alarm set for closest point of approach (CPA) and for time to closest point of approach (TCPA) are to be provided.
(F) Simulator function showing the likely effects of a course or speed change in relation with tracked targets is to be provided.
(G) Incorporated self-checking properties are to be provided.
(2) An electronic position-fixing system appropriate to the intended service areas
(3) Two independent radars. One of them is to operate within X-band.
(4) Gyro compass repeaters and a calibration facility
(5) An automatic steering system which complies with the following.
(A) An off-course alarm addressed to the navigator derived from a system independent from the automatic steering system is to be provided.
(B) An overriding control device is to be provided at the navigating and maneuvering workstation.
(6) A speed log system
(7) An echo sounding system
(8) A control device of the wheelhouse air conditioning system
(9) A NAVTEX receiver and an EGC receiver depending upon the intended service areas
(10) Control switches and indicators of signaling lights such as navigation lights
(11) Steering pump selector control switches
(12) A whistle control system
(13) A window wipe and wash control device
(14) Control devices for the lighting of main workstation consoles
(15) An internal communication system which complies with the following.
(A) At all times, even in the event of failure of the main electrical power supply, the navigator is to have access to facilities enabling two way communication with another qualified officer.
(B) The bridge is to have priority over the communication system.
(16) A VHF radio telephone installation which is immediately available at the conning positions.
(17) A main propulsion machinery remote control system which complies with the Rules for Automatic and Remote Control Systems

3. Illumination and individual lighting of equipment

(1) The indicator lights and the illumination of all equipment are to be designed and fitted to avoid unnecessary glare or reflection or the equipment being obscured by strong light.
(2) To avoid unnecessary light sources in the front area of the bridge, only equipment necessary for the safe navigation and maneuvering of the ship is to be located in the area.
(3) Warning and alarm indicators are to be designed to show no light in normal conditions or in safe situations. Means are to be provided to test the lamps.
(4) All illumination and lighting of equipment are to be adjustable down to zero, except the lighting of warning and alarm indicators and the control of the dimmers which are to be remain readable.
(5) Each equipment is to be fitted with an individual light adjustment. In addition, groups of equipment normally working together may be equipped with common light adjustment.

Section 5 Accident Prevention Systems

501. General

1. Scope

The requirements in this Section apply to systems to prevent accidents caused by the navigator's unfitness (hereinafter referred to as "accident prevention systems") for ships intended for one-man bridge operation in ocean areas under normal operating conditions.

2. General

(1) Accidents prevention systems are to be capable of continuous operation under the conditions of various sea states, vibration, humidity, temperature and electromagnetic interferences likely to be experienced in the ship which they are installed.
(2) Where computerized equipment is interconnected through a computer network, failure of the network is not to prevent individual equipment from performing their individual functions.

3. External sound signals

To enable the navigator inside the wheelhouse to hear external sound signals such as fog signals that are audible on the bridge wings with the doors to the bridge wings closed, a transmitting device is to be provided to reproduce such signals inside the wheelhouse.

4. Navigational equipment

(1) Navigational equipment specified in **Sec 4, 402. 2** is to give an alarm when;
  (A) The ship approaches a way-point.
  (B) The ship's position is deviated from a planned route.
  (C) The water depth beneath the ship is less than a predetermined value.
(2) The systems or controls under **Sec 4, 402. 2** (1) to (5) and (11) to (17) are to be arranged so that the navigator has easy access to them and is able to maintain a proper lookout from the bridge.

5. Electrical power supply

(1) Local distribution boards are to be arranged in the wheelhouse for all items of electrically operated accident prevention systems. These boards are to be supplied by two exclusive circuits, one fed from the main source of electrical power and one fed from the emergency source of electrical power, and these circuits are to be separated throughout their length as widely as practicable. Each item of accident prevention systems is to be individually connected to the distribution board. These boards may also be used for navigational equipment specified in **Sec 4**.
(2) The power supplies to the distribution boards are to be arranged with automatic changeover facilities between the two sources.
(3) Failure of the main electrical power supply to the distribution board is to initiate an audible and visual alarm at the distribution board.
(4) Following a loss of electrical power supply which has lasted for 45 *seconds* or less, all primary functions of the accident prevention systems are to be readily reinstated.

502. Accident Prevention Systems

1. General

(1) Indicator lamps are to be provided in the ship master's room which indicate the bridge navigational watch alarm system specified in **Sec 5, 502. 2** and the alarm and warning transfer system specified in **Sec 5, 502. 3** are functioning properly.
(2) Audible and visual alarms for a malfunction of the bridge navigational watch alarm system specified in **Sec 5, 502. 2** and the alarm and warning transfer system specified in **Sec 5, 502. 3** are to be provided on the bridge and in the ship master's room.

2. Bridge Navigational Watch Alarm System

A bridge navigational watch alarm system which complies with the following is to be provided.

(1) The bridge navigational watch alarm system is to be a vigilance system to verify periodically that the alert navigator is present on the bridge.
(2) The bridge navigational watch alarm system is not to cause undue interference with the performance of bridge functions.
(3) The bridge navigational watch alarm system is to be so designed and arranged that it could not be operated in an unauthorized manner.
(4) The bridge navigational watch alarm system is to be adjustable of its verification period up to 12 minutes intervals and constructed, fitted and arranged so that only the ship master has access to the component for setting the appropriate intervals.
(5) The bridge navigational watch alarm system is to initiate alarms that are able to be verified in the bridge and other places if the setting interval has elapsed.
(6) The bridge navigational watch alarm system is to provide for the acknowledgement by the navigator at the navigating and maneuvering workstation and other appropriate locations on the bridge from where a proper lookout may be kept.
(7) The bridge navigational watch alarm system is to be connected to the alarm and warning transfer system specified in **Sec 5, 502. 3.**

3. Alarm and warning transfer system

An alarm and warning transfer system which complies with the following is to be provided.

(1) Acknowledgement of alarms and warnings that require the navigator response is to only be possible from the bridge.
(2) Any alarm and warning that requires the navigator response is to be automatically transferred to the ship master, to the selected back-up navigator and to the public rooms if not acknowledged on the bridge within 30 seconds.
(3) The alarm and warning transfer is to be operated through a fixed installation.
(4) Provision which initiates a call-alarm clearly audible in the spaces specified in (B) is to be provided on the bridge for the operation of the navigator. The fixed installation required under (C) may serve the purpose.

Section 6 Bridge Work Assist Systems

601. General

1. Scope

The requirements in this Section apply to systems to assist navigator's works for one-man bridge operation under normal operating conditions (hereinafter referred to as "bridge work assist systems").

2. General

(1) Bridge work assist systems are to be capable of continuous operation under the conditions of various sea states, vibration, humidity, temperature and electro-magnetic interference likely to be experienced in the ship which they are installed.
(2) Where computerized equipment is interconnected through a computer network, failure of the network is not to prevent individual functions.

3. Centralized bridge workstation

(1) The centralized bridge workstation is to be arranged to enable a navigator to perform navigating and maneuvering works specified in **Sec 4, 402. 1** (1) and also two or more navigators to do those works together.
(2) The systems or controls under **Sec 4, 402. 2** (1), (5), (11) to (17), **Sec 6, 602. 2** and **3** are to be arranged centrally to enable the navigator to operate them easily at the centralized bridge workstation.

4. Electrical power supply

(1) Local distribution boards are to be arranged in the wheel house for all items of electrically operated bridge working assist systems. These boards are to be supplied by two exclusive circuits, one fed from main source of electrical power, and these circuits are to be separated throughout their length as widely as practicable. Each item of bridge working assist systems is to be individually connected to the distribution board. These boards may also be used for navigational equipment and accident prevention systems specified in **Sec 4** and **Sec 5.**
(2) The power supplies to the distribution boards are to be arranged with automatic changeover facilities between the two sources.
(3) Failure of the main electrical power supply to the distribution board is to initiate an audible and visual alarm at the distribution board.
(4) Following a loss of electrical power supply which has lasted for 45 seconds or less, all primary functions of the bridge work assist systems are to be readily reinstated.

602. Bridge Work Assist Systems

1. General

(1) Audible and visual alarms for a malfunction of the bridge information systems specified in **Sec 6, 602. 2**, ECDIS specified in **Sec 6, 602. 3** and the auto-trucking system specified in **Sec 6, 602. 4** are to be provided on the bridge and in the master's room.
(2) Electronic charts deemed appropriate by the Society are to be used for the ECDIS.

2. Bridge information system

Bridge information system which complies with the followings is to be provided.
(A) The system is to be capable of displaying at least the following information a) to l) for easy viewing from centralized bridge workstation.
(a) Ship's actual and planned course
(b) Rudder angle including its order value or direction
(c) Ship's speed (against water)
(d) Main engine revolution and direction (in the case of Controllable Pitch Propellers, main engine revolution and propeller pitch angle)
(e) Ship's position (longitude and latitude)
(f) Depth of water
(g) Wind direction (relative direction)
(h) Wind speed (relative speed)
(i) Rate of turn (10,000 GT or more)
(j) Side thruster pitch angle or its motor amperes and its thrust direction (if any)
(k) Onboard time
(l) Distance to a way-point and estimated time of arrival
(B) In order to display the information appropriate for each navigation areas, the system is to be capable of changing-over between harbor, ocean and other mode (if any). In addition, the system is to be capable of displaying the minimum information necessary for all modes at all times.
(C) The system is to be capable of displaying at least following information for harbor and ocean mode specified in the preceding (B) at all times.
(a) Harbour mode
Information of the preceding (A) (a) to (k).
(b) Ocean mode
Information of the preceding (A) (a) to (e), (g), (h), (k) and (l).

(D) The system is to be capable of acknowledging alarms and warnings which requires the navigator response.
(E) Other functions deemed necessary by the Society are to be provided.

3. Electronic chart display and information system (ECDIS)

An ECDIS, including associated back-up arrangements, which complies with the following is to be provided.
(A) The ECDIS is to be capable of displaying an electronic chart at centralized bridge work station.
(B) The ECDIS is to be capable of ship's position and vector on the electronic chart.
(C) The ECDIS is to be capable of displaying the electronic chart in a north-up and course-up orientation.
(D) The ECDIS is to be capable of carrying out route planning.
(E) The ECDIS is to be capable of adding a chart, ship's position, planned route, radar and ARPA information to the display.
(F) Other functions deemed necessary by the Society are to be provided.

4. Auto tracking system

An auto tracking system which complies with the following is to be provided.
(A) Auto tracking system is to be capable of performing automatic steering of the ship along a planned route on an electronic chart.
(B) Automatic course changes are not to occur without acknowledgement by the navigator.
(C) When there is no acknowledgement at a waypoint, the course is to be maintained and the audible and visual alarm is to be initiated after through the point. In the case, the audible alarm is to be distinguished from the pre-warning at the approach of a way point specified in **Sec 5, 501. 4**.
(D) It is to be possible to adjust a width of planned route within one mile.
(E) When the position of ship cannot be received continuously, the course of ship is to be maintained and the audible and visual alarm is to be initiated.
(F) Change-over to manual steering mode is to be easily possible.
(G) Other functions deemed necessary by the Society are to be provided. ⚓

CHAPTER 6 HULL MONITORING SYSTEMS

Section 1 General

101. Definition

Hull monitoring system (hereinafter referred to as "systems") are to monitor a behavior of hull girder during navigation, loading and unloading, and to provide real-time information on stress level due to longitudinal bending moment and acceleration level due to ship's motion. The systems will give warning when stress levels and acceleration of ship motions approach levels which require corrective action.

102. General

1. Application:

The requirements in this Chapter apply for a ship that the class notations assigned to the hull monitoring system to be classed or intended to be classed with the Society.

2. Class notations:

Ships complying with this Chapter may be assigned with one of the following class notations:
HMS : This notation will be assigned when the ship has been provided with a basic hull stress monitoring system in accordance with **Sec 2, 201.** and **202.**
HMS1 : This notation will be assigned when the ship has been provided with the **Sec 2, 203.** in addition to HMS.

3. Liability:

This system is intended as an aid to the Master's judgement and not as a substitute for it. Accordingly, any failure of the system does not, in anyway, remove the master from his/her absolute responsibility to take correct action in operation the ship.

103. Information and Plans

The following plans and information are to be submitted or approval:
(1) Drawings
- arrangement and layout of the system
- block diagram of the electric system
- flowchart of functions of sensors and the system

(2) Information
- list of instruments and equipment (name, kind, type, manufacturer, etc.)
- operating manual including procedures of maintenance, fault detection and management ad setting up and calibration
- in-service test program
- list of software modules and the description of the calculation method
- sensor specifications (accuracy, range, frequency response, etc.)
- description of the method to display the output

Section 2 System Requirements

201. General

All components are to be replaceable and designed for easy maintenance. Sensors are to be approved by this Society or to be approved by the other recognized organization.

202. System Requirements

1. Sensors

(1) Long based strain gauge
(A) Each long strain gauge is instrument for measure the longitudinal bending stress of ship. It is to be able to measure the strain which is characteristic for the structural response considered.
(B) The type and installation are in general to exclude the effects of local stress concentrations. The length of the long based strain gauge is recommended to be between 1.5 m and 2.5 m.
(C) The position of the long based strain gauge is to be planned to measure longitudinal hull girder bending stress. The minimum required number and approximate position of the strain gauges are as follows:
(a) Tankers, Bulk Carriers and General dry cargo ships:
- 2 at midship (one port, one starboard on deck)
- 1 at L/4 from the bow(on deck)
- 1 at L/4 from the stern(on deck)
(b) Container ship :
- 4 at midship in a ring around the section(two port, two starboard; on deck and upper turn of bilge)
- 1 at L/4 from the bow(on deck)
(D) Strain gauges are to have an accuracy better than ±20 $\mu\epsilon$. The linear range of each strain gauge is to be in excess of the full range of expected still water and dynamic stress variation. For dynamic stress range each strain gauge is to have a frequency response capable of measuring strain in the frequency range 0 to 5 Hz.
(E) When measuring longitudinal bending stresses of ship and corresponding loads the effects of temperature variations due to the daily environmental changes are to be considered. If possible, these effects are to be removed from any display of still water loading.
(F) Thermal loads due to cargo temperatures are to be considered separately. Consideration as to whether or not the thermal loads should be included in the still water or water loads are to be determined when taking into account the type of vessel and cargo and the approved ship's scantlings and their conditions of approval. (The data of calculation were to be submitted of the Society.)
(2) Accelerometer
(A) The vertical acceleration is to be measured on the centerline, at the main deck level within the forward 0.01 L of the ship.
(B) Accelerations are to be measured over a range of ±1 g. The measurement uncertainty of the acceleration is to be less than 1 % of the measured value in the frequency range of 0 to 5 Hz.
(3) Pressure Transducer
(A) If possible, the pressure transducers may be installed to measure the number of slam.
(B) Pressure gauge where fitted through the hull are to be arranged so that the pressure diaphragm is flush with the outside of the plating. The gauge is to be arranged with a suitable valve to enable the gauge to be removed and refitted with the vessel in the water at an operational draft.
(4) Clinometer
In order to measure the motion characteristics, the clinometer may be installed.

2. Date Processing and Output Display

(1) Display and alarm devices

(A) The hull monitoring system is to be able to provide real-time information to the bridge of the measured values while at sea and during loading and unloading operations. The system is to be able to record and display the following sets of data for each strain gauge and accelerometer:
- the peak value of the longitudinal hull girder bending stress or vertical acceleration
- the mean value of the longitudinal hull girder bending stress or vertical acceleration
- the standard deviation of the longitudinal hull girder bending stress or vertical acceleration

(B) The system is to include a computer that can process sensor signals and compare these with threshold levels approved by the Society. When values exceed these pre-set threshold values, the system is to give visual and audible alarm on the bridge.

(C) In order to verify intermediate and final stages of loading and unloading operations, the hull monitoring system is to have a direct link or easy connection to the loading computer.

(D) Each update of the display is to be based on statistics of the recorded data within 30 minutes interval. The sensor readings are to be displayed in a manner that enables the trends in the data over at least the last 1 hours to be seen.

(E) The number of acceleration peak exceeding a pre-set acceleration level, which indicates a slam in the bow are to be recorded and displayed. The pre-set acceleration level is to be reported.

(F) The recordings from strain sensors are to be processed using a type of cycle count method (e. g. "rain flow" method) to produce response histogram. The stress spectra may be used as basis for fatigue life predictions. The size of strain interval is not to exceed 50 $\mu\varepsilon$. The cycle count method is to be reported and submitted.

(2) Signal processing

(A) The sampling rates are to be suitable for the frequency response of the transducer and the use of the signal. In general the sampling rate is not to be less than 3 times the required frequency response. Special attention is to be paid to the sampling rate if it is intended to capture transient components of signals.

(B) The measured signal induced by wave is to be statistically calculated with the time interval of between 5 minutes and 30 minutes.

3. Storage device

(1) General

(A) For the purpose of verifying that all sensors are working under sea-going conditions the system is to have a minimum recording capability. This requires that a semi-permanent data storage medium is to be used to record, at least once per month and the following information processed over a period of 5 minutes.
- maximum peak to peak value of stress/acceleration
- mean value of stress/acceleration
- standard deviation of stress/acceleration
- average zero crossing period of stress/acceleration
- time reference

(B) Automatic post-processing of data on-board or ashore is to be available on shore or on the vessel to enable the data to be evaluated. Proposals will be considered for recording to be replaced by sending the data ashore via satellite on a regular basis.

(C) Where manual input, for example via a computer keyboard, is used, the input procedures are to be included in the operating manual and are to be submitted for review. This data is to be checked regularly against the criteria described in the checking procedure.

4. Electrical and mechanical equipment

(1) Flame proof

All electrical and mechanical equipments associated with the hull monitoring system located in hazardous areas is to be in accordance with the requirements in **Pt 7, Ch 1, Ch 5** and **Ch 6.**

(2) Uninterruptible Power Supply (UPS)

(A) The monitoring system is to be powered through an Uninterruptible Power Supply (UPS).

(B) In case of failure of the main input voltage the battery capacity is to be sufficient to maintain normal operation of the monitoring system for at least 10 minutes. Failure of any power supply to the system is to initiate an audible and visual alarm.

(C) In the case of power failure the system software and recorded date is stored safely. The system is to be able to return automatically to normal operating condition when the power is restored.

203. Additional Requirement for Hull Monitoring System(HMS1)

1. General :

Ship assigned with the class notation of HMS1 is to be complying with the sea environment and voyage data in accordance with the term **203. 2** in addition to **201.** and **202.** The necessary information suitable for this additional requirement is to be displayed and stored.

2. Additional requirement

(1) Ship position
The ship position is to be informed by Global Position System(GPS).
(2) Wind speed and direction
The system is to indicate the wind speed and direction provided by wind speed indicator and anemoscope.
(3) Ship speed and direction
The system is to indicate the real-time information of ship speed and direction provided by GPS and speed and distance indicator onboard.

Section 3 Approval for Plans and Documents, Installation and Installation Survey

301. Approval for plans and documents

(1) Instruction manuals
Instruction manuals are to be described in relevant language and kept on board. The manuals are to contain necessary instructions on:
- instruction of system
- interpretation of measuring results
- systematic maintenance and function testing
- identification of faults and repairs
- procedures of installation
- procedures of initial calibration and checking
- checking procedure
- components list

(2) Checking procedure
The plan for systematic maintenance and function testing is to show how components and systems are to be tested and what is to be observed during the tests. The procedure is to describe how to check the normal operation of the signal acquisition and analysis and display. The check list of checking procedure is to be included in instruction manuals.

302. Installation

1. General:

Information on how to initialize the sensors is to be verified by the Society. The system is to be installed with attendance of a surveyor.

2. Installation of the sensors

(1) Sensors are to be protected from mechanical damage, humidity by the sea water, effects of very high and low temperature and damage due to local vibration.
(2) Sensors mounted on deck of the ship are to be protected from heavy sea condition. For container ship, the system is to be located in the safety area where it is not disturb to remove/install the dropped container securing appliances during loading/unloading operation.
(3) Deck mounted strain gauge is to be protected from green sea on deck by appropriate siting of by using substantially constructed breakwaters or similar means. Attention is to be paid to the possibility of green water damage to other gauge, junction boxes, cable conduits, etc.

(4) Motion sensors to measure motions are to be placed in positions where their functioning will not be affected by vibrations. Accelerometers and motion monitoring devices are to be mounted on a hard structural point where local structural vibration will be minimal. If resilient mounts are used, it is to be demonstrated that they have frequency characteristics that do not affect the signal in the frequency range of interest.
(5) When gauges are welded to the hull welding procedures are to comply with Class Rules of the Society. Consideration is to be given to the damage and repair of coatings.
(6) Pressure gauges where fitted through the hull are to be constructed in accordance with the Class Rules of the Society.

303. Installation survey

1. Initial calibration and test

(1) Initial calibration
(A) Each long based strain gauge is to be initially set to a stress calculated in an associated loading condition.
(B) This calculated stress is to be compatible with the output of the loading instrument and calculations made using the loading manual. The set-up is not to be carried out when dynamic stresses are present and are to be made when temperature effects are minimized and in absence of large gradients due to loading condition. In the case of measuring local stresses the sensor stress is to be set to the stress calculated through the detailed structural analysis.
(C) Also, the motion measuring device is to be set according to the ship condition.
(2) Checking of the initialized value
(A) After installation, the initial set-up of each long strain gauge is to be checked at least one time within 6 months.
(B) This is to be undertaken by the ships operating personnel taking the relevant values from the Loading Instrument and the Hull Condition Monitor in accordance with the Verification Procedure and submitting them to the Surveyor.
(C) In the event that differences greater than 10 % of the calculated value occur, the set-up and subsequent checking procedure are to be repeated.

3. Sensor re-calibration

Each strain gauge is to be re-calibrated annually in accordance with the manufacturer's recommendations. The certificates of calibration, signed by an authorized person, are to be kept onboard the ship.

4. Other survey

In the case of set-up sensor on exposed deck, to be carried out hose test according to **Pt 3, Ch 1, Sec 2.**

Section 4 Periodical Survey

401. General

Periodical survey for the systems is to be carried out at the time of Annual/Intermediate/Special Survey specified in **Pt 1, Ch 2.**

402. Survey items

The general conditions of electrical, mechanical and hazardous area equipment are to be carried out so far as practicable on hull monitoring systems, with special attention being paid to the following;

1. The verification of location of sensors.

2. The operation of the system is to be verified in accordance with the approved verification procedure.

3. Current calibration certificates for the sensors and Operating Manual is to be established on board.

4. The protection of sensors is to be inspected. ⚓

KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 9

Additional Installations

GA-09-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for the Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 9 "ADDITIONAL INSTALLATIONS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date 20 May 2010 (based on the application date for classification survey)

CHAPTER 3 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 2 Surveys of Automatic and Remote Control Systems

- 206. Fig 9.3.1 and 9.3.2 have been amended.

Effective Date 1 July 2011

CHAPTER 2 CARGO HANDLING APPLIANCES

Section 2 Surveys

- 205. 1 (4) has been amended.

CHAPTER 3 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 2 Surveys of Automatic and Remote Control Systems

- 203. 1 (1) has been amended.

CHAPTER 4 DYNAMIC POSITIONING SYSTEMS

Section 2 Requirements of Dynamic Positioning Systems

- 203. has been newly added.

CHAPTER 5 NAVIGATION BRIDGE SYSTEMS

Section 5 Accident Prevention Systems

- 502. has been newly added.

CONTENTS

CHAPTER 1 CARGO REFRIGERATING INSTALLATIONS

Section 1 General

101. General

1. Scope

The refrigerants listed below are not to be used as refrigerants.

(1) Methyl chloride (CH_3Cl)
(2) R 12 (CCl_2F_2)
(3) R 502 (R 22/R 115 (48.8/51.2 wt%) $CHClF_2/CClF_2CF_3$)
(4) R 13B1 (CF_3Br)
(5) Other refrigerants as deemed inappropriate by the Society

Section 2 Surveys

203. Classification Maintenance Surveys

1. Special Surveys

(1) The wording ‘the interval of opening up’ specified in **203. 2** (1) of the Rules means the interval of 25,000 hours of operation.
(2) The wording 'operation tests' specified to in **203. 2** (10) of the Rules means the confirmation of the effectiveness of each unit under operating condition. At this time, leak tests of refrigerant are to be carried out. When necessary, the concentration of brine is to be measured.
(3) 'Continuous Surveys' specified in **201. 2** (2) (D) of the Rules is conform to the following requirements:
  (A) Submission of application for Continuous Survey system.
  When the shipowner or his representative desires to adopt a Continuous Survey system, he is to submit application to the Society for approval on application for that system.
  (B) Plans for Undergoing Continuous Surveys
  The owner of a ship to which continuous survey system is applied is to prepare 'Plan for Undergoing Continuous Surveys on Cargo Refrigerating Installations' or 'Plan for Maintaining Cargo Refrigerating Installations' taking into account items listed in the following (a) to (d) and carry it on board the ship so that it can be presented to the Surveyor whenever he requires it.
    (a) All items to be covered by continuous surveys are to be included in the plan.
    (b) Inspection interval of each survey item is not to exceed five years.
    (c) Inspection of each compressor is to be carried out alternately and with the same interval, as far as possible.
    (d) Inspection of each pump is to be carried out alternately and with the same interval, as far as possible, by its use.
  (C) Items to be covered by Continuous Surveys At continuous surveys, open-up inspection and pressure tests are to be carried out on the following machinery and equipment.
    (a) Compressors
    (b) Condenser cooling water pumps
    (c) Primary refrigerant pumps
    (d) Brine pumps
    (e) Condensers
    (f) Evaporators
    (g) Others to be considered appropriate by the Society

(D) Confirmatory Surveys
On the items listed in (a) to (d) of (C) above, confirmatory surveys may be carried out in accordance with the procedures specified in **Pt 1, Annex 1-7, 2** (2) (D) of the Guidance. For compressors, at least one unit of them is to be subject to open-up inspection during the period of one cycle of continuous surveys.

(E) Cancellation of Continuous Survey System
(a) Where the shipowner or his representative requests the cancellation of applying the continuous survey system, the subsequent surveys are to be in accordance with the following (i) and (ii).
(i) Where there are machinery and equipment of which their inspection intervals will exceed five years before the next special survey, they are to be inspected within five years from the dates on which the previous surveys were carried out.
(ii) At the next special survey, inspection is to be made on all items to be required at a special survey.
(b) Where continuous surveys are not carried out in accordance with the Guidance, the application of continuous survey system may be cancelled.

Section 3 Refrigerating Machinery

302. Construction, etc. of refrigerating machinery

1. Refrigerant compressors

'Automatic cut off devices' specified in **302. 1** (3) of the Rules includes flow switches.

303. Cooling appliances in refrigerated chambers

5. Temperature difference

Temperature difference between the refrigerated chamber and the refrigerant is, as a rule, to be within 5℃ for fruit, and 10℃ for frozen meat.

Section 4 Special Requirements for Refrigerating Machinery Using Ammonia as Refrigerant

407. Electrical installations

1. General

The wording 'certified safe types for use in the flammable atmosphere concerned' in **407. 1** (1) of the Rules means electrical equipment having intrinsically safe, flame-proof or pressurized construction grouped into Apparatus Group IIA and Temperature Class T1 as specified in (KS C) IEC 60079. ⚓

Annex 9-1 Spare Parts (for Reference)

101. Spare parts for general tools and equipment

1. One set of motor coupling bolts with nuts and washers of each size used.

2. One expansion valve of each size used.

3. One float regulator assembly of each size used.

4. At least two glass thermometers in the case of thermometers.

5. In the case of thermometers: 5 % of the total number of temperature sensors, but not less than one of each type used. Two sets of standard resisters of each size used.

6. Two sets of relief valves of each size used.

102. Spare parts for refrigerant compressors

1. Where screw type compressors are installed, the following spare parts are to be provided.

(1) One set of main bearing of each size used.
(2) One set of thrust bearing of each size used.
(3) One set of rotor seals of each size used.

2. Where reciprocating compressors are installed, the following spare parts are to be provided.

(1) One set of piston and piston rod or connecting rod of each size used.
(2) One set of crankshaft main bearing of each size used.
(3) One complete assembly of each size of compressor suction and delivery valves.
(4) One set of wearing parts of the crankshaft seals where the crankcase is subjected to the refrigerant pressure.
(5) One set of crankshaft coupling bolts with nuts and washers of each size used.
(6) One set of driving belts of each size used.

103. Spare parts for electrical equipment

Spare parts for the electrical equipment are to comply with the requirements in **Pt 6, Ch 1, Sec 19** of the Rules. ⚓

CHAPTER 2 CARGO HANDLING APPLIANCES

Section 1 General

101. General

1. Application

In application to **101. 1** (1) of the Rules, cargo handling appliances means that come under either of the followings:

(1) The cargo handling appliances, except cargo ramps, of safe working load not less than 1 ton which are installed in ships subject to the requirements of *Korean Ship Safety Act*.

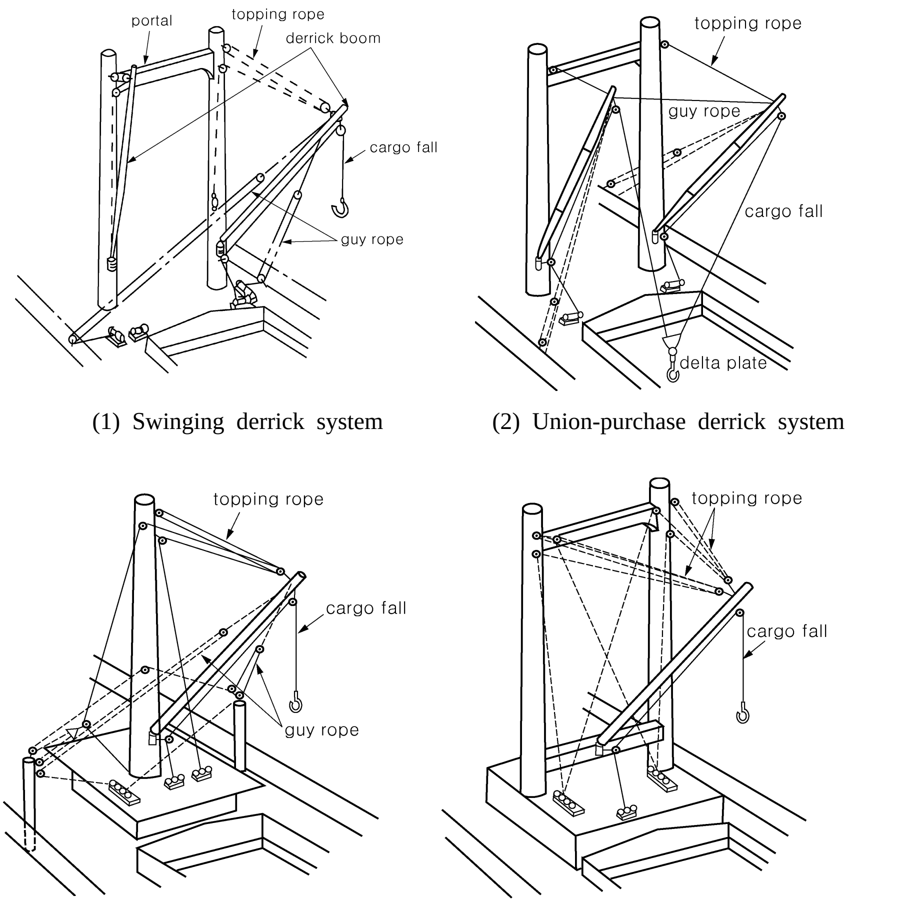
(2) The cargo handling appliances installed in the ships other than those specified in (1) above, for which the assignment of the safe working load, etc. is requested.

2. Equivalency

"Tests and inspection required by the Society" specified in **101. 2** (2) of the Rules mean, as a rule, the Design Examination specified in **203. 1** of the Rules and the Work Examination specified in **203. 2** of the Rules thereof. However, the Society may dispense with part of the plan investigation and examination for the machinery and gear which passed the plan investigation and examination of the official or third-party organizations considered appropriate by the Society and were certified by them.

102. Definitions

The derricks come under the requirements of the Rules include those illustrated in **Fig 9.2.1.**



(1) Swinging derrick system (2) Union-purchase derrick system

(3) One topping derrick crane system (4) Tow topping derrick crane system

Fig 9.2.1 Derrick Systems

103. Arrangement, Construction, Materials and Welding

1. General Construction

(1) The cargo gear which are to comply with the additional requirements considered appropriate by the Society in applying the Rules as specified in **103. 2** (1) of the Rules include the following (A) through (D):
(A) Cargo gear installed on mobile offshore units
(B) Cargo gear installed on workboats
(C) Hoisting and stowing equipment for submersibles and diving
(D) Other equipment to which the Society deems necessary to pay special attention

(2) "The Guidance relating to the Rules" specified in **103. 2** (2) of the Rules include the following requirements (A) through (D):
(A) Where steel materials of various strengths are used in the structural members, due considerations are to be given to the stress caused in the material of lower strength adjoining that of higher strength.
(B) For the members in which high tensile steels are used, special attention is to be paid to the structural details so that significant stress concentration may not take place.
(C) Where high tensile steels are extensively used in the structural members, careful considerations are required. In such cases, a thorough study with regard to ensuring buckling strength and the results of the study are to be submitted to the Society.
(D) Dimensions of the members are to comply with the following requirements (a) through (e):
(a) The minimum thickness of post specified in **303. 3** of the Rules may be obtained from the following formula:

$$5.0K+1.0 \quad (\mathrm{mm})$$

where:
$K=\sigma_{yM}/\sigma_{yH}$
σ_{yM} : Specified value of yield stress of mild steel
σ_{yH} : Specified value of yield stress of high tensile steel

(b) The minimum outside diameter of post at the base specified in **305. 2** of the Rules may be as obtained from the following formula:

$$5hK \quad (\mathrm{cm})$$

where :
h : As specified in **305. 2** of the Rules
K : As specified in (a) above

(c) The value of the coefficient C_2 specified in **Table 9.2.8** and **305. 3** (1) (A) of the Rules may be substituted by the value of C_2 multiplied by the coefficient K specified in (a) above.
(d) The minimum thickness of the structural members specified in **403. 6** of the Rules may be substituted by the value obtained from the following formula:

$$5.0K+1.0 \quad (\mathrm{mm})$$

where:
K : As specified in (a) above

(e) The minimum thickness of the structural members specified in **803. 4** of the Rules may be substituted by the value obtained from the following formula:

Weather part : $5.0K + 1.0$ (mm)

Enclosed part : $5.0K$ (mm)

where:

K : As specified in (a) above

2. Materials

(1) "Cases considered appropriate by the Society" mentioned in **103. 4** (1) of the Rules are the following cases (A) to (C):

(A) Where B of more than 25 mm in thickness are used in the following members (a) to (c) of the structural members of cranes:

(a) Flange for mounting slewing ring (bearing) of jib crane

(b) Housing base of jib crane

(c) Members constituting movable parts of gantry crane, etc. with increased plate thickness to ensure stiffness. However, requirements specified in **Table 9.2.1** of the Rules may be applied according to the magnitude of working stresses

(B) Where steel pipes conforming to the following requirements (a) through (d) are used to manufacture the structural members such as derrick booms, derrick posts, crane jibs, crane posts and other similar members:

(a) The steel pipes are to be of 20 mm or less in thickness.

(b) The steel pipes are to be of Grade 1 or 2 of steel pipes for pressure piping specified in **Pt 2** of the Rules, or the equivalent thereto.

(c) Steel pipes to be welded are to be of 0.23 % or less in carbon contents.

(C) Where rolled steel material and steel pipes, not exceeding 12.5 mm thick, complying with the standards recognized to be appropriate by the Society are used in the structural members of cargo gears which are not employed in cargo handling services excluding those used for cargo hoses. The materials of the structural members welded directly to the hull structure, however, are to comply with the requirements in **103. 4** (1) of the Rules or (2) (a) to (c) above.

(2) Classification of the steel materials used in the structural members, travelling girders, tracks, etc. of cargo gear regularly used in especially cold zones or refrigerated hold chambers are to comply with **Table 9.2.1** according to design temperatures.

(3) Forged or cast steel parts used in the following structural members (A) through (F) may be of the materials conforming to standards considered appropriate by the Society.

(A) Topping bracket of derrick system

(B) Gooseneck bracket and gooseneck pin of derrick system

(C) Derrick heel lugs and head fitting of derrick boom

(D) Heel bracket of jib crane

(E) Heel fitting of crane jib

(F) Bracket and pin for movable parts of gantry crane, cargo lift and cargo ramps

Table 9.2.1 Classification of Steel Materials Exposed to Low Temperature

Design temperature T (℃)	Material thickness t (mm)				
	$t \le 10$	$10 < t \le 20$	$20 < t \le 25$	$25 < t \le 40$	$40 < t$
$-10 \le T$	A/AH		B/AH	D/DH	E/EH
$-20 \le T < -10$	B/AH	D/DH	E/EH		
$-30 \le T < -20$	E/EH			$RL24A$	$RL24B$
$-40 \le T < -30$	$RL24A$		$RL24B$		*
$-50 \le T < -40$	$RL24B$		*		

(NOTES)
1. Steel grades for the construction capable of relieving thermal stress will be specially considered by the Society.
2. The Society may require materials having higher notch toughness according to the material thickness and construction if the design temperature is below -50℃ or working stress of the material exposed to low temperatures exceeds 60% of the yield point.
3. Steel grades for the members corresponding to classification asterisked * will be specially considered by the Society.
4. Symbols used in this Table are same as those in **Table 9.2.1** of the Rules.

3. Welding

In application to **103. 5** of the Rules, the followings are to be applied.

(1) Welding of derrick posts is to comply with the following requirements (A) through (H):

(A) Welding of post is to be both side welding as far as practicable.

(B) Welding of post to deck is to be of double grooved at the foot of post. If inside work of the post is difficult due to small diameter or any other reasons, penetration welding with the backing metal for single groove may be permitted.

(C) As for the welding of side plates to upper and lower plates constituting portal, the fillet size, at the portal ends and at the portions where topping brackets, eyes, etc. are fitted are to be of $F1$ weld specified in **Pt 3, Table 3.1.6** of the Rules.

(D) Welding for portal and post are to be both side welding as far as practicable. If the angle (α) shown in **Fig 9.2.2** is small, the ends of portal are to intersect orthogonally with the post surface by providing knuckle to carry out fillet welding as completely as practicable.

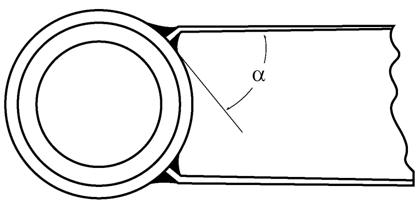


Fig 9.2.2 Welding for Portal and Post

(E) Topping brackets and gooseneck brackets are to be fitted by penetrating the post or mounting the base. If the plate thickness of the post or the mounting base exceeds 12.5 mm, the welding is to be penetration welding with grooves.

(F) The joint of derrick boom for circumferential is to be both side welding and back welding after removing defects of face run by back chipping. However, penetration welding with backing metal may be permitted limiting to such an unavoidable case as partial replacement for repair. In this case, the welded joint concerned is to be verified by suitable non-destructive inspection carried out along the whole length of weld line that it is free from injurious defects.

(G) The backing metal used for the joint derrick boom for longitudinal joint is to be jointless along the whole length with smooth surface.
(H) The requirements in (B), (E) and (F) above may be modified for the derricks not used in cargo handling service in consideration of the safe working load and the type of construction.

(2) Welding for cranes is to comply with the following requirements (A) to (E):
(A) The requirements in (1) (F) and (G) above are to be applied to the butt welding and longitudinal seam welding of jib by constructing the words "derrick boom" as "jib".
(B) Where welding from both sides (including fillet weld) is difficult for the welded joints other than butt welding and longitudinal seam welding of the jib, penetration bead welding or welding with backing strip is to be carried out.
(C) As for the welding of crane post, the requirements in (1) (A) and (B) above are to be applied.
(D) The following parts are, as a rule, to be fixed by full penetration type welding.
(a) Fixing part of crane post and post flange for slewing ring
(b) Fixing part of bracket for sheave to jib top
(c) Fixing part of bracket for sheave to crane house
(d) Fixing part of base bracket of jib
(e) Fixing part of crane house well and turning table
(E) The fillet weld applied to the primary structural members is, as a rule, to be *F*1 weld specified in **Pt 3, Table 3.1.6** of the Rules, or equivalent thereto.

(3) Welding for cargo lifts and cargo ramps is to comply with the following requirements (A) to (C):
(A) The fillet weld applied to the primary structural members is to comply with the requirements in (2) (E) above.
(B) Welding for non-slip bar, etc. fitted directly to the primary structural members is to be carried out in such a way that it may not give any injurious effect on the members.
(C) The method of welding for stoppers, their braces and similar fittings used in stowing the machinery are to be selected or carried out in such a way that they do not give any adverse effect on the structural members or hull structures.

(4) Welding for the structural members of cargo gear used regularly in especially cold zones or refrigerated hold chambers is to be carried out in such a way that it may not give any adverse effect on prevention of occurrence of low temperature brittle fracture in consideration of the structure, working stress, etc.

(5) When cast steel or forged steel parts are connected to steel plates by butt welding or lap welding, the details of welded joints are to comply with the requirements specified in **Pt 2, Sec 2, Ch 3** of the Rules.

(6) Non-destructive inspection for welded joints of structural members of cargo gear and cargo ramps is to comply with the following requirements (A) to (C):
(A) The following places (a) to (c) are to be subjected to radiographic test or ultrasonic test:
(a) Places specified in (1) (F) above
(b) For structural members of cranes, places specially considered by the Society according to their structure and method of construction as well as the places specified in (2) (A) above
(c) Places being suspicious in integrity of welded joints
(B) When the Society deems necessary, the following places corresponding to (a) to (d) are to be subjected to the magnetic particle test or dye penetrant test:
(a) Welded joint of rolled steel plate to cast or forged steel
(b) Trace of removing hanging pieces, jigs, etc. welded temporarily to the structural members
(c) Weld of cargo fitting
(d) Fillet welds of structural members being suspicious in integrity
(C) Method of non-destructive test specified in (A) and (B) above and judging criteria of defects are to be in accordance with the discretion of the Society according to the construction of the places concerned.

Section 2 Surveys

201. General

1. Application

In application to **201. 1** of the Rules, the followings are to be applied.

(1) Posts for derricks and cranes and supports for cargo lifts/ramps fixed directly to the hull structure are to be subjected to the tests and examinations specified in **Pt 1** of the Rules for the Survey and Construction of Steel Ships in addition to this chapter.

(2) Where cargo lifts and cargo ramps constitute part of the hull structure, they are to be subjected to the tests and examinations in compliance with the requirements in **Pt 1** of the Rules, according to the type and arrangement of hull structure.

(3) In applying the requirement in **201. 1** (4) of the Rules, the Load Tests specified in **202.** of the Rules may be omitted provided that the cargo gear is to comply with the condition in either of the following (A) or (B).

(A) For heavy derrick systems: they are not frequently used and the Load Tests will be carried out before use.

(B) For union-purchase derrick systems: they passed the Load Tests as a swinging derrick system and eye plates of preventer stays are in good order.

2. Preparation and Attendance for Tests and Surveys

In application to **201. 2** (3) of the Rules, "The Surveyor considers that the safety for execution of the tests and examinations is not ensured" means that the safety measure of prevention for downfall is not taken at high position survey, etc.

203. Registration Surveys

1. Drawings and Other Documents to be Submitted

In application to **203. 1** of the Rules, the followings are to be applied.

(1) Notwithstanding the requirements in **203. 1** of the Rules, where whole cargo handling appliances or any components thereof are manufactured on the basis of the drawings and documents already approved at the same works, submission of the drawings and documents other than the following documents (A) and (B) may be dispensed with.

(A) Application for omission of submission of drawings

(B) General arrangement of cargo handling appliances

(2) Submission of drawings of hydraulic motors, hydraulic pumps, steam cylinders, pneumatic motors or internal combustion engines for driving various winches and travelling machines used in cargo handling appliances are to be in accordance with the following requirements (A) to (C) according to the output:

(A) Where the output is less than 375 kW :
Submission of drawings may be dispensed with. However, name of manufacturer, type and principal particulars are to be described in the approval drawings of winches or travelling machines employed.

(B) Where the output is 375 kW or more:
Principal particulars, drawings of structural details and strength calculation sheet are to be submitted in one set for reference.

(C) Others:
Where the machinery is installed in ships under the classification of the Society for the first time, the requirements in (B) above are to be applied even when the output is less than 375 kW.

(3) General arrangement plan and structural drawings of derricks are to include at least the following items (A) and (B):

(A) General arrangement plan

(a) Masts, posts, guy posts, shrouds, stays(including attached rigging screws), derrick booms, and arrangement of cargo fittings fitted to hull structure, etc.

(b) Breadth of ship and outreach

(c) Positions and name of cargo blocks and arrangement of running ropes(for lifting and slewing)

(d) Positions, types and capacities of winches

(e) Self-weight of lifting beams, grabs, lifting magnets, spreaders, etc.

(B) Structural drawings

(a) Construction, dimensions and materials of masts, posts, guy posts and derrick booms

(b) Dimensions and materials of shrouds and stays

(c) Dimensions and materials of gooseneck brackets, topping brackets, eye plates at upper and lower ends of preventer stays and other cargo fittings

2. Examinations for Workmanship

In application to **203. 2** of the Rules, the followings are to be applied.

(1) Tests and examinations for driving machines, etc. for cargo gear and cargo ramps are to be in accordance with the following requirements (A) to (D):

(A) Hydraulic motors and regulating valves attached thereto:

(a) Where the output is less than 375 kW, shop tests may be replaced with the tests conducted by the manufacturer. In this case the Society may require submission of the test results, if it deems necessary.

(b) Where the output is 375 kW or more, hydraulic test may be dealt with in a same way as (a), but performance verification test and open-up examinations are to be carried out in the presence of the Surveyor. The hydraulic(water or oil) test is to be carried out at a pressure of 1.5 times the design pressure.

(c) Notwithstanding the requirements (a) and (b) where the driving machines are installed on the class ship of the Society for the first time, the hydraulic test, performance verification test, and open-up examination are all to be carried out in the presence of the Surveyor.

(B) Hydraulic pumps:

Hydraulic pumps are to be dealt with in similar ways to (A) (a) to (c) above depending on the outputs of the driving motors.

(C) Steam cylinders, pneumatic motors and internal combustion engines:

These are to be dealt with in similar ways to (A) (a) to (c) above depending on each output. The hydraulic tests for the steam cylinders are to be carried out at a pressure of 1.5 times the design steam pressure and those for the valves directly connected to the cylinder are to be carried out at a pressure of 2 times the design steam pressure.

(D) Driving motors for winches or hydraulic pumps and their control equipment:

These are to comply with the requirements specified in **Pt 6** of the Rules and to pass the tests and examinations specified in **Pt 6** of the Rules thereof.

(2) Winches which are used for the cargo gear and cargo ramps(except those specified in (3) below) are to be subjected to the tests and examinations mentioned in the following (A) and (B) at the shop tests after completion of assembly including installation of driving machines, etc. In this case, one winch selected from those of the same type manufactured at the same time and to be installed on the same ship is to be tested in the presence of the Surveyor, and, if the results are satisfactory, tests and examinations for other winches may be substituted by confirmation of the test results issued by the manufacturer.

(A) Electro-hydraulic winches

(a) Visual examinations and checking of the construction:

It is to be ascertained that no practically injurious defects exist in materials and workmanship and each movable part moves smoothly.

(b) No-load test:

The winch is to be operated with no load at the maximum speed for 30 minutes(15 minutes for each normal and reverse rotation) and be ascertained that the performance and each structural part is in good order.

(c) Load tests:
The winch is to hoist and lower the rated load for a period of 30 minutes continuously. (Pause of 20 seconds may be inserted between each hoisting and lowering operation, and effective lift is desirable to be 10 m or more.) During this operation, the temperature rise of the bearings, the hoisting speeds, the lowering speeds and the input power are to be measured and ascertained that they are in good order.

(d) Braking tests:
During hoisting and lowering the rated load for the winch, return the control handle to the neutral position and check the slip of the load to be 1.5 m or less. Manual releasing test of the brake is also to be carried out and ascertained to be in good order.

(e) Speed control tests

(f) Emergency assurance tests:
The emergency assurance devices provided in the winches is to be ascertained of the performance by cutting off power supply during lowering the rated load.

(g) Overload tests:
The winch is to hoist and lower a load weighing 125 % of the rated load several times. The winch is to be stopped at least three times during lowering the load and ascertained to be in good order.

(h) Adjustment of the over-pressure preventive device:
The adjusted pressure is to be checked as necessary.

(i) Open-up examinations
The Society may require an open-up examination of the part where abnormality is found.

(j) Other tests deemed necessary by the Surveyor.

(B) The shop test for steam winches, electric winches and winches driven by internal combustion engines are also to be carried out in accordance with the requirement specified in (A) above for electro-hydraulic winches(except (A) (h) above).

(3) Winches that are used for cranes, special derricks, cargo lifts or cargo ramps and are integrated in their moving bodies are, as a rule, to be handled in accordance with the requirements in (2) above. However, in case where deemed impracticable by taking into account the construction or arrangement of the winch, part or whole of the tests and examinations specified in (2) above may be permitted to be carried out at the time of the Load Tests specified in **205.** of the Rules.

204. Annual Surveys

In application to **204. 1** of the Rules, at Annual Surveys, the structural members and loose gear in which corrosion, abrasion or other defects specified in the followings are found are, as a rule, to be repaired or renewed:

(A) Structural members(plate members and cargo fittings other than pin construction):
Structural members in which amount of wear and tear reaches 10 % of the original dimensions. However, this may not be applied where steel plates having enough margin to the thickness required by the Rules is used.

(B) Cargo fittings of pin construction:
Structural members where clearance between pin or similar fitting and its mating hole increases up to 10 % of the original diameter of the pin. However, for gooseneck pin the limit of clearance between the cross bolt and the bracket hole is to be 5 % of the original diameter of the cross bolt.

(C) Loose gear(except wire ropes)
For loose gear except wire ropes, those corresponding to any of the followings:
(a) Those in which injurious deformation occurred
(b) Those in which injurious deformation occurred
(c) Those in which amount of abrasion or corrosion reaches 10 % or more of the original dimensions
(d) Blocks whose sheaves do not rotate smoothly

(D) Wire ropes
Wire ropes corresponding to any of the followings:
(a) Those in which 5 % or more of total number of independent wires(except filler wires) were broken within a length of 10 times the diameter of wire rope
(b) Those in which reduction in diameter of the wire rope reaches 7 % or more of the diameter
(c) Those in which kink or other injurious deformation occurred
(d) Those in which significant corrosion occurred at the surface of independent wires or inside the wire rope
(e) Those deemed necessary by the Surveyor

205. Load Tests

1. Load Tests

In application to **205.** of the Rules, the followings are to be applied.

(1) Load Tests for cranes which are newly constructed, as a rule, are to be carried out after having been assembled at the shops, as well as after having been installed on board the ships. If the results of the shop tests are satisfactory for one crane selected from those of the same type manufactured at the same time and to be installed on the same ship, those for other cranes my be substituted by confirmation of the test results issued by the manufacturer. Where any special reason is admitted by the Surveyor, the Load Tests at the shop may be dispensed with.

(2) For cargo gear exclusively using grabs, lifting beams, magnets, spreaders and other similar loose gear (hereinafter referred to as "cargo holding gear"), the test load and safe working load may be dealt with in either case of the following (A) or (B) in accordance with the application:

(A) Where the mass of loose gears is included in the safe working load:

Test load = α × {(maximum cargo mass) + (mass of cargo holding gear)}
Safe working load = (maximum cargo mass) + (mass of cargo holding gear)

where:
α : a factor obtained from the test load specified in **Table 9.2.2** of the Rules divided by the safe working load. However, for the safe working load not less than 20 t but less than 50 t, the test load is to be the safe working load plus 5 t.

(B) Where the mass of loose gears is not included in the safe working load and the maximum cargo mass only is assigned as the safe working load, the cargo gear whose safe working load is assigned by this procedure is to satisfy the following conditions:
(a) The load tests are to be carried out employing the loose gears used in the cargo gear concerned or other loose gears having same construction and mass.
(b) The loose gears used on board the ship is to be the same gears as used in the load test or those having same construction and mass.

Test load = α × (maximum cargo mass)
Safe working load = maximum cargo mass

where:
α : As specified in (A) above

(3) Load Tests for cargo gear which are used for solely conventional cargo handling by cargo hook are, as a rule, to be handled in accordance with the manners specified in (2) (B) above.

(4) Details of Load Tests and operation tests for cargo gear and cargo ramps are to comply with the following requirements in (A) to (E), in addition to those specified in the Rules.

(A) Derricks

Where assignment of additional safe working load specified in **902. 2** (A) of the Rules is made, the Load Test for the additional safe working load may be dispensed with. In this case the relationship between the safe working load, etc. and additional safe working load, etc. is to satisfy the following formula:

$$B = W\frac{\cos\alpha}{\cos\beta}$$

where:

W : Safe working load (t)

α : Allowable minimum angle (degree)

B : Additional safe working load (t)

β : Additional allowable angle (degree)

(B) Jib cranes

(a) Where assignment of additional safe working load specified in **902. 2** (B) of the Rules is made, the Load Test for the additional safe working load must not be dispensed with.

(b) For cranes with constant safe working load regardless of slewing radius, slewing tests are to be carried out at the maximum radius with test load based on the safe working load suspended on it and luffing operation to the minimum radius or the smallest possible radius is to be carried out and slewing test at that radius is also to be carried out as far as practicable.

(c) For cranes whose safe working load changes depending on the slewing radius, slewing tests are to be carried out at both the maximum and minimum slewing radius after hoisting the test loads corresponding to each radius.

(d) For cranes capable of doing all three of hoisting, slewing and luffing operations or any two out of these three operations simultaneously, these combined operations prescribed in the design specifications are to be verified that they are in satisfactory condition with the test loads corresponding to the limited radius suspended on it.

(C) Gantry cranes and other track-mounted cranes

(a) The crane is to run on the track within the traveling limits with the safe working load suspended on it. In this case, the hull structure supporting the traveling track is also to be confirmed that it is free from defects.

(b) Where traveling trolley is employed, it is to run the whole traveling range through with the safe working load suspended on it.

(c) Where sponson girder of stowing type for traveling trolley is employed, stretching and stowing operations of the girder are to be ascertained that they are in good order.

(D) In case of hydraulic cranes where limitations of pressure make it impossible to lift a test load 25 percent in excess of the safe working load, it will be sufficient to lift the greatest possible load, but in general this should not be less than 10 percent in excess of the safe working load.

(E) "The method considered appropriate by the Society" in **205. 1** (4) (B) of the Rules means the following requirements at least.

(a) Accuracy of the load weighing machine is to be within the range of ± 2.5 %.

(b) Load applying position is to be selected in such a way that the stress generated in the structural members be the most severe within the approved operating range.

(c) The load is to be sustained for a period of 5 minutes or more being sufficient to ensure the load indicator remains constant.

Section 3 Derrick Systems

302. Design Loads

1. Load Considerations

In application to **302. 1** of the Rules, where strength of derrick systems is to be calculated directly, external forces exerting on top of boom are to include tension in topping lifts, tension in guy ropes, tension in cargo falls(which is caused by the weight of cargo), tension in cargo relief, half of self-weight of boom, and additional loads including self-weight of cargo blocks, hooks, ropes, etc. However, the additional loads may be as given in **Table 9.2.2.**

2. Loads due to Ship Inclination

In application to **302. 3** of the Rules, the followings are to be applied.

(1) Where an angle of heel less than that specified in the Rules is used for the design of structural members, data concerning ship inclination in service condition in at least the following conditions (A) through (C) are to be submitted to the Society. Longitudinal strength of hull and stability in these conditions are to be separately examined.
   (A) Ship light condition
   (B) On going condition in service of cargo loading
   (C) Immediately before fully loaded condition

(2) In ships conducting ballast adjustment to keep angle of heel within that specified in **302. 3** of the Rules in working condition, data concerning the following (A) through (C) are to be submitted to the Society. All these date are to be entered in the Instruction Manual to Cargo Handling Machinery and Gear referred to in **905. 2** of the Rules.
   (A) Specifications of equipment for ballast adjustment
   (B) Method and procedure of ballast adjustment
   (C) Trouble-shooting of equipment for ballast adjustment

Table 9.2.2 Additional Loads

Safe working load W (t)	Additional Loads (t)
$W \leq 2$	$0.283W$
$2 < W \leq 15$	$0.4\sqrt{W}$
$15 < W \leq 50$	$0.1W$
$50 < W$	As considered appropriate by the Society

Section 4 Cranes

402. Design Loads

1. Load due to Ship Inclination

In application to **402. 7** of the Rules, in calculating loads due to ship inclination to be taken into consideration in the design of cranes, requirements in **302. 3** (1) and (2) specified for derrick systems may be also applied to cranes.

2. Load Combinations

In application to **402. 9** of the Rules, wind loading need not be taken into account for cargo gear mentioned in the following (A) and (B):

(A) Cargo gear used in cargo hold, engine room, and other enclosed spaces in ship
(B) Cargo gear installed on weather deck and used only for loading and unloading articles other than cargo. The Society may, however, require to take the wind loading into account considering the construction system, method of operation, and safe working load of the machinery and gear.

403. Strength and Construction

1. General

In application to **403. 1** of the Rules, the followings are to be applied.

(1) As for slewing ring of the crane, drawings and data given in the following (A) through (E) are to be submitted to the Society. However, for those having operational experiences aboard ships under the classification of the Society, the requirements may be reduced to only those specified in (B).
(A) Those giving structural details and materials of slewing ring
(B) Allowable values of vertical load, radial load, and upsetting moment exerting on the slewing ring
(C) Installation criteria of slewing ring
(D) Strength calculation sheet
(E) Data on operating experience and quality control during period of manufacture.
(2) In construction of jib crane house, such portions subjected to concentrated load as fixing parts of brackets for sheaves and wire rope stoppers are to be effectively reinforced.

2. Fixed Posts

In application to **403. 8** of the Rules, the followings are to be applied.

(1) Where the fixing flange of slewing ring of jib crane at the upper part of post is reinforced by brackets, the brackets are at least to be fitted at every two fixing bolts for the slewing ring.
(2) The method of reinforcement specified in (1) above is to be applied also to gantry cranes and other special cranes having slewing ring.

404. Special Requirements for Track-mounted Cranes

1. Stability

In application to **404. 1** of the Rules, Tracks for track-mounted cranes are to comply with the following requirements (A) through (C):

(A) The tracks are to have proper cross section, to be properly laid considering expansion and construction due to hull deformation and thermal effect, to be rigid and horizontal, and to have sufficient strength and monolithic travel surface.
(B) Where intended to serve as anchor to stop the crane under strong wind condition, the tracks are to be properly designed for the purpose intended.
(C) Tracks for electric cranes are to be properly earthed.

Section 6 Loose Gear

602. Cargo Blocks

1. Cargo Blocks for Wire Ropes

In application to **602. 1** of the Rules, diameters of equalizer sheaves and sheaves of overload sensing devices at the bottom of groove are to be not less than 10 times and 5 times the diameters of wire ropes to be used, respectively.

603. Ropes

1. Wire Ropes

In application to **603. 1** of the Rules, terminal connections of ropes are to comply with the following (A) through (F), as a standard:

(A) A loop splice should have at least three tucks with a whole strand of rope, followed by two tucks with half the wires cut out of each strand.

(B) All tucks other than the first should be against the lay of the rope. If another form of splice is used, it should be as efficient as that described in (A) above.

(C) A splice in which all the tucks are with the lay of the rope should not be used in the construction of a sling or in any part of a cargo handling appliance where the rope is apt to twist about its axis.

(D) If a loop is made or a thimble secured to a wire rope by means of a compressed metal ferrule, the ferrule should be made to a manufacturer’s standard conforming to the following (a) through (e):

- (a) The material used for the manufacture of the ferrule should be suitable, particularly to withstand plastic deformation without any sign of cracking.
- (b) The correct size(both in diameter and length) of ferrule should be used for the diameter of the rope.
- (c) The end of the rope that looped back should pass completely through the ferrule.
- (d) The correct dies should be used for the size of the ferrule.
- (e) The correct closing or compression pressure should be applied to the dies.

(E) Where zinc or other alloy is cast in socket to hold the end of rope, work is to be done in accordance with the manufacturer’s criteria conforming to the following requirements (a) through (d):

- (a) Rope length necessary to make alloy casting is to be ensured.
- (b) Oil and dirt adhering to independent wires are to be completely removed and proper clean surfaces are to be ensured by treatment before casting work.
- (c) Casting temperature suitable to the characteristics of the alloy is to be properly maintained.
- (d) Socket is to be preheated before casting of alloy.

(F) The terminal fitting of any wire rope should be capable of withstanding the following loads (a) or (b).

- (a) Not less than 95 % of the minimum breaking load of the rope in the case of a rope of a diameter of 50 mm or less
- (b) Not less than 90 % of the minimum breaking load of the rope in the case of a rope of a diameter above 50 mm

605. Equivalent Requirements

1. General

In application to **605. 1** of the Rules, the followings are to be applied.

(1) Construction and materials of cargo blocks and hooks are to comply with the following requirements in (A) through (C).

- (A) Steel blocks are to comply with other standards considered appropriate by the Society.
- (B) Wooden blocks are to comply with other standards considered appropriate by the Society.
- (C) Hooks are to comply with other standards considered appropriate by the Society.

(2) Sheaves, main parts of which are fabricated by welding steel plates, are to be verified prior to application that they have sufficient structural strength by the tests and inspections specified in the following (A) through (F):

(A) Welding procedure test(The test items are in accordance with the requirements specified in **Pt 2, Ch 2, Sec 4** of the Rules. They are, however, increased or decreased according to the type of joint.)

(B) Structural strength test(Local and/or total strength)

(C) Fatigue test(Test is to be carried out by rotating the sheave at least 10^6 turns under the most severe load condition of the block.)

(D) Load Test

(E) Verifying test for special process of manufacture such as quenching

(F) Verification test for process of manufacture conforming to manufacturing standard(No occurrence of defects such as distortion is to be verified.)

Section 7 Machinery, Electrical Installations and Control Engineering Systems

701. General

1. Application

In application to **701. 1** of the Rules, "They may be suitably modified" specified in the requirement of winches used for cargo ramps means that the requirements specified in **702. 2** (1) (A), (B), (E), (F), **704. 2** (3) and **704. 3** (1) of the Rules are not applied.

702. Machinery

1. Hoisting Machinery

In application to **702. 2** of the Rules, the followings are to be applied.

(1) Winches are to be so designed that the safety factor of the structural parts based on the ultimate tensile strength of the material is not less than the value given as follows according to the safe working load of cargo gear incorporating the winches concerned:

5 : for safe working load is 10 t or less
4 : for safe working load exceeds 10 t

(2) Winches which may have to continue stalling condition for a given period with load applied to winch drums are to be provided with devices capable of preventing positively rotation of the drum by means of such mechanism as ratchet in addition to the braking devices specified in **702. 2** (1) (D) of the Rules. In general, winches having mechanism shown in the following (A) and (B) correspond to these winches:

(A) Topping drum(or guy drum) of a winch, which drives its cargo hoist drum and topping drum(or guy drum) by a same driving unit through clutch

(B) Drum of a topping winch or guy winch, which is used as the end stopper of wire rope holding the boom at its working position

(3) "The rope at its end is to be secured to the drum" specified in **702. 2** (2) of the Rules means a force to sustain a load being double the drum load on condition that the wire rope is wound on the drum by four full turns.

703. Power Supply

1. General

In application to **703. 1** of the Rules, among cables used in power circuit of 600 V or less for electric equipment for movable cargo gear, rubber flexible cords used in portions requiring flexibility and bending strength are to be those conforming to other standards considered appropriate by the Society.

704. Control Engineering Systems

1. Safety System

In application to **704. 3** of the Rules, the followings are to be applied.

(1) It recommended that derrick systems are to be provided with limit switches to prevent over winding up, slewing and over luffing.

(2) Cranes are to be provided with safety devices specified in the following (A) through (D):

(A) Overload preventive device and overload alarm. Cranes not serving cargo handling may dispense with these devices.

(B) Limit switches to prevent over winding up, over slewing over luffing

(C) Where trolley or crab travels on horizontal jib or luffing jib and safe working load varies depending on the load and radial position of trolley or crab, radial load indicator clearly visible to the operator indicating the following items (a) and (b):
(a) Safe working load of crane corresponding to the radial position of hook or other hoisting gear fitted to the hoist rope
(b) Limit value for luffing motion of jib or longitudinal motion of trolley/crab. This, however, does not apply to the case where rated load diagram is posted in the operator cab.
(D) For cranes having travelling equipment on the body or hoisting device, overrun preventive device on the travelling tracks. In addition, it is recommended that overspeed preventive device be provided.
(3) Cargo lifts are to be provided with the safety devices given in the following (A) through (C) as far as practicable:
(A) Overload alarm
(B) Automatic cutout device for power supply to the driving equipment when hoisting rope or chain slacks
(C) Interlock device capable of functioning the following (a) and (b) where locking bars are used in stowing device of the lift
(a) Power is not to be supplied to the lift unless all locking bars are pulled out.
(b) For hydraulic lifts, locking bars can not be pulled out until oil pressure reaches a pressure sufficient to sustain the lift.
(4) The emergency stopping device specified in **704. 2** (4) of the Rules is to operate independently of other control devices.
(5) Cargo ramps are to be provided with the safety devices specified in the following (A) and (B):
(A) An alarm device generating alarm before inclination of the ship reaches the value determined in accordance with the requirements in **802. 1** (1)
(B) For ramps slewing or travelling with cargo loaded, safety devices determined by the requirements in (1) to (3) above depending on the operating system

Section 8 Cargo Lifts and Cargo Ramps

802. Design Loads

1. Loads due to Ship Inclination

In application to **802. 4** of the Rules, the followings are to be applied.
(1) The load due to ship inclination is, as a rule, to comply with the requirements in **402. 7** of the Rules. The Society, however, may permit to apply value of ship inclination offered, if the data on ship inclination in service conditions are submitted to and deemed appropriate by the Society.
(2) Cargo ramps are not, as a rule, to be designed to be capable of operating at a slope of exceeding 1/10.

803. Strength and Construction

1. Deflection Criteria

In application to **803. 5** of the Rules, concerning deflections of the cargo lifts and cargo ramps, the Society may permit application of values larger than those specified in **803. 5** of the Rules if it considers no obstruction exists in strength and operation of the equipment judging from the operating experience, results of model tests, etc. ⚓

CHAPTER 3 AUTOMATIC AND REMOTE CONTROL SYSTEMS

Section 2 Surveys of Automatic and Remote Control Systems

202. Classification surveys

1. Drawings and data

The following drawings and data are to be submitted as those for the specific automation equipment specified in **202. 1** (3) (D) of the Rules.

(1) Remote-controlled ballasting/deballasting arrangements
(A) Schematic diagrams for ballasting/deballasting piping systems(with arrangements of ballast tanks, valves, pumps and sea chests, and including the exclusive heel adjusting pipe lines)
(B) Arrangements of instruments on remote monitoring and alarm panels for ballasting/deballasting and remote control panels for pumps and valves
(C) Schematic diagrams of tank liquid level remote monitoring systems
(D) Schematic diagrams of valve operating and remote control systems for valves

(2) Automatic steering systems
The drawings for approval concerning the automatic steering systems are to include, at least, the following items:
(A) Constitution of systems for steering
(B) Block diagrams of alarms and indicators
(C) Arrangements of instruments on steering stand, alarm panels, etc.
(D) Explanatory notes on the functions of the systems

(3) Remote-controlled handling systems for liquid cargo in bulk
(A) Schematic diagrams of liquid cargo piping systems(with arrangements of cargo tanks, valves, and pumps, and tank capacities)
(B) Arrangement plans of equipment in the cargo-handling centralized cargo control room (station)
(C) Arrangements of instruments on remote monitoring and alarm panels, and remote control panels for pumps, valves, etc., installed in the cargo-handling centralized cargo control room (station)
(D) Schematic diagrams of tank liquid level remote monitoring systems
(E) Schematic diagrams of valve operating and remote control systems

(4) Power-driven opening/closing arrangements
(A) Arrangement plans of the systems, including their control positions
(B) Schematic diagrams of power source
(C) schematic diagrams of control source(only in case where separately provided from the power source)
(D) Detailed drawings for indicators or alarms, etc. to ensure the safety in opening/closing operations, if provided.

(5) Automatic recording devices for operating condition of main engine
(A) Service instructions for automatic recording devices of operating condition(with notations on constitution of systems, intervals of regular recordings, and details of recording functions including those for regular recording, alarm recording and arbitrary recording)

(6) Remote-controlled mooring arrangements
(A) Arrangement plans of mooring systems(with location of remote control stands and arrangements of mooring lines)
(B) Schematic diagrams of power source for mooring systems

(7) Air-conditioning arrangements for control stations
(A) Service instructions for air-conditioning arrangements for control stations
(B) Layout of the alarm panel
(C) Electrical diagrams of air-conditioning arrangements

(8) Remote-controlled fuel oil filling arrangements
  (A) Schematic diagrams of fuel oil filling piping system(with arrangements of tanks, valves, and pumps, and tank capacities)
  (B) Schematic diagrams of remote monitoring and alarm systems of the liquid level in tanks
  (C) Schematic diagrams of valve operating and remote control systems
  (D) Arrangement of instruments on remote monitoring and alarm panels and remote valve control panels
(9) Centralized monitoring devices for refrigerating containers
  (A) Arrangements of instruments on monitoring panels
  (B) Electrical diagrams of monitoring panels
  (C) Lists of monitoring and alarming items
(10) Cargo hose handling winches
  (A) General arrangements and layout drawings of cargo hose handling winches
  (B) Schematic diagrams of power source
  (C) Schematic diagrams of control source(only in case where separately provided from the power source)
(11) Automatic washing arrangements
  (A) General arrangements and layout drawings of washing arrangements
  (B) Schematic diagrams of washing water piping systems
  (C) Schematic diagrams of power source for washing arrangements and control systems
(12) Remote-controlled mooring arrangements at ship-sides
  (A) Layout of mooring arrangements(including layout of remote control stand and mooring rope)
  (B) Schematic diagrams of power source for mooring arrangements
(13) Power-operated pilot ladder winding appliances
  (A) General arrangements and Layout drawings of winding appliances
  (B) Schematic diagrams of power source
  (C) Schematic diagrams of control source(only in case where the control source is provided separately from the power source)
(14) Centralized monitoring systems for machinery
  (A) Arrangements of instruments on monitoring panels
  (B) Lists of monitoring and alarming items
(15) Centralized control systems for machinery
  (A) Arrangements of instruments on control panels
  (B) Lists of monitoring, alarm and control items
(16) Bridge wing control devices for main engine remote control and remote steering systems
  (A) General arrangements and layout drawings of bridge wing control devices for main engine remote control and remote steering systems
  (B) Schematic diagrams of power source
  (C) System diagram of control source(only in case of source independent of main power source)
(17) High level alarm for cargo hold bilge
  (A) Diagram and general arrangement of alarm system
  (B) Layout of the alarm panel
(18) Independent remote-controlled mooring arrangements
  (A) Layout of mooring arrangements(including layout of remote control stand and mooring rope)
  (B) Schematic diagrams of power source for mooring arrangements
  (C) Schematic diagrams of remote control systems for mooring arrangements
(19) Emergency towing rope winches
  (A) General arrangements and layout drawings of emergency towing rope winches
  (B) Schematic diagrams of power source
  (C) Schematic diagrams of control source(only in case where separately provided from the power source)

203. Shop tests

1. Type approval

(1) In application to **203. 1** of the Rules, "automatic equipments" to be type-approved are, in principle, as follows:
  (A) Alarm and monitoring systems
  (B) Control systems for, main engine, generators, boilers and essential auxiliary machinery, etc.
  (C) Computer-based systems
  (D) Fire detection systems
  (E) Gas detection systems
  (F) Electronic governor systems
  (G) Speed and shaft horsepower sensing equipment
  (H) Controller
  (I) Flow, level, limit, pressure, temperature switches
  (J) Oil mist detectors
  (K) UPS
  (L) Electrical and electronic indicators
  (M) Electric power converters for electric propulsion unit
  (N) Optical sensors and optical application device applied to the above (A) ~ (M)
  (O) Those considered necessary by the Society
(2) "Test methods approved by the Society" specified in **203. 1** of the Rules means the requirements specified in **Ch 3, Sec 23** of the Guidance for Approval of Manufacturing Process and Type Approval, Etc.

204. On-board tests

(1) The confirmations of the machinery and equipment's operation in case of failures of control systems as deemed necessary by the Society, in general, are to include followings:
  (A) In **204**. of the Rules, the confirmation that the rotational speed of propeller and direction of thrust are maintained as before failure, in case of failure of remote control devices for main propulsion machinery or controllable pitch propellers specified in **305. 2** of the Rules.
  (B) The confirmation that the boilers burning systems cease burning in case of failure of automatic and remote control system of boilers specified in **306.** of the Rules.
  (C) The confirmation that the burning systems cease burning in case of failure of automatic and remote control system of thermal oil installations specified in **308.** of the Rules.
(2) Following conditions, at least, are to be included as assumed failure conditions of control system
  (A) Power failure of control systems
  (B) Malfunction of computer for control use

206. Sea trials for the operating systems for periodically unattended machinery spaces

(1) As for the test procedures specified in **206. 2** of the Rules to test the main engine or controllable pitch propellers by bridge control devices, those shown in **Fig 9.3.1** (for diesel ships) or **Fig 9.3.2** (for steam turbine ships) of the Guidances are to be considered as the standard practice.
(2) In case of 2-engine 1-shaft propulsion systems, the following tests are to be carried out additionally.
  (A) While two engines are running at the maximum speed, one engine is to be stopped and the other engine is to be tested under the running condition and the other is to be equally tested.
  (B) While one engine is running at the maximum output, the other engine is to be put into parallel running.
  (C) While two engines are running at the maximum speed (at the 85 % output or more), one engine is to be declutched. Tests are to be carried out on each of the two engines.
(3) The test for controllable pitch propellers are to be applied with appropriate modification of the Guidances specified in above (2).
(4) Other tests considered necessary by the Society are to be carried out.
(5) In **206. 6** of the Rules, 4 hours of unattended machinery operation is to be regarded as the standard practice.

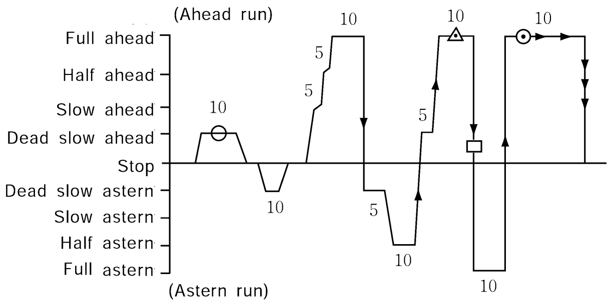


Fig 9.3.1 Trial Procedures for Diesel Ships

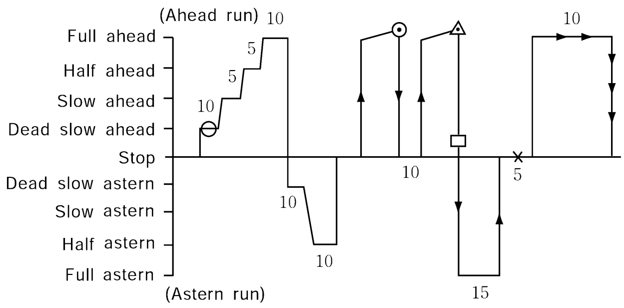


Fig 9.3.2 Trial Procedures for Steam Turbines Ships

[Remarks]

1. ⊖signifies putting over the rudder to hard port or bard starboard while proceeding at dead slow ahead.
2. ➤ signifies to operate as quick as practicable. However, where crash astern is performed and admitted by the Surveyor in a separate way(by shipyard's practice standard, etc), it (☐) may be dispensed.
3. ➤➤ signifies to cut off the power supply(electric, pneumatic or hydraulic) for the remote control systems and to confirm that the preset speed and direction of the propeller thrust for main propulsion machinery or controllable pitch propellers will be maintained and any abnormal condition will not take place, and the Society needs to confirm if the change-over from this condition to ECR is possible.
4. ➤➤➤ signifies to stop the main propulsion machinery by the emergency stop button.
5. ⊙signifies to raise the output of main propulsion machinery to that of the normal service condition.
6. △signifies to raise the ship's speed to that of the normal service condition.
7. ×signifies to stop the rotating of the main shaft.
8. Numerals signify running hours(in a unit of minute).

Section 3 Centralized Monitoring and Control Systems for Main Propulsion and Essential Auxiliary Machinery

302. System design

1. Computer-based systems

In application to **201. 7** (1) of the Rules, examples of computer-based systems are shown in **Pt 6, Ch 2, Table 6.2.1** of the Guidance. Where independent effective backup or other means of averting danger is provided, the system category Ⅲ may be downgraded to category Ⅱ.

303. Prevention of flooding and fire safety measures

2. Fire Safety Measures

(1) For the prevention of fires, the requirements specified below are to be complied with, in addition to those specified in **303. 2** of the Rules.
  (A) Joints for Class I piping used in fuel oil pipelines and lubricating oil pipe lines are to be of welded joints as far as practicable.
  (B) Flexible pipes used in fuel oil pipelines and lubricating oil pipe lines are to be of the approved type and to be protected by adequate means, considering their use, pressure and arrangement.
  (C) In case where either electric or steam heater is installed in fuel oil systems or lubricating oil systems, at least high temperature alarm or low flow alarm is to be provided in addition to the temperature controller, except when the maximum temperature of the heated oil can not be reached to the flash point.

305. Automatic and remote control of main engines or controllable pitch propellers

1. General

In case where the local control handle fitted to main propulsion machinery is moved to the main control station, the requirements in **305.** of the Rules may not apply except the case that the main control station is provided outside the space where main propulsion machinery is installed.

2. Remote control devices for main engines or controllable pitch propellers

(1) For the remote control system of main propulsion steam turbine, menas for automatic opening of astern intermediate valves at the operation into astern manoeuvring are to be provided.
(2) Effective countermeasures are to be provided against a failure of remote control system such that loss of power supply(electric, pneumatic or hydraulic power).
(3) Main engine starting by remote control system for main propulsion machinery and starting air low pressure alarm are in accordance with the followings:
  (A) In case where the low pressure alarm activate after satisfying the number of starting specified in **Pt 5, Ch 6, 1001. 1** of the Rules, startings after this are be controlled at the main control station.
  (B) In case where the low pressure alarm activate before satisfying the number of starting specified in **Pt 5, Ch 6, 1001. 1** of the Rules, the next startings is to be capable at the remote control station and the number of starting is to be satisfied in the requirements.

3. Bridge Control Devices

It is recommended that the operating handle (or button) of the bridge control devices is linked with the engine room telegraph.

4. Safety Measures

(1) For the remote control devices for the main propulsion machinery, inter-locking devices are to be provided so as not to allow main propulsion machinery to start on the following conditions:
  (A) When the turning gear is engaged.
  (B) When the lubricating oil pressure is low.

Section 5 Automatic Equipment

502. Class 1 automation equipment

1. In application to **502.** of the Rules, the wording "equipment considered acceptably by the Society may be omitted in consideration of the purpose of the ship, the method of cargo handling and so on" means those shown below :

(1) Items which may be omitted according to the purpose of the ship

(A) In case of oil tankers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk; Power-operated opening/closing appliances specified in **502. 4** of the Rules

(B) In case of ships other than above (A); Remote-controlled handling systems for liquid cargo in bulk specified in **502. 3** of the Rules

(2) Items which may be omitted according to the method of cargo handling

In case of ships where no ballasting/deballasting is necessary during cargo handling (Roll-on/Roll-off ships, etc.);

Remote-controlled ballasting/deballasting arrangements specified in **502. 1** of the Rules

(3) Other items which may be omitted based on the acceptance of the Society

In case less than 3 mooring ropes are required in each of fore and aft of the vessel according to the equipment number in **Pt 4, Ch 8, table 4.8.1** of the Rules, the remote-controlled mooring arrangements may control only that number of ropes, if it can be operated without failure.

2. Remote-controlled Ballasting/Deballasting Arrangements

The wording "control devices necessary for ballasting/deballasting" specified in **502. 1** (1) (B) of the Rules means the control valves fitted on the piping system to enable the ballasting/deballasting.

3. Remote-controlled Handling System for Liquid Cargo in Bulk

The wording "control devices necessary for cargo loading and unloading of cargos" specified in **502. 3** (3) (B) of the Rules means the control valves fitted on the piping system to enable the cargo loading and unloading.

4. Power-driven operated opening/closing appliances

In application to **502. 4** of the Rules, power operated opening/closing appliances are in accordance with the followings:

(1) An indicator showing opening/closing condition is to be provided at the operating position, in case where no visual verification is available.

(2) An audible alarm or a yellow rotating warning light is to be provided to ensure the safety at the time of opening/closing operation, in case where no visual verification is available at the operating position.

5. Automatic recording devices for main engine In application to **502. 5** of the Rules, automatic recording devices are in accordance with the followings:

(1) The automatic recording devices are to have a function of taking records once four hours (corresponding to one watch).

(2) The running conditions of main propulsion machinery are to include, at least, the following items:

(A) Lubricating oil pressure at main bearing inlet
(B) Cooling water temperature at each cylinder outlet.
(C) Steam pressure of main boiler
(D) Exhaust gas temperature at each cylinder outlet
(E) Revolutions per minute of main propulsion machinery or propeller shaft

6. Remote-controlled mooring arrangements

The wording "to be capable of effectively controlling" specified in **502. 6** (1) of the Rules means that speed controls (including starting/stopping controls) in both paying out and heaving in the mooring line are available.

503. Class 2 automation equipment

1. In application to **503.** of the Rules, the wording equipment considered acceptable by the Society may be omitted in consideration of the purpose of the ship, the method of cargo handling, etc. means those as shown below:

(1) Items which may be omitted according to the purpose of the ship

(A) Oil tankers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk;

(a) Power-driven opening/closing appliances specified in **502. 4** of the Rules

(b) Centralized monitoring devices for refrigerating containers specified in **503. 2** of the Rules

(B) Container carriers;

(a) Remote-controlled handling systems for liquid cargo in bulk specified in **502. 3** of the Rules

(b) Emergency towing rope winches specified in **503. 7** of the Rules

(c) Cargo hose handling winches specified in **503. 3** of the Rules

(C) Ships other than (A) and (B) above;

(a) Those specified in (B) above

(b) Centralized monitoring devices for refrigerating containers specified in **503. 2** of the Rules

(2) Items which may be omitted according to the method of cargo handling

Ships where no ballasting/deballasting is necessary during cargo handling;

Remote-controlled ballasting/deballasting arrangements specified in **502. 1** of the Rules

(3) Other items which may be omitted based on the acceptance of the Society

In case less than 3 mooring ropes are required in each of fore and aft of the vessel according to the equipment number in **Pt 4, Ch 8, table 4.8.1** of the Rules, the remote-controlled mooring arrangements at ship-side may control only that number of ropes, if it can be operated without failure.

2. Remote-controlled fuel oil filling arrangements

In application to **503. 1** of the Rules, the wording "cases considered acceptable by the Society in consideration of layout of tanks and valve, etc. for fuel oil filling arrangement" means that all valves required operating for fuel oil filling are located in one place and that maximum 4 fuel oil storage tanks are provided.

3. Cargo hose handling winches

In application to **503. 3** of the Rules, the wording "winch is to be easily operated" means those operable by one person.

4. Automatic deck washing arrangements

In application to **503. 4** (2) of the Rules, the wording "to have enough strength against its working pressure" means to be tested by 1.5 times the design pressure for hydraulic test.

504. Class 3 automation equipment

1. In application to **504.** of the Rules, "equipment considered acceptably by the Society may be omitted in consideration of the purpose of the ship, the method of cargo handling, and so on" means those specified below:

(1) Items which may be omitted according to the purpose of the ship

(A) Oil tankers, ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk;

(a) Power-driven opening/closing device specified in **502. 4** of the Rules

(b) Centralized monitoring devices for refrigerating containers specified in **503. 2** of the Rules

(c) Automatic deck washing arrangements specified in **503. 4** of the Rules

(B) Container carriers;

(a) Remote-controlled handling systems for liquid cargo in bulk specified in **502. 3** of the Rules

(b) Emergency towing rope winches specified in **503. 7** of the Rules

(c) Cargo hose handling winches specified in **503. 3** of the Rules
(d) Automatic deck washing arrangements specified in **503. 4** of the Rules

(C) In case of ore carriers or coal carriers in bulk;
(a) Remote-controlled handling systems for liquid cargo in bulk specified in **502. 3** of the Rules
(b) Centralized monitoring devices for refrigerating containers specified in **503. 2** of the Rules
(c) Emergency towing rope winches specified in **503. 7** of the Rules
(d) Cargo hose handling winches specified in **503. 3** of the Rules

(D) Ship other than (A) to (C) above;
(a) Those specified in (C) above
(b) Automatic deck washing arrangements specified in **503. 4** of the Rules

(2) Items which may be omitted according to the method of cargo handling
Ships where no ballasting/deballasting is necessary during cargo handling;
Remote-controlled ballasting/deballasting arrangements specified in **502. 1** of the Rules

(3) Other items which may be omitted based on the acceptance of the Society
In case less than 3 mooring ropes are required in each of fore and aft of the vessel according to the equipment number in **Pt 4, Ch 8, table 4.8.1** of the Rules, the remote-controlled mooring arrangements at ship-side may control only that number of ropes, if it can be operated without failure.

2. Centralized monitoring systems for machinery The centralized monitoring systems for machinery specified in **504. 1** of the Rules is to have the following functions. However, for those provided on the navigation bridge by other requirements of the Rules, these functions may be dispensed with.

(1) Monitoring of alarms for the abnormal conditions on the items given in **Table 9.3.1** through **Table 9.3.5** of the Guidance.
(2) Indications of the items given in **Table 9.3.1** through **Table 9.3.5** of the Guidance. But when two or more items to be indicated are delivered from a same pump or heat exchanger, indication for only one item may be accepted.

Table 9.3.1 Indications and Alarm Items for Diesel Engine

Item		For main propulsion machinery	For generator engine
Temperature	Cylinder cooling water	Each cylinder outlet	-
	Piston cooling water (oil)	Each cylinder outlet	-
	Lubricating oil (main)	Inlet	-
	Fuel oil	Inlet	-
	Exhaust gas	Each cylinder outlet	Each inlet of turbocharger or each cylinder outlet
	Scavenging air	Air cooler outlet	-
Pressure	Cylinder cooling water	Inlet	-
	Piston cooling water (oil)	Inlet	-
	Fuel oil valve cooling water (oil)	Inlet	-
	Lubricating oil (main)	Inlet	-
	Fuel oil	Inlet	-
	Cooling seawater	Pump outlet	-

Table 9.3.2 Indications and Alarm Items for Steam Turbine

Item		For main Propulsion machinery	For generator engine
Temperature	Lubricating oil	Inlet and each bearing outlet	-
Pressure	Lubricating oil	Inlet	-
	Exhaust steam	Condenser	-

Table 9.3.3 Indications and Alarm Items for Shafting

Item		For main Propulsion machinery	For generator engine
Temperature	Reduction gear lubricating oil	Inlet	−
Pressure	Reduction gear lubricating oil	Inlet	−

Table 9.3.4 Indications and Alarm Items for Boiler and Thermal Oil Installations

Item		Main boiler	Essential auxiliary boiler	Thermal oil installations
Temperature	Fuel oil Exhaust gas Superheated steam, thermal oil	Inlet Outlet Outlet	- - -	- - Outlet
Pressure	Fuel oil Steam	Inlet Outlet	- Outlet	- -

Table 9.3.5 Indications and Alarm Items for Other Machinery

Item	Points of indication
Items deemed necessary by the Society according to the construction and purpose of the machinery installations concerned.	Points required by the Society

3. Centralized control systems for machinery

(1) "to be capable of effectively controlling" specified in **504. 2** of the Rules means to be capable of controlling as follows.
  (A) For control of main propulsion diesel engines
    (a) Starting/stopping of the auxiliary blowers (However, in case where the auxiliary blowers are provided with automatic starting/stopping system, they may be omitted)
    (b) Starting/stopping of the fuel oil supply pumps
    (c) Starting/stopping fuel oil booster pumps
    (d) Starting/stopping of the main lubricating oil pump
    (e) Starting/stopping of the crosshead lubricating oil pumps
    (f) Starting/stopping of the piston cooling water (oil) pumps
    (g) Starting/stopping of the cylinder cooling water pumps
    (h) Starting/stopping of the cooling sea water pumps
  (B) For control of main propulsion steam turbine
    (a) Main boiler control (But, except starting at the cold condition of the main boiler)
      (i) Starting/stopping of the feed water pumps
      (ii) Starting/stopping of the fuel oil pumps
      (iii) Starting/stopping of the blowers
      (iv) Oil burning assembly control
    (b) Pump control for steam turbine
      (i) Starting/stopping of the lubricating oil pumps
      (ii) Starting/stopping of the cooling water pumps
      (iii) Starting/stopping of the control hydraulic oil pumps
    (c) Starting/stopping of the soot blower for economizer
  (C) For control of diesel engines driving generators
    (a) Starting/stopping of the diesel engines
    (b) Control of the fuel oil change-over devices
    (c) Starting/stopping of the cooling sea water pumps
    (d) Selection of the automatic starting engine in **503. 3** (1) (B) of the Rules
  (D) For control of steam turbines driving generators
    (a) Starting/stopping of the water circulating pumps

(b) Change-over of the steam supply between exhaust gas economizers and boilers in case where the steam turbine generators are usually driven by the steam from exhaust gas economizers and are used at anchoring.

(E) For control of essential auxiliary boilers

(a) Starting/stopping of the soot blowers for exhaust gas economizers in case where the steam turbine generators are driven by the steam from exhaust gas economizers

(b) Starting/stopping of the boiler water circulating pumps

(F) For control of other machinery which are necessary

(a) Operating of automatic synchronous making devices and automatic load sharing devices

(b) Operating of automatic load shifting devices and load tripping devices

4. Independent remote-controlled mooring arrangements

In application to **504. 5** of the Rules, independent remote-controlled mooring arrangements are in accordance with the followings:

(1) "To be capable of controlling each drum of mooring winches independently" of the Rules means those of an arrangement having one winch to which an exclusive drum is belonging or an arrangement capable of remote-controlling the clutches and brakes.

(2) In case where minimum 5 drums are provided at the bow or stern of a ship, it may be acceptable to control 5 drums independently at the bow or stern. ⚓

CHAPTER 4 DYNAMIC POSITIONING SYSTEMS

Section 2 Requirements of Dynamic Positioning Systems

203. Additional requirements for dynamic positioning systems

DPS(2)

(1) In application to **203. 2** (3) of the Rules, essential services are those defined in **Pt 6, Ch 1. 101. 4** (12) of the Rules together with thruster auxiliaries, computers, generator and thruster control equipment, position reference systems, environmental sensors and electrically driven thrusters.

(2) In application to **203. 2** (6) (F) of the Rules, when considering single failures of switchboards, the possibility of short-circuit of the bus-bars has to be considered. ⚓

CHAPTER 5 NAVIGATION BRIDGE SYSTEMS

Section 5 Accident Prevention Systems

502. Accident Prevention Systems

In application to **502. 2** (E) of the Rules, bridge navigational watch alarm system(BNWAS) is to comply with the following requirements.

(1) At the end of this setting period, the alarm system should initiate a visual indication on the bridge.

(2) If not reset, the BNWAS should additionally sound a first stage audible alarm on the bridge 15 seconds after the visual indication is initiated.

(3) If not reset, the BNWAS should additionally sound a second stage remote audible alarm in the back-up officer's and/or master's location 15 seconds after the first stage audible alarm is initiated.

(4) If not reset, the BNWAS should additionally sound a third stage remote audible alarm at the locations of further crew members capable of taking corrective actions 90 seconds after the second stage remote audible alarm is initiated.

(5) In vessels other than passenger vessels, the second or third stage remote audible alarms may sound in all the above locations at the same time. If the second stage audible alarm is sounded in this way, the third stage alarm may be omitted.

(6) In larger vessels, the delay between the second and third stage alarms may be set to a longer value on installation, up to a maximum of 3 minutes, to allow sufficient time for the back-up officer and/or master to reach the bridge. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 9 ADDITIONAL INSTALLATIONS

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2011

Rules for the Classification of Steel Ships

Part 10 Hull Structure and Equipment of Small Steel Ships

Rules

2011

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Part 10

Hull Structure and Equipment of Small Steel Ships

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KOREAN REGISTER OF SHIPPING

APPLICATION OF PART 10
"HULL STRUCTURE AND EQUIPMENT OF SMALL STEEL SHIPS"

1. Unless expressly specified otherwise, the requirements in these Rules apply to ships for which contracts for construction are signed on or after 1 July 2011.

2. The amendments to the Rules for 2010 edition and their effective date are as follows;

Effective Date 1 July 2011

CHAPTER 1 GENERAL

Section 2 General
- 202. has been amended.

Section 3 Materials, Welding and Construction
- 308. has been amended.

CHAPTER 6 SINGLE BOTTOMS

Section 1 General
- 101. has been amended.

CHAPTER 14 WATERTIGHT BULKHEADS

Section 1 Arrangement
- 101. 1. has been amended.

Section 3 Watertight Doors
- 301. 2. has been amended.
- 302. 2. has been amended.
- 304. 3. has been deleted.

CONTENTS

CHAPTER 1 GENERAL

Section 1 Definitions

101. Application

The definitions of term which appear in this rule are to be as specified in this section, unless otherwise specified elsewhere, and the definitions of terms not specified in this rule are to be as specified **Part 3** and **4.**

102. Length

The length of ship (L) is the distance in *metres* on the load line defined in **108.** from the fore side of stem to the after side of rudder post in case of a ship with rudder post, or to the axis of rudder stock in case of a ship without rudder post. However, L is not to be less than 96 % and need not be greater than 97 % of the extreme length on the load line.

103. Length for freeboard

The length of ship for freeboard (L_f) is 96 % of the length in *metres* measured from the fore side of stem to the aft side of aft end shell plate on a waterline at 85 % of the least moulded depth measured from the top of keel, or the length in metres measured from the fore side of stem to the axis of rudder stock on that waterlines, whichever is the greater. However, where the stem contour is concave above the waterline at 85 % of the least moulded depth, the forward terminal of this length is to be taken at the vertical projection to this waterline of the after most point of the stem contour. The waterline on which this length is measured is to be parallel to the load line defined in **108.**

104. Breadth

The breadth of ship (B) is the horizontal distance in *metres* from the outside of frame to the outside of frame measured at the broadest part of the hull.

105. Depth

The depth of ship (D) is the vertical distance in *metres* at the middle of L measured from the top of keel to the top of the freeboard deck beam at side. Where watertight bulkheads extend to a deck above the freeboard deck and are to be registered as effective to that deck, D is the vertical distance to that bulkhead deck.

106. Midship

The midship part of ship is the part for 0.4 L amidships unless otherwise specified.

107. Fore and aft end

The fore and aft end means the part covering 0.1 L from the fore and aft end of the ship.

108. Load line

The load line is the waterline corresponding to the designed summer load draught in case of a ship which is required to be marked with load lines and the waterline corresponding to the designed maximum draught in case of a ship which is not required to be marked with load lines.

109. Load draught

The load draught (d) is the vertical distance in *metres* from the top of keel to the load line measured at the middle of L_f in case of a ship which is required to be marked with load lines and at the middle of L in case of a ship which is not required to be marked with load lines.

110. Full load displacement

The full load displacement (Δ) is the displacement (including shell platings and appendages, etc.) in tons corresponding to the summer load line.

111. Block coefficient

Block coefficient (C_b) is the coefficient given by dividing the volume of moulded displacement by LBd.

112. Strength deck

The strength deck at a part of ship's length is the uppermost deck at that part to which the shell plates extend. However, in way of superstructures, except sunken superstructures, not exceeding 0.15 L in length, the strength deck is the deck just below the superstructure deck. The deck just below the superstructure deck may be taken as the strength deck even in way of the superstructure exceeding 0.15 L in length at the option of the designer.

113. Freeboard deck

1. The freeboard deck is normally the uppermost continuous deck. However, in cases where openings without permanent closing means exist on the exposed part of the uppermost continuous deck or where openings without permanent watertight closing means exist on the side of the ship below that deck, the freeboard deck is the continuous deck below that deck.

2. In a ship having a discontinuous freeboard deck, the lowest line of the exposed deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck.

3. Where the designed load draught is less than the draught determined assuming the existing deck below the freeboard deck as the freeboard deck in accordance with the provision in **Pt 1, Ch 1, 1202.** The existing lower deck is taken as the freeboard deck in the application of this rule. In this case, the lower deck is to be continuous at least between the machinery space and peak bulkheads and continuous athwartships. Where a lower deck in stepped, the lowest line of the deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck.

114. Fore end and after end

Fore end is the start point of forward side, where measuring the length of ship L in **102.,** and after end is the end point of afterward side of L.

Section 2 General

201. Application

1. The requirements in this Part, unless otherwise specified elsewhere, are framed for ships of normal form and proportions of less than 90 m in length to be classed for unrestricted service. The requirements not specified in this Part are generally to comply with those in **Pt 3** and **4.**

2. Hull construction, equipment and scantlings of ships to be classed for restricted service may be appropriately modified according to the condition of service.

3. In the application of relevant provisions in this rule to ships which are not required to be marked with load line, L_f is to be read as L and B_f as B.

202. Exception in application

In ships of which length is less than 24 m or in ships to which requirements in this rule for some special reason are not directly applicable, hull construction, equipment, arrangement and scantlings are to be at the discretion of the Society, notwithstanding the provisions in **201.**

203. Ships of unusual form or proportion, or intended for carriage of special cargoes

In ships of unusual form or proportion, or intended for carriage of special cargoes, the requirements concerning hull construction, equipment, arrangement and scantlings will be decided individually basing upon the general principle of this rule, notwithstanding the requirements in this rule.

204. Equivalency

Alternative hull construction, equipment, arrangement and scantlings will be accepted by the Society, provided that the Society is satisfied that such construction, equipment, arrangement and scantlings are equivalent to those required in this rule.

205. Passenger ships

Hull construction, equipment, arrangement and scantlings of passenger ships are to be specially considered with respect to the design features in addition to the requirements in **201.** to **203.**

206. Stability of ship

The requirements in this rule are framed for ships having appropriate stability in all conceivable conditions. The Society emphasizes that the special attention be paid to the stability by the builders in design and construction stage and by the masters while in service.

207. Carriage of oil or other flammable liquid substances

1. The requirements for construction and arrangement for carriage of fuel oils specified in this rule are to be applied to the case intended to carry fuel oils having a flashpoint of 60°C or above at a closed cup test.

2. The construction and arrangement for carriage of fuel oils having a flashpoint 60°C or below at a closed cup test, are to be in accordance with the requirements provided in Part, and to comply with the requirements in **Pt 8, Ch 1, Sec 4** in addition.

3. The construction and arrangement of deep oil tanks intended to carry cargo oils are to be correspondingly in accordance with the requirements in **Ch 23** and **24.**

208. Equipments

Masts, riggings, cargo handling gears, anchoring and mooring arrangements, and other than those specified in this rule are to be suitably arranged according to their uses and are to satisfy the tests as may be required by the Surveyor.

209. Fittings for examination

In ships registered in Korea, ladders, steps or other facilities, by which internal examination can be performed safely, are to be provided in fore and after peak tanks, deep tanks, cofferdams and enclosed compartments which are similar to the above-mentioned tanks, except those exclusively used for fuel oil or lubricating oil.

Section 3 Materials, Welding and Construction

301. Materials

1. The materials used for hull construction and equipments are to be those complying with the requirements in **Pt 2, Ch 1,** unless otherwise specified.

2. Where high tensile steels are used, the construction and scantlings are to be in accordance with the discretion of the Society, unless otherwise specified.

3. Where materials other than those specified in this rule are used, the use of such materials and corresponding scantlings are to be specially approved by the Society.

4. Materials used for the hull construction of ships classed for smooth water service are to be in accordance with the discretion of the Society.

5. Application of steels

(1) The steels used for hull structures are to be of the grades provided in **Pt 2, Ch 1** in accordance with the requirements given in **Tables 10.1.1** and **10.1.3.** In applying these requirements, *B*, *D* or *E* may be substituted for *A*; *D* or *E* for *B*; *E* for *D*; *DH* 32 or *EH* 32 for *AH* 32; *EH* 32 for *DH* 32; *DH* 36 or *EH* 36 for *AH* 36; and *EH* 36 for *DH* 36; *DH* 40 or *EH* 40 for *AH* 40; and *EH* 40 for *DH* 40, respectively.

(2) For strength members not mentioned in **Table 10.1.1,** grades *A*, *AH* 32, *AH* 36 and *AH* 40 may generally be used. The steel grade is to correspond to the as-built plate thickness when this is greater than the Rule requirement.

(3) The grades of steel to be used in the hull construction are to be clearly indicated on the hull structural plans.

Table 10.1.1 Material classes

Structural member category	Material classes
○ SECONDARY : A1 Longitudinal bulkhead strakes, other than those belonging to the Primary category A2 Deck plating exposed to weather, other than that belonging to the Primary or Special category A3 Side plating	- Within 0.4 L amidships : I - Outside 0.4 L amidships : *A/AH*
○ PRIMARY : B1 Bottom plating including keel plate B2 Strength deck plating, excluding that belonging to the Special category B3 Continuous longitudinal members above strength deck, ex cluding longitudinal hatch coamings B4 Uppermost strake in longitudinal bulkhead B5 Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank B6 Longitudinal hatch coamings of length greater than 0.15L	- Within 0.4 L amidships : II - Outside 0.4 L amidships : *A/AH*
○ SPECIAL : C1 Sheer strake at strength deck(1) C2 Stringer plate in strength deck(1) C3 Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships(1)	- Within 0.4 L amidships : III - Outside 0.4 L amidships : II - Outside 0.6 L amidships : I
C4 Strength deck plating at outboard corners of cargo hatch openings (bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations)	- Within 0.6 L amidships : III - Outside 0.6 L amidships : II
C5 Bilge strake in ships with double bottom over the full breadth and length less than 150 m(1)	- Within 0.6 L amidships : II - Outside 0.6 L amidships : I
C6 Bilge strake in other ships(1)	- Within 0.4 L amidships : III - Outside 0.4 L amidships : II - Outside 0.6 L amidships : I

Notes:
(1) Single strakes required to be class III within 0.4 L amidships are to have breadths not less than $800+5L$ (mm), need not be greater than 1800 mm, unless limited by the geometry of the ship's design.
(2) The symbols in the table mean the grades of steel as follows :
AH : *AH* 32, *AH* 36 and *AH* 40
DH : *DH* 32, *DH* 36 and *DH* 40
EH : *EH* 32, *EH* 36 and *EH* 40

Table 10.1.2 Minimum Material Grades for ships with ice strengthening

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	*B/AH*

Table 10.1.3 Steel grades

Thickness(mm) \ Class	I		II		III	
	MS	*HT*	*MS*	*HT*	*MS*	*HT*
$t \le 15$ $15 < t \le 20$	*A* *A*	*AH* *AH*	*A* *A*	*AH* *AH*	*A* *B*	*AH* *AH*
$20 < t \le 25$ $25 < t \le 30$	*A* *A*	*AH* *AH*	*B* *D*	*AH* *DH*	*D* *D*	*DH* *DH*
$30 < t \le 35$ $35 < t \le 40$	*B* *B*	*AH* *AH*	*D* *D*	*DH* *DH*	*E* *E*	*EH* *EH*
$40 < t \le 50$	*D*	*DH*	*E*	*EH*	*E*	*EH*

Note:
The symbols in the table mean the grades of steel as follows:
AH : *AH* 32, *AH* 36 and *AH* 40
DH : *DH* 32, *DH* 36 and *DH* 40
EH : *EH* 32, *EH* 36 and *EH* 40
MS : Mild steels
HT : High tensile steels

302. Scantlings

1. Unless otherwise specially specified, the section modulus of members required by this rule are those including the steel plates with the effective breadth of 0.1 l on either side of the members. However, the breadth of 0.1 l is not to exceed one-half of the spacing of member. l is the length specified in the relevant chapter.

2. Where flat bars, bulb plates, inverted angles or flanged plates are welded to form beams, frames or stiffeners for which section moduli are specified, they are to be of suitable depth and thickness in proportion to the section modulus specified in this Part.

3. The inside radius of flanged plates is not to be less thant twice but not more than three times the thickness of steel plates.

4. As for the face plates composing girders and transverses, the thickness is not to be less than that of web plates and the full width is not to be less than that obtained from the following formula:

$$b = 2.7\sqrt{d_0 l} \text{ (mm)}$$

where:

d_0 = depth of girders and transverses specified in the relevant chapter (mm).

l = distance between supports of girders and transverses specified in the relevant chapter (m). Where, however, effective tripping brackets are provided, they may be taken as supports.

303. Welding

Welding to be used in hull construction and important equipment is to be in accordance with the requirements in **Pt 2, Ch 2.**

304. Connection of ends of stiffeners, girders and frames

1. Where the ends of girders are connected to the bulkheads, tank tops, etc., the end connections of all girders are to be balanced by effective supporting members on the opposite sides of bulkheads, tank tops, etc.

2. Length of the frame-side arm of bracket, connected to the frames or stiffeners of the bulkhead or deep tanks, etc., is not to be less than one-eighth of l specified in the relevant chapter, unless otherwise specially specified.

305. Brackets

1. Secondary members, such as longitudinals, beams, frames and stiffeners forming part of the hull structure, are generally to be connected at their ends with t_b not to be less than that obtained from the following formula. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

$$t_b = C_1\sqrt{Z} + 4.5 \quad \text{(mm)}$$

where :

Z = section modulus (cm^3) specified in the following (a) through (c) :

(a) Bracket connecting stiffener to primary member, section modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates, section modulus of the frame.
(c) Elsewhere the lesser section modulus of the members being connected by the bracket.

C_1 = coefficient given in followings.

C_1 = 0.27, where a flange is not fitted.

C_1 = 0.23, where a flange is fitted.

2. Where a flange is fitted, its breadth w_f is not to be less than that obtained from following formula. Where the length of larger arm exceeds 800 mm, the free edges of brackets are to be stiffened by flange or other means, except where tripping brackets or the like are provided.

$$w_f = \frac{Z}{33} + 45 \quad \text{(mm)}$$

where :

Z = as specified in **Par 1.**

3. The lengths of bracket arms measured from shown in **Fig 10.1.1** are not to be less than those obtained from the following formulae. The lengths of bracket arms of tank side and hopper side are to be increased by 20 % greater than those required.

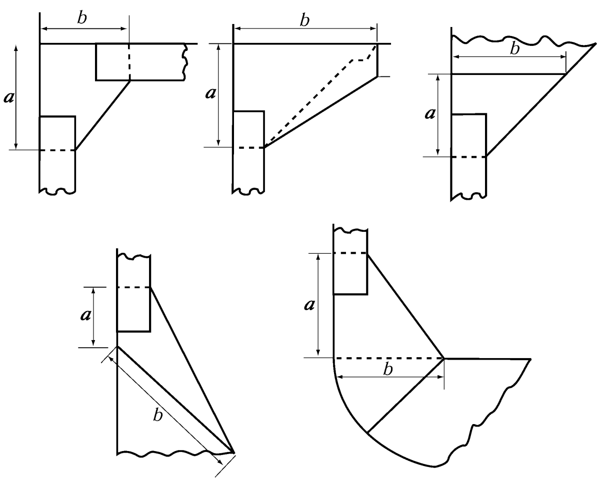


Fig 10.1.1 Measurement of a and b for arms

$a+b \geq 2.0\,l$ $\quad$ a and $b \geq 0.8\,l$

where :

l = as given by the following formula, but in no case is to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

$$l = 180\sqrt{\frac{Z}{14+\sqrt{Z}}} - 90 \ \ \text{(mm)}$$

where : Z = as specified in **Par 1.**

306. Modification of l

Where brackets of not less thickness than that of the girder plates, the value of l specified in **Ch 9, 11, 12, 14** and **15** may be modified in accordance with the following:

(1) Where the face area of the bracket is not less than one-half of that of the girder and the face plates or flange on the girder is carried to the bulkhead, deck, tank top, etc., the length l may be measured to a point 0.15 m inside the toe of bracket. (See **Fig 10.1.2** (a))

(2) Where the face sectional area of the bracket is less than one-half of that of the girder and the face plate or flange on the girder is carried to the bulkhead, deck, tank top, etc., l may be measured to a point where the sum of sectional area of the bracket outside the line of girder and its free flanges is equal to the sectional area of free flanges of girder, or to a point 0.15 m inside the toe of bracket, whichever is the greater. (See **Fig 10.1.2** (b))

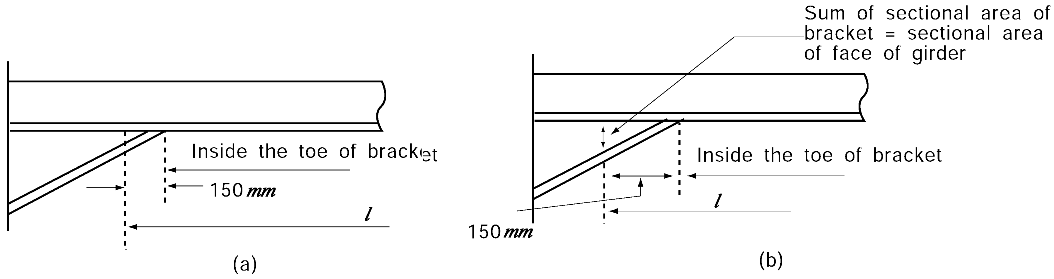


Fig 10.1.2 Modification of l

(3) Where brackets are provided and the face plate or flange on the girder are extended along the brackets to the bulkhead, deck, tank top, etc., the face plate or flange of bracket may be curved, but l is to be measured to the toe of bracket.
(4) Brackets are not to be considered effective beyond the point where the arm on the girder is 1.5 times the length of arm on the bulkhead, deck, tank top, etc.
(5) In no case is the allowance in l at either end to exceed one-quarter of the overall length of the girder.

307. Approved corrosion control

1. Where an approved measure of corrosion control is applied to tanks, the required scantlings of structural members in the tanks may be reduced at the discretion of the Society.

2. For the ships of the scantlings reduced in accordance with **Par 1,** the notation "*CoC*" will be entered in the Register of Ships.

308. Corrosion protection coating

1. For ships not intended to receive a corrosion control notation specified in **307.,** all sea water ballast spaces having boundaries formed by the hull envelop are to have an effective corrosion protection coating in accordance with the manufacturer's requirements.

2. Corrosion protection coating for dedicated sea water ballast tanks in all types of Ships and double-side skin space of bulk carriers are to be in accordance with the requirements in the **Guidance Pt 3, Ch 1, 803.** ⚓

CHAPTER 2 STEMS AND STERN FRAMES

Section 1 Stems

101. Plate stems

1. The thickness of steel plate stems at the load waterline is not to be less than that obtained from the following formula. However, above and below the load waterline, the thickness may be gradually tapered toward the stem head and the keel. And at the upper end of stem, it may be equal to the thickness of the side shell plating (at the fore end part) of the ship, and at the lower end of stem, it may be equal to the thickness of plate keel.

$t = 0.1L + 3.0$ (mm)

2. Horizontal ribs are to be provided on the stem plates at an interval preferably not exceeding 1 m, and where the radius of curvature at the fore end of stem is large, proper reinforcement is to be made by providing with a centre line stiffener or by other means.

Section 2 Stern Frames

201. Application

The requirements in this section apply only to stern frames without rudder post.

202. Propeller posts

1. Propeller posts of cast steel stern frames and those of plate stern frames are to be of shape suitable for the stream line at the after part of hull, and the scantlings are to be equivalent to the standards given by the formulae and figures in **Table 10.2.1.** Below the propeller boss, the breadth and thickness of propeller post are to be gradually increased in order to provide with strength and stiffness in proportion to those of the shoe pieces.

2. The thickness of boss of propeller post is not to be less than that obtained from the following formula:

$t = 0.23d_p + 30$ (mm)

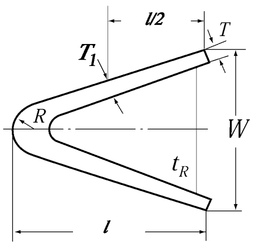
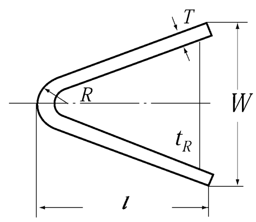
where :

d_p = diameter (mm) of propeller shaft specified in **Pt 5, Ch 3, 204.**

3. The propeller posts of cast steel stern frames and those of plate stern frames are to be provided with ribs at a suitable interval. Where the radius of curvature is large, a centre line stiffener is to be provided.

4. In ships with relatively high speed for their length and in ships exclusively engaging in towing purposes, the scantlings of various parts of propeller posts are to be suitably increased.

Table 10.2.1 Standards of propeller posts

Cast steel	Steel plate
$W = 30\sqrt{L}$ $l = 40\sqrt{L}$ (mm) $T = \frac{3\sqrt{L}}{\sqrt{K^{(1)}}}$ (mm) $T_1 = \frac{3.7\sqrt{L}}{\sqrt{K^{(1)}}}$ (mm) $t_R = 0.6T$ (mm) $R_{min} = 40$ (mm)	$W = 37\sqrt{L}$ $l = 53\sqrt{L}$ (mm) $T = \frac{2.4\sqrt{L}}{\sqrt{K^{(2)}}}$ (mm) $t_R = 0.55T$ (mm) $R_{min} = 40$ (mm)
	

Note :
(1) Material factor K for the Propeller post of cast steel is to be as **Pt 4, Ch 1, Table 4.1.1.**
(2) Material factor K for the Propeller post of steel plate is to be as **Pt 4, Ch 1, Table 4.1.2.**

203. Shoe pieces

1. The scantlings of each cross-section of the shoe piece is to be determined by the following formulae (1) to (4), considering the bending moment and shear force acting on the shoe piece when the rudder force specified in **Pt 4, Ch 1, 201.** is applied to the rudder.

(1) The section modulus Z_Z around the vertical Z-axis is not to be less than obtained from the following formula:

$$Z_z = \frac{MK_{sp}}{80} \quad (\text{cm}^3)$$

where:

M = bending moment at the section considered, which is obtained from the following formula (N・m).

$$M = Bx \quad (\text{N}\cdot\text{m})$$
$$M_{max} = Bl \quad (\text{N}\cdot\text{m})$$

where :

B = supporting force in the pintle bearing (N), as given in **Pt 4, Ch 1, 102.**

x = distance from the mid-point of the pintle bearing to the section considered (m). (See **Fig. 10.2.1**).

l = distance from the mid-point of the pintle bearing to the fixed point of the shoe piece (m). (See **Fig 10.2.1**)

K_{sp} = material factor for the shoe piece as given in **Pt 4, Ch 1, 102.**

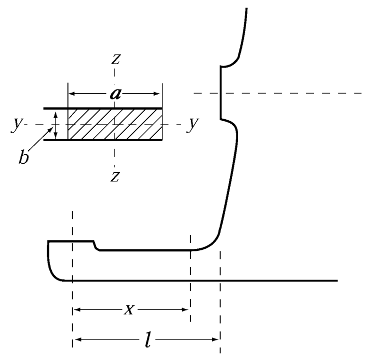


Fig 10.2.1 Shoe piece

(2) The section modulus Z_y around the transverse Y-axis is not to be less than obtained from the following formula:

$$Z_y = 0.5\,Z_z \text{ (cm}^3\text{)}$$

where :

Z_z = as specified in (1).

(3) The total sectional area A_s of the members in the Y-direction is not to be less than obtained from the following formula:

$$A_s = \frac{BK_{sp}}{48} \text{ (mm}^2\text{)}$$

where :

B and K_{sp} = as specified in (1).

(4) At no section within length l the equivalent stress σ_e is to exceed $115/K_{sp}$ (N/mm^2). The equivalent stress σ_e is to be obtained from the following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2} \quad \text{(N/mm}^2\text{)}$$

where :

σ_b = the bending stress acting on the shoe piece, are to be obtained from the following formula (N/mm^2).

$$\sigma_b = \frac{M}{Z_z(x)} \text{ (N/mm}^2\text{)}$$

τ = the shear stress acting on the shoe piece, are to be obtained from the following formula (N/mm^2).

$$\tau = \frac{B}{A_s(x)} \quad (\text{N/mm}^2)$$

where :

$Z_z(x)$ = the actual section modulus around the Z-direction at the section considered (cm^3).

$A_s(x)$ = the actual sectional area around the Y-direction at the section considered (mm^2).

M and B = as specified in (1).

2. The thickness of steel plates forming the main part of shoe piece of steel plate stern frame is not to be less than that of steel plates forming the main part of propeller post. Ribs are to be arranged in the shoe piece below the propeller post, under brackets and at other suitable positions.

204. Heel pieces

Heel piece of stern frame is to be of length at least three times the frame space at that part and is to be strongly connected to the keel.

205. Attachment of stern frame to floor plates

Stern frame is to be sufficiently extended upward immediately in front of the rudder stock, and is to be strongly connected to the transom floor of thickness not less than that obtained from the following formula. The transom floor is to be reinforced at the top of extended portion of the stern frame in order to avoid abrupt change of rigidity.

$$t = 0.035L + 9.0 \quad (\text{mm})$$

206. Gudgeons

1. The bearing length of the pintle lp is to be such that :

$$d_p \leq l_p \leq 1.2d_p \quad (\text{mm})$$

where :

d_p = diameter of pintle (mm).

2. The length of the pintle housing in the gudgeon is not to be less than pintle diameter d_p.

3. The thickness of the pintle housing is not to be less than 0.25 d_p. For ships specified in **Pt 4, Ch 1, 103.,** however, the thickness of the pintle housing is to appropriately increased. ⚓

CHAPTER 3 LONGITUDINAL STRENGTH

Section 1 General

101. Special case in application

In case there are items for which direct application of the requirements in this chapter is deemed unreasonable, these items are to be in accordance with the discretion of the Society.

102. Continuity of strength

Longitudinal members are to be so arranged as to maintain the continuity of strength.

103. Loading manual

As specified in **Pt 3, Ch 3, 103.**

104. Longitudinal strength loading instrument

As specified in **Pt 3, Ch 3, 103.**

Section 2 Bending Strength

201. Bending strength at amidships

1. The section modulus of the transverse sections of the hull, at the midship part is not to be less than the value of Z_1 obtained from the formula given in **Table 10.3.1.** However, application of the requirement may be dispensed with to ships not exceeding 65 m in length at the discretion of the Society.

2. Notwithstanding the requirements of the preceding paragraph, the section modulus of the transverse section of hull at the midship part is not to be less than the value of Z_{min} obtained from the formula given in **Table 10.3.1.**

3. Moment of inertia of the transverse section of hull at the middle point of L is not to be less than the value of I_{min} obtained from the formula given in **Table 10.3.1.** and the calculation method for moment of inertia of the actual transverse section is to be correspondingly in accordance with the requirements in **203.**

4. Scantlings of all continuous longitudinal members of hull girder based on the section modulus requirement in **Pars 2** and **3** are to be maintained within 0.4 L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0.4 L part.

202. Bending strength at sections other than amidships

The bending strength of hull at sections other than 0.4 L amidships is to be determined according to the requirements of **Ch 5, Sec 2.**

Table 10.3.1 Section modulus of transverse sections of hull, etc.

Item	Requirement
Section modulus	$Z_1 = \dfrac{(M_s + M_w)}{\sigma} \times 10^3$ (cm^3)
Minimum section modulus	$Z_{min} = C_1 L^2 B (C_b + 0.7) K$ (cm^3)
Minimum moment of inertia	$I_{min} = 3 C_1 L^3 B (C_b + 0.7)$ (cm^4)

M_s = maximum longitudinal bending moments in still water (kN・m) for sagging and hogging, respectively, which are calculated at the transverse section under consideration along the length of hull for all conceivable loading conditions by a method of calculation deemed appropriate by the Society.

M_w = wave induced longitudinal bending moment (kN・m) at the transverse section under consideration along the length of hull, which is to be obtained from the following table.

Condition		M_w (kN・m)
M_s	Hogging	$0.19 C_1 C_2 L^2 B C_b$
	Sagging	$0.11 C_1 C_2 L^2 B (C_b + 0.7)$

σ = allowable bending stress obtained from the following formula.

σ = $175/K$ (N/mm^2)

K = material factor given by the following table.

Steel grades	K
A, *B*, *D* and *E*	1.0
AH 32, *DH* 32 and *EH* 32	0.78
AH 36, *DH* 36 and *EH* 36	0.72
AH 40, *DH* 40 and *EH* 40	0.68

C_1 = coefficient given by the following formula.
$C_1 = 0.03 L_1 + 5$

L_1 = length of ship (m) specified in **Ch 1,102.**, or 0.97 times the length of ship (m) on the load line, whichever is the smaller.

C_2 = distribution factor specified along the length of L at positions where the transverse section of the hull is under consideration, as given in **Fig. 10.3.1.**

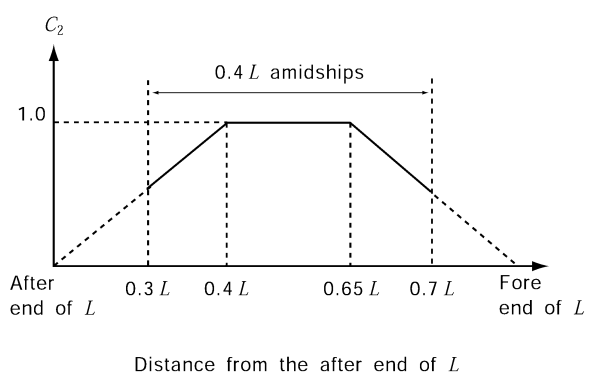


Fig 10.3.1 Distribution factor of bending moment C_2

C_b = block coefficient, however, to be taken as 0.6, where it is less than 0.6.

203. Calculation of hull section modulus

As for calculation of the hull section modulus, the following (1) through (6) are to be applied:

(1) All longitudinal members which are considered effective to the longitudinal strength of the ship may be included in the calculation.

(2) Deck openings on the strength deck are to be deducted from the sectional area used in the section modulus calculation. However, small openings not exceeding 2.5 m in length or 1.2 m in breadth need not be deducted, provided that the sum of their breadths in one transverse section is not more than $0.06(B-\Sigma b)$. Where, Σb is the sum of the openings exceeding 1.2 m in breadths or 2.5 m in length (m).

(3) Notwithstanding the requirement in (2), deck openings on the strength deck need not be deducted, provided that the sum of their breadths in one transverse section is not reducing the section modulus at deck or bottom by more than 3 %.

(4) Deck openings prescribed in (2) and (3) include shadow area which is obtained by drawing two tangential lines with an opening angle of 30 degrees having the focus on the longitudinal line of the ship.

(5) The section modulus at the strength deck is to be calculated by dividing the moment of inertia of the athwartship section about its horizontal neutral axis by the following distance (a) or (b), whichever is the greater.

(a) Vertical distance from the neutral axis to the top of the strength deck beam at side.

(b) Distance obtained from the following formula:

$$Y\left(0.9+0.2\frac{X}{B}\right)$$

where:

X = horizontal distance from the top of continuous strength member to the centre line of the ship (m).

Y = vertical distance from the neutral axis to the top of continuous strength member (m).

X and Y are to be measured to the point giving the largest value of the above formula.

(6) The section modulus at the bottom is to be calculated by dividing the moment of inertia of the athwartship section about its horizontal neutral axis by the vertical distance from the neutral axis to the top of keel.

Section 3 Buckling Strength

301. Compressive buckling strength

The requirements in this section apply to the strength deck plating and bottom shell plating, etc. subject to large compressive stresses due to longitudinal bending, and only compressive stress is to be considered among the requirements in **Pt 3, Ch 3, Sec 4.** ⚓

CHAPTER 4 PLATE KEELS AND SHELL PLATINGS

Section 1 General

101. Consideration for corrosion

The thickness of shell plating at such parts that the corrosion is considered excessive due to the location and/or special service condition of the ship is to be properly increased over that required in this chapter.

102. Special consideration for contact with quay, etc.

In case where the service condition of the ship is considered to be such that there is possibility of indent of shell plating due to contact with the quay, etc., special consideration is to be given to the thickness of shell plating.

103. Continuity in thickness of the shell plating

Sufficient consideration is to be paid to the continuity in the thickness of shell plating and to the avoidance of remarkable difference between the thickness of the shell plating under consideration and that of the adjacent shell plating.

Section 2 Plate Keels

201. Breadth and thickness

1. The breadth of plate keel over whole length of the ship is not to be less than that obtained from the following formula:

$b = 4.5L + 775$ (mm)

2. The thickness of plate keel over whole length of the ship is not to be less than the bottom shell thickness obtained from the requirement in **304.** increased by 1.5 mm. This thickness, however, is not to be less than that of the adjacent bottom shell plating.

Section 3 Shell Plating for Midship Part of Ship

301. Minimum thickness

The minimum thickness of shell plating below the strength deck for the midship part of ship is not to be less than that obtained from the following formula:

$t = 0.044L + 4.6$ (mm)

302. Thickness of side shell plating

The thickness of side shell plating other than the sheer strake at the strength deck for the midship part of ship is not to be less than that obtained from the following formula:

$t = 4.1S\sqrt{d + 0.04L} + 1.5$ (mm)

where:

S = spacing of longitudinal or transverse frames (m).

303. Sheer strakes for midship part

The thickness of sheer strakes at the strength deck for midship part is not to be less than 0.75 times that of the stringer plate of the strength deck. In no case, however, is the thickness to be less than that of the adjacent side shell plating.

304. Thickness of bottom shell plating

The thickness of bottom shell plating including bilge strake (excluding keel plate) for the midship part of ship is not to be less than that obtained from the formulae given in **Table 10.4.1.**

Table 10.4.1 Thickness of bottom shell plating

Framing	Thickness (mm)
Transverse	$t=4.7S\sqrt{d+0.035L}+1.5$
Longitudinal	$t=4.0S\sqrt{d+0.035L}+1.5$
S = spacing of longitudinal or transverse frames (m).	

Section 4 Shell Plating for End Parts

401. Shell plating for end parts

Beyond the midship part, the thickness of shell plating below the strength deck may be gradually reduced, but at the end parts the thickness is not to be less than that obtained from the following formula. However, for the parts specified in **402.** to **405.,** the thickness is not to be less than that required in the respective provisions.

$t=0.044L+4.6$ (mm)

402. Shell plating for 0.3L from the fore end

The thickness of shell plating for 0.3 L from the fore end is not to be less than that obtained from the following formula:

$t=1.34\,S\sqrt{L}+1.5$ (mm)

where:

S = spacing of longitudinal or transverse frames (m).

403. Shell plating for 0.3 L from the after end

The thickness of shell plating for 0.3 L from the after end is not to be less than that obtained from the following formula. In ships with machinery aft or in ships with high power engines, the thickness is to be properly increased:

$t=1.20\,S\sqrt{L}+1.5$ (mm)

where:

S = spacing of longitudinal or transverse frames (m).

404. Strengthened bottom forward

1. The thickness of shell plating at the strengthened bottom forward specified in **Ch 7, 902.** is to be in accordance with the requirements in **Pt 3, Ch 4, 404.**
2. Notwithstanding the requirement of **Par 1,** in ship of which C_b is less than 0.7 and $V/\sqrt{L}$ (kt/m) is 1.4 and over, the area and thickness of shell plating at the strengthened bottom forward of the ship is to be stiffened to an extent in accordance with the discretion of the Society.

405. Shell plating fitted up on spectacle bossings and stern frames

The thickness of shell plating fitted up on spectacle bossings and stern frames is not to be less than that obtained from the following formula:

$t = 0.09L + 3.5$ (mm)

Section 5 Side Plating in way of Superstructure

501. Side platings in way of superstructure deck designed as strength deck

Where the superstructure deck is designed as strength deck, the thickness of superstructure side plating is to be as specified in **301., 302.** and **401.** to **403.** However, superstructure side plating at end parts may be of thickness specified in **502.**

502. Side platings in way of superstructure deck not designed as strength deck

Where the superstructure deck is not designed as strength deck, the thickness of superstructure side plating is not to be less than obtained from the formulae given in **Table 10.4.2,** but in no case is it to be less than 5.5 mm.

Table 10.4.2 Thickness of superstructure side plating

Location	Thickness (mm)
For 0.25 L from the fore end	$t = 1.15S\sqrt{L} + 1.0$
Elsewhere	$t = 0.94S\sqrt{L} + 1.0$
S = spacing of longitudinal or transverse frames (m).	

503. Compensation at ends of superstructure

Side plating at the ends of superstructure is to be suitably constructed to maintain the continuity of strength.

Section 6 Local Compensation of Shell Plating

601. Openings in shell

All openings in the shell plating are to have well rounded corners and to be compensated as necessary.

602. Thickness of sea chest

In case where a sea chest is provided in the shell plating for sea suction or discharge, the thickness of sea chest is not to be less than obtained from the following formula and to be suitably stiffened so as to provide sufficient rigidity as necessary.

$t = 0.07L + 4.0$ (mm)

603. Hawse pipes and the plating below

The shell plating fitted with hawse pipes and the plating below is to be increased in thickness or to be doubled, and their longitudinal seams are to be protected against damages by anchors or cables.

604. Shell plating framed transversely

In ships with transverse framing, sufficient consideration is to be paid to the prevention of buckling of the shell. ⚓

CHAPTER 5 DECKS

Section 1 General

101. Steel deck plating

Decks are to be plated from side to side of the ship except deck openings, etc. Decks, however, may be provided with only stringer plates and tie plates, subject to the approval by the Society.

102. Watertightness of decks

Weather decks are to be made watertight.

103. Continuity of steps of decks

Where strength decks or effective decks (the decks below the strength deck which are considered as strength members in the longitudinal strength of hull) change in level, the change is to be accomplished by gradual sloping, or each of structural members which form deck is to be extended, and is to be effectively tied together by diaphragms, girders, brackets, etc. and special care is to be taken for the continuity of strength.

104. Compensation for openings

Hatchways or other openings on strength or effective decks are to have well rounded corners, and compensation is to be suitably provided as necessary.

105. Rounded gunwales

Rounded gunwales, where adopted, are to have a sufficient radius for the thickness of plates.

Section 2 Effective Sectional Area of Strength Deck

201. Definition

The effective sectional area of strength deck is the sectional area, on each side of the ship's centre line, of steel plating, longitudinal beams, longitudinal girders, etc. extending for 0.5 L amidships.

202. Effective sectional area of strength deck

1. The effective sectional area for the midship part is to be so determined as not to give less modulus of athwartship section of the hull specified in **Ch 3.**

2. Beyond the midship part, the effective sectional area may be gradually reduced. However, at 0.15 L from each end it is not to be less than 40 % for ships with machinery amidship and 50 % for ships with machinery aft, of the area required for the midship part.

3. Where the section modulus of the hull at 0.15 L from each end is calculated and approved by the Society, the requirements specified in **Par 2** may not be applied.

203. Strength deck beyond 0.15 L from each end

Beyond 0.15 L from each end, the effective sectional area and the thickness of strength deck may be gradually reduced avoiding abrupt change.

204. Long poop

Notwithstanding the requirements of **202.,** the effective sectional area of strength deck within long poop may be properly modified.

205. Superstructure deck designed as strength deck

Where the superstructure deck is designed as strength deck, the strength deck plating clear of the superstructure is to extend into the superstructure for about 0.05 L without reducing the effective sectional area, and may be gradually reduced within.

Section 3 Deck Plating

301. Thickness

1. The thickness of deck plating is not to be less than obtained from the formula given in **Table 10.5.1.** However, within such enclosed spaces as superstructures, deckhouses, etc., the thickness may be reduced by 1 mm.

2. Where strength deck is transversely framed, or decks inside the line of openings are longitudinally framed, sufficient care is to be taken to prevent buckling of the deck plating.

Table 10.5.1 Thickness of deck plating

Kind of deck	Location	Framing	Thickness (mm)
Strength deck	Outside the line of openings for the midship part	Longitudinal	$t = 1.47S\sqrt{h} + 1.5$
		Transverse	$t = 1.63S\sqrt{h} + 1.5$
	Elsewhere	$t = 1.25S\sqrt{h} + 1.5$	
Other deck			
S = spacing of longitudinal or transverse beams (m). h = deck load as specified in **Ch 10, 201.** (kN/m^2).			

302. Thickness of the top of tanks

The thickness of deck plating forming the top of tanks is not to be less than required in **Ch 15, 206.** for deep tank bulkhead plating, taking the beam spacing as the stiffener spacing.

303. Thickness of the bulkhead recesses

The thickness of deck plating forming the top of shaft tunnels, thrust recesses or bulkhead recesses is not to be less than required in **Ch 14, 207.** for watertight bulkhead plating, taking the beam spacing as the stiffener spacing.

304. Under boilers or refrigerated cargoes

1. The thickness of effective deck plating under boilers is to be increased by 3 mm above the normal thickness.

2. The thickness of deck plating under refrigerated cargoes is to be increased by 1 mm above the normal thickness. Where special means for the protection against the corrosion of the deck is provided, the thickness need not be increased.

305. Deck plating carrying unusual cargoes

The thickness of deck plating subject to cargo loads which can not be treated as evenly distributed loads is to be determined taking account of load distribution for particular cargoes. ⚓

CHAPTER 6 SINGLE BOTTOMS

Section 1 General

101. Application

The requirements in this chapter apply to ships whose double bottom is omitted partially or wholly in accordance with the requirements in **Ch 7, 101. 2** to **3.**

Section 2 Centre Keelsons

201. Arrangements and construction

1. All single bottom ships are to have centre girder composed of web plates and face plates, and the centre keelsons are to extend as far forward and afterward as practicable.

2. The bottom constructions in way of fore and after peaks are to be in accordance with the requirements in **Ch 13, Sec 2** and **3.**

202. Web plates

1. The thickness of web plates is not to be less than that obtained from the following formula. Beyond the midship part, the thickness may be gradually reduced and it may be 0.85 times the midship value at the ends of the ship.

$$t = 0.065L + 4.2 \text{ (mm)}$$

2. The height of web plates is not to be less than that of floors.

203. Face plates

1. The thickness of face plates is not to be less than that of web plate amidships and the face plates are to extend from the collision bulkhead to the after peak bulkhead.

2. The sectional area of face plates is not to be less than that obtained from the following formula. Beyond the midship part, the sectional area may be gradually reduced and it may be 0.85 times the midship value at the ends of the ship.

$$A = 0.6L + 9 \text{ (cm}^2\text{)}$$

3. The breadth of face plates is not to be less than that obtained from the following formula:

$$b = 2.3L + 160 \text{ (mm)}$$

Section 3 Side Keelsons

301. Arrangements

Side keelsons are to be so arranged that their spacing is not more than 2.5 m between the centre keelsons and the side shell plating.

302. Construction

The side keelsons are to be composed of continuous web plates in association with face plates, and they are to extend as far forward and afterward as practicable.

303. Web plates

1. The thickness of web plates is not to be less than that obtained from the following formula for the midship part. Beyond the midship part, the thickness may be gradually reduced and it may be 0.85 times the midship value at the ends of the ship.

$$t = 0.042L + 4.8 \text{ (mm)}$$

2. In the engine space, the thickness of web plates is not to be less than that required for the centre keelsons web plates specified in **202.**

304. Face plates

The thickness of face plates is not to be less than that required for the web plates, and the sectional area of face plates amidships is not to be less than obtained from the following formula. Beyond the midship part, the sectional area may be gradually reduced and it may be 0.85 times the midship value at the ends of the ship.

$$A = 0.45L + 8.8 \text{ (cm}^2\text{)}$$

Section 4 Floor Plates

401. Arrangements

1. In ships with the bottom of transverse framing, the standard spacing of floors is to comply with the requirements in **Ch 8, 201.**

2. In ships with the bottom of longitudinal framing, floors are to be so arranged that their spacing is not more than about 3.5 m.

402. Shapes

1. Upper edges of floor plates at any part are not to be below the level of upper edge at the centre line.

2. In the midship part, the depth of floors measured at a distance d_0 specified in **403. 1** from the inner edge of frames along the upper edge of floors, is not to be less than 0.5 d_0. Where frame brackets are provided, the depth of floors at the inner edge of brackets may be 0.5 d_0.

3. In ships having unusually large rise of floor, the depth of floor plates at the centre line is to be suitably increased.

4. Face plates provided on the floor plates are to be continuous from the upper part of bilge at one side to the upper part of bilge on the opposite side in case of curved floors, and extending over the floor plate in case of floors connected by frame brackets.

403. Scantlings

1. The scantlings of floor plates are not to be less than obtained from the formulae given in **Table 10.6.1.**

Table 10.6.1 Scantlings of floor plates

Items	Scantlings
(1) Depth at the centre line (2) Thickness (3) Section modulus	$d_0 = 62.5l$ (mm) $t^{(1)} = 0.01d_0 + 3$ (mm) $Z = 4.27Shl^2$ (cm^3)
S = spacing of floor (m). h = d or 0.66 D, whichever is the greater (m). l = span between the toes of frame brackets measured at amidship plus 0.3 m, Where curved floors are provided, the length l may be suitably modified, (See **Fig 10.6.1**).	
NOTE (1) The thickness of floor plates need not exceed 12 mm.	

2. The thickness of face plates on the floor plates is not to be less than that required for the floor plates, and the breadth of face plates is to be adequate for lateral stability of the floors.

3. Beyond 0.5 L amidships, the thickness of floor plates may be gradually reduced and at the end parts of the ship it may be 0.85 time the value specified in **Par 1,** except for the forward flat bottom.

4. Floors under engines and thrust seats are to be of ample depth and to be specially strengthened. Their thickness is not to be less than that of the centre girder web plates.

5. At the strengthened bottom forward specified in **Ch 7, 902.** the depth of floor plates is to be increased, or alternatively, the section modulus of floor plates required by **Par 1** is to be suitably increased.

404. Frame brackets

The scantlings of frame brackets are to be determined in accordance with the requirements of the following. The free edge of the bracket is to be flanged.

(1) The height of the bracket measured from the top of keel is not to be less than twice the required depth of the floor plate at the centreline of the ship. (See **Fig 10.6.1**).

(2) The arm of the bracket measured along the upper edge of the floor plate from the inner edge of frame is not to be less than the depth of the floor plate required at the centreline of the ship. (See **Fig 10.6.1**).

(3) The thickness of frame brackets is not to be less than that of floor plates.

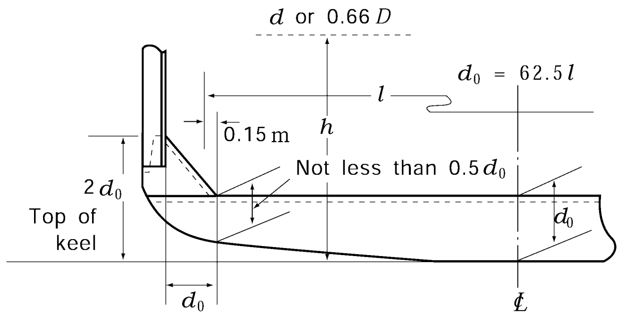


Fig 10.6.1 Shape of floors

405. Drainage holes

Drainage holes are to be provided on the floor plates on both sides of the centreline and for ships with flat bottom also at the low parts of the turn of bilge.

406. Lightening holes

Lightening holes may be provided in floor plates. Where the holes are provided, appropriate strength compensation is to be made by increasing the floor depth or by some other suitable means.

407. Floor plates forming part of bulkheads

Floor plates forming part of bulkheads are to be in accordance with the requirements in **Ch 14, 15.**

Section 5 Longitudinals

501. Spacing

The standard spacing of bottom longitudinals is obtained from the following formula:

$$S = 2L + 550 \text{ (mm)}$$

502. Scantlings

The section modulus of bottom longitudinals is not to be less than that obtained from the following formula:

$$Z_b = 9Shl^2 \quad \text{(cm}^3\text{)}$$

where:

l = spacing of solid floors (m).

S = spacing of bottom longitudinals (m).

h = vertical distance from the longitudinals to a point of $d + 0.026L$ above the top of keel (m).

Section 6 Strengthened Bottom Forward

601. Application

Strengthening of the forward bottom is to be in accordance with the requirements in **Ch 7, Sec 9.**
⚓

CHAPTER 7 DOUBLE BOTTOMS

Section 1 General

101. Application

1. Ships, in principle, are to be provided with double bottoms extending from the collision bulkhead to the after peak bulkhead.

2. For ships which are impossible to apply double bottom construction due to their structural configuration, hull form and purposes etc, and whose gross tonnages are less than 500 gross tonnage or not engaged in international voyage, double bottom may be omitted partially or wholly.

3. Double bottoms may be omitted in way of tanks of moderate size used exclusively for the carriage of liquids subject to the approval by the Society.

4. The requirements in this chapter may be suitably modified, where partial double bottoms are provided and where special arrangements such as longitudinal bulkheads or inner skins are made to reduce the unsupported breadth of double bottoms.

5. Where the longitudinal system of framing is transformed into the transverse system, or the depth of double bottom changes suddenly, special care is to be taken for the continuity of strength by means of additional intercostal girders or floors.

6. Bottom structure of holds is to be subjected to special consideration when the hold is intended to carry heavy cargoes or where cargo loads can not be treated as evenly distributed loads.

102. Manholes and lightening holes

1. Manholes and lightening holes are to be provided in all non-watertight members to ensure accessibility and ventilation, except in way of widely spaced pillars and where such openings are not permitted by this rule.

2. The number of manholes in tank tops is to be kept to the minimum compatible with securing free ventilation and ready access to all parts of the double bottom. Care is to be taken for locating the manholes to avoid the possibility of inter connection of main subdivision compartments through the double bottom so far as practicable.

3. Covers of manholes specified in **Par 2** are to be of steel, and where no ceiling is provided in the cargo holds, the covers and their fittings are to be effectively protected against damages by cargoes.

4. Air and drainage holes are to be provided in all non-watertight members of the double bottom structure.

5. The proposed locations and sizes of manholes and lightening holes are to be indicated in the plans submitted for approval.

103. Drainage

1. Efficient size of bilge wells are to be provided for draining water on the tank top.

2. The bottoms of bilge wells, except after the tunnel well, are to be situated at a distance of at least 460 mm from the top of keel.

3. Bilge wells specified in **Par 2** are not to be formed by shell plating. Where, however, the bilge wells are inevitably formed by shell platings due to the hull arrangement subject to the approval by the Society, the thickness of the side shell platings forming of bilge wells is to be increased by 2.5 mm than those of the adjacent shell platings.

104. Cofferdams

1. The following dedicated tanks are to be separated from adjacent tanks of other uses by cofferdams. However, these cofferdams may be omitted provided that the common boundaries of lubricating oil and fuel oil tank have full penetration welds.

(1) Fuel oil
(2) Lubrication oil
(3) Vegetable oil
(4) Fresh water

2. The cofferdams specified in **Par 1** are to be provided with the air pipes to comply with the requirements in **Pt 5, Ch 6, 201.** and with the manholes of adequate size which are well accessible.

105. Watertight girders and floors

The thickness of watertight girders and floors, and the scantlings of stiffeners attached to them are to comply with the relevant requirements for girders and floors, as well as the requirements in **Ch 15, 202.** and **203.**

106. Minimum thickness

No member of the double bottom structure is to be less than 6 mm in thickness.

Section 2 Centre Girders

201. Arrangement and construction

1. Centre girders are to extend as far forward and afterward as practicable.

2. Where double bottoms are used for carriage of fuel oil or fresh water, the centre girders are to be watertight and may be suitably modified in narrow tanks at the end parts of the ship or

3. Where double bottoms are used for carriage of fuel oil or fresh water, the centre girders are to be watertight.

4. The requirements in **Par 3** may be suitably modified, in narrow tanks at the end parts of the ship or where other watertight longitudinal divisions are provided at about 0.25 B from the centre line or where deemed appropriate by the Society.

202. Manholes

1. Manholes may be provided on centre girders in every frame space outside 0.75 L amidships.

2. Manholes may be provided on centre girders in alternate frame spaces for 0.75 L amidships, provided that the depth of holes does not exceed one-third of the depth of centre girder.

203. Depth

The depth of centre girders is not to be less than $B/16$ unless specially approved by the Society, but in no case is it to be less than 700 mm.

204. Thickness

The thickness of centre girder plates is not to be less than that obtained from the following formula:

$$t = 0.05L + 5 \text{ (mm)}$$

205. Brackets

1. Where longitudinal framing system is adopted in the double bottom, transverse brackets are to be provided between the solid floors with a spacing not more than about 1.75 m connecting the centre girder plates to the bottom shell plating as well as the adjacent bottom longitudinals. Where the spacing of these brackets exceeds 1.25 m, additional stiffeners are to be provided for the centre girder plates.

2. The thickness of the brackets specified in **Par 1** is not to be less than that obtained from the following formula. However, it need not be greater than that of the solid floors at the same location.

$$t = 0.6\sqrt{L} + 1.5 \ \text{(mm)}$$

3. The strength of stiffeners specified in **Par 1** is not to be less than that of a flat bar having the same thickness as that of girder plates and having the depth not less than 0.08 d_0, where d_o is the depth of centre girder (mm).

Section 3 Side Girders

301. Arrangement

1. Side girders in 0.5 L amidships are to be so arranged that the distance from the centre girder to the first side girder, between girders, or from the outermost girder to the side shell plating does not exceed approximately 4.6 m and to extend as far forward and afterwards as practicable.

2. In the strengthened bottom forward specified in **902.** of ships, side girders and half-height girders are to be provided as required in **903.**

3. Adequate strengthening is to be made under main engines and thrust seatings by means of additional full or half-height girders.

302. Thickness

The thickness of side girder plates is not to be less than that obtained from the following formula and in engine room it is to be increased by 1.5 mm.

$$t = 0.65\sqrt{L} + 1.5 \ \text{(mm)}$$

303. Thickness of half-height girders

The thickness of half-height girders is not to be less than obtained from the formula specified in **302.**

304. Scantlings of vertical stiffeners and struts

1. Vertical stiffeners are to be provided to side girders at every open floor, or at a suitable distance if the double bottom is framed longitudinally, and vertical struts are to be provided on half-height girders at every open floor.

2. The strength of vertical stiffeners required by **Par 1** is not to be less than that of a flat bar having the same thickness as that of the girder plates and having the depth not less than 0.08 d_0 (mm), where d_0 is the height of side girder (mm).

3. The sectional area of vertical struts required by **Par 1** is not to be less than obtained from the formula in **503.** with necessary modification.

305. Lightening holes

Within 10 % of the length of a hold from its end bulkheads, the diameter of lightening holes in the side girder is not to exceed one-third of the depth of girders. This requirement may, however, be modified in a short hold and outside 0.75 L amidships and where suitable compensation is made to the girder plate.

Section 4 Solid Floors

401. Arrangements

1. Solid floors are to be provided at a spacing not exceeding about 3.5 m.

2. In addition to complying with the requirements in **Par 1,** solid floors are to be provided at the following locations:

(1) At every frame in the main engine room. Solid floors may, however, be provided at alternate frames outside the engine seatings, if the double bottom is framed longitudinally.
(2) Under thrust seatings and boiler bearers.
(3) Under transverse bulkheads.
(4) At the location specified in **903.,** between the collision bulkhead and the after end of the strengthened bottom forward specified in **902.**

3. Watertight floors are to be so arranged that the subdivision of the double bottom generally corresponds to that of the ship.

402. Thickness

The thickness of solid floors is not to be less than that obtained from the following formulae and in the engine room the thickness is to be increased by 1.5 mm.

In ships with transverse framing : $t = 0.6\sqrt{L} + 1.5$ (mm)

In ships with longitudinal framing : $t = 0.7\sqrt{L} + 1.5$ (mm)

403. Vertical stiffeners

1. Vertical stiffeners are to be provided on the solid floors at a suitable spacing in case of the double bottom framed transversely, and at every longitudinal in case of the double bottom framed longitudinally.

2. The vertical stiffeners prescribed in **Par 1** is to be a flat bar having the same thickness as that of the floor plate and the depth not less than 0.08 d_0 or the equivalent, where d_0 is the depth of the floor at the point under consideration (mm).

404. Lightening holes

Within $0.1B$ from side shell plating, the diameter of lightening holes provided in the solid floors in the middle half length of a hold is not to exceed about one-fifth of the depth of floors. This requirement may, however, be suitably modified at the end parts of ship and in exceptionally short holds and where the solid floors are suitably compensated for.

Section 5 Bottom Longitudinals

501. Spacing

The standard spacing of longitudinals is obtained from the following formula :

$$S = 2L + 550 \text{ (mm)}$$

502. Scantlings

1. The section modulus of bottom longitudinals is not to be less than that obtained from the following formula and in no case is it to be less than 30 cm^3.

$$Z_b = CShl^2 \ (\text{cm}^3)$$

where:

l = spacing of solid floors (m).

S = spacing of longitudinals (m).

h = vertical distance from the longitudinals to a point of $d + 0.026L$ above the top of keel (m).

C = coefficient given in **Table 10.7.1.**

Table 10.7.1 Coefficient C

Case		C
In case where no strut specified in **503.** is provided midway between floors		8.6
In case where a strut specified in **503.** deep tanks is provided midway between floors	Lower part of deep tanks	6.2
	Elsewhere	4.1

2. The section modulus of inner bottom longitudinals is not to be less than obtained from the formula in **Par 1** with C equal to 0.85 times the value specified for bottom longitudinals in the same location. Where vertical struts are not provided to the longitudinals under deep tanks, the section modulus of inner bottom longitudinals is to be as specified in **Ch 15, 203.**

503. Vertical struts

1. Vertical struts are to be rolled sections other than flat bars or bulb plates and to be well overlapped with the webs of bottom and inner bottom longitudinals.

2. The sectional area of the vertical struts is not to be less than that obtained from the following formula:

$$A = 2.2Sbh \ (\text{cm}^2)$$

where:

S = spacing of longitudinals (m).

b = breadth of the area supported by the strut (m). (See **Fig 10.7.1**)

h = as specified in **502. 1.**

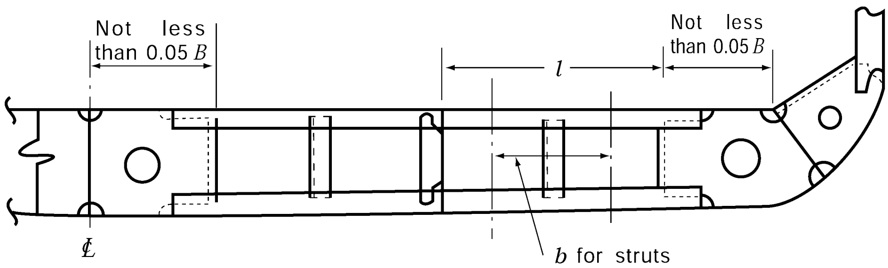


Fig 10.7.1 Open Floors

Section 6 Inner Bottom Plating and Margin Plates

601. Thickness of inner bottom plating

The thickness of inner bottom plating is not to be less than that obtained from the following formula and the thickness is to be increased by 2 mm in main engine room and under hatchway, if no ceiling is provided:

$$t = 3.8S\sqrt{d} + 1.5 \text{ (mm)}$$

where:

S = spacing of inner bottom longitudinals for longitudinally framed inner bottom plating, or spacing of floor plates for transversely framed inner bottom plating (m).

602. Ships handling cargoes regularly by mechanical appliances such as grabs

In ships which regularly handle cargoes by grabs or similar mechanical appliances, the thickness of inner bottom plating is to be increased by 2 mm above that specified in **601.,** unless ceiling is provided.

603. Arrangements of margin plates

It is recommended that the margin plates are to be of sufficient height to protect the bottom up to the turn of bilge and for forward 0.2 L from the stem the margin plates are to extend to the ship's sides horizontally as far as practicable.

604. Thickness of margin plates

The thickness of margin plates is to be increased by 1.5 mm above that obtained from the formula in **601.**

605. Breadth of margin plates

Margin plates are to be of adequate breadth and to extend well inside from the line of toes of tank side brackets.

606. Brackets

1. Where the double bottom is framed longitudinally, brackets are to be transversely provided at every hold frame extending from the margin plate to the adjacent bottom and inner bottom longitudinals.

2. The thickness of brackets specified in **Par 1** is not to be less than that obtained from the formula in **205. 2.**

Section 7 Hold Frame Brackets

701. Tank side brackets

1. The thickness of brackets connecting hold frames to margin plates is to be increased by 1.5 mm above that obtained from the formula in **205. 2.**

2. The free edges of brackets are to be stiffened.

3. Where the shape of ship requires exceptionally long brackets, additional stiffness is to be provided by fitting angles longitudinally across the top of flanges, or by other suitable means.

Section 8 Open Floors

801. Arrangements

Where the double bottom is framed transversely, open floors are to be provided at every hold frame between solid floors in accordance with the requirements in this section.

802. Scantlings of frames and reverse frames

1. The section modulus of frames is not to be less than that obtained from the following formula and in no case is it to be less than 30 cm^3.

$$Z_b = CShl^2 \quad (cm^3)$$

where:

l = distance between the brackets attached to the centre girder and the margin plate (m). Where side girders are provided, l is the greatest distance between the vertical stiffeners on side girders and the brackets. (See **Fig. 10.7.1**)

S = spacing of frames (m).

h = $d + 0.026L$ (m).

C = coefficient given in **Table 10.7.2.**

Table 10.7.2 Coefficient C

Case		C
In case where no vertical strut specified in **803.** is provided		6.0
In case where vertical struts specified in **803.** are provided.	Under deep tanks	4.4
	Elsewhere	2.9

2. The section modulus of reverse frames is not to be less than that obtained from the formula in **Par 1** with C equal to 0.85 times the value specified for frames at the same location. Where no vertical strut is provided to the open floors under deep tanks, C is to be the value as specified in **Ch 15, 203.**

803. Vertical struts

1. Vertical struts are to be rolled sections other than flat bars and bulb plates and to be well overlapped with the webs of frames and reverse frames.

2. The sectional area of vertical struts is not to be less than that specified in **503.** with necessary modifications.

804. Brackets

1. Frames and reverse frames are to be connected to the centre girder and margin plates by brackets of not less thickness than obtained from the formula in **205. 2.**

2. The breadth of brackets specified in **Par 1** is not to be less than 0.05 B and the brackets are to be well overlapped with frames and reverse frames. The free edges of brackets are to be properly stiffened.

Section 9 Construction of Strengthened Bottom Forward

901. Application

1. The requirements in this section are framed for ships having the minimum bow draught not more than 0.037 L at the ballast condition.

2. Notwithstanding the requirement in **Par 1,** in ships of which C_b is less than 0.7 and $V / \sqrt{L}$ (kt/m) is 1.4 and over, the area of strengthened bottom forward of ship is to be in accordance with the discretion of the Society.

902. Strengthened bottom forward

1. The strengthened bottom forward is the part of the ship's bottom up to a height of 0.05 d_F (d_F : Bow draught at the ballast condition) from the top of keel at forward from the position specified in **Table 10.7.3.**

Table 10.7.3 Range of strengthened bottom forward

$V/\sqrt{L}$ $(=a)$	Position (from Fore Perpendicular)
$a \leq 1.1$	0.15 L
$1.1 < a \leq 1.25$	0.175 L
$1.25 < a \leq 1.4$	0.2 L
$1.4 < a \leq 1.5$	0.225 L
$1.5 < a \leq 1.6$	0.25 L
$1.6 < a \leq 1.7$	0.275 L
$1.7 < a$	0.3 L

2. Notwithstanding the requirement of **Par 1,** in case of the ships of which C_b are especially small, the ships of which the draft in the ballast condition are especially small, and so on, the extent of the strengthened bottom forward is to be extended up to the satisfaction of the Society.

903. Construction

1. Between the collision bulkhead and 0.05 L abaft the after end of strengthened bottom forward, full or half height girders are to be provided in accordance with **Table 10.7.4.** Where transverse framing is adopted between the collision bulkhead and 0.025 L abaft the after end of strengthened bottom forward, half height girders or longitudinals shell stiffeners are to be provided between the side girders.

2. Between the collision bulkhead and the after end of strengthened bottom forward, solid floors are to be provided in accordance with **Table 10.7.4.**

Table 10.7.4 Construction of strengthened bottom forward

Double bottom \ Side \ Members		Side girders	Half-height girders or longitudinals shell stiffeners	Solid floors
Transverse framing	Transverse framing	To be provided at intervals within 2.5 m	To be provided between side girders	To be provided at every frame
	Longitudinal framing			To be provided at intervals within 2.5 m
Longitudinal framing	Transverse framing		-	To be provided at alternate frames
	Longitudinal framing			To be provided at intervals within 2.5 m

3. The solid floors are to be strengthened by fitting vertical stiffeners in way of half-height girders or longitudinal shell stiffeners except where the shell stiffeners are spaced considerably close and the solid floors are adequately strengthened, the vertical stiffeners may be provided on alternate shell stiffeners.

4. Solid floors and side girders are to be adequately stiffened for those ships, of which the minimum bow draught is not less than 0.025 L but not more than 0.037 L, where the construction and arrangement of the strengthened bottom forward are not in accordance with the requirements in **Par 1** and **2.**

904. Scantlings of longitudinal shell stiffeners or bottom longitudinals

The section modulus of longitudinal shell stiffeners or bottom longitudinals in way of the strengthened bottom forward are to be in accordance with **Pt 3, Ch 7, 804.** ⚓

CHAPTER 8 FRAMES

Section 1 General

101. Application

The requirements in this chapter apply to ships having transverse strength due to bulkheads not less effective than that specified in **Ch 14.** Where the transverse strength due to bulkheads is not sufficient or hold length is over 25 m in length, additional stiffening is to be made by means of increasing scantlings of frames, provision of web frames, etc.

102. Frames in way of deep tanks

The strength of frames in way of deep tanks is not to be less than that required for stiffeners on deep tank bulkheads.

103. Frames in way of tank tops

Frames are not to extend through the tops of tanks, unless the effective watertight or oiltight arrangements are specially submitted and approved.

104. Frames in boiler spaces and in way of bossing

1. In boiler spaces, the scantlings of frames and side stringers are to be appropriately increased.

2. The construction and scantlings of frames in way of bossing are to be to the satisfaction of the Society.

Section 2 Frame Spacing

201. Transverse frame spacing

1. The standard spacing of transverse frame is obtained from the following formula:

$$S = 2L + 450 \text{ (mm)}$$

2. Transverse frame spacing in peaks or cruiser sterns as well as between 0.2 L from the fore end and the collision bulkhead is not to exceed 610 mm or the standard spacing specified in **Par 1**, whichever is the smaller.

3. The requirements in **Par 2** may be modified, where structural arrangement or scantlings are suitably considered.

202. Longitudinal frame spacing

The standard spacing of longitudinal frames is to be obtained from the following formula:

$$S = 2L + 550 \text{ (mm)}$$

203. Consideration for frame spacing exceeding the standard

Where the spacing of frames is equal to or above the spacing of 170 mm greater than the standard spacing in **201.** and **202.,** the scantlings and structural arrangement of single and double bottoms and of other relevant structures are to be specially considered.

Section 3 Transverse Hold Frames

301. Application

1. Transverse hold frame is the frame provided below the lowest deck from the collision bulkhead to the after peak bulkhead, including the machinery space.

2. The transverse hold frames of ships which have hopper side tanks, top side tanks, or which have a special construction such as inner hulls, will be specially considered.

302. Scantlings of transverse hold frames

1. The section modulus of transverse hold frames is not to be less than obtained from the formulae given in **Table 10.8.1,** but in no case is it to be less than 30 cm^3.

Table 10.8.1 Section modulus

Location	Section modulus (cm^3)
(1) Between 0.15 L from the fore end and the after peak bulkhead	$Z = 2.6 S h l^2$
(2) Between 0.15 L from the fore end and the collision bulkhead	$Z = 3.4 S h l^2$
(3) For the frames under transverse web beams supporting deck longitudinals	$Z = 2.4n \left\{0.17 + \frac{1}{9.81} \cdot \frac{h_1}{h} \cdot \left(\frac{l_1}{l}\right)^2 - 0.1 \frac{l}{h}\right\} S h l^2$

S = frame spacing (m).
l = vertical distance from the top of inner bottom plating or single bottom floors at side to the top of deck beams above the frames (m).
h = vertical distance from the lower end of l at the place of measurement to a point of $d + 0.044L - 0.54$ above the top of keel (m).
n = ratio of the transverse web beam spacing to the frame spacing.
h_1 = deck load stipulated in **Ch 10, Sec 2** for the deck beam at the top of frame (kN/m^2).
l_1 = total length of the transverse web beam (m).

2. Where the depth of bottom centre girder is less than B/16, the scantlings of frames are to be suitably increased.

303. Connection

1. Transverse hold frames are to be overlapped with tank side brackets by at least 1.5 times the depth of frame sections and are to be effectively connected thereto.

2. The upper end of transverse hold frame are to be effectively connected by brackets with the deck or deck beams, and where the deck at the top of frames is longitudinally framed, the upper end brackets are to be extended and connected to the deck longitudinals adjacent to the frames.

Section 4 Side Longitudinals

401. Side longitudinals

1. The section modulus of side longitudinals in the midship part below the freeboard deck is not to be less than that obtained from the following formulae, whichever is the greater, but in no case is it to be less than 30 cm^3.

$Z_1 = 8.6 Shl^2$ (cm³)

$Z_2 = 2.9\sqrt{L} Sl^2$ (cm³)

where:

S = spacing of longitudinals (m).

l = distance between the web frames or between the transverse bulkhead and the web frame including the length of connection (m).

h = vertical distance from the longitudinals to a point of $d + 0.044L - 0.54$(m) above the top of keel.

2. Beyond the midship part, the section modulus of side longitudinals may be gradually reduced towards the ends of ships, and may be 0.85 times that obtained from the formula in **Par 1** at the ends. However, the section modulus of side longitudinals between 0.15 L from the fore end and the collision bulkhead is not to be less than obtained from the formula in **Par 1.**

3. The depth of flat bars used for longitudinals is not to exceed 15 times the thickness of flat bars.

4. Side longitudinals on sheer strakes in midship part are to be, as far as possible, of slenderness ratio not greater than 60.

5. The section modulus of bilge longitudinals need not exceed that of bottom longitudinals.

402. Side transverse

1. The side transverses supporting side longitudinals are to be arranged at an interval not exceeding 4.8 m at sections where solid floors are provided.

2. The scantlings of side transverses are not to be less than those obtained from the following formulae:

Depth: $d = 100l$ (mm) or 2.5 times the depth of slot for the longitudinals, whichever is the greater.

Section modulus: $Z = C_1 Shl^2$ (cm³)

Thickness of web: $t = \dfrac{C_2 Shl}{d_0} + 1.5$ (mm)

where:

S = side transverses spacing (m).

l = vertical distance from the top of inner bottom plating or single bottom floors at side to the deck at the top of side transverses. Where, however, there are effective deck transverses, l may be measured up to the lower surface of such transverses (m).

d_0 = depth of side transverses (mm). However, the depth of slots for side longitudinals is to be deducted from the web depth.

h = vertical distance measured from the midpoint of l to a point of $d + 0.044L - 0.54$ (m) above the top of keel, but in no case is it to be less than 1.43 l (m).

C_1, C_2 = coefficients as defined in **Table 10.8.2.**

Table 10.8.2 Coefficients C_1 and C_2

Coefficient	For side transverses abaft 0.15 L from the fore end	For side transverses between 0.15 L from the fore end and the collision bulkhead.
C_1	4.7	6.0
C_2	45	58

3. Side transverses are to be provided with tripping brackets at an interval of about 3 m and stiffeners are to be provided on the webs at every longitudinal except for the middle part of the span of side transverses where they may be provided at alternate longitudinals.

Section 5 Tween Deck Frames

501. General

1. The scantlings of tween deck frames are to be determined in relation to the strength of hold frames, the arrangement and transverse stiffness of bulkheads, etc.

2. In the design of tween deck framing, considerations are to be given to the provision of a reasonable degree of continuity in the framing from the bottom to the top of hull in conjunction with hold frames.

3. The provisions in this section are based on the standard structural arrangement so as to maintain transverse stiffness of ships by means of efficient tween deck bulkheads provided above the hold bulkheads or by web frames extended to the top of superstructures at a proper interval.

502. Scantlings

1. The section modulus of tween deck frames is not to be less than that obtained from the following formula:

$$Z = CSlL \quad (\text{cm}^3)$$

where:

S = frame spacing (m).

l = tween deck height (m), but to be taken as 1.8 m where the height is less than 1.8 m for superstructure frames and as 2.15 m where the height is less than 2.15 m for others, respectively.

C = coefficient given in **Table 10.8.3.**

2. The scantlings of tween deck frames below the free board deck within 0.125 L from the fore and after ends are to be appropriately increased above those given by **Par 1.**

Table 10.8.3 Coefficient C

Description of tween deck frames	C
Superstructure frames (excluding the following two lines)	0.44
Superstructure frames for 0.125 L from after end of ship	0.57
Superstructure frames for 0.125 L from fore end and cant frames at stern	0.74
Tween deck frames between the freeboard deck and the second deck	0.74
Tween deck frames between the second deck and the third deck	0.89
Tween deck frames between the third deck and the fourth deck	0.97

3. Where decks are supported by longitudinal beams and transverse strong beams, the section modulus of tween deck strong frames which support beams is not to be less than that given by **Pars 1** and **2** multiplied by the coefficient obtained from the following formula. In this case, the section modulus of tween deck frames between strong frames is not to be less than 0.85 times that given by **Pars 1** and **2** and the upper ends are to be connected with brackets.

$$C = 0.2n + 1$$

where:

n = number of tween deck frames between web frames.

503. Special care to tween deck frames

1. Care is to be taken so that the strength and stiffness of framing at the ends of ship may be increased in proportion to the actual unsupported length of frame as well as the vertical height of tween decks.

2. In ships having specially large freeboard, the scantlings of tween deck frames may be properly reduced.

504. Superstructure frames

1. Superstructure frames are to be provided at every frame located below.

2. Superstructure frames for four frame spaces at the ends of bridges and of detached superstructures within 0.5 L amidships are not to be less than the section modulus obtained from the formula in **502.** using 0.74 as the coefficient C.

3. Web frames or partial bulkheads are to be provided above the bulkheads required by **Ch 14** or at other positions such as may be considered necessary to give effective transverse rigidity to the superstructures.

Section 6 Frames in Both Peaks

601. Transverse frames in fore peaks

The section modulus of transverse frames below the freeboard deck forward collision bulkhead is not to be less than that obtained from the following formula, but in no case is it to be less than 30 cm^3.

$$Z = 8Shl^2 \quad (cm^3)$$

where:

S = web frame spacing (m).

l = distance between the supports of transverses (m), but to be taken as 2 m where the distance is less than 2 m.

h = vertical distance from the midpoint of l to a point of 0.12 L above the top of keel (m).

602. Longitudinal frames in fore peaks

The section modulus of longitudinals below the freeboard deck forward collision bulkhead is not to be less than that obtained from the following formula. However, the modulus obtained from the formula is to be increased by 25 % between 0.05 D and 0.15 D from the top of keel and 50 % below 0.05 D from the top of keel.

$$Z = 8Shl^2 \quad (\text{cm}^3)$$

where:

S, l = as specified in **401.**

h = vertical distance from the longitudinals to a point of 0.12 L above the top of keel (m), but in no case is it to be less than 0.06 L (m).

603. Transverse frames in after peaks

The section modulus of transverse frames below the freeboard deck abaft after peak bulkhead is not to be less than that obtained from the following formula, but in no case is it to be less than 30 cm^3:

$$Z = 8Shl^2 \quad (\text{cm}^3)$$

where:

S = web frame spacing (m).

l = as specified in **Table 8.1,** but to be taken as 2 m where the height is less than 2 m.

h = vertical distance from the midpoint of l to a point of $d + 0.044L - 0.54$ (m) above the top of keel. ⚓

CHAPTER 9 CANTILEVER BEAM CONSTRUCTION

Section 1 Cantilever Beams

101. Construction and scantlings

Cantilever beams are to comply with the requirements in (1) to (7):

(1) The root depth of cantilever beams measured at the toe of end brackets at side is not to be less than one-fifth of the horizontal distance from the inboard end of cantilever beam to the toe of end bracket at side.

(2) The depth of cantilever beams may be gradually tapered from the root towards the inboard end where it may be reduced to about a half of the root depth.

(3) The section modulus of cantilever beams at the toe of end brackets is not be less than obtained from the following formula: (See **Fig 10.9.1**)

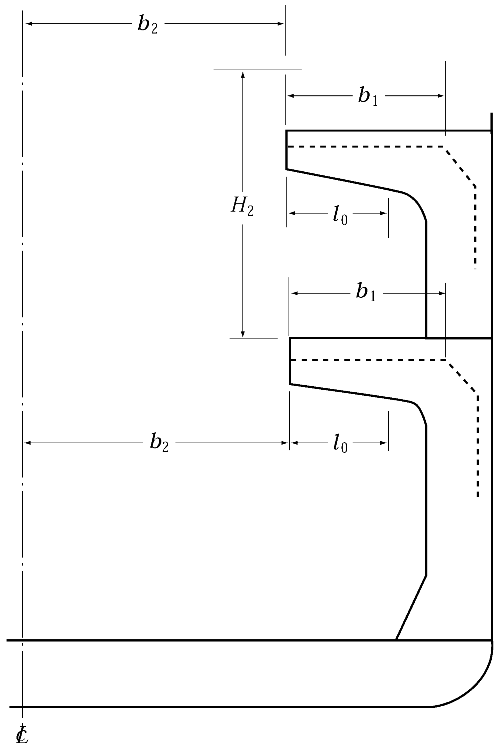


Fig 10.9.1 Measurement of l_0, b_1, b_2, etc.

$$Z = 7.1\,Sl_0\left(\frac{1}{2}b_1h_1 + b_2h_2\right) \quad (\text{cm}^3)$$

where:

S = cantilever beam spacing (m).

l_0 = horizontal distance from the inboard end of cantilever beams to the toe of end brackets (m).

b_1 = horizontal distance from the inboard end of cantilever beams to the toe of end brackets of beam or transverse deck girder at side (m). Where, however, the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, b_1 is to be taken as l_0.

b_2 = a half of the breadth of hatch opening in the deck supported by the cantilever beams (m).

h_1 = deck load stipulated in **Ch 10, Sec 2** for the deck transverses supported by the cantilever beams (kN/m^2).

h_2 = load on hatch covers of the deck supported by the cantilever beams which is not to be less than obtained from the following (a) to (c), depending on the type of the deck (kN/m^2):

(a) For the weather deck, $h_2 h_2$ is the deck load stipulated in **Ch 10, 201. 2** for the deck transverses or the maximum design cargo weight on hatches per unit area (kN/m^2), whichever is the greater. In **Ch 10, 201. 2**(1), the value of y may be taken as the vertical distance from the load line to the upper edge of hatch coaming. In either case, h_2 is not to be less than 17.5 (kN/m^2) for hatches at Position I and 12.8 (kN/m^2) for those at Position II, specified in **Ch 19,** respectively.

(b) For decks other than the weather deck where ordinary cargoes or stores are intended to be carried, h_2 is the deck load stipulated in **Ch 10, 201. 1.**

(c) For decks other than those specified in (a) or (b) above, h_2 is the value equals to h_1.

(4) The section modulus of cantilever beams may be gradually tapered from the inner edge of end brackets toward the inboard end of cantilever beams, where it may be reduced to 0.60 times that at the inner edge of end brackets.

(5) The web thickness of cantilever beams is not to be less than obtained from the following formulae, whichever is the greater:

$$t_1 = 9.5\frac{S\left(\frac{1}{2}b_1 h_1 + b_2 h_2\right)}{d_c} + 1.5 \text{ (mm)}$$

$$t_2 = 0.0075 d_c + 0.46 t_1 + 0.5 \text{ (mm)}$$

where:

S, b_1, b_2, h_1 and h_2 = as stipulated in (3). Where, however, the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, a horizontal distance in *metre* from the inboard end of cantilever beams to the section under consideration is to be substituted for $b_1/2$ in the formula for t_1.

d_c = depth of the cantilever beams at the section under consideration (mm), However, in the calculation of t_1, the depth of slots for deck longitudinals, if any, is to be deducted from the depth of cantilever beams. Where the webs are provided with horizontal stiffeners, the divided web depth may be used for d_c in the formula for t_2.

(6) Cantilever beams are to be provided with tripping brackets at an interval of about 3 m. Where the breadth of face bars of cantilever beams exceeds 180 mm on either side of the web, the tripping brackets are to support the face bars as well. And stiffeners are to be provided on the webs at every deck longitudinal adjacent to the root of cantilever beams and at alternate longitudinals elsewhere.

(7) Web plates adjacent to the inner edge of end brackets are to be specially reinforced.

Section 2 Web Frames

201. Construction and scantlings

Web frames supporting cantilever beams are to comply with the requirements in (1) to (7):

(1) The depth of web frames is not to be less than one-eighth of the length including the length of connections at both ends.

(2) The section modulus is not to be less than that obtained from the following formula. Where, however, a tween deck web frame in association with cantilever beam supporting the deck above is provided at the top of web frame, the value of the formula may be reduced to 60 %.

$$Z = 7.1 S l_1 \left(\frac{1}{2} b_1 h_1 + b_2 h_2 \right) \quad (\text{cm}^3)$$

where:

S = web frame spacing (m).

l_1 = horizontal distance from the end of supported cantilever beams to the inside of web frames (m).

b_1, b_2, h_1 and h_2 = as stipulated in **101.** (3) for the supported cantilever beams. Where, however, the deck is framed longitudinally and no deck transverse is provided between the cantilever beams, l_1 is to be substituted for b_1.

(3) The section modulus of tween deck web frames is to be in accordance with the requirements in (2), and additionally, it is not to be less than that obtained from the following formula:

$$Z = 7.1\, C_1 S l_1 \left(\frac{1}{2} b_1 h_1 + b_2 h_2 \right) \quad (\text{cm}^3)$$

where:

S, l_1, b_1, b_2, h_1 and h_2 = as stipulated in (2).

C_1 = coefficient obtained from the following formula:

$$C_1 = 0.5 \left(\frac{\frac{1}{2} b_1' h_1' + b_2' h_2'}{\frac{1}{2} b_1 h_1 + b_2 h_2} \right) + 0.15$$

b_1', b_2', h_1' and h_2' = b_1, b_2, h_1 and h_2 respectively stipulated in (2) in respect of cantilever beams to be provided below the web frames concerned.

(4) The web thickness is not to be less than that obtained from the following formulae, whichever is the greater:

$$t_1 = 9.5 \frac{C_2 S \left(\frac{1}{2} b_1 h_1 + b_2 h_2 \right)}{d_w} \cdot \frac{l_1}{l} + 1.5 \quad (\text{mm})$$

$$t_2 = 0.0075 d_w + 0.46 t_1 + 0.5 \quad (\text{mm})$$

where:

S, b_1, b_2, h_1, h_2 and l_1 = as stipulated in (2).

d_w = the smallest depth of web frames (mm). However, in the calculation of t_1, the depth of slots for side longitudinals, if any, is to be deducted from the web depth. Where the depth of webs is divided by vertical stiffeners, in the calculation of t_2, the divided depth may be used for d_w.

l = length of web frames including the length of connections at the both ends (m).

C_2 = coefficient given in **Table 10.9.1,** where, however, C_1 is as specified in (3).

Table 10.9.1 Coefficient C_2

Location		C_2
For hold web frames	Where web frame in association with cantilever beam supporting the deck above is provided at the top of them	0.9
	Elsewhere	1.5
For tween deck web frames		C_1 + 0.6

(5) Where the web frames supporting cantilever beams also support side longitudinals or side stringers, their scantlings are to comply with the following requirements in addition to those in **Ch 8, 402.**

(a) The section modulus is not to be less than that obtained from the formula in (2), in which is to be multiplied by the following coefficient:

Where tween deck web frame together with cantilever beam is provided above:

$$\alpha = 9.81\left\{\frac{0.05hl^2 + 0.09\,h_u l_u^2}{1.4\left(\frac{1}{2}b_1 h_1 + b_2 h_2\right)l_1}\right\} + 0.6$$

Elsewhere: $\alpha = 1.0$

where:

l = length of hold web frames including the length of end connections (m).

l_u = length of tween deck web frames provided directly above, including the length of end connections (m).

h = vertical distance from the middle of l to a point of $d + 0.038L$ above the top of keel (m).

h_u = vertical distance from the middle of l_u to a point to which h is to be measured (m). However, in case where the point is below the middle of l_u, h_u is to be taken as zero.

b_1, b_2, h_1, h_2 and l_1 = as given by (2).

(b) The web thickness is not to be less than that given by (4), in which the value of t_1 is to be increased by the amount obtained from the following formula:

$$\beta = 30\frac{Shl}{d_w} \quad \text{(mm)}$$

where:

S = web frame spacing (m).

h, l = as stipulated in (a) above.

d_w = as stipulated in (4).

(6) Tripping brackets are to be provided on the webs at an interval of about 3 m and stiffeners are to be provided at every side longitudinal at the ends of frames and at alternate longitudinals elsewhere.

(7) The web frames are to be effectively connected with those located beneath or solid floors so as to maintain strength continuity.

Section 3 Connection of Cantilever Beams to Web Frames

301. Connections

Cantilever beams and their supporting web frames are be effectively connected by brackets to meet the requirements in (1) to (4).

(1) The radius of curvature of the free edges of brackets is not to be less than the depth of cantilever beams at the toe of brackets.

(2) The thickness of brackets is not to be less than that of webs of cantilever beams or web frames, whichever is the greater.

(3) The brackets are to be sufficiently strengthened by stiffeners.

(4) The free edges of brackets are to have face bars of a sectional area not less than that of cantilever beams or web frames, whichever is the greater, and the face bars are to be connected with those of cantilever beams and web frames. ⚓

CHAPTER 10 BEAMS

Section 1 General

101. Standard camber

The standard camber of weather decks is 0.02 B at midship.

102. Connections of ends of beams

1. Longitudinal beams are to be continuous or to be connected with brackets at their ends in such a manner as to effectively develop the sectional area and to have sufficient strength to bending and tension.

2. Transverse beams are to be connected to frames by brackets.

3. Transverse beams provided at positions where frames are omitted in tween decks or superstructures, are to be connected to the side plating by brackets.

4. Transverse beams on boat decks, promenade decks, etc. may be connected by clips at their ends.

103. Continuity of strength

In parts where longitudinal beams are transformed to transverse beams, special care is to be taken to keep the continuity of strength.

Section 2 Deck Load

201. Value of h

1. Deck load h (kN/m^2) for decks intended to carry ordinary cargoes or stores is to be in accordance with the following (1) through (3):

(1) h is to be equivalent to the standards given by 7 times the tween deck height at side of the space (m), or 7 times the height from the deck concerned to the upper edge of hatch coaming of the above deck (m). However, h may be specified as the maximum design cargo weight per unit area of deck (kN/m^2). In this case, the value of h is to be determined by considering the loading height of cargo.

(2) Where timber and/or other cargoes are intended to be carried on the weather deck, h is to be the maximum design cargo weight per unit area of deck (kN/m^2), or the value specified in **Par 2,** whichever is the greater.

(3) Where cargoes are suspended from the deck beams or deck machinery is installed, h is to be suitably increased.

2. Deck load h (kN/m^2) for the weather deck is to be as specified in the following (1) to (4):

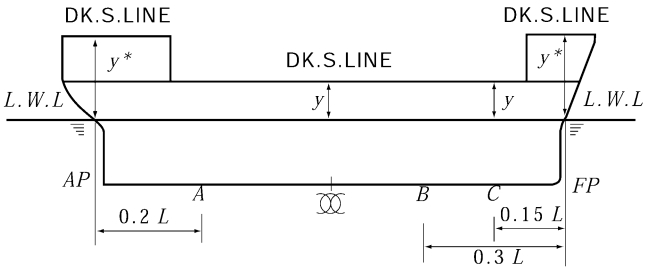
(1) For the freeboard decks, superstructure deck and top of deckhouses on the freeboard deck, h is not to be less than that obtained from the following formula:

$$h = a(0.067bL - y) \quad (\text{kN/m}^2)$$

where:

a, b = as given by **Table 10.10.1** according to the position of decks. However, where C_b is less than 0.7, value of b will be specially considered.

y = vertical distance from the load line to the weather deck at side (m), and y is to be measured at fore end for deck forward of 0.15 L abaft the fore end; at 0.15 L abaft the fore end for deck between 0.3 L and 0.15 L abaft the fore end; at midship for deck between 0.3 L abaft the fore end and 0.2 L afore the aft end; and at aft end for deck afterward of 0.2 L afore the aft end. (See **Fig 10.10.1**)



* In case of no superstructure, y is the distance to the upper deck.

Abaft A	y is measured at AP
Between A and B	y is measured at ⊗
Between B and C	y is measured at C
Afore C	y is measured at FP

Fig 10.10.1 Position of measuring y

(2) h for deck given in Column II in **Table 10.10.2** need not exceed that in Column I.
(3) Notwithstanding the provision in (1) and (2), h is not to be less than that obtained from the formulae given by **Table 10.10.2,** but to be taken as 12.8 where h for decks is less than 12.8.
(4) Value of h is to be in accordance with the discretion of the Society, where the ship has an unusual large freeboard.

Table 10.10.1 Values of a and b

Column	Position of Deck	a				b
		Deck plating	Beams	Pillars	Deck girders	
I	Forward of 0.15 L abaft the fore end	14.7	9.80	4.90	7.35	1.42
II	Between 0.1 L and 0. L abaft the fore end	11.8	7.85	3.90	5.90	1.20
III	Between 0. L abaft the fore end and 0. L afore the aft end	6.90	4.60	2.25	2.25(1), 3.45(2)	1.00
IV	Afterward of 0. L afore the aft end	9.80	6.60	3.25	4.90	1.15

NOTES:
(1) In case of longitudinal deck girders outside the line of hatchway opening of the strength deck in midship part of ship.
(2) In case of deck girders other than (1).

Table 10.10.2 Minimum value of h

<table>
<tr><td rowspan="2">Column</td><td rowspan="2">Position of Deck</td><td rowspan="2">h</td><td colspan="3">C</td></tr>
<tr><td>Beams</td><td>Pillars, Longitudinal and transverse deck girders</td><td>Deck Plating</td></tr>
<tr><td>I and II</td><td>Forward of 0.3 L abaft the fore end</td><td rowspan="2">$C\sqrt{L+50}$</td><td>2.85</td><td>1.37</td><td>4.20</td></tr>
<tr><td>III</td><td>Between 0.3 L abaft the fore end and 0.2 L afore the aft end</td><td>1.37</td><td>1.18</td><td>2.05</td></tr>
<tr><td>IV</td><td>Afterward of 0.2 L afore the aft end</td><td rowspan="2">$C\sqrt{L}$</td><td>1.95</td><td>1.47</td><td>2.95</td></tr>
<tr><td colspan="2">Second tier superstructure deck above the freeboard deck</td><td>1.28</td><td>0.69</td><td>1.95</td></tr>
</table>

3. For an enclosed part of superstructure decks and of top of deckhouses in accommodation or navigation spaces, at the first and second tier above the freeboard deck, h is to be 5.0 kN/m^2.

Section 3 Longitudinal Beams

301. Spacing

The standard spacing of the longitudinal beams is obtained from the following formula:

$$S = 2L + 550 \text{ (mm)}$$

302. Proportion

1. Longitudinal beams are to be supported by deck transverses of appropriate spacing. In midship part of the strength deck, the slenderness ratio of deck longitudinals is not to exceed 60. This requirement may, however, be suitably modified where longitudinal beams are given a sufficient strength to prevent buckling.

2. Flat bars used for longitudinals are not to be of depth thickness ratio exceeding 15.

303. section modulus

1. The section modulus of longitudinal beams outside the line of openings of the strength deck for the midship part is not to be less than that obtained from the following formula:

$$Z = 1.14 S h l^2 \text{ (cm}^3\text{)}$$

where:

S = spacing of longitudinal beams (m).

h = deck load specified in **Sec 2** (kN/m^2).

l = horizontal distance between bulkhead and deck transverse or between deck transverses (m).

2. The section modulus of longitudinal beams outside the line of openings of the strength deck at 0.1 L of fore end and after end of ship is not to be less than that obtained following formula:

$$Z = 0.43 S h l^2 \text{ (cm}^3\text{)}$$

where:

S, h, l = as specified in **Par 1.**

3. The section modulus of longitudinal beams outside the line of openings of the strength deck for the parts forward and afterward midship part of ship may be gradually reduced section modulus by **Par 1.** In no case, however, is the section modulus to be less than obtained from **Par 2** at 0.1 L of fore end and after end of ship.

4. The section modulus of longitudinal beams for the parts other than stipulated in **Pars 1** and **2** is not to be less than obtained from the formula in **Par 2.**

304. Deck transverses

In single deck ships, the deck transverses are to be provided in line with the solid floors in double bottom, and in two deck ships, the transverses are also to be provided in line with the solid floors in double bottoms as far as practicable.

Section 4 Transverse Beams

401. Arrangements

Transverse beams are to be provided on every frame.

402. Proportion

It is preferable that the length depth ratio of transverse beams be 30 or less at the strength deck, and 40 or less at effective decks (the decks below the strength deck which are considered as strength members in the longitudinal strength of hull) and superstructure decks as far as practicable.

403. Section modulus

The section modulus of transverse beams is not to be less than that obtained from the following formula:

$$Z = 0.43\,S h l^2 \quad (\text{cm}^3)$$

where:

S = spacing of transverse beams (m).

h = deck load specified in **Sec 2** (kN/m^2).

l = horizontal distance from the inner edge of beam brackets to the longitudinal deck girder, or between the longitudinal deck girders (m).

Section 5 Beams on Bulkhead Recesses and Others

501. Section modulus

The section modulus of beams at deck forming the top of bulkhead recesses, tunnels and tunnel recesses is not to be less than that obtained from the formula in **Ch 14, 207.**

Section 6 Beams on the Top of Deep Tanks

601. Section modulus

The section modulus of beams at deck forming the top of deep tanks is to be in accordance with this chapter, and not to be less than that obtained from the formula in **Ch 15, 203.,** taking the top of deck beams as the lower end of h and beams as stiffeners.

Section 7 Deck Beams Supporting Specially Heavy Loads

701. Reinforcement of deck beams

The deck beams supporting specially heavy loads or arranged at the ends of superstructures or deckhouses, in way of masts, windlasses and auxiliary machinery, etc. are to be properly reinforced by increasing the scantlings of beams, or by the additional deck girders or pillars.

Section 8 Beams on Deck Carrying Unusual Cargoes

801. Section modulus of beams

The section modulus of beams on deck subject to cargo loads which can not be treated as evenly distributed loads is to be determined taking account of load distribution for particular cargoes. ⚓

CHAPTER 11 DECK GIRDERS

Section 1 General

101. Application

Transverse deck girders supporting longitudinal deck beams and longitudinal deck girders supporting transverse deck beams are to be in accordance with the requirements in this chapter.

102. Arrangement

In way of the bulkhead recesses and the top of tanks, deck girders are to be arranged at an interval not exceeding 4.6 m as far as practicable.

103. Construction

1. Deck girders are to be composed of face plates provided along the lower edge.

2. Tripping brackets are to be provided at an interval of about 3 m and where the breadth of face plates exceeds 180 mm on either side of the girder, these brackets are to be so arranged as to support the face plates as well.

3. The thickness of face plates forming girders is not to be less than that of web plates and the width of the face plates is not to be less than that obtained from the following formula:

$$b = 2.7\sqrt{d_0 l} \quad \text{(mm)}$$

where:

d_0 = depth of webs (mm).

l = distance between the supports of girders (m). Where, however, effective tripping brackets are provided, they may be taken as supports.

4. The depth of girders is more than 2.5 times that of slots for beams, and is to be kept constant between two adjacent bulkheads for the longitudinal girders.

5. The girders are to have a sufficient rigidity to prevent excessive deflection of decks and excessive additional stresses in deck beams.

104. End connection

1. End connections of deck girders are to be in accordance with the requirements in **Ch 1, 304.**

2. Bulkhead stiffeners or girders at the ends of deck girders are to be suitably strengthened to support deck girders.

3. Longitudinal deck girders are to be continuous or to be effectively connected so as to maintain the continuity at ends.

Section 2 Longitudinal Deck Girders

201. Section modulus

1. The section modulus of longitudinal deck girders outside the lines of hatchway opening of the strength deck for midship part is not to be less than that obtained from the following formula:

$Z = 1.29l(bhl + kW)$ (cm^3)

where:

l = distance between the centres of pillars or from the centre of pillar to the bulkhead (m). Where the deck girder is effectively bracketed to bulkhead, l may be modified as specified in **Ch 1, 306.** (See **Fig 10.11.1**)

b = distance between the centres of two adjacent spans of beams supported by the girders or the frames (m). (See **Fig 10.11.1**)

h = deck load specified in **Ch 10, Sec 2** for the deck supported (kN/m^2).

W = deck load supported by the tween deck pillar (kN).

k = as specified in the following (a) and (b):

(a) Coefficient obtained from the following formula according to the ratio of the horizontal distance from the pillar or bulkhead supporting the deck girder to the tween deck pillar a (m) and l. (See **Fig 10.11.1**)

$$k = 12\frac{a}{l}\left(1 - \frac{a}{l}\right)^2$$

(b) Where there is only one tween deck pillar, k is to be obtained basing upon the smaller value of a. Where there are two or more tween deck pillars, a is to be measured from the same end of l for each tween deck pillar, and the sum of kW is to be used for the computation of the formula. In this case, the greater value between the sums of kW obtained basing upon a measured from each end of l is to be used.

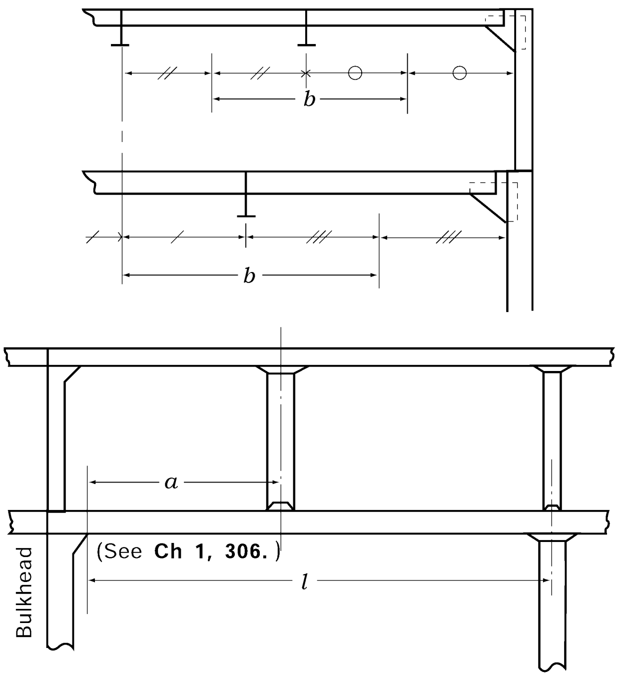


Fig 10.11.1 Measurement of b, l and a

2. The section modulus of longitudinal deck girders outside the lines of hatchway opening of the strength deck for the parts forward and afterward the midship part may be gradually reduced. In no case, however, is the section modulus to be less than that obtained from the following formula:

$$Z = 0.484l(bhl + kW) \quad (\text{cm}^3)$$

where: b, h, l, W, k = as specified in **Par 1.**

3. The section modulus of longitudinal deck girders for the parts other than stipulated in **Pars 1** and **2** is not to be less than obtained from the formula in **Par 2.**

4. Where a deck carrying cargoes which loads can not be treated as evenly distributed loads, deck load supported by a pillar is to be determined taking account of load distribution for particular cargoes. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **1.** to **3.** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillar (W).

202. Moment of inertia

It is advised that the moment of inertia of girders is not to be less than obtained from the following formula:

$$I = CZl \quad (\text{cm}^4)$$

where:

C = coefficient obtained from the following:

For deck girders arranged outside the line of deck openings of strength deck of midship part of ship ························· 1.6

For other deck girders ························· 4.2

Z = required section modulus of girders specified in **201.** (cm^3).

l = as specified in **201.1.**

203. Thickness of web plates

1. The thickness of web plates is not to be less than that obtained from the following formula:

$$t = 10S_1 + 1.5 \quad (\text{mm})$$

where:

S_1 = spacing of web stiffeners or depth of girders, whichever is the smaller (m).

2. The thickness of web plates at both end parts for 0.2 l is not to be less than that specified in **Par 1** and obtained from the following formula, whichever is the greater:

$$t = \frac{4.43bhl}{d_0} + 1.5 \quad (\text{mm})$$

where:

d_0 = depth of webs (mm).

b, h, l = as specified in **201. 1.**

3. The thickness of web plates provided in the deep tanks is to be 1 mm thicker than those obtained from the formulae in **Pars 1** and **2.**

Section 3 Transverse Deck Girders

301. Section modulus

1. The section modulus of transverse deck girders is not to be less than that obtained from the following formula:

$$Z = 0.484l(bhl + kW) \ (\text{cm}^3)$$

where:

l = distance between the centres of pillars or from the centre of pillar to the inner edge of beam bracket (m).

b = distance between the centres of two adjacent girders or bulkhead (m).

h = deck load specified in **Ch 10, Sec 2** (kN/m^2)

W, k = in accordance with **201.**

2. Where a deck carrying cargoes which loads can not be treated as evenly distributed loads, deck load supported by a pillar is to be determined taking account of load distribution for particular cargoes. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **1.** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillar (W).

302. Moment of inertia

It is advised that the moment of inertia of girders is not to be less than that obtained from the following formula:

$$I = 4.2Zl \ (\text{cm}^4)$$

where:

Z = required section modulus of girders specified in **301.** (cm^3).

l = as specified in **301.**

303. Thickness of web plates

The thickness of web plates is to be in accordance with the requirements in **203.**

Section 4 Deck Girders in Tanks

401. Section modulus

The section modulus of deck girders in tanks is to be in accordance with the requirements in **201.** or **301.**, and is to be in compliance with the requirements in **Ch 15, 204.1** as well.

402. Moment of inertia

The moment of inertia of girders is to be in accordance with the requirement in **Ch 15, 204. 2.**

403. Thickness of web plates

The thickness of web plates is to be in accordance with the requirements in **203.** or **303.** and is to be in compliance with the requirements in **Ch 15, 204. 3** as well.

Section 5 Hatch Side Girders

501. Deep coamings on decks

Where deep coamings are provided on decks as in the case of hatchway on weather deck, the horizontal coaming stiffener and the coaming up to its stiffener may be included in the calculation of the section modulus, subject to the approval by the Society.

502. Strength continuity

At hatchway corners, the face plates of hatch coamings and longitudinal deck girders or their extension parts and the face plates on both sides of hatch end girders are to be effectively connected so as to maintain the strength continuity.

Section 6 Hatch End Girders

601. Scantling

The scantlings of hatch end girders are to be in accordance with the requirements in **Sec 3** and **4.**
⚓

CHAPTER 12 PILLARS

Section 1 General

101. Pillars in tween decks

Pillars in tween decks are to be arranged directly above those under the deck, or effective means are to be provided for transmitting their loads to the supports below.

102. Pillars in holds

Pillars in holds are to be provided in line with the keelsons or double bottom girders or as close thereto as practicable, and the structure under pillars is to be of ample strength to provide effective distribution of the load.

103. End connection of pillars

The head and heel of pillars are to be secured by thick doubling plates and brackets as necessary. Where the pillars which may be subjected to tensile loads such as under bulkhead recesses, tunnel tops or deep tank tops, the head and heel of pillars are to be efficiently secured to withstand the tensile loads.

104. Reinforcements

Where the pillars are connected to the deck plating, the top of shaft tunnels, or the frames, these structures are to be efficiently strengthened.

Section 2 Scantling of Pillars

201. Sectional area

1. The sectional area of pillars is not to be less than that obtained from the following formula:

$$A = \frac{0.223\,W}{2.72 - \frac{l}{k_0}} \quad (\mathrm{cm}^2)$$

where:

l = distance from the top of inner bottom, deck or other structures on which the pillars are based to the underside of beam or girder supported by the pillars (m). (See **Fig. 10.12.1**)

k_0 = minimum radius of gyration of the section of pillars (cm).

W = deck load (kN) supported by the pillar obtained from the following formula:

$$W = kw_0 + Sbh \quad (\mathrm{kN})$$

where:

S = distance between the mid-points of two adjacent spans of girders supported by the pillars or the bulkhead stiffeners or bulkhead girders (m). (See **Fig. 10.12.1**)

b = mean distance between the mid-points of two adjacent spans of beams supported by the pillars or the frames (m). (See **Fig. 10.12.1**)

h = deck load specified in **Ch 10, Sec 2** for the deck supported ($\mathrm{kN/m^2}$).

w_0 = deck load supported by the upper tween deck pillar (kN)

k = as obtained from the following formula according to the ratio of the horizontal distance a_i (m) from the pillar to the tween deck pillar above to the distance l_i (m) from the pillar to the pillar or bulkhead. (See **Fig 10.12.1**)

$$k = 2\left(\frac{a_i}{l_j}\right)^3 - 3\left(\frac{a_i}{l_j}\right)^2 + 1$$

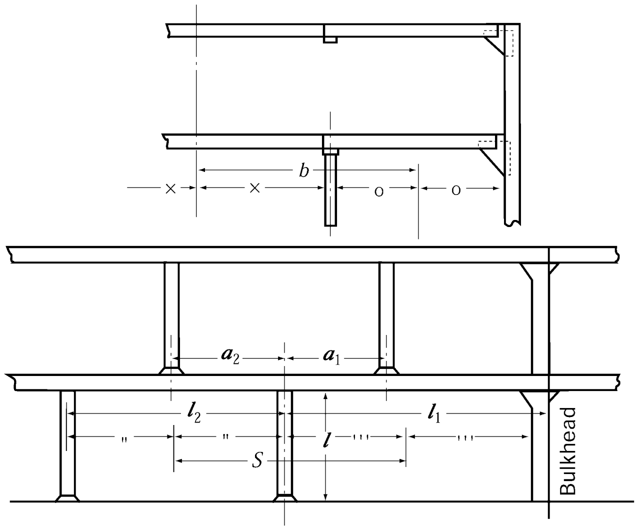


Fig 10.12.1 Measurement of S, b, l, etc.

2. Where there are two or more tween deck pillars provided on the deck girder supported by a line of lower pillars, the lower pillar is to be of the scantlings required by **Par 1,** taking kw_0 for each tween deck pillar provided on two adjacent spans supported by the lower pillars.

3. Where tween deck pillars are shifted from the lower pillars in athwartship direction, the scantlings of lower pillars are to be determined in accordance with the principle in **Pars 1** and **2.**

4. Where a deck carrying cargoes which loads can not be treated as evenly distributed loads, deck load supported by pillar is to be determined taking account of load distribution for particular cargoes. Where cargo loads can be treated as concentrated loads acting on specific points, the provisions of **1.** and **2.** above may be applied so that such concentrated loads are treated as deck loads supported by the upper tween deck pillar (w_o).

202. Thickness

1. The plate thickness of tubular pillars is not to be less than that obtained from the following formula. This requirement may, however, be suitably modified for the pillars provided in accommodation spaces.

$$t = 0.022 d_p + 3.6 \text{ (mm)}$$

where:

d_p = outside diameter of the tubular pillar (mm).

2. The thickness of web and flange plates of built-up pillars is to be sufficient for the prevention of local buckling.

203. Outside diameter of round pillars

The outside diameter of solid round pillars and tubular pillars is not to be less than 50 mm.

204. Pillars provided in deep tank

1. Pillars provided in deep tank are not to be tubular pillars.

2. The sectional area of pillars is not to be less than that specified in **201.** or obtained from the following formula, whichever is the greater.

$$a = 1.09\,Sbh \quad (\text{cm}^3)$$

where:

S, b = as specified in **201.**

h = 0.7 times the vertical distance from the top of deep tank to the point of 2 m above the top of over flow pipe (m).

205. Longitudinal bulkheads and others provided in lieu of pillars

The transverse bulkheads supporting longitudinal deck girders and the longitudinal bulkheads provided in lieu of pillars are to be stiffened in such a manner as to provide supports not less effective than required for pillars.

206. Casings provided in lieu of pillars

The casings provided in lieu of pillars are to be of sufficient scantlings to withstand the deck load and side pressure. ⚓

CHAPTER 13 ARRANGEMENTS TO RESIST PANTING

Section 1 General

101. Application

1. The requirements in this chapter are to apply to the bottom and the side constructions in way of both peaks.

2. The side frames are to be in accordance with the requirements in **Ch 8.**

102. Swash plates

In fore and after peaks to be used as deep tanks, effective swash plates are to be provided at the centre line of the ship or the scantlings of structural members are to be suitably increased.

103. Stringers fitted up with extremely small angles

Where the angle between the web of stringers and the shell plating is extremely small, the scantlings of stringers are to be suitably increased above the normal requirements and, where necessary, appropriate supports are to be provided to prevent tripping.

Section 2 Arrangements to resist Panting Forward the Collision Bulkhead

201. Constructions and arrangements

1. In the place forward the collision bulkhead, the deep centre girder or the longitudinal bulkhead at the centre line is to be provided.

2. In ships with transverse framing, the floor is to be arranged in every frame with sufficient depth and they are to be supported by the side girders provided at an interval of about 2.5 m and below. Frames are to be supported by the constructions specified in **Pars 5** to **7** of **202.** with the spacing of about 2.5 m.

3. In ships with longitudinal framing, bottom and side longitudinals are to be supported by bottom and side transverse girders having an interval of about 2.5 m. Bottom and side transverse girders are to be supported by side girders and side stringers, or cross tie provided at an interval of about 4.6 m, respectively. And side transverse girders are to be effectively connected with bottom transverse girders.

202. Transverse framing

1. The thickness of floors and centre girders is not to be less than that obtained from the following formula:

$$t = 0.045L + 4.5 \text{ (mm)}$$

2. The floors are to be of adequate depth and to be properly stiffened with stiffeners as may be required.

3. The upper edges of the floors and centre girders are to be properly stiffened.

4. The thickness of side girders is to be approximately equal to that of centre girders and side girders are to extend to such a proper height as may be required according to the height of floors.

5. Where the panting beams are provided at every frame together with perforated steel plates fitted up thereon from side to side, the scantlings of panting beams and steel plates are not to be less than that obtained from the following formulae:

Sectional area of panting beams : $A = 0.1L + 5$ (cm^2)

Thickness of steel plates : $t = 0.02L + 4.5$ (mm)

6. Where the side stringers are provided, their scantlings are not to be less than those obtained from the following formulae:

Depth : $d_1 = 200l$ (mm), $d_2 = 5.3L + 250$ (mm) or 2.5 times the depth of slot for the transverse frames(mm), whichever is the greatest.

Section modulus : $Z = 8Shl^2$ (cm^3)

Thickness of web : $t = 0.02L + 5.5$ (mm)

where:
S = breadth of area supported by the side stringer (m).
h = vertical distance from the centre of S to a point of 0.12 L (m) above the top of keel (m), but in no case is it to be less than 0.06 L (m).
l = distance between the supports of side stringers (m).

7. Where panting beams are provided on alternate frames and stringer plates which are connected to the shell plating are provided at each tier of panting beams, the scantling of panting beams and stringer plates are to comply with the following requirements.

Sectional area of panting beam : $A = 0.3L$ (cm^2)

Scantlings of stringer plates :
Breadth : $b = 5.3L + 250$ (mm)
Thickness : $t = 0.02L + 5.5$ (mm)

203. Longitudinal framing

1. Where the bottom transverses are supported along the centre line, their scantlings are not to be less than those obtained from the following formulae:
Web depth : $d_1 = 200l$ (mm) or $d_2 = 8.5L + 180$ (mm), whichever is the greater.

Section modulus : $Z = 1.2SLl^2$ (cm^3)

Web thickness : $t_1 = 5\frac{SLl}{d_0} + 1.5$ (mm), $t_2 = 0.6\sqrt{L} + 3$ (mm)

whichever is the greater.

where:
S = spacing of transverses (m).

l = length of transverses between the supporting points (m).

d_0 = depth of transverses subtracted by the depth of slot for longitudinals (mm).

2. The scantlings of centre girders are not to be less than those of bottom transverses specified in **Par 1.**

3. The scantlings of side transverses supporting longitudinals are not to be less than those obtained from the following formulae:

Web depth : $d_1 = 200 l_0$ (mm), $t_2 = 0.6\sqrt{L} + 3$ (mm) or 2.5 times the depth of slots for longitudinals (mm), whichever is the greatest.

Section modulus : $Z = 8 S h l_0^2$ (cm^3)

Thickness of web : $t_1 = 42 \dfrac{S L l_0}{d_0} + 1.5$ (mm), $t_2 = 0.02L + 5.5$ (mm)

whichever is the greater.

where:

S = spacing of transverses (m).

d_0 = as specified in **Par 1.**

h = vertical distance from the centre of l_0 to a point of 0.12 L (m) above the top of keel (m), but in no case is it to be less than 0.06 L (m)

l_0 = length of side transverses between the supporting points (m).

4. Side transverses are to be provided with tripping brackets at an interval of about 3 m and with stiffeners on webs at every longitudinals.

5. The scantlings of side stringers which support side transverses are not to be less than those obtained from the following formulae:

Web depth : $d_1 = 200 l_1$ (mm) or $d_2 = 5.3L + 250$ (mm), whichever is the greater.

Section modulus : $Z = 4 S h l_0 l_1$ (cm^3)

Thickness of web:

$$t_1 = 31 \frac{S h l_1}{d_0} + 1.5 \text{ (mm)}$$

$$t_2 = 0.02L + 5.5 \text{ (mm)}$$

whichever is the greater.

where:

S = breadth of area supported by the stringer (m).

h = vertical distance from the centre of S to a point of 0.12 L (m) above the top of keel (m), but in no case is it to be less than 0.06 L (m).

l_0 = as stipulated in **Par 3.**

l_1 = length of side stringers (m).

d_0 = depth of side stringers subtracted by the depth of slot (m).

6. The sectional area of cross ties supporting the transverses is not to be less than that obtained from the following formulae:

Where l/k is 0.6 and above : $A = \dfrac{0.77Sbh}{1 - 0.5\dfrac{l}{k}}$ (cm^2)

Where l/k is less than 0.6 : $A = 1.1Sbh$ (cm^2)

where:

S = spacing of transverses (m).

b = breadth of area supported by the cross ties (m).

h = vertical distance from the centre of b to a point of 0.12 L (m) above the top of keel (m), but in no case is it to be less than 0.06 L (m).

l = length of cross ties (m).

k = minimum radius of gyration of cross ties, obtained from the following formula (cm).

$$k = \sqrt{\frac{I}{A}}$$

I = the least moment of inertia of the cross ties (cm^4).

A = sectional area of the cross ties (cm^2).

(1) Cross ties are to be effectively connected to the transverses by brackets or other suitable arrangements and the transverses are to be provided with tripping brackets in way of the cross ties.

(2) Where the breadth of face plate of cross ties on either side of the web exceeds 150 mm, stiffeners are to be provided on the webs and so arranged as to support the face plate at a suitable interval.

Section 3 Arrangements to resist Panting Abaft Aft Peak Bulkhead

301. Floors

The scantlings and arrangements of floors in after peak are to be in accordance with the requirements in **202.**

302. Frames

Where the length of girth between the supporting points of frames exceeds 2.5 m, the scantlings of frames are to be increased or suitably strengthened to give adequate stiffness to the structure.

303. Other construction members

Where the constructions in after peak are in compliance with the requirements for fore peak in **Sec 2,** the scantlings of transverses, stringers and struts may be 0.67 times the values specified in **Sec 2.** ⚓

CHAPTER 14 WATERTIGHT BULKHEADS

Section 1 Arrangement

101. Collision bulkheads

1. All ships are to have a collision bulkhead, at a position not less than 0.05 L_f, but not more than 0.08 L_f or 0.05 $L_f + 3$ m, whichever greater except where the larger distance be accepted by the Society due to a special reason as to structure, from the forward terminal of the length for freeboard. However, where any part of the ship below the waterline at 85 % of the least moulded depth extends forward beyond the forward terminal of the length for freeboard, the above-mentioned distance is to be measured from a point either:

(a) at the mid-length of such extension; or
(b) at a distance 0.015 L_f forward from the abovementioned forward terminal;
whichever gives the smaller measurement.

2. The bulkhead may have steps or recesses within the limits specified in the above **Par 1.**

3. Arrangement of collision bulkhead in a ship provided with bow door is to be at the discretion of the Society. However, where a slopping ramp forms a part of the collision bulkhead above the freeboard deck, the part of the ramp which is more than 2.3 m above the freeboard deck may extend forward of the limit specified in the above **Par 1.** In this case, the ramp is to be weathertight over its complete length.

102. After peak bulkheads

1. All ships are to have an after peak bulkhead situated at a suitable position.

2. The stern tube is to be enclosed in a watertight compartment by the after peak bulkhead or other suitable arrangements.

103. Machinery space bulkheads

1. A watertight bulkhead is to be provided at each end of the machinery space.

2. Where the machinery space is arranged in aft end of ship, the after side bulkhead of machinery space among the bulkheads in **Par 1** may be regarded as an aft peak bulkhead of ship.

104. Hold bulkheads

1. Cargo ships, of the ordinary type and of 67 m or above in length are to have hold bulkheads in addition to the bulkheads specified in **101.** to **103.** at a reasonable interval so that the total number of the watertight bulkheads may not be less than that given by **Table 10.14.1.**

2. The arrangement of bulkheads may not apply the requirement in **Par 1** subject to the approval by the Society.

Table 10.14.1 Number of watertight bulkheads

Length of ships (m)	Total number of bulkheads	
	Ships with machinery space at aft end of ship	Ships with machinery space other than at aft end of ship
$67 \le L < 87$	4	4
$87 \le L < 90$	4	5

105. Height of watertight bulkheads

The watertight bulkheads required in **101.** to **104.** are to extend to the freeboard deck with the following exceptions:

(1) A watertight bulkheads in way of the raised quarter or the sunken forecastle deck is to extend up to the said deck.

(2) Where a forecastle having opening without closing appliances led to a space below the freeboard deck, or a long forecastle is provided, the collision bulkhead is to extend to the superstructure deck and to be made weathertight. However, where the extension is located within the limits specified in **101.** and the part of the deck which forms the step is made effectively weathertight, it need not be fitted directly above the bulkhead thereunder.

(3) The aft peak bulkhead may terminate at a deck below the freeboard deck and above the load line, provided that this deck is made watertight to the stern of the ship.

106. Construction

1. Where the watertight bulkheads required in **101.** to **105.** are not extended up to the strength deck, deep webs or partial bulkheads situated immediately or nearly above the main watertight bulkheads are to be provided so as to maintain the transverse strength and stiffness of the hull.

2. Where the length of a hold exceeds 30 m, suitable means are to be provided so as to maintain the transverse strength and stiffness of the hull.

107. Chain lockers

1. Chain lockers located abaft the collision bulkhead or in forepeak tanks are to be watertight and to be provided with means for effective drainage by pumps.

2. Chain lockers are to be subdivided by centre line screen walls.

Section 2 Construction

201. Thickness

The thickness of bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.2S\sqrt{h} + 1.5 \text{ (mm)}$$

where:

S = spacing of stiffeners (m).

h = vertical distance from the lower edge of plate to the bulkhead deck at centre (m), but in no case is it to be less than 3.4 m.

202. Increase of thickness

1. The thickness of lowest strake of plating is not to be less than obtained from the above formula given in **201.** plus 1 mm.

2. The lowest strake of bulkhead plating is to extend at least 610 mm above the top of inner bottom plating in way of double bottom or 915 mm above the top of keel in way of single bottom. Where the double bottom is provided only on one side of the bulkhead, the extension of the lowest strake is to be of the greater value among the two cases above.

3. The bulkhead platings in way of bilge wells are to be at least 2.5 mm thicker than given by **201.**

4. The bulkhead plating is to be doubled or increased in thickness in way of stern tube opening, notwithstanding the requirements in **201.**

203. Stiffeners

The section modulus of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$Z = CShl^2 \ (\text{cm}^3)$$

where :

l = span measured between the adjacent supports of stiffeners including the length of connection (mm). Where girders are provided, it is the distance from the heel of end connection to the first girder or the distance between the girders.

S = spacing of stiffeners (m).

h = vertical distance measured from the midpoint of l for vertical stiffeners, and from the midpoint of distance between the adjacent stiffeners for horizontal stiffeners, to the top of bulkhead deck at the centre line of ship (mm). Where the vertical distance is less than 6.0 m, h is to be taken as 1.2 m greater than 0.8 times the vertical distance.

C = coefficient given in **Table 10.14.2** according to the type of end connection.

204. Collision bulkheads

For collision bulkheads, the plate thickness and section modulus of stiffeners are not to be less than those specified in **201.** and **203.** taking h as 1.25 times the specified height.

205. Girders

1. The section modulus of girders supporting bulkhead stiffeners (hereinafter referred to as girder) is not to be less than that obtained from the following formula:

$$Z = 4.75\,Shl^2 \ (\text{cm}^3)$$

where:

S = breadth of the area supported by the girder (m).

h = vertical distance measured from the midpoint of l for vertical girders, and from the mid-point of S for horizontal girders, to the top of bulkhead deck at the centre line of ship (m). Where the vertical distance is less than 6.0 m, h is to be taken as 1.2 m greater than 0.8 times the vertical distance.

l = span measured between the adjacent supports of girders (m).

2. The moment of inertia of girders is not to be less than obtained from the following formula. In no case is the depth of girders to be less than 2.5 times the depth of slots for stiffeners.

$$I = 10\,hl^4 \ (\text{cm}^4)$$

where:

h, l = as specified in **Par 1.**

Table 10.14.2 Value of C

<table>
<tr><td rowspan="6">Vertical Stiffener</td><td rowspan="2">Upper end / Lower end</td><td rowspan="2">Lug-connection of supported by horizontal girders</td><td colspan="2">Connection</td><td rowspan="2">End of stiffener unattached</td></tr>
<tr><td>Type A</td><td>Type B</td></tr>
<tr><td>Lug-connection or supported by horizontal girders</td><td>2.80</td><td>2.80</td><td>3.22</td><td>3.78</td></tr>
<tr><td>Bracketed</td><td>2.24</td><td>2.24</td><td>2.52</td><td>2.80</td></tr>
<tr><td>Only the web of stiffener attached at end</td><td>3.22</td><td>3.22</td><td>3.78</td><td>4.48</td></tr>
<tr><td>End of stiffener unattached</td><td>3.78</td><td>3.78</td><td>4.48</td><td>5.60</td></tr>
<tr><td rowspan="3">Horizontal Stiffener</td><td>One end / The other end</td><td colspan="3">Lug-connection, bracketed or supported by vertical girders</td><td>End of stiffener unattached</td></tr>
<tr><td>Lug-connection bracketed or supported by vertical girders</td><td colspan="3">2.80</td><td>3.78</td></tr>
<tr><td>End of stiffener unattached</td><td colspan="3">3.78</td><td>5.60</td></tr>
</table>

NOTE:

1. "Lug-connection" is such a connection as both web and face bar of stiffener are effectively attached to the bulkhead plating, decks or inner bottoms which are strengthened by effective supporting members on the opposite side of plating.
2. "Connection-Type A" of vertical stiffeners is a connection by bracket to the longitudinal members or to the adjacent members, in line with the stiffeners, of the same or larger sections. (See **Fig 10.14.1** (a))
3. "Connection-Type B"of vertical stiffeners is a connection by bracket to the transverse members such as beams, or other connections equivalent to the connections mentioned above. (See **Fig 10.14.1** (b))

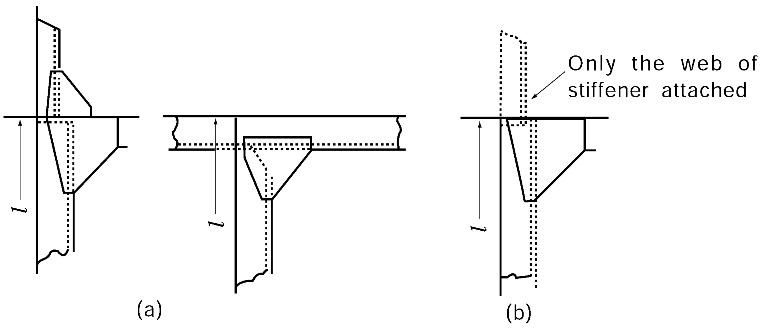


Fig 10.14.1 Types of end connection

3. The thickness of web plates is not to be less than that obtained from the following formula;

$$t = 0.01S_1 + 1.5 \text{ (mm)}$$

where:

S_1 = spacing of web stiffeners or depth of girders, whichever is the smaller (mm).

4. Tripping brackets are to be provided at an interval of about 3 m and where the breadth of face plates exceeds 180 mm on either side of the girder, these brackets are to be so arranged as to support the face plates.

206. Strengthening of bulkhead plating, deck plating, etc.

Platings of bulkheads, decks, inner bottoms, etc. are to be, if necessary, strengthened at the location of the end brackets of stiffeners and the end of girders.

207. Bulkhead recesses

1. In way of bulkhead recesses, beams are to be provided at every frame and under the upper bulkhead in accordance with the requirements in **Ch 10, 403.** and **Ch 14, 203.** taking the beam spacing as the stiffener spacing, Where the lower end of upper bulkhead is specially strengthened, the beam under the upper bulkhead may be dispensed with.

2. The thickness of deck plating in way of bulkhead recesses is to be at least 1 mm greater than that given by **201.,** regarding the deck plating as bulkhead plating and the beams as stiffeners respectively. In no case is the thickness to be less than that required for deck plating in that location.

3. The thickness of pillars supporting bulkhead recesses is to be determined taking account of the water pressure which might be applied on the upper surface of recesses, and their end connections are to be sufficient to withstand the water pressure which might be applied on the under surface.

208. Construction of bulkheads in way of watertight doors

Where stiffeners are cut or the spacing of stiffeners is increased in order to provide the watertight door in the bulkhead, the opening is to be suitably framed and strengthened as to maintain the full strength of the bulkhead. In no case are the door frames to be considered as stiffeners.

Section 3 Watertight Doors

301 General

1. Any access openings, doors, manholes or ducts for ventilation, etc. are not to be cut in the collision bulkhead below freeboard deck. The number of openings in collision bulkheads above the freeboard deck is to be kept to a minimum as possible and all such openings are to be provided with weathertight means of closing.

2. Watertight doors(or access hatch cover) are to be provided for all access openings in the watertight bulkheads or openings to ensure the watertight integrity of the inner decks in accordance with the requirements in the following **302.** to **305.**

302. Type of watertight doors

1. Watertight doors are to be of sliding type. Hinged or rolling type may, however, be accepted having regard to the position or the service condition of the door.

2. Notwithstanding the provisions in **1.** above, where watertight door is as small as crew can pass, the watertight door may be of hinged type or rolling type, except where the doors are required to be capable of being closed remotely in accordance with **304. 2.**

3. Notwithstanding the provisions in **1.** above, watertight doors in large cargo hold division may be of a type other than sliding type provided that such doors are permanently closed at sea.

4. Doors which are closed by dropping or by the action of a dropping weight are not permitted.

303. Strength and watertightness

1. Watertight doors are to be of ample strength and watertightness for water pressure to a head up to the bulkhead deck, and door frames are to be effectively secured to the bulkheads. Where deemed necessary by the Society, watertight doors are to be tested by water pressure before they are fitted.

2. Where watertight doors are provided in cargo spaces, such doors are to be protected against damages due to cargoes, etc. by suitable means.

304. Control

1. All watertight doors, except those which are to be permanently closed at sea, are to be capable of being opened and closed by hand locally, from both sides of the doors, with the ship listed of 30 degrees to either side.

2. In addition to the requirements of **1.** above, watertight doors which are used at sea or normally open at sea, are to be capable of being remotely closed by power from the navigation bridge.

3. It is not to be possible to remotely open any watertight door. In addition, watertight doors which are applying to the provisions of **302. 3**, are not to be remotely controlled.

305. Indication

1. Watertight doors, except those permanently closed at sea, are to be provided with position indicators showing whether the doors are opened or closed at all operating positions.

2. In addition to the requirements of **1.** above, for watertight doors which are to be capable of being remotely closed, an indication is to be placed locally showing that the door is in remote control mode.

306. Alarms

Watertight doors which are capable of being remotely closed are to be provided with an audible alarm which will sound at the door position whenever such a door is remotely closed.

307. Source of power

1. The remote controls, indications and alarms required in **404.** to **406.** are to be operable in the event of main power failure.

2. Electrical installations for devices specified in **1.** except water-proof type approved by the Society are to be not provided with under freeboard deck.

3. Cables for devices specified in **1.** are to comply with the requirements of **Pt. 6 Ch 1, Sec 4** of the Rules.

308. Notices

1. Watertight doors which are to be normally closed at sea are to have notices fixed to both sides of the doors stating "**To be kept closed at sea**".

2. Watertight doors which are to be permanently closed at sea are to have notices fixed to both sides stating "**Not to be opened at sea**". Such doors which are accessible during the voyage are to be fitted with a device which prevents opening.

309 Sliding doors

1. Sliding watertight doors are to be capable of being operated from an accessible position above the bulkhead deck and are to have an index at the operating position showing whether the door is open or closed, This remote control of the door may, however, be omitted where the Society is satisfied with such an arrangement having regard to the service condition of the door.

2. Where the above control means is operated by rods, the lead of operating rods is to be as direct as possible and the screw is to work in a nut of gun-metal or other approved material.

3. Sliding doors controlled from remote positions are also to be capable of being operated at the position of the door.

4. The frames of vertical sliding watertight doors are to have no groove at the bottom in which dirt might lodge and prevent the door from closing.

310. Hinged and rolling doors

1. For hinged and rolling watertight doors, the hinge pins and the wheel axle of these doors are to be of gun-metal or other approved materials.

2. Hinged and rolling watertight doors except those are to be permanently closed at sea, are to be of quick acting or single acting type which is capable of being closed and secured from both sides of the doors. ⚓

CHAPTER 15 DEEP TANKS

Section 1 General

101. Definition

The deep tank is a tank used for carriage of water, fuel oil and other liquids, forming a part of the hull in holds. The deep tanks used for carriage of oils are designated as “deep oil tanks”, if necessary.

102. Application

1. Peak tank bulkheads and boundary bulkheads of deep tank (excluding the deep tanks for carriage of oils having flashpoint below 60°C) are to be constructed in accordance with the requirements in this chapter. Where the bulkhead of deep tank partly serves as a watertight bulkhead, the part of the bulkhead is to be in accordance with the requirements in **Ch 14.**

2. The requirements in **Ch 23** and **24** are to be applied to the bulkheads of the deep tanks for carriage of oils having a flashpoint below 60°C, in addition to those in this chapter.

103. Divisions in tanks

1. Deep tanks are to be of proper size and to be provided with such longitudinal watertight divisions as necessary to meet the requirements for stability in service conditions as well as while the tanks are being filled or discharged.

2. Tanks for fresh water or fuel oil or those which are not intended to be kept entirely filled in service conditions are to have additional divisions or deep wash plates as necessary to minimize the dynamic forces acting on the structure.

3. Where it is impracticable to comply with the requirements in **Par 2,** the scantlings required in this chapter are to be properly increased.

4. Longitudinal watertight divisions which will be subjected to pressure from both sides, in tanks which are to be entirely filled or emptied in service conditions, may be of the scantlings required for ordinary watertight bulkheads by **Ch 14.** In such cases, the tanks are to be provided with deep hatches, etc., fitted with inspection plugs in order to ensure that the tanks are kept full in service conditions.

Section 2 Bulkheads of Deep Tanks

201. Application

The construction of bulkheads and decks forming boundaries of deep tanks is to be in accordance with the requirements in **Ch 14,** unless otherwise specified in this chapter.

202. Bulkhead plates

The thickness of deep tank bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.6S\sqrt{h} + 2.5 \text{ (mm)}$$

where :

S = spacing of stiffeners. (m).

h = distance given below, whichever is the greater:

(1) Vertical distance measured from the lower edge of plate to the midpoint of the distance between the top of tanks and the top of overflow pipes (m). For bulkheads of large tanks, additional water pressure is to be considered.
(2) 0.7 times the vertical distance measured from the lower edge of plate to the point of 2.0 m above the top of overflow pipes (m).

203. Bulkhead stiffeners

The section modulus of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$Z = CShl^2 \quad (\text{cm}^3)$$

where:

S, l = as specified in **Ch 14, 203.**

h = vertical distance given below, whichever is the greater, the lower end being regarded as the midpoint of l for vertical stiffeners and as the midpoint of distance between the adjacent stiffeners for horizontal stiffeners.

(1) Vertical distance measured from the lower end to the mid-point of the distance between the top of tanks and the top of overflow pipes (m).
For bulkhead stiffeners of large tanks, additional water pressure is to be considered.
(2) 0.7 times the vertical distance measured from the lower end to the point of 2.0 m above the top of overflow pipes (m).

C = coefficient given in **Table 10.15.1** according to the type of end connections.

Table 10.15.1 Value of C

The other end of stiffeners \ One end of stiffeners	Connection by hard bracket	Connection by soft bracket	Supported by girders or lug connection	Snip
Connection by hard bracket	4.90	8.05	5.95	9.10
Connection by soft bracket	8.05	5.95	9.10	8.05
Supported by girders or lug connection	5.95	9.10	7.00	10.50
Snip	9.10	8.05	10.50	10.50

NOTES:
1. Connection by hard bracket is a connection by bracket to the double bottoms or to the adjacent members, such as longitudinals or stiffeners in line, of the same or larger sections, or a connection by bracket to the equivalent members mentioned above. (See **Fig. 10.14.1** (a)).
2. Connection by soft brackets is a connection by bracket to the transverse members such as beams or equivalent thereto. (See **Fig. 10.14.1** (b)).

204. Girders supporting bulkhead stiffeners

1. The section modulus of girders supporting bulkhead stiffeners (hereinafter referred to as girder) is not to be less than that obtained from the following formula:

$$Z = 7.13\,Shl^2 \quad (\text{cm}^3)$$

where:

S = breadth of the area supported by the girders (m).

h = vertical distance measured from the midpoint of S for horizontal girders, and from the mid-point of l for vertical girders, to the top of h specified in **203.** (m).

l = span specified in **Ch 14, 203.** (m).

2. The moment of inertia of girders is not to be less than that obtained from the following formula. In no case is the depth of girders to be less than 2.5 times the depth of slots for stiffeners.

$$I = 30hl^4 \quad (\text{cm}^4)$$

where:

h, l = as specified in **Par 1.**

3. The thickness of plates of web parts is not to be less than that obtained from the following formula:

$$t = 0.01S_1 + 2.5 \quad (\text{mm})$$

where:

S_1 = spacing of web stiffeners or the depth of girders, whichever is the smaller (mm).

205. Cross ties

1. Where efficient cross ties are provided across deep tanks connecting girders on each side of the tanks, the span of girders specified in **204.** may be measured between the end of girder and the centre line of cross tie or between the centre lines of adjacent cross ties.

2. The sectional area of cross ties is not to be less than that obtained from the following formula:

$$A = 1.3\,Sb_s h \quad (\text{cm}^2)$$

where:

S, h = as specified in **204.**

b_s = breadth of the area supported by the cross ties (m).

3. The end of cross ties is to be bracketed to girders.

206. Top and bottom construction

The scantlings of the members forming the top or the bottom of deep tanks are to be in accordance with the requirements in this chapter, regarding the members as the members forming the deep tank bulkheads at the location. In no case are they to be less than required for the deck plating or the bottom plating at the location. For top plating of deep tanks the thickness of plates is to be at least 1 mm greater than the thickness specified in **202.**

207. Scantling of members not in contact with sea water

The thickness of plates of bulkheads and girders which are not in contact with sea water in service conditions may be reduced from the requirements in **202.** and **204.** by the values given below:

For the plates of which only one side is in contact with sea water ···················· 0.5 mm

For the plates of which neither side is in contact with sea water ······················· 1.0 mm

However, bulkhead plates in way of the location such as bilge wells are to be regarded as the plates in contact with sea water.

Section 3 Fittings of Deep Tanks

301. Limbers and air holes

Limbers and air holes are to be cut suitably in the structural members to ensure that air or water does not remain stagnated in any part of the tank.

302. Drainage

Efficient arrangement is to be made for draining bilge water on the top of deep tanks.

303. Inspection plugs

The inspection plugs provided on deep tank tops as required in **103.4** are to be located in readily accessible positions, and the filling of water is to be done leaving the plugs open as far as possible.

304. Cofferdams

1. The following dedicated tanks are to be separated from adjacent tanks of other uses by cofferdams. However, these cofferdams may be omitted provided that the common boundaries of lubricating oil and fuel oil tank have full penetration welds.

(1) Fuel oil
(2) Lubrication oil
(3) Vegetable oil
(4) Fresh water

2. The cofferdams specified in **Par 1** are to be provided with the air pipes to comply with the requirements in **Pt 5, Ch 6, 201.** and with the manholes of adequate size which are well accessible.

3. Crew spaces and passenger spaces are not to be directly adjacent to the tanks for carriage of fuel oil. Such compartments are to be separated from the fuel oil tanks by cofferdams which are well ventilated and are not less than 600 mm in width for easy access. Where the top of fuel oil tanks has no opening and is coated with incombustible coverings of 38 mm and over in thickness, the cofferdam between such compartments and the top of fuel oil tanks may be omitted. ⚓

CHAPTER 16 SUPERSTRUCTURES AND DECKHOUSES

Section 1 General

101. Application

1. All ships are to have forecastles except where an adequate bow freeboard is deemed sufficient by the Society.

2. The construction and scantlings of superstructures and deckhouses are to be in accordance with the requirements in the relevant chapters in addition to this chapter.

3. The requirements in this chapter are prescribed for the superstructures and deckhouses up to the third tier above the freeboard deck. As for the superstructures and deckhouses above the third tier, the construction and scantlings thereof are to be as deemed appropriate by the Society.

4. As for the superstructures and deckhouses in ships with specially large freeboard, the construction of bulkhead may be suitably modified subject to the approval by the Society.

Section 2 Construction

201. Head of water

1. The head of water for the calculation of the scantlings of superstructure end bulkheads and boundary wall of deckhouses is not to be less than that obtained from the following formula:

$$h = ac(0.067bL - y) \text{ (m)}$$

where:

a = as given in **Table 10.16.1.**

b = as given in **Table 10.16.2.**

c = as given in **Table 10.16.3.**

y = vertical distance from the summer waterline to the mid-point of span of stiffener in case where the scantlings of stiffeners are determined, and to the mid-point of plate in case where the thickness of bulkhead plating is determined (m).

2. The head of water for the calculation of the scantlings of superstructure end bulkheads and boundary walls of deckhouses is not to be less than obtained from the formulae in **Table 10.16.4,** irrespective of the provisions in **Par 1.**

Table 10.16.1 Values of a

Bulkhead and wall	Location	a
Exposed front bulkhead and wall	First tier	$\frac{L}{120}+2.0$
	Second tier	$\frac{L}{120}+1.0$
	Third tier	$\frac{L}{150}+0.5$
Side Walls and protected end bulkheads and front walls of the all tier		
Aft bulkhead and wall	Afterward of the midship	$\frac{L}{1000}-0.8\frac{x}{L}+0.7$
	Forward of the midship	$\frac{L}{1000}-0.4\frac{x}{L}+0.5$

L = length of ship (m).
x = distance from the bulkhead or end wall to the after perpendicular, or distance from the mid-point of side wall to the after perpendicular (m). Where, however, the length of side wall exceeds $0.15L$, the side wall is to be nearly equally subdivided as not to exceed $0.15L$ and the distance from the mid-point of the subdivision to the after perpendicular is to be taken.

Table 10.16.2 Values of b

$\frac{x}{L}$	b
$\frac{x}{L}<0.45$	$\left(0.5-1.1\frac{x}{L}\right)^2+1.0$
$\frac{x}{L}\geq 0.45$	$1.5\left(1.1\frac{x}{L}-0.5\right)^2+1.0$

L, x = as specified in **Table 10.16.1.**

Table 10.16.3 Values of c

Locations	c
End bulkheads of superstructures	1.0
Boundary walls of deckhouses	$0.7\frac{b'}{B'}+0.3$ However, $\frac{b'}{B'}$ is less than 0.25, b'/B' is to be taken as 0.25

b' = breadth of deckhouse at the position under consideration (m).
B' = breadth of ship on the exposed deck at the position under consideration (m).

Table 10.16.4 Head of water, h (m)

Length of ship (m)	Exposed front bulkhead of the 1st tier superstructure	Others
$L \leq 50$	3.0	1.5
$50 < L < 90$	$\frac{L}{100}+2.5$	$\frac{L}{200}+1.25$

202. Thickness of bulkhead and wall platings

1. The thickness of unprotected front bulkhead and side wall plating at the first and second tier for ships not less than 50 m in length, is not to be less than obtained from the following formula, however, it is not to be less than that obtained from the formula in **Par 2.**

$t = 3S\sqrt{h}$ (mm)

where:

h = head of water specified in **201.** (m).

S = spacing of stiffeners (m).

2. The thickness of bulkhead and wall platings other than that specified in **Par 1** is not to be less than that obtained from the following formulae or 5 mm, whichever is the greater.

For the first tier: $t = \frac{L}{100} + 4.0$ (mm)

For others: $t = \frac{L}{100} + 3.0$ (mm)

203. Stiffeners

1. The section modulus of stiffeners on superstructure end bulkheads and deckhouse boundary walls is not to be less than that obtained from the following formula:

$Z = 3.5Shl^2$ (cm^3)

where:

S, h = as specified in **202.**

l = tween deck height (m). Where, however, l is less than 2 m, l is to be taken as 2 m.

2. Both ends of stiffeners on the exposed bulkheads of superstructures and boundary walls of deckhouses are to be connected to the deck by welding except where otherwise approved by the Society.

Section 3 Access Openings in Superstructure End Bulkheads

301. Closures for access openings.

1. The doors to be provided on the access openings in the end bulkheads of enclosed superstructures and deckhouses protecting companion ways giving access to the spaces under the freeboard deck or the spaces in the enclosed superstructures are to be in accordance with the requirements in (1) through (5) :

(1) The doors are to be made of steel or other equivalent materials and to be permanently and rigidly fitted up to the bulkheads.
(2) The doors are to be rigidly constructed, to be of equivalent strength to that of intact bulkhead and to be weathertight when closed.
(3) The means for securing weathertightness are to consist of gaskets and clamping devices or other equivalent devices and to be permanently fitted up to the bulkhead or the door itself.
(4) The doors are to be operated from the both sides of the bulkheads.
(5) Hinged doors are, as a rule, to open outward.

2.

(1) The height of sills of access openings specified in **Par 1** is not to be less than 380 mm above the upper surface of the deck except where higher sills may be required when deemed necessary by the Society.

(2) In principle, portable sills are not permitted.

3. Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height, are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway, provided that the height of the deckhouse is at least the standard height of a superstructure. Openings in the top of the deckhouse on a deckhouse of less than a standard superstructure height may be treated in a similar manner. ⚓

CHAPTER 17 MACHINERY SPACES AND ENGINE CASINGS

Section 1 General

101. Application

The construction of machinery space in addition to this chapter is to be in accordance with the requirements in relevant chapters.

102. Compensation

Machinery space is to be sufficiently strengthened by means of web frames, strong beams and pillars or other suitable arrangements.

103. Construction

Machineries, shafting, etc are to be efficiently supported and the adjacent structures are to be adequately stiffened.

104. Twin screw ships and others of high power

In twin screw ships and others of high power, the structure and attachments of the seatings are to be specially strengthened in relation to the proportion of the height of engines to their length or width, weight, power, type, etc.

Section 2 Main Engine Foundations

201. Ships with single bottoms

1. In ships with single bottoms, the main engines are to be seated upon thick rider plates laid across the top of deep floors or heavy foundation girders efficiently bracketed and stiffened and having sufficient strength in proportion to the power and size of engines.

2. Girder plates are to be provided beneath the main lines of bolting of main engines and the holding down bolts are to pass through the rider plates on the girder plates.

3. In ships having the engine on the centre line of hull, where the longitudinal girders are to be provided under the engine and their spacing is not very wide, the centre girder may be omitted.

202. Ships with double bottoms

1. In ships with double bottoms, the main engines are to be seated directly upon thick inner bottom plating or thick seat plates on the top of heavy foundations so arranged as to effectively distribute the weight.

2. Additional side girders are to be provided within the double bottom beneath the main lines of bolting and other suitable positions so as to ensure satisfactory distribution of the weight and rigidity of the structure.

Section 3 Construction of Boiler Rooms

301. Boiler foundations

1. Boilers are to be supported by deep saddle type floors or by transverse or longitudinal girders so arranged as to effectively distribute the weight.

2. Where boilers are supported by transverse saddles or girders, the floors in way of same are to be specially stiffened.

302. Boiler location

1. Boilers are to be so placed as to ensure accessibility and proper ventilation.

2. Boilers are to be at least 457 mm clear of tank tops, etc. The thickness of adjacent members is to be increased as may be required where the clear space is unavoidably less. The available clearance is to be indicated on the plans submitted for approval.

3. Hold bulkheads and decks are to be kept well clear of the boilers and uptakes, or provided with suitable insulating arrangements.

4. Side sparrings are to be provided on the bulkheads adjacent to the boilers, keeping suitable clearance on their hold sides.

Section 4 Thrust Blocks and Foundations

401. Thrust blocks and foundations

1. Thrust blocks are to be bolted to efficient foundations extending well beyond the thrust blocks and so arranged as to effectively distribute the loads into the adjacent structures.

2. Additional girders are to be provided in way of the foundations as necessary.

402. Plummer blocks and auxiliary machinery seats

Plummer blocks and auxiliary machinery seats are to be of ample strength and stiffness in proportion to the weight supported and to the height of foundations.

Section 5 Machinery Space Openings

501. Protection of machinery space openings

Machinery space openings are to be enclosed by steel casings.

502. Exposed machinery space casings

1. Exposed machinery space casings are to have scantlings not less than those required in **Ch 16, 201.** and **202.,** taking C value as 1.0.

2. The thickness of top plating of exposed machinery space casing is not to be less than that obtained from the formulae given in **Table 10.17.1.**

Table 10.17.1 Thickness of top plating of exposed casing

Position	Thickness (mm)
I	$t = 6.3S + 1.5$
II	$t = 6.0S + 1.5$
S = spacing of stiffeners (m).	

503. Machinery space casings below freeboard deck or within enclosed spaces

The scantlings of machinery space casings below the freeboard deck or within enclosed superstructures or deckhouses are to comply with the following requirements:

(1) The thickness of plating is to be at least 6.5 mm, where the spacing of stiffeners is greater than 760 mm, the thickness is to be increased at the rate of 0.5 mm per 100 mm excess in spacing. In accommodation spaces the thickness of plating may be reduced by 2 mm.

(2) The section modulus of stiffeners is not to be less than that obtained from the following formula:

$$Z = 1.2 S l^3 \quad (\mathrm{cm}^3)$$

where:

l = tween deck height (m).

S = spacing of stiffeners (m).

504. Access openings to machinery spaces

1. All access openings to machinery spaces are to be located in protected positions as far as possible and provided with steel doors capable of being closed and secured from both sides. Such doors in exposed machinery space casings on the freeboard deck are to comply with the requirements in **Ch 16, 301. 1.**

2. The sills of doorways in machinery space casings are not to be less than 600 mm in height above the upper surface of the deck in Position I and 380 mm in Position II.

3. In ships having a reduced freeboard, doorways in the exposed machinery space casings on the freeboard or raised quarter deck are to lead to a space or passageway which is of strength equivalent to that of the casing and is separated from the stairway to the machinery spaces by a second steel weathertight door of which the doorway sill is to be at least 230 mm in height.

505. Miscellaneous openings in machinery space casing

1. Coamings of any fiddle, funnel and machinery space ventilator in an exposed position on the freeboard or superstructure deck are to be as high above the deck as reasonable and practicable.

2. In exposed positions on the freeboard and superstructure decks, fiddle openings and all other openings in the machinery space casings are to be provided with strong steel weathertight covers permanently fitted up in their proper positions.

3. Annular spaces around funnels and all other openings in the machinery space casings are to be provided with closing means capable of being operated from outside the machinery space in case of a fire.

506. Machinery space casings within unenclosed superstructure or deckhouses

Machinery space casings within unenclosed superstructures or deckhouses and doors provided thereon are to be constructed to the satisfaction of the Society, having regard to the degree or protection afforded by the superstructure or deckhouse. ⚓

CHAPTER 18 TUNNELS AND TUNNEL RECESSES

Section 1 General

As specified in **Pt 3, Ch 19, Sec 1.** ⫝̸

CHAPTER 19 HATCHWAYS AND OTHER DECK OPENINGS

Section 1 General

101. Application

1. The requirements in this Chapter apply to steel hatch covers and coaming in position I and II on weather decks. The requirements in **Pt 4, Ch 9** apply to steel hatch covers of small hatches fitted on exposed fore deck. Except for those specially provided for in this Chapter, **Pt 4, Ch 2** is to be applied.

2. Relaxation from the requirements in this chapter will be specially considered where the ship has an unusually large freeboard.

3. The construction and means for securing the watertightness of cargo and other hatchways in position 1 and 2 defined in **102.** shall be at least equivalent to the requirements of hatchways closed by weathertight covers of steel or other equivalent materials unless the application of regulation **Sec 3** to such hatchways is granted by the Administration.

102. Position of exposed deck openings

For the purpose of this chapter, two positions of exposed deck openings are defined as follows:

Position I : Upon exposed freeboard and raised quarter decks and upon exposed superstructure decks situated forward of a point 0.25 L_f from the forward perpendicular.

Position II : Upon exposed superstructure decks situated abaft 0.25 L_f from the forward perpendicular and located at least one standard heights of superstructure above the freeboard deck.
Upon exposed superstructure decks situated forward of a point 0.25 L_f from the forward perpendicular and located at least two standard heights of superstructure above the freeboard deck.

103. External pressures on hatch covers

1. The wave pressure acting on hatch cover plate is as following **Table 10.19.1**. The still water lateral pressure and loads are to be considered when the hatch cover is intended to carry uniform cargoes, wheeled cargoes or containers.

Table 10.19.1 Wave pressures on hatch covers

Pressure P_W (kN/m^2)		
Location	Position I	Position II
$0 \le x/L_f \le 0.75$	$14.9+0.195L_f$	$11.3+0.142L_f$
$0.75 < x/L_f < 1$	$12.2+\frac{L_f}{9}(5\frac{x}{L_f}-2)+3.6\frac{x}{L_f}$	-

Note
L_f : length for freeboard defined in **Ch 1 Sec 1** (m)
$x(m)$: distance from the end of astern to the center of hatch cover that should be considered.

104. Corrosion additions

The corrosion addition for both sides to be considered for the plating and internal members of hatch covers, hatch coamings and coaming stays is equal to the value specified as follows

Corrosion addition t_c (mm)		
Member	Bulk carriers Ore carriers Combination carriers	Others except left column
Plating and stiffeners of single skin hatch cover	2.0	2.0 *
Top and bottom plating of double skin hatch cover	2.0	1.5 *
Internal structures of double skin hatch cover	1.5	1.0
Hatch coamings structures and coaming stays	1.5	1.5
* Corrosion addition t_c=1.0 mm for the hatch covers in may of cellular cargo holds intended for containers.		

105. Allowable stresses

The allowable stresses σ_a and τ_a, in N/mm^2, are to be obtained as follows.

Members of:	σ_a (N/mm^2)	τ_a (N/mm^2)
Weathertight hatch cover	0.80 σ_y	0.46 σ_y
Pontoon hatch cover	0.68 σ_y	0.39 σ_y
Hatch coaming	0.95 σ_y	0.50 σ_y

σ_a : normal Stresses
τ_a : shear Stresses
σ_y : yielding Stresses

Section 2 Hatchways

201. Application

The construction and the closing means of cargo and other hatchways are to comply with the requirements in this section.

202. Height of hatchway coamings

1. The height of coamings above the upper surface of deck is to be at least 600 mm in Position I and 450 mm in Position II.

2. For hatchways closed by weathertight steel hatch covers as specified in **401.,** the height of coamings may be reduced from those prescribed in **Par 1** or omitted entirely subject to the satisfaction of the Society.

3. The height of hatchway coamings other than those provided in exposed portions of the freeboard or superstructure decks is to be to the satisfaction of the Society having regard to the position of hatchways or the degree of protection provided.

203. Construction of hatchway coamings

1. The thickness of hatchway coamings including the corrosion addition is not to be less than that obtained from the following formula:

$t = 0.05L + 6$ (mm)

2. Coamings for hatchways in Position I or coamings of 760 mm or more in height provided to hatchways in Position II are to be stiffened in a suitable position below the upper edge by a horizontal stiffener: the breadth of horizontal stiffener is not to be less than that obtained from the following formula, but need not exceed 180 mm.

$b = 1.7L + 50$ (mm)

3. Coamings are to be additionally supported by efficient brackets or stays provided from the horizontal stiffeners specified in **Par 2** to the deck at an interval of approximately 3 m.

4. Coamings for all exposed hatchways are to be stiffened on their upper edges by half-round bars or similar section bars and their lower parts are to be constructed efficiently by flanging or other suitable means.

5. For the construction and scantlings of coamings of small hatchways, the requirements in **Pars 1** to **4** may be suitably modified.

6. The construction and scantlings of coamings over 900 mm in height, coamings of hatchways to deep tanks and coamings of hatchways closed by a special type of closing means to which the requirements in **203.** are not applicable, are to be to the satisfaction of the Society.

Section 3 Hatch Openings closed by Portable Covers and secured Weathertight by Tarpaulins and Battening Devices

301. Hatch rests

Hatch rests are to be provided with at least 65 mm bearing surface and are to be bevelled, if required, to suit the slope of the hatchways.

302. Wood hatch covers

Wood covers are to comply with the following requirements:

(1) The finished thickness is not to be less than obtained from the following formula. Covers intended to carry cargoes on them are to be increased in thickness in direct proportion either where the tween deck height exceeds 2.6 m or the weight of cargoes to be carried on the hatchway covers exceeds 17.5 kN/m^2, but in no case is the finished thickness to be less than 60 mm.

$t = 40S$ (mm)

where:

S = spacing of portable beams (m)

(2) The wood for hatchway covers is to be of good quality, straight grained and reasonably free from knots, sap and shakes.

(3) The ends of all wood covers are to be protected by encircling steel band.

(4) Where portable beams for supporting wooden hatch covers are made of steel, the maximum allowable stress and deflection of the member not considering the corrosion margin under the design loads in **103.** are as follows.

Maximum allowable stress : in accordance with **105**. in this chapter
Maximum allowable deflection : 0.0044 times the span

Where the cross section of portable beams is not constant along the span, article in **304.** may be used to determine required beam scantlings. Thickness is to be added an appropriate corrosion margin in **104**.

303. Steel Hatch Cover

1. Where steel hatch covers are fitted the maximum allowable stress and deflection of the member not considering the corrosion margin under the design loads in **103.** are as follows.

Maximum allowable stress : in accordance with **105.** in this chapter

Maximum allowable deflection : 0.0056 times the span

2. Top plate thickness is to be 0.01 times the spacing of stiffeners, but not less than 6 mm.

3. Where the cross section of portable beams is not constant along the span, article in **304.** may be used to determine required beam scantlings.

4. Thickness is to be added an appropriate corrosion margin in **104.**

304. Primary supporting members

1. Application

The requirements in **3.** to **5.** apply to primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in **4.**

2. Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in **1**, the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained from the following formulae:

$$\sigma = \frac{SP_w l^2 10^3}{8Z} \quad (\text{N/mm}^2)$$

$$\tau = \frac{5SP_w l}{A_{sh}} \quad (\text{N/mm}^2)$$

l : span of the primary supporting member (m)

A_{sh} : shear sectional area (cm^2)

S : the spacing of stiffeners (m)

3. Checking criteria

The normal stress σ and the shear stress τ, calculated according to 3. or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae:

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

4. Deflection limit

Deflection does not exceed the values as follows :
- 0.0056 times the span of stiffeners for weathertight hatch covers
- 0.0044 times the span of stiffeners for pontoon hatch covers

5. Primary supporting members of variable cross-section

The net section modulus of primary supporting members with a variable cross-section is to be not less than the greater of the value obtained from the following formulae. But the use of these formulae is limited to the determination of the strength of primary supporting members in which abrupt changes in the cross-section do not occur along their length.

$$Z_V = Z \quad (\mathrm{cm}^3)$$

$$Z_V = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) Z \quad (\mathrm{cm}^3)$$

Z : net section modulus for constant cross-section

$$\alpha = \frac{l_1}{l}$$

$$\psi = \frac{Z_1}{Z_0}$$

l_1 : length of the variable section part

l : span measured between end supports

Z_1 : net section modulus at end

Z_0 : net section modulus at mid-span

Moreover, the net moment of inertia of primary supporting members with a variable cross-section is to be not less than the greater of the values obtained from the following formulae :

$$I_V = I \quad (\mathrm{cm}^4)$$

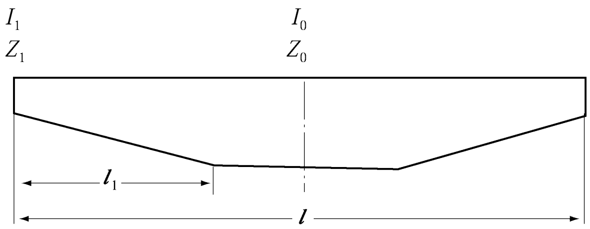
$$I_V = \left(1 + 8\alpha^3\left(\frac{1-\phi}{0.2 + 3\sqrt{\phi}}\right)\right) I \quad (\mathrm{cm}^4)$$

I : net moment of inertia with a constant cross-section

$$\phi = \frac{I_1}{I_0}$$

I_1 : net moment of inertia at end

I_0 : net moment of inertia at mid-span,



305. Pontoon Covers

1. Where steel pontoon covers are fitted the maximum allowable stress and deflection of the member not considering the corrosion margin under the design loads in **103.** are as follows :

Maximum allowable stress : in accordance with **105.** in this chapter
Maximum allowable deflection : 0.0044 times the span

2. Top plate thickness is to be 0.01 times the spacing of stiffeners, but not less than 6 mm.

3. Where the cross section of stiffener is not constant along the span, article in **304.** may be used to determine required scantlings.

4. Thickness is to be added an appropriate corrosion margin in **104.**

5. The depth of steel pontoon covers at supports is not to be less than one-third the depth at mid-span or 150 mm, whichever is greater.

6. The width of bearing surface for steel pontoon covers is to be not less than 75 mm.

Section 4 Hatchways Closed by Weathertight Covers Fitted with Gaskets and Clamping Devices

401. Steel weathertight covers

1. Where steel weathertight covers are fitted the maximum allowable stress and deflection of the member not considering the corrosion margin under the design loads in **103.** are as follows :

Maximum allowable stress : in accordance with **105.** in this chapter
Maximum allowable deflection : 0.0056 times the span

2. Top plate thickness is to be 0.01 times the spacing of stiffeners, but not less than 6 mm.

3. Where the cross section of stiffener is not constant along the span, article in **304.** may be used to determine required scantlings.

4. Thickness is to be added an appropriate corrosion margin in **104.**

5. The depth of steel pontoon covers at supports is not to be less than one-third the depth at mid-span or 150 mm, whichever is greater.

6. The strength and closing arrangements of small or special types of steel weathertight covers to which the requirements in **1.** through **5.** above are not applicable and those of covers for hatchways, coaming of which is omitted by article **2** of **202**, will be specially considered.

Section 5 Hatchway Covers for Sand Carrier and Dredger

501. Hatchway covers for sand carrier and dredger

In the case of sand carriers and dredgers, hatchway covers may be omitted at the discretion of the Society.
In this article sand carrier and dredger mean that the ships are be engaged in gathering, transporting, dredging or reclamation etc. for sand, soil, gravel etc.

1. For the ship which operates in domestic-costal service area, the requirement for exemption of hatchway covers of sand carrier and dredger is as follows.

(1) Barge and Ship having hopper door
Ships which is fitted with a buoyancy tank in each side and hopper door in bottom should have sufficient reserved buoyancy and stability in assumed the worst flooded condition of cargo hold.

(2) Barge not having a hopper door
Barge which is fitted with a buoyancy tank in each side and operates within 20 nautical miles

out of the Korean peninsula(excluding those intend to sail to Che-ju Island) should have sufficient reserved buoyancy and stability in assumed the worst flooded condition of cargo hold.

(3) For the exemption of hatchway cover installation, it should be met with the following conditions in assumed the worst flooded condition.
  (A) The upper deck side line should be not flooded
  (B) For self-propelled ship : $G_0M \geq 0.15$ m
  For non self-propelled ship : $G_0M \geq 0.095B$ m
  (where, B = Breadth)

2. For the ship which operates in international service area and is fitted with door or valve in bottom, the requirement for exemption of hatchway cover installation of sand carrier and dredger is as follows.

(1) The intact stability is to be met with the requirement of **Pt 1, annex 1-2** of the Guidance. In this case, the calculation is to include the homogeneous full load condition of cargo in each cargo hold loaded up to the top of the hatchway coaming.
(2) When the wetted cargo with the design bulk density of minimum 2.2 ton/m^3 is homogeneously loaded to the assigned freeboard in each hold and assuming that the void space of the cargo hold above the cargo surface is filled with the sea water induced by the flooding, the stability of the above (1) is to be satisfied.
(3) The damage stability is to be met with **SOLAS Ch. II-1, B-1**
(4) The doors or valves on bottom area are to be met with following requirements.
  (A) The opening of the bottom dump doors should be effective in less than one(1) minute.
  (B) In the case of bottom door not to be opened by gravity, the opening should be possible even after the main power source or the ram mechanism actuating the bottom dump doors have been put out of order.
  In this case, it should be possible to operate both systems from bridge, and the cargo releasing arrangements should be such that asymmetrical jettisoning of the cargo should not be possible even partially.
(5) Draft indicator is to be fitted on the bridge.
(6) Where the additional requirements other than described above are necessary, the ship is to be met with those requirements also.

Section 6 Companion ways and Other Deck Openings

601. Manholes and flush scuttles

Manholes and flush scuttles in exposed positions on the freeboard and superstructure decks or within superstructures other than enclosed superstructures are to be closed by steel covers capable of being made watertight. These covers are to be secured by closely spaced bolts or to be permanently fitted up.

602. Companion ways

1. Access openings in the freeboard deck are to be protected by enclosed superstructures or by deckhouses or companion ways of equivalent strength and weathertightness.

2. Access openings in exposed superstructure decks or in the top of deckhouses on the freeboard deck which give access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by efficient deckhouses or companion ways.

3. Doorways in deckhouses or companion ways such as specified in **Pars 1** and **2** are to be provided with doors complying with the requirements in **Ch 16, 301.1.**

4. The sills of doorways specified in **Pars 1** to **3** are not to be less than 600 mm in height above the upper surface of the deck in Position I and 380 mm in Position II.

603. Openings to cargo spaces

Access and other openings to cargo spaces are to be provided with closing means capable of being operated from outside the spaces in case of a fire. Such closing means for any opening leading to any other space inboard the ship is to be of steel. ⚓

CHAPTER 20 BOW DOORS, SIDE AND STERN DOORS

Section 1 Bow doors and Inner doors

As specified in **Pt 4, Ch 3, Sec 1.**

Section 2 Side and Stern door

As specified in **Pt 4, Ch 3, Sec 2.** ⚓

CHAPTER 21 BULWARKS FREEING PORTS, SIDE SCUTTLES, VENTILATORS AND PERMANENT GANGWAYS

Section 1 Bulwarks

As specified in **Pt 4, Ch 4, Sec 1.**

Section 2 Freeing Ports

As specified in **Pt 4, Ch 4, Sec 2.**

Section 3 Side Scuttles

As specified in **Pt 4, Ch 4, Sec 3.**

Section 4 Ventilators

As specified in **Pt 4, Ch 4, Sec 4.**

Section 5 Permanent Gangways

As specified in **Pt 4, Ch 4, Sec 5.** ⚓

CHAPTER 22 EQUIPMENT NUMBER AND EQUIPMENT

Section 1 General

101. General and application

1. All ships, according to their equipment number of provisions in **201.** are to be provided with anchors, chain cables, ropes, etc. which are not less than given in **Table 10.22.1.**

2. Anchors, chain cables, ropes, etc. for ships having equipment number not more than 50 or more than 1,670 are to be at the discretion of the Society.

3. The bower anchors given in **Table 10.22.1** are to be connected to their cables and stored on board ready for use. A spare anchor in addition to the requirements given in **Table 10.22.1** may be required for the ships such as cable layer, observation, research, patrol and fishing vessels in consideration of kind of ships, condition in service area, etc.

4. The anchors, chain cables and ropes, etc. which are required to be tested and inspected to be used for ships classed with the Society are to comply with the requirements in **Pt 4, Ch 8.**

5. All ships are to be provided with suitable appliances for handling of anchors.

6. The inboard end of chain cable is to be secured to the hull through a strong eye plate by means of shackle or by other equivalent means.

Section 2 Equipment Number

201. Equipment number

1. Equipment number is the value obtained from the following formula :

$$E = \triangle^{\frac{2}{3}} + 2.0Bh + 0.1A$$

where:

Δ = molded displacement in tons to the summer load waterline.

h, A = values specified in the following (1), (2) and (3).

(1) h is the value obtained from the following formula :

$$h = f + h' \text{ (m)}$$

where:

f = vertical distance, at the midship, from the load line to the top of uppermost continuous deck beam at side (m).

h' = height from the uppermost continuous deck to the top of uppermost superstructures or deckhouses having a breadth greater than $B/4$ (m). In the calculation of h, sheer and trim may be ignored. Where a deckhouse having a breadth greater than $B/4$ is located above a deckhouse with a breadth of $B/4$ or less, the narrow deckhouse may be ignored.

(2) A is the value obtained from the following formula :

$$A = fL + \sum h'' l \quad (\mathrm{m}^2)$$

where:

f = value specified in (1).

$\sum h'' l$ = summing up of the products of the height h''(m) and length l(m) of superstructures, deckhouses or trunks which are located above the uppermost continuous deck within the length of ship and also have a breadth greater than $B/4$ and a height greater than 1.5 m.

(3) In the application of (1) and (2), screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

2. Notwithstanding **1** above, for tugs the equipment number is to be obtained from the following formula :

$$E = \triangle^{\frac{2}{3}} + 2.0(fB + \sum h'' b) + 0.1A$$

Δ, f, A : As specified in **1**. above.

$\sum h'' b$ = Summing up the products of the height h''(m) and the breadth b(m) of each widest superstructure and deckhouse which have a breadth greater than $B/4$ and are located above the uppermost continuous deck.

202. Weight of anchors

1. The weight of individual bower anchors may vary by ± 7 % of the weight given in **Table 10.22.1,** provided that the total weight of stipulated number of bower anchors is not less than obtained from multiplying the weight per anchor by the number given in **Table 10.22.1.** Where, however, an approval by the Society is obtained, the anchors which are increased in weight by more than 7 % may be used.

2. Where stocked anchors are used, the weight excluding the stock, is not to be less than 0.80 times the weight specified in **Table 10.22.1** for ordinary stockless bower anchors.

3. Where high holding power anchors are used, the weight of each anchor may be 0.75 times the weight specified in **Table 10.22.1.**

4. Where super high holding power anchors are used, the mass of each anchor may be 0.5 times the mass required for the ordinary stockless anchor. However, super high holding power anchor mass is generally not to exceed 1,500 kg.

203. Chain cables and stream lines

Chain cables for bower anchors are to be stud link chains of Grade 1, 2 or 3 specified in **Pt 4, Ch 8, Sec 4.** However, Grade 1 chains made of Class 1 chains bars (*RSBC* 31) are not to be used in association with high holding power anchors.

204. Tow lines and mooring lines

1. As for wire ropes and hemp ropes used as tow lines and mooring lines, the breaking test load specified in **Pt 4, Ch 8, Sec 5** or **6** is not to be less than the breaking load given in **Table 10.22.1** respectively.

2. For ships having the ratio A/E above 0.9, the number of ropes given in **Table 10.22.2** should be added to the number required by **Table 10.22.1** for mooring lines.

3. The requirements for synthetic fibre ropes used as tow lines or mooring lines are to be as deemed appropriate by the Society.

4. The length of individual mooring lines may be reduced up to 7 % of the length given in **Table 10.22.1,** provided that total length of the stipulated number of mooring lines is not less than obtained from multiplying the length by the number given in **Table 10.22.2.**

5. For mooring lines connected with powered winches where the rope is stored on the drum, steel cored wire ropes of suitable flexible construction may be used instead of fibre cored wire ropes subject to the approval by the Society.

Table 10.22.1 Bower anchors, chain cables and ropes

Equipment letter	Equipment number		Stockless bower anchors		Stud link chain cables for bower anchors				Tow line		Mooring line		
	Exceeding	Not exceeding	Number	Weight per anchor (kg)	Total length (m)	Diameter (mm) Grade 1	Grade 2	Grade 3	Length (m)	Breaking load (kg) (kN)	Number	Length of each line(m)	Breaking load (kg) (kN)
A1	50	70	2	180	220	14	12.5		180	↑ 10000 (98)	3	80	↑ 3500 (34)
A2	70	90	2	240	220	16	14		180	⋮ 10000 (98)	3	100	⋮ 3750 (37)
A3	90	110	2	300	247.5	17.5	16		180	⋮ 10000 (98)	3	110	⋮ 4000 (39)
A4	110	130	2	360	247.5	19	17.5		180	⋮ 10000 (98)	3	110	⋮ 4500 (44)
A5	130	150	2	420	275	20.5	17.5		180	⋮ 10000 (98)	3	120	⋮ 5000 (49)
B1	150	175	2	480	275	22	19		180	⋮ 10000 (98)	3	120	⋮ 5500 (54)
B2	175	205	2	570	302.5	24	20		180	● 11400 (112)	3	120	⋮ 6000 (59)
B3	205	240	2	660	302.5	26	22	20.5	180	⋮ 13200 (129)	4	120	⋮ 6500 (64)
B4	240	280	2	780	330	28	24	22	180	⋮ 15300 (150)	4	120	⋮ 7000 (69)
B5	280	320	2	900	357.5	30	26	24	180	⋮ 17700 (174)	4	140	⋮ 7500 (74)
C1	320	360	2	1020	357.5	32	28	24	180	↓ 21100 (207)	4	140	● 8000 (78)
C2	360	400	2	1140	385	34	30	26	180	↑ 22800 (224)	4	140	⋮ 9000 (88)
C3	400	450	2	1290	385	36	32	28	180	⋮ 25500 (250)	4	140	⋮ 10000 (98)
C4	450	500	2	1440	412.5	38	34	30	180	⋮ 28200 (277)	4	140	⋮ 11000 (108)
C5	500	550	2	1590	412.5	40	34	30	190	⋮ 31200 (306)	4	160	⋮ 12500 (123)
D1	550	600	2	1740	440	42	36	32	190	⊗ 34500 (338)	4	160	⋮ 13500 (132)
D2	600	660	2	1920	440	44	38	34	190	⋮ 37800 (371)	4	160	⋮ 15000 (147)
D3	660	720	2	2100	440	46	40	36	190	⋮ 41400 (406)	4	160	⋮ 16000 (157)
D4	720	780	2	2280	467.5	48	42	36	190	⋮ 45000 (441)	4	170	⋮ 17500 (172)
D5	780	840	2	2460	467.5	50	44	38	190	↓ 48900 (480)	4	170	⋮ 19000 (186)
E1	840	910	2	2640	467.5	52	46	40	190	↑ 52800 (518)	4	170	⋮ 20500 (201)
E2	910	980	2	2850	495	54	48	42	190	⋮ 57000 (559)	4	170	↓ 22000 (216)
E3	980	1060	2	3060	495	56	50	44	200	⋮ 61500 (603)	4	180	↑ 23500 (230)
E4	1060	1140	2	3300	495	58	50	46	200	⋮ 66000 (647)	4	180	⋮ 25500 (250)
E5	1140	1220	2	3540	522.5	60	52	46	200	◎ 70500 (691)	4	180	⋮ 27500 (270)
F1	1220	1300	2	3780	522.5	62	54	48	200	⋮ 75300 (738)	4	180	⋮ 29000 (284)
F2	1300	1390	2	4050	522.5	64	56	50	200	⋮ 80100 (786)	4	180	⋮ 31500 (309)
F3	1390	1480	2	4320	550	66	58	50	200	⋮ 85200 (836)	4	180	⊗ 33000 (324)
F4	1480	1570	2	4590	550	68	60	52	200	⋮ 90600 (888)	5	190	⋮ 33000 (324)
F5	1570	1670	2	4890	550	70	62	54	200	↓ 96000 (941)	5	190	↓ 34000 (333)

NOTES:
1. Where steel wire ropes are used, the following wire ropes corresponding to the marks shown in the Table, ● (6×12), ⊗ (6×24), ◎ (6×37), are to be provided.
2. Length of chain cables may be that including shackles for connection.
3. Tow line is not a condition of classification, but is listed in this table only for guidance.

Table 10.22.2 Number of ropes

$\frac{A}{E}$	Number of mooring line
$0.9 < \frac{A}{E} \leq 1.1$	1
$1.1 < \frac{A}{E} \leq 1.2$	2
$\frac{A}{E} > 1.2$	3

NOTES:
A =value specified in **201**. (2).
E =equipment number.

Section 3 Shipboard Fittings and Supporting Hull Structures associated with Towing and Mooring

301. As specified in **Pt 4, Ch 10.** ⚓

CHAPTER 23 OIL TANKERS

Section 1 General

101. Application

1. The construction and equipment of ships intended to be registered and classed as "tanker" are to be in accordance with the requirements in this chapter, where "tanker" means a ship intended to carry crude oil, petroleum products having the vapour pressure (absolute pressure) less than 0.28 MPa at 37.8°C or other similar liquid cargoes in bulk.

2. Except where specifically required in this chapter, the general requirements for steel ships are to be applied.

3. The requirements in this chapter are framed for tankers with machinery aft, having one or more rows of longitudinal bulkheads, single decks, single bottoms and longitudinal framing.

4. In tankers intended to carry liquid cargoes other than crude oil and petroleum products, having the vapour pressure (absolute pressure) less than 0.28 MPa at 37.8°C and having no hazard as poisonous, corrosive, etc. and moreover less inflammability than that of crude oil and petroleum products, the structural arrangements and scantlings are to be to the satisfaction of the Society, having regard to the properties of the cargoes to be carried.

102. Arrangement of bulkheads

In cargo oil tanks, longitudinal and transverse oiltight bulkheads and wash bulkheads are to be arranged suitably.

103. Cofferdams

1. Cofferdams of airtight construction and of sufficient width as required for ready access are to be provided at the forward and after ends of cargo oil spaces and between cargo oil spaces and accommodation spaces. In tankers intended to carry oils having a flashpoint exceeding 60°C, however, the preceding requirements may be modified.

2. The cofferdams described in the preceding paragraph may be used as pump rooms.

3. Ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

4. Fuel oil or ballast water tanks may be concurrently used as the cofferdams to be provided between cargo oil tanks and fuel oil or ballast water tanks, subject to the approval by the Society.

5. Location and separation of spaces in tankers of 500 tons gross and above carrying oils having a flashpoint not exceeding 60°C are to be in accordance with the requirements in **Pt 8, Ch 1.**

104. Airtight bulkheads

Airtight bulkheads are to be provided for the isolation of all cargo oil pumps and pipings from spaces containing stoves, boilers, propelling machinery, electric installations other than those of explosion-proof type specified in **Pt 6, Ch 1, Sec 9** or machinery space where source of ignition is normally present. In tankers carrying oils having a flashpoint exceeding 60°C, however, the preceding requirements may be modified.

105. Ventilation

1. Efficient ventilation is to be provided in spaces adjacent to cargo oil tanks. Air holes are to be cut in every part of the structure where there might be a chance of gases being "pocketed".

2. Efficient means are to be provided for cleaning oil tanks and pump rooms of dangerous vapours by means of mechanical ventilation or by steam.

3. Ventilation systems of mechanical extraction type are to be provided for the cargo oil pump room specified in **Par 2.** The outlets of exhaust ducts are to be led to the safe position above the open deck and to be fitted with wire mesh screens with mesh of suitable size. This ventilation systems are to be capable of circulating sufficient air to give at least 20 air changes per hour for the total volume of the pump room to prevent accumulation of cargo vapours. The ventilation fan is to be of non-sparking construction. Also the ducts are to be arranged, to permit ventilation from the vicinity of the pump room bilge, above the transverse floor plate or bottom longitudinals. An emergency intake located nearly 2 m above the pump room lower grating is to be arranged to the ducts, and this emergency intake is to have a damper which is capable of being opened or closed from the weather deck and lower grating level.

4. In tankers carrying oils having a flashpoint above 60°C, the capacity of ventilation in the pump rooms specified in **Par 3** may be modified.

5. The requirements in **Par 3** are applied to the ventilation fans and wire mesh screen for the spaces adjacent to the cargo oil tank specified in **Par 1**.

106. Openings for ventilation

Ventilation inlets and outlets are to be arranged so as to minimize the possibilities of vapours of cargoes being admitted to an enclosed space containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. Especially, openings of ventilation for machinery spaces are to be situated as far afterwards apart from the cargo spaces as practicable.

107. Openings of superstructure and deckhouse

The arrangement of openings on the boundaries of superstructure and deckhouse are to be such as to minimize the possibility of accumulation of vapours of cargoes. Due consideration in this regard is to be given when the ship is equipped to load or unload at the stern. Side scuttles to the poop front or other similar walls are to be of fixed type. Such openings of tankers of 500 gross tons and above carrying oils having a flash point not exceeding 60°C are to be in accordance with the requirements in **Pt 8, Ch 1, 402.**

108. Thickness of structural members in cargo oil spaces

The thickness of structural members in cargo oil spaces is to be in accordance with the following:

(1) The shell plating is not to be of less thickness than that obtained from the formulae in **Ch 4, 302., 304., 402., 403.** and **404.** using 2.0 instead of 1.5 in the formulae.

(2) The deck plating of freeboard deck is not to be of less thickness than that obtained from the formulae in **Ch 5, 301.** using 2.0 instead of 1.5 in the formulae.

(3) Where frames, beams, stiffeners and other members for which the scantlings are specified by the section modulus only consist of flanged plates, special sections of web and face plates, the thickness of web plates is not to be less than that obtained from the following formula. Where the depth of web plates, however, is specially made deeper due to other reasons than of strength, the preceding requirements may be modified.

$$t = 0.015 d_0 + 2.5 \text{ (mm)}$$

where:

d_0 = depth of web plates (mm)

(4) The thickness of various girders, longitudinal, transverse, vertical or horizontal, the cross ties and end connecting brackets thereof and various bulkhead platings is not to be less than 8 mm.

(5) The thickness of flat bars, tripping brackets, etc. fitted up on webs of longitudinal girders, transverses and stiffeners of bulkheads is not to be less than that obtained from the following formula. The thickness, however, need not exceed that of web plates to which they are connected.

$$t = 0.5\sqrt{L} + 2.5 \text{ (mm)}$$

(6) In no case is the thickness of structural members to be less than 7 mm.

Section 2 Hatchways, Gangways and Freeing Arrangements

201. Ships having unusually large freeboard

Relaxation from the requirements specified hereunder will be considered to ships having an extra-ordinarily large freeboard.

202. Hatchways to cargo oil tanks

1. The thickness of coaming plates is not to be less than 10 mm. Where the length and coaming height of a hatchway exceed 1.25 m and 760 mm respectively, vertical stiffeners are to be provided to the side or end coamings and the upper edge of coamings is to be suitably stiffened.

2. Hatchway covers are to be of steel or other approved materials. The construction of steel hatch-way covers is to comply with the following requirements. The construction of hatchway covers of materials other than steel is to be in accordance with the discretion of the Society.

(1) The thickness of cover plates is not to be less than 12 mm. In ships not more than 60 m in length, however, the requirement may be modified.
(2) Where the area of a hatchway exceeds 1 m^2 but does not exceed 2.5 m^2, cover plates are to be stiffened by flat bars of 100 mm in depth spaced not more than 610 mm apart. Where, how-ever, the cover plates are 15 mm or more in thickness, the stiffeners may be dispensed with.
(3) Where the area of a hatchway exceeds 2.5 m^2, cover plates are to be stiffened by flat bars of 125 mm in depth spaced not more than 610 mm apart.
(4) The covers are to be secured by fastenings spaced not more than 457 mm apart in circular hatchways or 380 mm apart and not more than 230 mm from the corners in rectangular hatchways.

3. The cover is to be provided with an opening at least 150 mm in diameter which is to be so con-structed as to be capable of being closed oiltight by means of a screw plug or a cover of peep hole.

4. Hatchway coamings are to be provided with gas cocks or other suitable exhausting devices.

203. Hatchways to spaces other than cargo oil tanks

In exposed positions on the freeboard and forecastle decks or on the top of expansion trunks, hatchways serving spaces other than cargo oil tanks are to be provided with steel watertight covers having scantlings complying with the requirements in **Ch 20, Sec 4.**

204. Permanent gangway and passage

1. A fore and aft permanent gangway complying with the requirements of **Ch 22, 503.** is to be pro-vided at the level of the superstructure deck between the midship bridge or deck house and the poop or aft deck house, or equivalent means of access is to be provided to carry out the purpose of the gangway, such as passage below deck. Elsewhere and in ships without midship bridge or deck house, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

2. Safe and satisfactory access from the gangway level is to be available between crew accom-modations and machinery space or between separated crew accommodations spaces.

205. Freeing arrangements

1. Ships with bulwarks are to have open rails fitted for at least a half of the length of the exposed part of the freeboard deck or to have other effective freeing arrangements. The upper edge of sheer strake is to be kept as low as practicable.

2. Where superstructures are connected by trunks, open rails are to be provided for the whole length of the exposed parts of the freeboard deck.

Section 3 Longitudinal Frames and Beams in Cargo Oil Spaces

301. General

Longitudinal frames and beams provided in permanent ballast water tanks and such spaces that cargo oil is loaded including void spaces and pump rooms are to be in accordance with the requirements stated hereunder.

302. Scantlings

1. The section modulus of bottom longitudinals and side longitudinals including bilge frames is not to be less than that obtained from the formulae given in **Table 10.23.1.**

Table 10.23.1 Section modulus of bottom and side longitudinals

Positions	Section modulus (cm^3)		
	Bottom longitudinals	Side longitudinals including bilge frames	
Midship part and between a point 0.15 L from the fore end and the collision bulkhead	$Z=10Shl^2$	$Z=9.3Shl^2$ $Z_{min}=3.2\sqrt{L}Sl^2$	However, this value need not exceed the requirements for the bottom longitudinsls and it may be suitably modified for side longitudinals within 0.25 D_s from a point of 0.5 D_s above the top of keel.
Forward and afterward end parts	$Z=8.5Shl^2$	$Z=7.9Shl^2$ $Z_{min}=2.72\sqrt{L}Sl^2$	

l = spacing of bottom transverses (m)
S = spacing of bottom longitudinals (m).
h = distance from the longitudinal under consideration to the point of h' above the top of keel (m).
h' = as specified in the following table.

	h' (m)
Bottom longitudinals	$h'=d+0.026L$
Side longitudinals including bilge frames	$h'=d+0.044L-0.54$

2. The section modulus of longitudinal beams is not to be less than 1.1 times that obtained from the formula in **Ch 10, 303.**

3. Notwithstanding the provisions in **Pars 1** and **2,** the section modulus of longitudinal frames and beams is not to be less than obtained assuming them as stiffeners on deep tank bulkhead and taking the distance from the longitudinal frames or longitudinal beams to the top of hatchways as h.

4. Longitudinal beams and side longitudinals attached to the sheer strake are to be of such dimensions as slenderness ratio not exceeding 60 at the midship part as far as practicable.

5. As for flat bars used for longitudinal beams and frames, the ratio of depth to thickness is not to exceed 15.

6. The extreme width of face plates of longitudinal beams and frames is not to be less than that obtained from the following formula:

$b = 2.2\sqrt{d_0 l}$ (mm)

where:

d_0 = depth of web of longitudinal beams or frames (mm).

l = spacing of transverses (m).

303. Attachment

Longitudinal frames and beams are to be continuous or to be attached at their ends in such a manner as to effectively develop the sectional area and the resistance to bending.

Section 4 Girders and Transverses in Cargo Oil Spaces

101. General

1. The requirements specified hereunder are framed for structures consisting of two to five transverses arranged at approximately equal intervals between transverse bulkheads or between the transverse bulkhead and the wash bulkhead.

2. Girders or transverses in the same plane are to be so arranged that abrupt change in the strength and rigidity is avoided; they are to have brackets of sufficient scantlings and with properly rounded corners at their ends.

3. The depth of girders or transverses is not to be less than 2.5 times that of slots for frames, beams and stiffeners.

4. As for the face plates composing girders, the thickness is not to be less than that of web plates and the width of the face plates is not to be less than that obtained from the following formula:

$b = 2.7\sqrt{d_0 l}$ (mm)

where:

d_0 = depth of girder (mm). In case where it is a balanced girder, d_0 is the depth from the surface of plate to the face plate (mm).

l = distance between supports of girder (m). Where, however, effective tripping brackets are provided, they may be taken as supports.

5. The requirements in this section are also to be applied to pump rooms, ballast water tanks or void spaces in the midship part as far as practicable.

402. Transverses in cargo oil spaces

1. The depth and section modulus of bottom transverses are not to be less than those obtained from the following formulae respectively:

Depth : $d = 160 l_0$ (mm)

Section modulus : $Z = 9.7k^2(d + 0.026L)Sl_0^2$ (cm^3)

where:

l_0 = overall length of transverses (m), which is equal to the distance from the inner surface of face plates of side transverses to the inner surface of face plates of vertical webs on the centre line bulkhead. (See **Fig. 10.23.1**)

S = spacing of transverses (m).

k = correction factor due to bracket given by the following formula : $k = 1 - \frac{0.65(b_1 + b_2)}{l_0}$

b_1, b_2 = arm length of brackets at both ends of transverses (m). (See **Fig. 10.23.1**)

2. The depth and section modulus of side transverses are not to be less than those obtained from the following formulae respectively.

Depth : $d = 150 l_0$ (mm)

Section modulus : $Z = 8.7 k^2 S h l_0^2$ (cm^3)

where:

l_0 = overall length of side transverses (m), which is equal to the distance between the inner surfaces of face plates of bottom transverses and deck transverses.

S = spacing of transverses (m).

h = distance from the mid-point of l_0 to the point of $h = d + 0.044L - 0.54$ above the top of keel (m).

k = correspondingly as specified in **Par 1.**

3. The section modulus of transverses at bilge is not to be less than that obtained from the following formula. However, in calculating the section modulus of transverses, the neutral axis of section is to be assumed as to situate at the mid-point of the depth of transverses. (See **Fig. 10.23.2**).

$Z = 7.8 S h l_0^2$ (cm^3)

where:

S, h, l_0 = as specified in **Par 2** respectively.

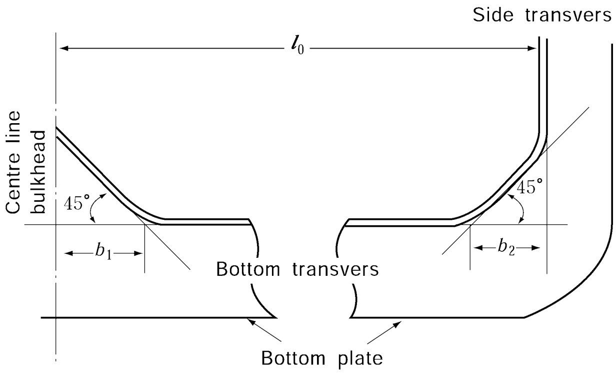


Fig. 10.23.1 Measurement of b_1, b_2, and l_0

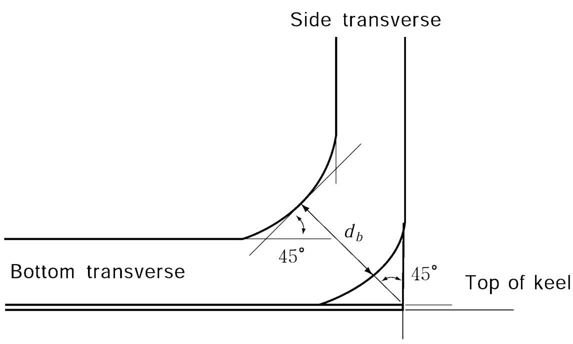


Fig. 10.23.2 Measurement of d_b

4. The depth and section modulus of deck transverses are not to be less than those obtained from the following formulae respectively:

Depth of transverses : $d = 100 l_0$ (mm)

Section modulus of transverses : $Z = 1.82k^2 \sqrt{L} S l_0^2$ (cm^3)

where:

l_0 = overall length of deck transverse (m), which is equal to the distance between the inner surface of face plate of side transverses and the centre line bulkhead.

S = spacing of transverses (m).

k = as specified in **Par 1.**

5. As for vertical webs provided on the centre line bulkhead, the requirements in **Par 3** for side transverses are to be correspondingly applied, but the depth and section modulus are not to be less than obtained from the formulae with each coefficient multiplied by 0.8 respectively.

Section 5 Trunks

501. Construction and scantlings

1. In ships with trunks, deck transverses extending from side to side of the ship across the trunk are to be provided as far as practicable In this case, the depth of deck transverses regarded as being supported by trunks may be 0.03 B.

2. Trunks are to be provided with stiffening transverses in line with the deck transverses. The section modulus of stiffening transverses is not to be less than that obtained from the following formula:

$Z = 1.4 \sqrt{L} S l^2$ (cm^3)

where:

l = half breadth of trunks (m).

S = spacing of transverses (m).

3. The thickness of trunk top and side plating is not to be less than that obtained from the following formula:

$t = 6.5S + 2.0$ (mm)

where:

S = spacing of longitudinal stiffeners (m).

4. The section modulus of longitudinal stiffeners provided on trunks is not to be less than that obtained from the following formula:

$Z = 2 \sqrt{L} S l^2$ (cm^3)

where:

l = spacing of transverses (m).

S = spacing of longitudinal stiffeners (m).

5. Both ends of trunk are to be sufficiently stiffened for the continuity of strength.

Section 6 Bulkheads in Cargo Oil Space

601. Thickness of bulkhead plating

1. The thickness of bulkhead plating is not to be less than obtained from the formula in **Ch 15** for deep tank bulkhead plating, using h measured from the lower edge of plating to the top of hatches (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

2. The breadth of the uppermost and lowest strakes of longitudinal bulkhead plating is not to be less than 0.1 D and the thickness of these is not to be less than that obtained from the following formulae:

For the lowest strakes : $t = 1.1S\sqrt{L} + 2.5$ (mm)

For the uppermost strakes : $t = 0.8S\sqrt{L} + 2.5$ (mm)

where:

S = spacing of stiffeners (m).

602. Stiffeners

1. The section modulus of stiffeners is not to be less than that obtained from the formula in **Ch 15** for deep tank bulkhead stiffeners, using h measured from the midpoint of l in case of vertical stiffeners or from the centre of the width of plating supported by the stiffener in case of horizontal stiffeners to the top of hatches (m) or $0.3\sqrt{L}$ (m), whichever is the greater.

2. Horizontal stiffeners provided on upper and lower parts of longitudinal bulkhead plating are to be of increased scantlings above those specified in the preceding paragraph.

3. The full width of face plates of horizontal stiffeners on longitudinal bulkhead is not to be less than required in **302. 6.**

603. Additional strengthening of bulkhead in large tanks

Additional strengthening of bulkhead in large tanks is to be as required by the Society.

604. Wash bulkheads

1. Stiffeners and girders are to be of adequate strength in conformity with the size and opening ratio of tanks.

2. The thickness of bulkhead plating is not to be less than that required by **108.** (4) or obtained from the following formula, whichever is the greater. The thickness of the lowest strake of transverse wash bulkheads is to be properly increased.

$t = 0.3S\sqrt{L+150} + 2.5$ (mm)

where:

S = spacing of stiffeners (m).

3. It is recommended that a special consideration be given to the thickness of wash bulkhead plating to prevent the plating from shear buckling. ⚓

CHAPTER 24 DOUBLE HULL TANKERS

Section 1 General

101. Application

1. The requirements in this chapter are applied to tankers with machinery aft having one or more longitudinal bulk heads and single decks with double bottom or with double hull structures. Where, tanker means a ship intended to carry crude oil, petroleum products having a vapour pressure (absolute pressure) less than 0.28 MPa at 37.8°C or other similar liquid cargoes in bulk.

2. The construction, equipment and scantlings of ships intended to carry liquid cargoes having a vapour pressure (absolute pressure) less than 0.28 MPa at 37.8°C in bulk other than crude oil and petroleum products are to be the satisfaction of the Society, having regard to the properties of the cargoes to be carried.

3. In case where the construction differs from that specified in **Par 1** and the requirements in this chapter are considered to be not applicable, matters are to be determined as deemed appropriate by the Society.

4. Except where specially required in this chapter, is to be complied with the requirement in chapter concerned.

5. In addition to the requirements specified in **Par 4** the relevant requirements in **Pt 7, Ch 1, Sec 10** and **Pt 8, Ch 1, Sec 4** are to be applied to ships specified in **1.**

102. Arrangement and separation of spaces

1. In cargo oil spaces, longitudinal and transverse oil-tight bulkheads and swash bulkheads are to be suitably arranged.

2. Cofferdams are to be provided in accordance with the following (1) to (3):

(1) Cofferdams of air-tight construction with 600 mm and over in width for access are to be provided at fore and aft terminations of cargo oil spaces and the space between the cargo space and accommodation space. Where, however, for oil tankers intended to carry cargo oil having a flashpoint above 60°C, the preceding requirements may be suitably modified.
(2) Cofferdams specified in (1) may be used as pump rooms.
(3) Fuel oil or ballast water tanks may be concurrently used as the cofferdams subject to the approval by the Society.

3. Passageways leading to cargo areas are to be provided in accordance with the following (1) through (4):

(1) Access to cofferdams, ballast tanks, cargo oil tanks and other spaces in the cargo area are to be direct from the open deck and such as to ensure their complete inspection. Access to double bottom spaces may be through a cargo pump room, pump room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.
(2) For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self contained air breathing apparatus and protective equipment to ascend or descend any ladder, without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is not to be less than 600 mm × 600 mm.
(3) For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening should be not less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.
(4) For tankers with a deadweight tonnage of less than 5,000 tons, smaller dimensions of minimum clear opening specified in (2) and (3) may be approved by the Society in special circumstances, if the ability to traverse such openings or to remove an injured person can be proved to the satisfaction of the Society.

4. Airtight bulkhead

All areas, where cargo oil pumps and cargo oil piping are provided, are to be segregated by an air-tight bulkhead from areas where stoves, boilers, propelling machinery, electric installations other than those of explosion-proof type in accordance with the requirements in **Pt 6, Ch 1, Sec 9** or machinery where source of ignition is normally present. Where, however, for oil tankers carrying cargo oil having a flashpoint above 60°C the requirements may be suitably modified.

5. Ventilation inlets and outlet

Ventilation inlets and outlets are to be arranged so as to minimize the possibilities of vapours of cargoes being admitted to an enclosed space containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. Especially, openings of ventilation for machinery spaces are to be situated as far afterwards apart from the cargo spaces as practicable.

6. Ullage openings, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

7. Openings on the boundaries of superstructures and deckhouses

The arrangement of openings on the boundaries of superstructures and deckhouses are to be such as to minimize the possibility of accumulation of vapours of cargoes. Due consideration in this regard is to be given for the openings in superstructures and deckhouses when the ship is equipped with cargo piping to load or unload at the stern.

8. Pipe duct in double bottom

Pipe ducts in the double bottom are to comply with the following requirements:

(1) They are not to communicate with the engine room.
(2) Provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.
(3) In the duct, provision is to be made for adequate mechanical ventilation.
(4) For ships to which the convention applies, refer to SOLAS 1974(as amended) Regulation ll-2/56.9

103. Minimum thickness

1. The thickness of structural members in cargo oil tanks and deep tanks such as bulkhead platings, floors, girders including struts and their end brackets is not to be less than 8 mm.

2. In no case is the thickness of structural members in cargo oil tanks and deep tanks other than structural members in **Par 1** to be less than 7 mm.

Section 2 Bulkhead Plating

201. Bulkhead plating of cargo oil tanks and deep tanks

1. Thickness of bulkhead plating is not to be less than that obtained from the following formula when h is substituted with h_1 or h_2 :

$$t = 3.6S\sqrt{h} + 2.5 \quad \text{(mm)}$$

where :

S = spacing of stiffeners (m)

h = a head of water given in **Table 10.24.1.**

Table 10.24.1 A head of water

	Cargo Oil Tank	Deep Tank
h_1	Vertical distance from the lower edge of the bulkhead plating under consideration to the top of hatchway. For bulkheads of large tanks, a suitable water head given in **Pt 3, Ch 15** is to be considered.	Vertical distance from the lower edge of the bulkhead plating under consideration to the midpoint between the point on tank top and the upper end of the overflow pipe. For bulkheads of large tanks, suitable water head given in **Pt 3, Ch 15** is to be considered,
h_2	$h_2 = 0.3\sqrt{L}$ (m)	0.7 times the vertical distance from the lower edge of the bulkhead plating under consideration to the point 2.0 mabove the top of overflow pipe.

2. For the uppermost and lowermost plating of longitudinal bulkheads, the breadth is not to be less than 0.1 D, and the thickness is not to be less than that obtained from the following formulae:

Lowermost plating : $t = 1.1S\sqrt{L} + 2.5$ (mm)
Uppermost plating : $t = 0.85S\sqrt{L} + 2.5$ (mm)

where
S = spacing of stiffeners (m)

202. Swash bulkheads

1. Stiffeners and girders are to be of sufficient strength deemed appropriate by the Society considering the size of tanks and opening ratios.

2. Thickness of bulkhead plating is not to be less than that obtained from the following formula:

$$t = 0.3S\sqrt{L+150} + 2.5 \quad \text{(mm)}$$

where:
S = spacing of stiffeners (m)

3. In determining the thickness of swash bulkhead plating, sufficient consideration is to be given for buckling.

203. Trunks

1. The thickness of trunk top plating and side wall plating are to be obtained applying the requirements in **Ch 5** in addition to the requirements in **201.**

2. Both ends of trunk are to be sufficiently stiffened for the continuity of strength.

Section 3 Frames, Stiffeners and Longitudinal Beams

301. Longitudinals

1. The section modulus of bottom longitudinals is not to be less than that obtained from the following formula :

$Z = 8.6\,Shl^2$ (cm^3)

where:

l = spacing of floors (m.

S = spacing of bottom longitudinals (m)

h = distance from the bottom longitudinals under consideration to a point of $d+0.026L$ above top of keel (m)

2. The section modulus Z of side longitudinals, including bilge longitudinals is to be the greater of that obtained from the following formulae:

$Z_1 = 8.6\,Shl^2$ (cm^3)

$Z_2 = 2.9\sqrt{L}\,Sl^2$ (cm^3)

where

l = spacing of transverses (m).

S = spacing of side longitudinals (m).

h = distance from the side longitudinals under consideration to a point of $d+0.044L-0.54$ above top of keel (m).

3. For the parts forward and afterward of the midship part, the section modulus of side longitudinals may be gradually reduced to 85 % of that obtained from the requirements in **Par 2** at the end parts of the ship in no case longitudinals to be less than required in **Par 2** for the part between a point 0.15 L from the fore end and the collision bulkhead.

4. In addition to **Pars 1** to **3**, the section modulus of longitudinal frames and beams forming boundaries of deep tank is to be in accordance with the requirements in **302.**

302. Bulkhead stiffeners in cargo oil tanks and deep tanks

1. The section modulus of stiffeners is not to be less than that obtained from the following formula:

$Z = 7\,CShl^2$ (cm^3)

where:

S = spacing of stiffeners (m).

l = overall length between supporting points of stiffeners (m) including the length of connected parts at ends. However, in case where stiffening girders are provided, the distance to the nearest stiffening girder from the connected heel end or the distance between stiffening girders is to be taken.

h = as specified in **Table 10.24.1** where, however, "from the lower edge of the bulkhead plating under consideration" is to be construed as "from the mid-point of l" for vertical stiffeners, and as "from the mid-point of the upper and lower stiffeners" for horizontal stiffeners.

C = coefficient given in **Table 10.24.2** according to the type of end connection.

Table 10.24.2 Value of C

The other end of stiffeners \ One end of stiffeners	Connection by hard bracket	Connection by soft bracket	Supported by girders or lug connection	Snip
Connection by hard bracket	0.70	1.15	0.85	1.30
Connection by soft bracket	1.15	0.85	1.30	1.15
Supported by girders or lug connection	0.85	1.30	1.00	1.50
Snip	1.30	1.15	1.50	1.50

NOTES:
1. Connection by hard bracket is a connection by bracket to the double bottoms or to the adjacent members, such as longitudinals or stiffeners in line, of the same or larger sections, or a connection by bracket to the equivalent members mentioned above. (See **Fig. 10.14.1** (a))
2. Connection by soft brackets is a connection by bracket to the transverse members such as beams or equivalent thereto. (See **Fig. 10.14.1** (b))

303. Buckling strength

1. Buckling strength of longitudinal frames, beams and stiffeners is to be in accordance with the requirements in (1) to (3) below. In case where, the Society specially considers necessary according to the materials, scantlings, geometries and the point of arrangement of these structural members, detailed assessment may be required.

(1) Longitudinal beams, side longitudinals attached to the sheer strakes and longitudinal stiffeners attached to the longitudinal bulkhead within 0.1 D from the strength deck are to have a slenderness ratio not exceeding 60 at the midship part as far as practicable.

(2) As for flat bars used for longitudinal beams, frames and stiffeners, the ratio of depth to thickness is not to exceed 15.

(3) The full width of face plates of longitudinal beams, frames and stiffeners is not to be less than that obtained from the following formula:

$$b = 2.2\sqrt{d_0 l} \quad \text{(mm)}$$

where:

d_0 = depth of web of longitudinal beams, frames or stiffeners (m).

l = spacing of transverses (m).

2. In case where flanged plates other than flat bars are used for frames, longitudinal beams or stiffeners in cargo oil tanks and deep tanks whose scantlings are specified only in terms of section modulus, the thickness of webs is not to be less than that obtained from the following formula. In case where, however, the depth of webs is intended to be greater than the required level due to reasons other than strength, it may be suitably modified.

$$t = 0.015 d_0 + 2.5 \quad \text{(mm)}$$

where:

d_0 = depth of web (mm).

Section 4 Structural Members in Double Bottoms

401. Scantlings of girders and floors

The arrangements and scantlings of girders, floors and various structural members connected to them provided in double bottoms are to be in accordance with the relevant requirements in **Ch 7** in addition to the requirements in this chapter.

402. Other structural members

Structural members other than specified in **401** are to be in accordance with the requirements in **Ch 7** in addition to the requirements in this chapter.

Section 5 Structural Members in Double Side Hull

501. Arrangement

1. In case where a ship is provided with double side hull, the width of the double side hull is not to be less than 760 mm.

2. In double side hull, transverses are to be provided at a spacing not exceeding about 3.5 m.

3. In addition to the requirements in **Par 2**, the following spaces are to be provided with transverses:
(1) Spaces where solid floors are provided in double bottom
(2) Side of transverse bulkheads

502. Thickness of transverses

Thickness of transverses is not to be less than that obtained from the following formulae:

Transverse system : $t = 0.6\sqrt{L} + 1.5$ (mm)
Longitudinal system : $t = 0.7\sqrt{L} + 1.5$ (mm)

503. Lightening holes

Within about 0.2 D from inner bottom plating, the diameter of lightening holes provided in transverses in the middle half length of cargo oil tank is not to exceed about 1/5 of the width of transverses. However, if adequate reinforcements are provided, this requirements may be suitably modified for cases where the length of cargo oil tank is especially short.

Section 6 Girders and Transverses in Cargo Oil Tanks and Deep Tanks

601. Scantlings

1. The section modulus of girders is not to be less than that obtained from the following formula:

$Z = 7.13\,Shl^2$ (cm^3)

where:

S = breadth of area supported by girders (m).
l = overall length of girder (m), which is equal to the distance between the inner surfaces of face plates of girders.
h = as specified in **Table 24.1.1,** where, however, "from the lower edge of the bulkhead

Plating under consideration" is to be construed as "from the mid-point of S" for horizontal girders, and as "from the mid-point of l" for vertical girders.

2. Moment of inertial of girders is not to be less than that obtained from the following formula. However, the depth of girders is not to be less than 2.5 times the depth of slots.

$$I = 30hl^4 \quad (\text{cm}^4)$$

where:

h, l = as specified in **Par 1.**

3. Thickness of girders is not to be less than that obtained from the following formula:

$$t = 10S_1 + 2.5 \quad (\text{mm})$$

where:

S_1 : spacing of stiffeners or depth of girders, whichever is the smaller (m).

4. Thickness of flat bar stiffeners and tripping brackets provided on girders, transverses and stiffeners attached to bulkhead is not to be less than obtained that from the following formula. However, it needs not exceed the thickness of webs of the girder to which they are provided.

$$t = 0.5\sqrt{L} + 2.5 \quad (\text{mm})$$

5. The thickness of face plates forming a girder is not to be less than the thickness of webs, and the full width is not to be less than that obtained from the following formula:

$$b = 2.7\sqrt{d_0 l} \quad (\text{mm})$$

where

d_0 = depth of girder (m). In case where girders are of the balanced girder type, depth from the plate surface to face plate (m).

l = distance between supporting points of girder. In case where, however, effective tripping brackets are provided, they may be regarded as supporting points.

602. Side transverses for ships without double side hull

1. In addition to the requirements in **601. 1** depth and the section modulus of side transverses in areas carrying cargo oil are not to be less than the value obtained from the following formulae respectively, where, however, the depth of side transverses is not to be less than 2.5 times the depth of slots:

$$d_0 = 0.15l_0 \quad (\text{m})$$
$$Z = 8.7k^2Shl_0^2 \quad (\text{cm}^3)$$

where:

l_0 = overall length of side transverses (m), which is equal to the distance between the inner surfaces of face plates of deck transverses and inner bottom plating.

S = spacing of transverse (m).

h = distance from the mid-point of l0 to a point of $d+0.044L-0.54$ above top of keel (m).

k = correction factor for brackets obtained from the following formula. (See **Fig.10.23.1**)

$$k=1-\frac{0.65(b_1+b_2)}{l_0}$$

where :

b_1, b_2 = length of bracket arm at ends of transverse (m).

2. For ships with trunks, the construction of providing continuous deck transverses across the trunks is to be considered as the standard. In this case, the depth of deck transverses that can be regarded as those supported by trunks may be 0.03 B.

Section 7 Strengthened Bottom Forward

701. Strengthened area of the forward bottom

The area of strengthened bottom forwards to be in accordance with the requirements in **Ch 4, 404** and **Ch 7, Sec 9.**

Section 8 Structural Details

801. General

1. The principal structural members are to be arranged so that continuity of strength can be secured throughout the cargo area. In forward and afterward parts of the cargo area, the structures are to be effectively strengthened so that continuity of strength is not impaired sharply.

2. For the principal structural members, sufficient consideration is to be given for fixity at ends, supporting and stiffening systems against out-of plane deflections, and the construction is to minimize local stress concentrations.

802. Frames and stiffeners

Longitudinal beams, frames and stiffeners are to be of continuous structures, or to be connected securely so that their sectional areas at ends can be properly maintained providing sufficient resistance against bending moments.

803. Girders and cross ties

1. Girders provided within the same plane are to be arranged to avoid sharp changes in strength an rigidity, and brackets in suitable size are to be provided at the ends of girders, and bracket toes are to sufficiently rounded.

2. In case where the depth of longitudinal girders is large, stiffeners are to be arranged in paralled with face plates.

3. Tripping brackets are to be provided on the web plate transverses at the inner edge of end brackets, etc. and also at proper intervals in order to support transverses effectively.

4. The upper and lower end brackets for transverses and transverses for longitudinal bulkheads and webs in the vicinity are to be suitably stiffened.

Section 9 Special Requirements for Corrosion

901. Thickness of shell plating

1. The thickness of shell plating forming the casing of cargo oil tanks planned to carry ballast water in ships without double side hull is not to be less than a thickness added with 0.5 mm to that obtained from the requirements in **Ch 4.**

2. 0.5 mm may be reduced for the thickness of shell plating when applying the requirements of this chapter from the thickness obtained from the formula given in **201.**

902. Thickness of deck plating

1. 0.5 mm may be reduced for the thickness of freeboard deck plating when applying the requirements in this chapter from the obtained by the formula given in **201.**

2. At least 0.5 mm is to be added for the thickness of freeboard deck plating in spaces carrying cargo oil from the thickness obtained by the formula given in **Ch 5.**

903. Thickness of tank top plating

The thickness of tank top plating in cargo oil tanks and deep tanks is not to be less than the thickness corresponding to that obtained from the formula given in **201.** added by 1.0 mm. Such an addition, however, is not required for the thickness of inner bottom plating.

904. Section modulus of longitudinal beams, frames and stiffeners

1. The section modulus of longitudinal beams provided on deck plating in spaces carrying cargo oil is not to be less than 1.1 times that calculated according to the requirements of **302.**

2. The section modulus of frames and stiffeners provided on shell plating and bulkheads forming cargo oil tanks planned to carry ballast water, except the tank to carry ballast water only in heavy weather conditions, is not to be less than the value obtained from the Z_1 in the requirements of **301. 2** using a coefficient as 9.3, and the Z_2 using a coefficient as 3.2 respectively. The section modulus of stiffeners in above mentioned cargo oil tanks is not to be less than 1.1 times that calculated in accordance with the requirements in **302.**

Section 10 Special requirements for Hatchways and Permanent Gangways

1001. Ships having unusually large freeboard

Relaxation from the requirements in this section will be considered to ships having an unusually large freeboard.

1002. Hatchways to cargo oil tanks

1. The thickness of coaming plates is not to less than 10 mm. Where the length and coaming height of a hatchway exceed 1.25 m and 760 mm respectively, vertical stiffeners are to be provided to the side or end coamings, and the upper edge of coamings is to be suitably stiffened.

2. Hatch covers are to be of steel or other approved materials. The construction of steel hatch covers is to comply with the following requirements (1) through (4). The construction of hatch covers of materials other than steel is to be in accordance with the discretion of the Society.

(1) The thickness of cover plates is not to be less than 12 mm. In ships not exceeding 60 m, in length, however, the requirement may be modified.

(2) Where the area of a hatchway exceeds 1 m^2 but does not exceed 2.5 m^2, cover plates are to be stiffened by flat bars of 100 mm in depth spaced not more than 610 mm apart. Where, however, the cover plates are 15 mm or more in thickness the stiffener may be dispensed with.

(3) Where the area of a hatchway exceed 2.5 m^2 cover plates are to be stiffened by flat bars of 125 mm in depth spaced not more than 610 mm apart.
(4) The covers are to be secured by fastenings spaced not more than 457 mm apart in circular hatchways or 380 mm apart and not more than 230 mm from the corners in rectangular hatchways.

3. The cover is to be provided with an opening at least 150 mm in diameter which is to be so constructed as to be capable of being closed oiltight by means of a screw plug or a cover of peep hole.

4. Hatchway coamings are to be provided with gas cocks or other suitable exhausting devices.

1003. Hatchways to spaces other than cargo oil tanks

In exposed positions on the freeboard and forecastle decks or on the top of expansion trunks, hatchways serving spaces other than cargo oil tanks are to be provided with steel watertight covers having scantlings complying with the requirements in **Ch 19, Sec 4.**

1004. Gangway and Access

1. A fore and after permanent gangway complying with the requirements in **Ch 21, 503.** is to be provided at the level of the superstructure deck between the midship bridge or deckhouse and the poop or after deckhouse, or equivalent means of access is to be provided to carry out the purpose of the gangway such as passage below deck. Elsewhere, and in ships without midship bridge and deckhouse, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

2. Safe and satisfactory access from the gangway level is to be available between crew accommodation spaces and machinery spaces or between separated crew accommodation spaces.

3. Where superstructures are connected by trunks, open rails are to be provided for the whole length of exposed parts of freeboard deck. ⚓

KOREAN REGISTER

2011

Guidance Relating to the Rules for the Classification of Steel Ships

Part 10

Hull Structures and Equipment of Small Steel Ships

GA-10-E

KOREAN REGISTER OF SHIPPING

APPLICATION OF THE GUIDANCE

This "Guidance relating to the Rules for Classification of Steel Ships" (hereafter called as the Guidance) is prepared with the intent of giving guidines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules.
As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

APPLICATION OF PART 10
"HULL STRUCTURE AND EQUIPMENT OF SMALL STEEL SHIPS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2011.
2. The amendments to the Guidance for 2010 edition and their effective date are as follows;

Effective Date : 10 Jan. 2011

CHAPTER 15 DEEP TANKS

Section 2 Bulkheads of Deep Tanks

- 202. has been newly added.

Effective Date : 1 July 2011

CHAPTER 1 GENERAL

Section 2 General

- 201. Table 10.1.2 has been amended.

CONTENTS

CHAPTER 1 GENERAL

Section 1 Definitions

101. Application

As specified in **Pt 3, Ch 1, 101.** of the Guidance.

102. Length

As specified in **Pt 3, Ch 1, 102.** of the Guidance.

104. Breadth

As specified in **Pt 3, Ch 1, 104.** of the Guidance.

105. Depth

As specified in **Pt 3, Ch 1, 106.** of the Guidance.

Section 2 General

201. Application

1. For the ships classed for coastal service area, reduction for scantlings of the ship is to be as followings.

(1) For the requirements of the applicable chapters of Rules, scantlings of structural members may be lightened with the rate specified in **Table 10.1.1,** however, not less than the minimum dimensions specified in **Table 10.1.1.**

(2) For the reduction for scantlings of the members not specified in **Table 10.1.1,** it is to be in accordance with the discretion of the Society.

(3) When the cargoes loaded on the deck beams or heavy cargoes loaded on inner bottom plates and longitudinals, deep tanks and etc, the reduction for scantlings of the members is not permitted

(4) The height of hatch coaming and seals for every access opening may be in accordance with **Table 10.1.2.** However, closures of hatchways are to be in accordance with the discretion of the Society.

(5) The equipment number and equipment are to be in accordance with **Ch. 22** of the Rules. However, one anchor is to be more than the weight specified in **Table 10.22.1** of the Rules. and another anchor is to be more than 85 % the weight specified in **Table 10.22.1** of the Rules.

2. For the ships classed for smooth water service area, reduction for scantlings of the members is to be as followings.

(1) For the requirements of the applicable chapters of Rules, scantlings of structural members may be lightened with the rate specified in **Table 10.1.1,** however, not less than the minimum dimensions specified in **Table 10.1.1.**

(2) For the reduction for scantlings of the members not specified in **Table 10.1.1,** it is to be in accordance with the discretion of the Society.

(3) When the cargoes loaded on the deck beams or heavy cargoes loaded on inner bottom plates and longitudinals, deep tanks and etc, the reduction for scantlings of the members is not permitted

(4) The height of hatch coaming and seals for every access opening may be in accordance with **Table 10.1.2.** However, closures of hatchways are to be in accordance with the discretion of the Society.

(5) In case of the cargoes being not loaded on the steel hatch covers, 4.5 mm thick plates may be used for the steel hatch covers.

(6) The steel hatch covers are to be set up stiffeners in proper space and for not intended to carry cargos or stores on them, the section modulus of the stiffeners may be properly considered as the scantlings of provisions specified in **Ch. 19, 303.** of the Rules.
(7) The equipment number and equipment are to be in accordance with above **1,** (5). However, for the equipment letters specified in **Table 10.22.1** of the Rules. one lower grade of the letter may be applied according to the equipment number required in **Ch. 22, 201** of the Rules.

Table 10.1.1 Minimum dimension and lightening of the members

Item		Coastal services	Smooth water services	Minimum dimension
Longitudinal strength	M_w	20 %	30 %	-
	Z_{min}	10 %	15 %	-
Shell plating(including plate keels)		5 %	10 %	6 mm, (excluding superstructure)
Min. thickness of deck		1 mm	1 mm	5 mm
Section modulus of frame(including bottom longitudinals)		10 %	20%	30 cm^3
Section modulus of deck frame		15 %	15 %	-
Section modulus of girder under deck		15 %	15 %	-
Plate thick. of double bottom		1 mm	1 mm	5.5 mm
Plate thick. of single bottom		0.5 mm	10 % or 1 mm whichever is smaller	-
Plate thick. of B.H.D of super. structure end and section modulus of B.H.D stiffener		10 %	10 %	-

Note :
1. For the ships engaging in international services may not be lightened the thickness of B.H.D of superstructure end and moment of inertia of B.H.D stiffeners.
2. Z_{min} & M_w : refer to **Table 10.3.1** of the Rules

Table 10.1.2 Height of sills of hatch coaming and other access openings

Service area	Type	Normal Hatchway		Small Hatchway (area of hatchway) less than 0.45 m^2		Small Hatchway (area of hatchway) 0.45～1.5 m2		Companion ways		Access opening of superstructure end		Ventilation tunnel	
	Ship length / Position	less than 30 m	more than 30 m	less than 30 m	more than 30 m	less than 30 m	more than 30 m	less than 30 m	more than 30 m	less than 30 m	more than 30 m	less than 30 m	more than 30 m
Costal service	I	450	600	230	380	380	450	300	450	300	380	760	900
	II	300	450	180	230	230	380	150	300	100	300	450	760
Smooth water service	I	300	450	150	230	230	380	150	300	150	300	450	760*
	II	150	300	100	180	150	230	100	100	100	100	450	450

Note:
1. For the ships engaging in international services are to be excluded
2. * : For the tug boats not engaging in international services, the height of ventilation tunnel may be more than 450 mm

203. Ships on unusual form or proportion, or intended for carriage of special cargoes

As specified in **Pt 3, Ch 1, 203.** of the Guidance.

Section 3 Materials, Welding and Construction

301. Materials

1. As for ships 60 m and above in length, plating materials for stern frames, rudder horns, rudders and shaft brackets are to be used of higher than Grade I of **Table 10.1.2** of the Rules.

2. Where high tensile steels are used, the formulas for thickness of deck and shell platings, the section modulus of stiffeners, and other scantlings etc., are to be in accordance with the requirements of **Pt 3.** ⚓

CHAPTER 2 STEMS AND STERN FRAMES

Section 1 Stems

101. Plate stems

As specified in **Pt 3, Ch 2, 101.** of the Guidance.

Section 2 Stern Frames

202. Propeller posts

1. The welding of cast steel stern frames are to be in accordance with the **Pt 3, Ch 2, 202.** of the Guidance.

2. The connection of cast steel boss and plate parts of built-up stern frame is to be in accordance with the **Pt 3, Ch 2, 203.** of the Guidance.

203. Shoe pieces

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As specified in **Pt 3, Ch 3, 201.** of the Guidance.

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Section 3 Shell Plating for Midship Part of Ship

303. Sheer strakes for midship part

As specified in **Pt 3, Ch 4, 303.** of the Guidance.

Section 4 Shell Plating for End Parts

401. Shell plating for end parts

1. The thickness of shell plating of curved parts within 0.3 L from the forward and aft end may be calculated with the value of S taken as equal to 1.1times the vertical or horizontal distance between frames a as shown in **Fig. 10.4.1.**

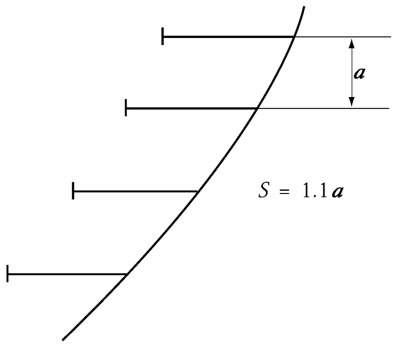
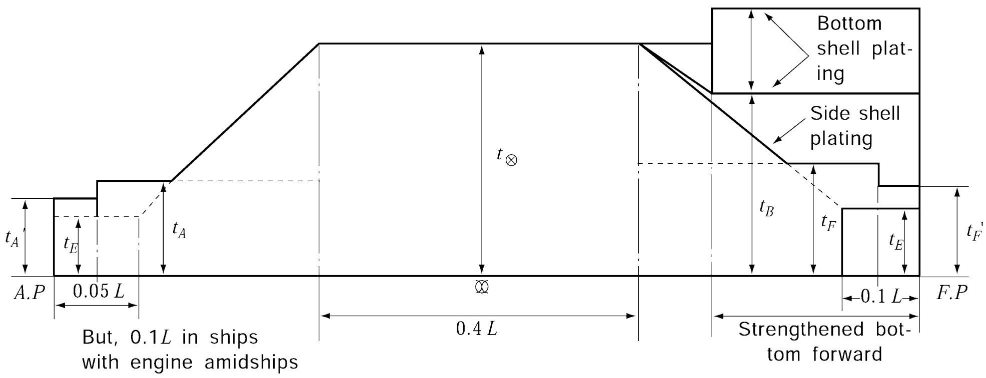


Fig 10.4.1 Relation of S and a in end parts

2. The thickness of shell plating is not to be less than the thickness shown in **Fig. 10.4.2** approximately at the middle of length of each plates.



$t_{\otimes}$: Required thickness of shell plating in midship part(to be the actual thickness, if actual thickness is greater than required due to assuring the longitudinal strength)
t_E : Required thickness of shell plating in end parts($4.6 + 0.44L$) (mm)
$t_F(t_F')$: Required thickness of shell plating within 0.3L from the fore end($1.34\,S\sqrt{L} + t_C$) (mm)
$t_A(t_A')$: Required thickness of shell plating within 0.3L from the aft end($1.20\,S\sqrt{L} + t_C$) (mm)
t_B : Required thickness of shell plating in strengthened bottom forward (mm)

Fig 10.4.2 Tapering of shell plating thickness

404. Strengthened bottom forward

As specified in **Pt 3, Ch 4, 404.** of the Guidance.

Section 5 Side Plating in way of Superstructure

503. Compensation at end Superstructure

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601. Opening in shell

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CHAPTER 7 DOUBLE BOTTOMS

Section 1 General

101. Application

1. For the ships subject to **SOLAS** or **Korean Ship Safety Act.,** inner bottom plate is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. And the inner bottom is not to be lower at any part than a plan parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

$$h = B/20$$

However, in no case is the value of h to be less than 760 mm, and need not be taken as more than 2,000 mm.

2. For the ships subject to **SOLAS** or **Korean Ship Safety Act.,** and whose gross tonnages are more than 500 and engaged in international service, a double bottom may be omitted provided it is satisfied for flooding calculation of **Pt 3, Ch 7, 101. 2.**

103. Drainage

1. Small wells constructed in the double bottom in connection with drainage arrangements of holds are not to be extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel.

2. Other wells (e.g., for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this Chapter.

3. For the ships subject to **SOLAS** or **Korean Ship Safety Act.,** except a well at the end of the shaft tunnel, the vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than 500 mm.

Section 5 Bottom Longitudinals

502. Scantlings

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601. Thickness of inner bottom plating

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901. Application

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CHAPTER 9 CANTILEVER BEAM CONSTRUCTION

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201. Constructions and arrangements

Where bottom plates of chain lockers, which are located forward collision bulkhead and reach side shell, are not situated in the level of side stringer, horizontal girders are recommended to be fitted in chain lockers at the stringer level.(See **Fig. 10.13.1**) ⚓

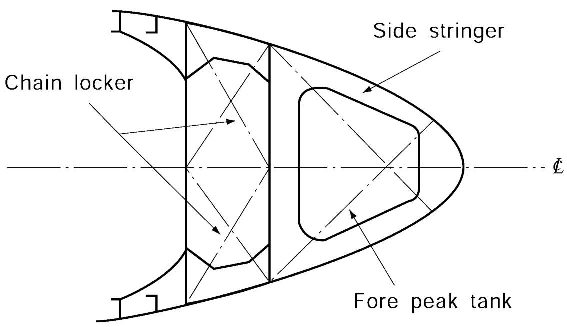

Fig 10.13.1 Construction and arrangement to resist panting in way of chain locker

CHAPTER 14 WATERTIGHT BULKHEADS

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101. Collision bulkheads

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104. Hold bulkheads

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301. Closures for access openings

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CHAPTER 17 MACHINERY SPACES AND ENGINE CASINGS

Section 1 General

102. Compensation

Sectional area of face plates of web frames in machinery spaces is not to be less than the values obtained from following formula. However, scantlings of web frames may be determined by the other suitable calculation approved by the Society.

$$A = \frac{8KlSL}{d_w} - \frac{d_w t_w}{600} \quad (\text{cm}^2)$$

Where :

K = coefficient obtained in following formula

in case that P is equal to C and over : $K = 0.4(P/C-1)+l$

in case that P is less than C and over : $K = 0.2(P/C-1)+l$

P = maximum continuous output of main engine (PS)

C = coefficient obtained in following formula

in case that ships are 50 m in length and smaller : C = 10 L

in case that ships are over 50 m in length : C = 35 L - 1250

l = vertical distance from the top of inner bottom platings to the top of beams of lowest deck at side of ships (m)

S = spacing of web frames (m)

L = length of ships (m)

d_w = depth of web plates of web frames (mm)

t_w = thickness of web plates of web frames (mm)

Section 2 Main Engine Foundations

201. Sips with single bottoms

Where spacing of girders beneath main engines is narrow, center girder may be omitted. However, intercostal plates are recommended to be fitted with along centre line.

202. Ships with double bottoms

As specified in **Pt 3, Ch 18, 202.** of the Guidance. ⚓

CHAPTER 19 HATCHWAYS AND OTHER DECK OPENINGS

Section 1 General

101. Application

The regulation of **101. 3** of the Rules is not to be applied to the vessel which engaged in domestic service only.

102. Position of exposed deck openings

As specified in **Pt 4, Ch 2, 102.** of the Guidance.

Section 2 Hatchways

202. Height of hatchway coamings

As specified in **Pt 4, Ch 2, 201.** of the Guidance.

203. Construction of hatchway coamings

1. The thickness of small hatch way coaming (t) provided with weathertight steel hatch covers is to be as following formula;

$$t = 0.05L + 4 \quad \text{(mm)}$$

2. Construction and scantling of hatch way coamings for deep tanks is to be complied with **Pt 3, Ch 15** of the Rules as well as **Pt 4, Ch 2** of the Rules.

Section 4 Hatchways Closed by Weathertight Covers fitted with Gaskets and Clamping Devices

401. Steel weathertight covers

The details of gaskets and clamping devices for steel weathertight covers are to apply the provisions in **Pt 4, Ch 2, Sec 7** of the Rules. However, the standard spacings of securing devices are 0.5 m or less at the corner of the cover, and 1.0 m or less elsewhere.

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602. Companion ways

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As specified in **Pt 4, Ch 4, 204.** of the Guidance.

Section 3 Side Scuttles

302. Application

As specified in **Pt 4, Ch 4, 302.** of the Guidance. ⚓

CHAPTER 22 EQUIPMENT NUMBER AND EQUIPMENT

Section 1 General

101. General and application

1. Where Danforth anchors having constructions of special shape and dimensions are used,(provided with ships less than 30 m in length) drawings and data related to the anchor are to be submitted to the Society for obtaining approval prior to making it.

2. Where the equipment number is to be calculated in accordance with the requirements of **57** of **Regulation for Ships Equipments**, danforth anchor, anchor ropes and mooring ropes in specified **Table 10.22.1** may be provided with according to the equipment number.

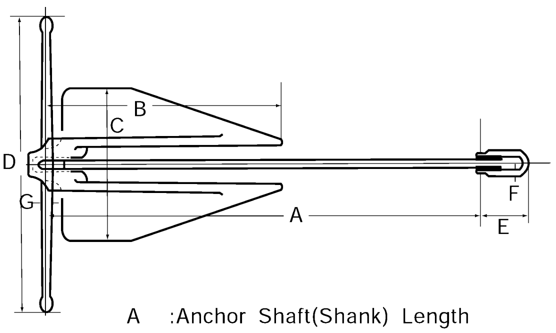
Table 10.22.1 Danforth anchor and ropes

Equipment Number		Danforth Anchor		Ropes for anchor(per each anchor)						Tow Line		Mooring Line		
					Diameter (mm)									
								Chain						
Exceeding	Not exceeding	Number	Weight per abchor (kg)	Length (m)	Manilar Rope	Nylon Rope	Vinyl Rope	Grade 1	Grade 2	Length (mm)	Diameter (mm)	Number	Length (mm)	Diameter (mm)
80	90	2	20	60	24	17	20	·		110	28	·	·	·
90	105	2	25	70	28	20	24	·		110	30	1	165	20
105	140	2	30	80	32	22	27	·		110	32	1	165	20
140	175	2	40	90	35	25	30	·		135	34	1	165	22
175	215	2	50	100	38	27	33	·		135	36	1	165	24
215	255	2	60	100	42	30	36	14	12.5	135	40	1	165	24
255	295	2	70	110	45	32	38	14	12.5	135	45	1	165	24
295	390	2	95	110	50	35	42	16	14	135	50	1	165	32
390	445	2	125	120	60	42	50	17.5	16	135	50	1	165	32

3. Dimensions of danforth anchor are to be in accordance with the **Table 10.22.2.** and other denforth anchors having dimensions not specified in above **1** and **2** are to be in accordance with the discretion of the Society.

Table 10.22.2 Dimensions of danforth anchor

Size(mm) / Weight(kg)	A	B	C	D	E	F	G
20	825	463	361	685	95	18	23
25	890	500	390	740	104	20	25
30	945	565	414	784	109	21	26
40	1,049	590	460	872	122	24	29
50	1,154	647	506	960	134	26	32
60	1,190	668	521	988	137	27	33
75	1,280	719	561	1,063	149	29	35
100	1,400	790	616	1,170	163	31	43
120	1,500	840	657	1,240	174	34	45



A :Anchor Shaft(Shank) Length
B :Bill(pea)↔Stock Center
C :Anchor Arm(p)↔Anchor Arm(s)
D :Stock length
E :Anchor Ring(Shackle) Length
F :Anchor Ring(Shackle) Dia.
G :Stock Dia.

Section 2 Equipment Number

201. Equipment number

As specified in **Pt 4, Ch 8, 201.** of the Guidance.

202. Weight of anchors

"High holding power anchors" in **202. 3** of the Rules means the anchors that have the holding power more than 2 times the holding power of stockless anchor with the same weight when the holding power test specified in **Ch 3, Sec 14.** of the Guidance for approval of manufacturing process and type approval, etc is to be carried out. ⚓

CHAPTER 23 OIL TANKERS

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101. Application

As specified in **Pt 7, Ch 1, 101. 3.** of the Guidance.

102. Arrangement of bulkheads

As specified in **Pt 7, Ch 1, 102.** of the Guidance.

103. Cofferdams

As specified in **Pt 7, Ch 1, 103.** of the Guidance.

104. Airtight bulkheads

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102. Arrangement and separation of spaces

As specified in **Pt 7, Ch 10, 102.** of the Guidance.

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As specified in **Pt 7, Ch 10, 202.** of the Guidance. ⚓

Rules for the Classification of Steel Ships
Guidance Relating to the Rules for the Classification of Steel Ships

PART 10 HULL STRUCTURE AND EQUIPMENT OF SMALL STEEL SHIPS

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2011

Rules for the Classification of Steel Ships

Part 11

Common Structural Rules for Bulk Carriers

RA-11-E

KOREAN REGISTER OF SHIPPING

COMMON STRUCTURAL RULES FOR BULK CARRIERS

Foreword

1. This version of the Rules is effective as of 1st July 2010.

2. This version incorporates rule changes made to the 1 July 2008 consolidated edition.

2.1 Note that changes included in Rule Change Notice 1 to the 1 July 2008 consolidated edition are effective from 1 July 2009.

3. The Rules contain structural requirements for the Classification of Bulk Carriers of 90 m in length or greater.

4. The Rules contain thirteen chapters.

5. The following table provides a revision history of the Rules.

	Amendment Type / No.	Approval Date	Effective Date*	Reference Rule Edition
1	Corrigenda 1	15 May 2006	1 April 2006	1 Jan 2006 edition
2	Corrigenda 2	29 Jan 2007	1 April 2006	1 Jan 2006 edition
3	Corrigenda 3	19 July 2007	1 April 2006	1 Jan 2006 edition
4	Corrigenda 4	3 Sept 2007	1 April 2006	1 Jan 2006 edition
5	Rule Change Notice 1	30 Nov 2007	1 April 2008	1 Jan 2006 edition
6	Rule Change Notice 2	25 Feb 2008	1 July 2008	1 Jan 2006 edition
7	Corrigenda 5	15 May 2008	1 April 2006	1 Jan 2006 edition
8	Rule Change Notice 3 (Urgent)	12 Sept 2008	12 Sept 2008	1 Jan 2006 edition

	Amendment Type / No.	Approval Date	Effective Date*	Reference Rule Edition
9	Rule Change Notice 1 (1 July 2008 consolidated edition)	30 Jan 2009	1 July 2009	1 July 2008 consolidated edition
10	Rule Change Notice 2 (1 July 2008 consolidated edition)	12 Apr 2010	1 July 2010	1 July 2008 consolidated edition

* For effective date, refer to the implementation statements of relevant Corrigenda / Rule Changes.

Note: When the word '(void)' appears in the text, it means that the concerned part has been deleted. This is to keep the numbering of the remainder unchanged.

Table of Contents

Chapter 1

General Principles

Section 1 – APPLICATION

1. General

1.1 Structural requirements

1.1.1

These Rules apply to ships classed with the Society and contracted for construction on or after 1 April 2006.

Note: The "contracted for construction" means the date on which the contract to build the ship is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contracted for construction", refer to IACS Procedural Requirement (PR) No.29.

1.1.2

These Rules apply to the hull structures of single side skin and double side skin bulk carriers with unrestricted worldwide navigation, having length L of 90 m or above.

With bulk carrier is intended sea going self-propelled ships which are constructed generally with single deck, double bottom, hopper side tanks and topside tanks and with single or double side skin construction in cargo length area and intended primarily to carry dry cargoes in bulk, excluding ore and combination carriers.

Hybrid bulk carriers, where at least one cargo hold is constructed with hopper tank and topside tank, are covered by the present Rules. The structural strength of members in holds constructed without hopper tank and/or topside tank is to comply with the strength criteria defined in the Rules.

1.1.3

The present Rules contain the IACS requirements for hull scantlings, arrangements, welding, structural details, materials and equipment applicable to all types of bulk carriers having the following characteristics:

- $L < 350$ m
- $L / B > 5$
- $B / D < 2.5$
- $C_B \geq 0.6$

1.1.4

The Rule requirements apply to welded hull structures made of steel having characteristics complying with requirements in **Ch 3, Sec 1**. The requirements apply also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in **Ch 3, Sec 1**.

1.1.5

Ships whose hull materials are different than those given in **[1.1.4]** and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the present Rules.

1.1.6

The scantling draught considered when applying the present Rules is to be not less than that corresponding to the assigned freeboard.

1.1.7

Where scantlings are obtained from direct calculation procedures which are different from those specified in **Ch 7**, adequate supporting documentation is to be submitted to the Society, as detailed in **Sec 2**.

1.2 Limits of application to lifting appliances

1.2.1

The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts), only for that part directly interacting with the hull structure. The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2

The fixed parts of lifting appliances and their connections to the ship's structure may be covered by the Society's Rules for lifting appliances, and / or by the certification (especially the issuance of the Cargo Gear Register) of lifting appliances when required.

1.2.3

The design of the structure supporting fixed lifting appliances and the structure that might be called to support a mobile appliance should be designed taking into account the additional loads that will be imposed on them by the operation of the appliance as declared by the shipbuilder or its sub-contractors.

1.3 Limits of application to welding procedures

1.3.1

The requirements of the present Rules apply also for the preparation, execution and inspection of welded connections in hull structures. They are to be complemented by the general requirements relevant to fabrication by welding and qualification of welding procedures given by the Society when deemed appropriate by the Society.

2. Rule application

2.1 Ship parts

2.1.1 General

For the purpose of application of the present Rules, the ship is considered as divided into the following three parts:

- fore part
- central part
- aft part.

2.1.2 Fore part

The fore part includes the structures located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stem.

In addition, it includes:

- the reinforcements of the flat bottom forward area
- the reinforcements of the bow flare area.

2.1.3 Central part

The central part includes the structures located between the collision bulkhead and the after peak bulkhead. Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part

The aft part includes the structures located aft of the after peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1

The various chapters and sections are to be applied for the scantling of ship parts according to **Table 1**.

Table 1: Chapters and sections applicable for the scantling of ship parts

<table>
<tr><th rowspan="2">Part</th><th colspan="2">Applicable Chapters and Sections</th></tr>
<tr><th>General</th><th>Specific</th></tr>
<tr><td>Fore part</td><td rowspan="3">Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 9[(1)], excluding:
Ch 9, Sec 1
Ch 9, Sec 2
Ch 11</td><td>Ch 9, Sec 1</td></tr>
<tr><td>Central part</td><td>Ch 6
Ch 7
Ch 8</td></tr>
<tr><td>Aft part</td><td>Ch 9, Sec 2</td></tr>
<tr><td colspan="3">(1) See also [2.3].</td></tr>
</table>

2.3 Rules applicable to other ship items

2.3.1

The various Chapters and Sections are to be applied for the scantling of other ship items according to **Table 2**.

Table 2: Chapters and sections applicable for the scantling of other items

Item	Applicable Chapters and Sections
Machinery spaces	Ch 9, Sec 3
Superstructures and deckhouses	Ch 9, Sec 4
Hatch covers	Ch 9, Sec 5
Hull and superstructure openings	Ch 9, Sec 6
Rudders	Ch 10, Sec 1
Bulwarks and guard rails	Ch 10, Sec 2
Equipment	Ch 10, Sec 3

3. Class Notations

3.1 Additional service features BC-A, BC-B and BC-C

3.1.1

The following requirements apply to ships, as defined in **[1.1.2]**, having length L of 150 m or above.

3.1.2

Bulk carriers are to be assigned one of the following additional service features:

a) BC-A : for bulk carriers designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above with specified holds empty at maximum draught in addition to BC-B conditions.

b) BC-B : for bulk carriers designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above with all cargo holds loaded in addition to BC-C conditions.

c) BC-C : for bulk carriers designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3.

3.1.3

The following additional service features are to be provided giving further detailed description of limitations to be observed during operation as a consequence of the design loading condition applied during the design in the following cases:

- {maximum cargo density (in t/m^3)} for additional service features BC-A and BC-B if the maximum cargo density is less than 3.0 t/m^3(see also **Ch 4, Sec 7, [2.1]**).
- {no MP} for all additional service features when the ship has not been designed for loading and unloading in multiple ports in accordance with the conditions specified in **Ch 4, Sec 7, [3.3]**.
- {allowed combination of specified empty holds} for additional service feature BC-A(see also **Ch 4, Sec 7, [2.1]**).

3.2 Additional class notation GRAB [X]

3.2.1 Application

The additional class notation GRAB [X] is mandatory for ships having one of the additional service features BC-A or BC-B, according to **[3.1.2]**. For these ships the requirements for the GRAB [X] notation given in **Ch 12, Sec 1** are to be complied with for an unladen grab weight X equal to or greater than 20 tons.

For all other ships the additional class notation GRAB [X] is voluntary.

3.3 Class notation CSR

3.3.1 Application

In addition to the class notations granted by the assigning Society and to the service features and additional class notations defined hereabove, ships fully complying with the present Rules will be assigned the notation CSR.

Section 2 - VERIFICATION OF COMPLIANCE

1. General

1.1 New buildings

1.1.1

For new buildings, the plans and documents submitted for approval, as indicated in **[2]**, are to comply with the applicable requirements in **Ch 1** to **Ch 12** of the present Rules, taking account of the relevant criteria, as the additional service features and classification notation assigned to the ship or the ship length.

1.1.2

When a ship is surveyed by the Society during construction, the Society:

- approves the plans and documentation submitted as required by the Rules
- proceeds with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works
- carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the rule requirements in relation to the approved drawings
- attends tests and trials provided for in the Rules
- assigns the construction mark.

1.1.3

The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

1.1.4

As part of his interventions during the ship's construction, the Surveyor will:

- conduct an overall examination of the parts of the ship covered by the Rules
- examine the construction methods and procedures when required by the Rules
- check selected items covered by the rule requirements
- attend tests and trials where applicable and deemed necessary.

1.2 Ships in service

1.2.1

For ships in service, the requirements in **Ch 13** of the present Rules are to be complied with.

2. Documentation to be submitted

2.1 Ships surveyed by the Society during the construction

2.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in **Table 1**. In addition, the Society may request for approval or information, other plans and documents deemed necessary for the review of the design.

Structural plans are to show details of connections of the various parts and are to specify the design materials, including, in general, their manufacturing processes, welding procedures and heat treatments. See also **Ch 11, Sec 2, [1.4]**.

2.1.2 Plans and documents to be submitted for information

In addition to those in **[2.1.1]**, the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution
- docking plan.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society (see **[3]**).

2.2 Ships for which the Society acts on behalf of the relevant Administration

2.2.1 Plans and documents to be submitted for approval

The plans required by the National Regulations concerned are to be submitted to the Society for approval, in addition to those in **[2.1]**.

Table 1: Plans and documents to be submitted for approval

Plan or document	Containing also in formation on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Contractual service speed Density of cargoes Design loads on decks and double bottom Steel grades Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	
Aft part structure	
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and rpm of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers and hatch coamings	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	

Plan or document	Containing also in formation on
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Windows and side scuttles, arrangements and details	
Scuppers and sanitary discharges	
Rudder and rudder horn(1)	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets(1)	
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Plan of outer doors and hatchways	
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	
Hawse pipes	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces and location and height of air vent outlets of various compartments
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Loading manual and loading instruments	Loading conditions as defined in **Ch 4, Sec 7** (see also **Ch 4, Sec 8**)
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes

(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see **Ch 10, Sec 1, [11]**.

3. Computer programs

3.1 General

3.1.1

In order to increase the flexibility in the structural design direct calculations with computer programs are acceptable (see **Ch 7**). The aim of such analyses is to assess the structure compliance with the rule requirements.

3.2 General programs

3.2.1

The choice of computer programs according to currently available technology is free. The programs are to be able to manage the model and load cases as required in **Ch 7** and/or **Ch 8**. The programs may be checked by the Society through comparative calculations with predefined test examples. A generally valid approval for a computer program is, however, not given by the Society.

3.2.2

Direct calculations may be used in the following fields:

- global strength
- longitudinal strength
- beams and grillages
- detailed strength.

3.2.3

For such calculation the computer model, the boundary condition and load cases are to be agreed upon with the Society.
The calculation documents are to be submitted including input and output. During the examination it may prove necessary that the Society performs independent comparative calculations.

Section 3 – FUNCTIONAL REQUIREMENTS

1. General

1.1 Application

1.1.1

This section defines the set of requirements relevant to the functions of the ship structures to be complied with during design and construction, to meet the following objectives.

1.2 Design life

1.2.1

The ship is to remain safe and environment-friendly, if properly operated and maintained, for her expected design life, which, unless otherwise specifically stated, is assumed to be equal to 25 years. The actual ship life may be longer or shorter than the design life, depending on the actual conditions and maintenance of the ship, taking into account aging effects, in particular fatigue, coating deterioration, corrosion, wear and tear.

1.3 Environmental conditions

1.3.1

The ship's structural design is to be based on the assumption of trading in the North Atlantic environment for the entire design life. Hence the respective wave conditions, i.e. the statistical wave scatter takes into account the basic principle for structural strength layout.

1.4 Structural safety

1.4.1

The ship is to be designed and constructed, and subsequently operated and maintained by its builders and operators, to minimise the risk for the safety of life at sea and the pollution of the marine environment as the consequence of the total loss of the ship due to structural collapse and subsequent flooding, loss of watertight integrity.

1.5 Structural accessibility

1.5.1

The ship is to be designed and constructed to provide adequate means of access to all spaces and internal structures to enable overall and close-up inspections and thickness measurements.

1.6 Quality of construction

1.6.1

As an objective, ships are to be built in accordance with controlled quality production standards using approved materials as necessary.

2. Definition of functional requirements

2.1 General

2.1.1

The functional requirements relevant to the ship structure are indicated in **[2.2]** to **[2.6]**.

2.2.1

Ships are to be designed to withstand, in the intact condition, the environmental conditions during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations have to include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

2.2.2

Ships are to be designed to have sufficient reserve strength to withstand the wave and internal loads in damaged conditions that are reasonably foreseeable, e.g. collision, grounding or flooding scenarios. Residual strength calculations are to take into account the ultimate reserve capacity of the hull girder, considering permanent deformation and post-buckling behaviour.

2.2.3

Ships are to be assessed according to the expected design fatigue life for representative structural details.

2.3 Coating

2.3.1

Coating, where required, is to be selected as a function of the declared use of the ship spaces, e.g. holds, tanks, cofferdams, etc., materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternative means. The protective coating systems, applied and maintained in accordance with manufacturer's specifications concerning steel preparation, coating selection, application and maintenance, are to comply with the SOLAS requirements, the flag administration requirements and the Owner specifications.

2.4 Corrosion addition

2.4.1

The corrosion addition to be added to the net scantling required by structural strength calculations is to be adequate for the operating life. The corrosion addition is to be assigned in accordance with the use and exposure of internal and external structure to corrosive agents, such as water, cargo or corrosive atmosphere, in addition to the corrosion prevention systems, e.g. coating, cathodic protection or by alternative means.

2.5 Means of access

2.5.1

Ship structures subject to overall and close-up inspection and thickness measurements are to be provided with means capable of ensuring safe access to the structures. The means of access are to be described in a Ship Structure Access Manual for bulk carriers of 20,000 gross tonnage and over. Reference is made to SOLAS, Chapter II-1, Regulation 3-6.

2.6 Construction quality procedures

2.6.1

Specifications for material manufacturing, assembling, joining and welding procedures, steel surface preparation and coating are to be included in the ship construction quality procedures.

3. Other regulations

3.1 International regulations

3.1.1

Attention of designers, shipbuilders and shipowners of ships covered by these Rules is drawn on the following :
Ships are designed, constructed and operated in a complex regulatory framework prescribed internationally by IMO and implemented by flag states or by classification societies on their behalf. Statutory requirements set the standard for statutory aspects of ships such as life saving, subdivisions, stability, fire protection, etc.
These requirements influence the operational and cargo carrying arrangements of the ship and therefore may affect its structural design.
The main international instruments normally to be applied with regard to the strength of bulk carriers are:

- International Convention for Safety of Life at Sea (SOLAS)
- International Convention on Load Lines

3.2 National regulations

3.2.1

Attention is drawn on the applicable national flag state regulations.
Compliance with these regulations of national administrations is not conditional for class assignment.

4. Workmanship

4.1 Requirements to be complied with by the manufacturer

4.1.1

The manufacturing plant is to be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes, structural components, etc.
The manufacturing plant is to have at its disposal sufficiently qualified personnel. The Society is to be advised of the names and areas of responsibility of the supervisory and control personnel in charge of the project.

4.2 Quality control

4.2.1

As far as required and expedient, the manufacturer's personnel has to examine all structural components both during manufacture and on completion, to ensure that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.
Upon inspection and corrections by the manufacturing plant, the structural components are to be shown to the surveyor of the Society for inspection, in suitable sections, normally in unpainted condition and enabling proper access for inspection.
The Surveyor may reject components that have not been adequately checked by the plant and may demand their re-submission upon successful completion of such checks and corrections by the plant.

5. Structural Details

5.1 Details in manufacturing documents

5.1.1

Significant details concerning quality and functional ability of the component concerned are to be entered in the manufacturing documents (workshop drawings, etc.). This includes not only scantlings but – where relevant - such items as surface conditions (e.g. finishing of flame cut edges and weld seams), and special methods of manufacture involved as well as inspection and acceptance requirements and where relevant permissible tolerances. So far as for this aim a standard is used (works or national standard etc.) it is to be submitted to the Society. For weld joint details, see **Ch 11, Sec 2**.
If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component is doubtful, the Society may require appropriate improvements to be submitted by the manufacturer. This includes the provision of supplementary or additional parts (for example reinforcements) even if these were not required at the time of plan approval.

Section 4 - SYMBOLS AND DEFINITIONS

1. Primary symbols and units

1.1

1.1.1

Unless otherwise specified, the general symbols and their units used in the present Rules are those defined in **Table 1**.

Table 1: Primary symbols

Symbol	Meaning	Units
A	Area	m^2
	Sectional area of ordinary stiffeners and primary members	cm^2
B	Moulded breadth of ship (see **[2]**)	m
C	Coefficient	-
D	Depth of ship (see **[2]**)	m
E	Young's modulus	N/mm^2
F	Force and concentrated loads	kN
I	Hull girder inertia	m^4
	Inertia of ordinary stiffeners and primary members	cm^4
L	Length of ship (see **[2]**)	m
M	Bending moment	kN.m
Q	Shear force	kN
S	Spacing of primary supporting members	
T	Draught of ship (see **[2]**)	m
V	Ship's speed	knot
Z	Hull girder section modulus	m^3
a	Acceleration	m/s^2
b	Width of attached plating	m
	Width of face plate of ordinary stiffeners and primary members	mm
g	Gravity acceleration (see **[2]**)	m/s^2
h	Height	m
	Web height of ordinary stiffeners and primary members	mm
k	Material factor (see **[2]**)	-
ℓ	Length / Span of ordinary stiffeners and primary supporting members	m
m	Mass	t
n	Number of items	-
p	Pressure	kN/m^2

Symbol	Meaning	Units
r	Radius	mm
	Radius of curvature of plating or bilge radius	m
s	Spacing of ordinary stiffeners	m
t	Thickness	mm
w	Section modulus of ordinary stiffeners and primary supporting members	cm^3
x	X coordinate along longitudinal axis (see **[4]**)	m
y	Y coordinate along transverse axis (see **[4]**)	m
z	Z coordinate along vertical axis (see **[4]**)	m
γ	Safety factor	-
δ	Deflection / Displacement	mm
θ	Angle	deg
ξ	Weibull shape parameter	-
ρ	Density	t/m^3
σ	Bending stress	N/mm^2
τ	Shear stress	N/mm^2

2. Symbols

2.1 Ship's main data

2.1.1

L : Rule length, in m, defined in **[3.1]**

L_{LL} : Freeboard length, in m, defined in **[3.2]**

L_{BP} : Length between perpendiculars, in m, is the length of the ship measured between perpendiculars taken at the extremities of the deepest subdivision load line, i.e. of the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable

FP_{LL} : Forward freeboard perpendicular. The forward freeboard perpendicular is to be taken at the forward end of the length L_{LL} and is to coincide with the foreside of the stem on the waterline on which the length L_{LL} is measured

AP_{LL} : After freeboard perpendicular. The after freeboard perpendicular is to be taken at the aft end of the length L_{LL}.

B : Moulded breadth, in m, defined in **[3.4]**

D : Depth, in m, defined in **[3.5]**

T : Moulded draught, in m, defined in **[3.6]**

T_S : Scantling draught, in m, taken equal to the maximum draught (see also **Ch 1, Sec 1, [1.1.6]**)

T_B : Minimum ballast draught at midship, in m, in normal ballast condition as defined in **Ch 4, Sec 7, [2.2.1]**

T_{LC} : Midship draught, in m, in the considered loading condition

Δ : Moulded displacement, in tonnes, at draught T, in sea water (density $\rho = 1.025\ t/m^3$)

C_B : Total block coefficient

$$C_B = \frac{\triangle}{1.025LBT}$$

V : Maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system.

2.2 Materials

2.2.1

E : Young's modulus, in N/mm^2,tobetakenequalto:

$E = 2.06 \times 10^5\ N/mm^2$, for steels in general

$E = 1.95 \times 10^5\ N/mm^2$, for stainless steels

$E = 7.0 \times 10^4\ N/mm^2$, for aluminium alloys

R_{eH} : Minimum yield stress, in N/mm^2,of the material

k : Material factor, defined in **Ch 3, Sec 1, [2.2]**

ν : Poisson's ratio. Unless otherwise specified, a value of 0.3 is to be taken into account,

R_m : Ultimate minimum tensile strength, in N/mm^2,of the material

R_Y : Nominal yield stress, in N/mm^2, of the material, to be taken equal to $\frac{235}{k}\ N/mm^2$, unless otherwise specified.

2.3 Loads

2.3.1

g : Gravity acceleration, taken equal to 9.81 m/s^2

ρ : Sea water density, taken equal to 1.025 t/m^3

ρ_L : Density, in t/m^3, of the liquid carried

ρ_C : Density, in t/m^3, of the dry bulk cargo carried

C : Wave parameter, taken equal to:

$C = 10.75 - \left(\frac{300-L}{100}\right)^{1.5}$ for $90 \leq L < 300$ m

$C = 10.75$ for $300 \leq L < 350$ m

h : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

z_{TOP} : Vertical distance, in m, of the highest point of the tank from the baseline. For ballast holds, z_{TOP} is the vertical distance, in m, of the top of the hatch coaming from the baseline

ℓ_H : Length, in m, of the compartment

M_{SW} : Design still water bending moment, in kN.m, at the hull transverse section considered:

$M_{SW} = M_{SW,H}$ in hogging conditions

$M_{SW} = M_{SW,S}$ in sagging conditions

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered:

$M_{WV} = M_{WV,H}$ in hogging conditions

$M_{WV} = M_{WV,S}$ in sagging conditions

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered,

Q_{SW} : Design still water shear force, in kN, at the hull transverse section considered

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered

p_S : Still water pressure, in kN/m^2

p_W : Wave pressure or dynamic pressures, in kN/m^2

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m^2, in flooded conditions

σ_X : Hull girder normal stress, in N/mm^2

a_X, a_Y, a_Z : Accelerations, in m/s^2, along X, Y and Z directions, respectively

T_R : Roll period, in s

θ : Roll single amplitude, in deg

T_P : Pitch period, in s

Φ : Single pitch amplitude, in deg

k_r : Roll radius of gyration, in m

GM : Metacentric height, in m

λ : Wave length, in m

2.4 Scantlings

2.4.1 Hull girder scantlings

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis

Z_{AB}, Z_{AD} : Section moduli, in m^3, at bottom and deck, respectively

N : Vertical distance, in m, from the base line to the horizontal neutral axis of the hull transverse section

2.4.2 Local scantlings

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

S : Spacing, in m, of primary supporting members, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffener or primary supporting member, as the case may be, measured along the chord

ℓ_b : Length, in m, of brackets

t_C : Corrosion addition, in mm

h_w : Web height, in mm, of ordinary stiffener or primary supporting member, as the case may be

t_w : Net web thickness, in mm, of ordinary stiffener or primary supporting member, as the case may be

b_f : Face plate width, in mm, of ordinary stiffener or primary supporting member, as the case may be

t_f : Net face plate thickness, in mm, of ordinary stiffener or primary supporting member, as the case may be

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener or a primary supporting member, as the case may be

b_p : Width, in m, of the plating attached to the stiffener or the primary supporting member, for the yielding check

A_s : Net sectional area, in cm^2, of the stiffener or the primary supporting member, with attached plating of width s

A_{sh} : Net shear sectional area, in cm^2, of the stiffener or the primary supporting member

I : Net moment of inertia, in cm^4, of ordinary stiffener or primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating

I_p : Net polar moment of inertia, in cm^4, of ordinary stiffener or primary supporting member, as the case may be, about its connection to plating

I_w : Net sectional moment of inertia, in cm^6, of ordinary stiffener or primary supporting member, as the case may be, about its connection to plating

I_S : Net moment of inertia, in cm^4, of the stiffener or the primary supporting member, with attached shell plating of width s, about its neutral axis parallel to the plating

Z : Net section modulus, in cm^3, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

3. Definitions

3.1 Rule length

3.1.1

The rule length L is the distance, in m, measured on the summer load waterline, from the forward side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post. L is to be not less than 96 % and need not exceed 97 % of the extreme length on the summer load waterline.

3.1.2

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the rule length L is to be taken equal to 97 % of the extreme length on the summer load waterline.

3.1.3

In ships with unusual stem or stern arrangements, the rule length L is considered on a case by case basis.

3.2 Freeboard length

3.2.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(1,a))
The freeboard length L_{LL} is the distance, in m, on the waterline at 85 % of the least moulded depth from the top of the keel, measured from the forward side of the stem to the centre of the rudder stock. L_{LL} is to be not less than 96 % of the extreme length on the same waterline.

3.2.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(1,c))
*Where the stem contour is concave above the water-line at 85 % of the least moulded depth, both the forward end of the extreme length and the forward side of the stem are to be taken at the vertical projection to that waterline of the aftermost point of the stem contour (above that waterline) (see **Fig 1**).*

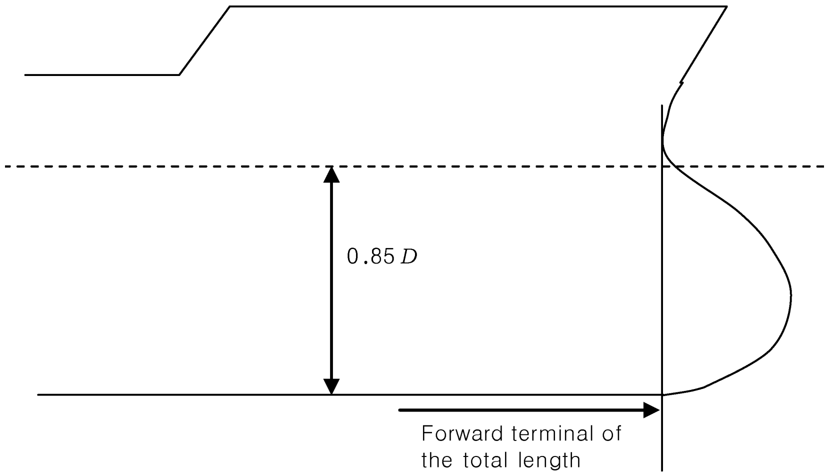


Fig 1: Concave stem contour

3.3 Ends of rule length *L* and midship

3.3.1 Fore end

The fore end (FE) of the rule length *L*, see **Fig 2**, is the perpendicular to the summer load waterline at the forward side of the stem.

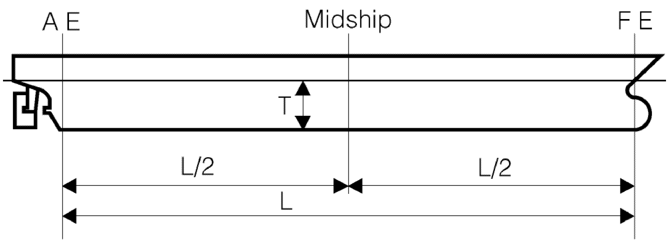


Fig 2: Ends and midship

The aft end (AE) of the rule length *L*, see **Fig 2**, is the perpendicular to the waterline at a distance *L* aft of the fore end.

3.3.2 Midship

The midship is the perpendicular to the waterline at a distance $0.5L$ aft of the fore end.

3.3.3 Midship part

The midship part of a ship is the part extending $0.4L$ amidships, unless other wise specified.

3.4 Moulded breadth

3.4.1

The moulded breadth *B* is the greatest moulded breadth, in m, measured amidships below the weather deck.

3.5 Depth (The least moulded depth)

3.5.1

The depth D is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the top of the deck beam at side on the upper-most continuous deck.

3.6 Moulded draught

3.6.1

The moulded draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the summer load line.

3.7 Lightweight

3.7.1

The lightweight is the displacement, in t, without cargo, fuel, lubricating oil, ballast water, fresh water and feed water, consumable stores and passengers and crew and their effects.

3.8 Deadweight

3.8.1

The deadweight is the difference, in t, between the displacement, at the summer draught in sea water of density $\rho = 1.025\ \mathrm{t/m^3}$, and the lightweight.

3.9 Freeboard deck

3.9.1

Ref. ILLC, as amended (Resolution MSC. 143(77) Reg. 3(9))
The freeboard deck is defined in Regulation 3 of the International Load Line Convention, as amended.

3.10 Bulkhead deck

3.10.1

Ref. SOLAS Reg.II-1/2 .5
The bulkhead deck is the uppermost deck to which the transverse watertight bulkheads, except both peak bulkheads, extend and are made effective.

3.11 Strength deck

3.11.1

The strength deck at a part of ship’s length is the uppermost continuous deck at that part to which the shell plates extend.

3.12 Superstructure

3.12.1 General

Ref. ILLC. As amended (Resolution MSC.143(77) Reg. 3(10,a))
A superstructure is a decked structure on the free-board deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04 B.

3.12.2 Enclosed and open superstructure

A superstructure may be:

- enclosed, where:
  (1) it is enclosed by front, side and aft bulkheads complying with the requirements of **Ch 9, Sec 4**
  (2) all front, side and aft openings are fitted with efficient weathertight means of closing
- open, where it is not enclosed.

3.13 Forecastle

3.13.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(10,g))
A forecastle is a superstructure which extends from the forward perpendicular aft to a point which is forward of the after perpendicular. The forecastle may originate from a point forward of the forward perpendicular.

3.14 Raised quarterdeck

3.14.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 3(10,i))
A raised quarterdeck is a superstructure which extends forward from the after perpendicular, generally has a height less than a normal superstructure, and has an intact front bulkhead (sidescuttles of the non-opening type fitted with efficient deadlights and bolted man hole covers)(see ***Fig 3****). Where the forward bulkhead is not intact due to doors and access openings, the superstructure is then to be considered as a poop.*

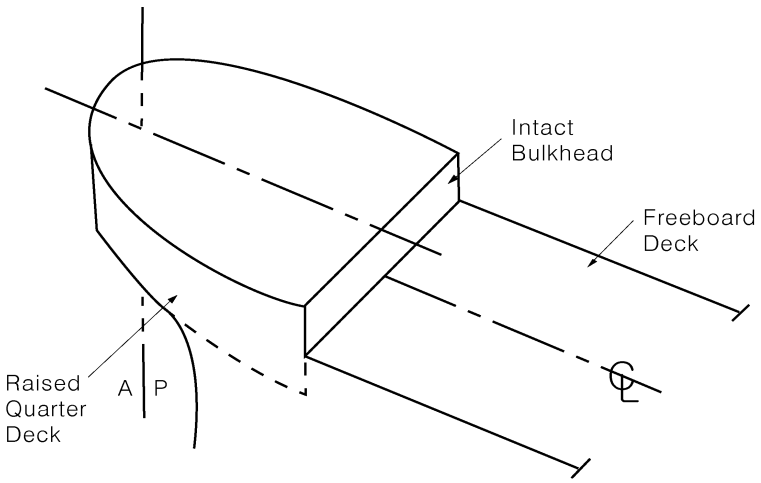


Fig 3: Raised quarter deck

3.15 Deckhouse

3.15.1

A deckhouse is a decked structure other than a superstructure, located on the freeboard deck or above.

3.16 Trunk

3.16.1

A trunk is a decked structure similar to a deckhouse, but not provided with a lower deck.

3.17 Wash bulkhead

3.17.1

A wash bulkhead is a perforated or partial bulkhead in a tank.

3.18 Standard height of superstructure

3.18.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 33)
The standard height of superstructure is defined in ***Table 2****.*

Table 2: Standard height of superstructure

Freeboard length L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$90 < L_{LL} < 125$	$0.3 + 0.012\ L_{LL}$	$1.05 + 0.01\ L_{LL}$
$L_{LL} \geq 125$	1.80	2.30

3.19 Type A and Type B ships

3.19.1 Type A ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.1)
A Type A ship is one which:

- *is designed to carry only liquid cargoes in bulk;*
- *has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material*
- *has low permeability of loaded cargo compartments.*

A Type A ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

3.19.2 Type B ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.5)
All ships which do not come within the provisions regarding Type A ships stated in ***[3.19.1]*** *are to be considered as Type B ships.*
A Type B ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

3.19.3 Type B-60 ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.9)
A Type B-60 ship is any Type B ship of over 100 metres in length which, according to applicable requirements of in the International Load Line Convention 1966, as amended, is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the "B" and "A" tabular values for the appropriate ship lengths.

3.19.4 Type B-100 ship

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 27.10)
A Type B-100 ship is any Type B ship of over 100 metres in length which, according to applicable requirements of in the International Load Line Convention 1966, as amended, is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the "B" and "A"

tabular values for the appropriate ship lengths.

3.20 Positions 1 and 2

3.20.1 Position 1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 13)
Position 1 includes:

- *exposed freeboard and raised quarter decks,*
- *exposed superstructure decks situated forward of 0.25* L_{LL} *from the perpendicular, at the forward side of the stem, to the waterline at 85 % of the least moulded depth measured from the top of the keel.*

3.20.2 Position 2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 13)
Position 2 includes:

- *exposed superstructure decks situated aft of 0.25* L_{LL} *from the perpendicular, at the forward side of the stem, to the waterline at 85 % of the least moulded depth measured from the top of the keel and located at least one standard height of superstructure above the freeboard deck,*
- *exposed superstructure decks situated forward of 0.25* L_{LL} *from the perpendicular, at the forward side of the stem, to the waterline at 85 % of the least moulded depth measured from the top of the keel and located at least two standard heights of superstructure above the freeboard deck.*

4. Reference co-ordinate system

4.1

4.1.1

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see **Fig 4**):

- Origin: at the intersection among the longitudinal plane of symmetry of ship, the aft end of *L* and the baseline
- X axis: longitudinal axis, positive forwards
- Y axis: transverse axis, positive towards portside
- Z axis: vertical axis, positive upwards.

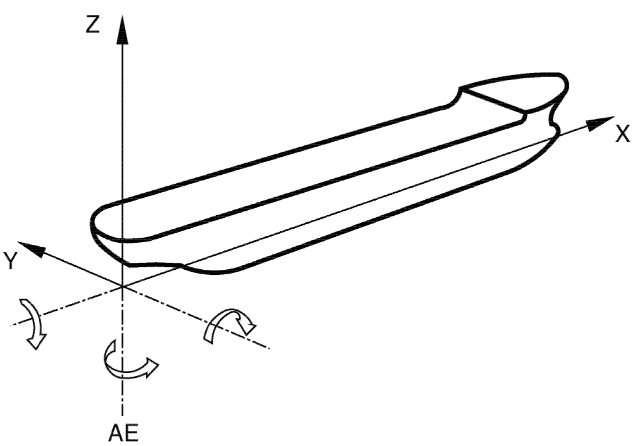


Fig 4: Reference co-ordinate system

4.1.2

Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes. ⫝̸

Chapter 2

General Arrangement Design

Section 1 - SUBDIVISION ARRANGEMENT

1. Number and arrangement of transverse watertight bulkheads

1.1 Number of watertight bulkheads

1.1.1 General

All ships, in addition to complying with the requirements of **[1.1.2]**, are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

1.1.2 Additional bulkheads

For ships not required to comply with subdivision regulations, transverse bulkheads adequately spaced, and not less in number than indicated in **Table 1**, are to be fitted.

Table 1: Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery(1)	Numbers of bulkheads for other ships
$90 \leq L < 105$	4	5
$105 \leq L < 120$	5	6
$120 \leq L < 145$	6	7
$145 \leq L < 165$	7	8
$165 \leq L < 190$	8	9
$L \geq 190$	To be defined on a case by case basis	
(1) After peak bulkhead and aft machinery bulkhead are the same.		

2. Collision bulkhead

2.1 Arrangement of collision bulkhead

2.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 11
A collision bulkhead is to be fitted which is to be watertight up to the freeboard deck. This bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than 5 per cent of the length L_{LL} of the ship or 10 m, whichever is the less, and not more than 8 per cent of L_{LL}.

2.1.2

Ref. SOLAS Ch. II-1, Part B, Reg. 11
*Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in **[2.1.1]** are to be measured from a point either:*

- *at the mid-length of such extension, or*
- *at a distance 1.5 per cent of the length L_{LL} of the ship forward of the forward perpendicular, or*

- *at a distance 3 metres forward of the forward perpendicular,*

whichever gives the smallest measurement.

2.1.3

Ref. SOLAS Ch. II-1, Part B, Reg. 11
*The bulkhead may have steps or recesses provided they are within the limits prescribed in [**2.1.1**] or [**2.1.2**]. No door, manhole, ventilation duct or any other opening is to be fitted in this bulkhead.*

3. After peak, machinery space bulkheads and stern tubes

3.1

3.1.1 General

Ref. SOLAS Ch. II-1, Part B, Reg. 11
An after peak bulkhead, and bulkheads dividing the machinery space from the cargo spaces forward and aft, are also to be fitted and made watertight up to the freeboard deck. The after peak bulkhead may, however, be stepped below the bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

3.1.2 Sterntubes

Ref. SOLAS Ch. II-1, Part B, Reg. 11
Sterntubes are to be enclosed in a watertight space (or spaces) of moderate volume. Other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society.

4. Number and arrangement of tank bulkheads

4.1 Bulkheads in compartments intended for the carriage of liquid cargoes

4.1.1

The number and location of transverse and longitudinal watertight bulkheads in compartments intended for the carriage of liquid cargoes are to comply with the subdivision requirements to which the ship is subject.

5. Arrangement of transverse watertight bulkheads

5.1 General

5.1.1

Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

6. Openings in watertight bulkheads

6.1 General

6.1.1

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9 and IMO Res. A.684(17) - Part B
The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are

necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Society may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.

6.1.2

No door, manhole ventilation duct or any other opening is permitted in the collision bulkhead below the subdivision deck.

6.1.3

Lead or other heat sensitive materials may not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

6.1.4

Valves not forming part of a piping system are not permitted in watertight subdivision bulkheads.

6.1.5

The requirements relevant to the degree of tightness, as well as the operating systems, for doors or other closing appliances complying with the provisions in **[6.2]** and **[6.3]** are specified in **Table 2.**

6.2 Openings in the watertight bulkheads below the freeboard deck

6.2.1 Openings used while at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

6.2.2 Openings normally closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with means of indication locally and on the bridge showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open. The use of such doors and hatch covers is to be authorised by the officer of the watch.

6.2.3 Doors or ramps in large cargo spaces

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely con-trolled.
Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.
The word "satisfactory" means that scantlings and sealing requirements for such doors or ramps are to be sufficient to withstand the maximum head of the water at the flooded waterline.

6.2.4 Openings permanently kept closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

6.3 Openings in the bulkheads above the freeboard deck

6.3.1 General

The openings in flooding boundaries located below the waterline at the equilibrium of the final stage of flooding are to be watertight. The openings immersed within the range of the positive righting lever curve are only to be weathertight.

Table 2: Doors

			Sliding type			Hinged type			Rolling type (cargo between deck spaces)
			Remote operation indication on the bridge	Indicator on the bridge	Local operation only	Remote operation indicatio n on the bridge	Indicator on the bridge	Local operation only	
Watertight	Below the freeboard deck	Open at sea	X						
		Normally closed (2)		X			X (3)		
		Remain closed (2)			X (4) (5)			X (4) (5)	X (4) (5)
Weathertight/ watertight(1)	Above the freeboard deck	Open at sea	X						
		Normally closed (2)		X			X		
		Remain closed (2)						X (4) (5)	

(1) Watertight doors are required when they are located below the waterline at the equilibrium of the final stage of flooding; otherwise a weathertight door is accepted.
(2) Notice to be affixed on both sides of the door: “to be kept closed at sea”.
(3) Type A ships of 150 m and upwards, and Type B ships with a reduced freeboard may have a hinged watertight door between the engine room and the steering gear space, provided that the sill of this door is above the summer load waterline.
(4) The door is to be closed before the voyage commences.
(5) If the door is accessible during the voyage, a device which prevents unauthorised opening is to be fitted.

6.3.2 Doors used while at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
The doors used while at sea are to be sliding doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at

the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It should be possible to open and close the door by hand at the door itself from both sides.

6.3.3 Doors normally closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
The doors normally closed at sea are to be provided with means of indication locally and on the bridge showing whether these doors are open or closed. A notice is to be affixed to each door to the effect that it is not to be left open.

6.3.4 Openings kept permanently closed at sea

Ref. SOLAS Ch. II-1, Part B-1, Reg. 25-9
The doors kept closed at sea are to be hinged doors. Such doors and the other closing appliances which are kept closed at sea are to be provided with a notice affixed to each closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Section 2 – COMPARTMENT ARRANGEMENT

1. Definitions

1.1 Cofferdam

1.1.1

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow proper inspection, maintenance and safe evacuation.

1.2 Machinery spaces of category A

1.2.1

Ref. SOLAS Ch. II-2, Part A, Reg. 3.31
Machinery spaces of category A are those spaces or trunks to such spaces which contain:

- *internal combustion machinery used for main propulsion; or*
- *internal combustion machinery used for purposes other than propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or*
- *any oil fired boiler or fuel oil unit.*

2. Cofferdams

2.1 Cofferdam arrangement

2.1.1

Cofferdams are to be provided between compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2

Cofferdams separating fuel oil tanks from lubricating oil tanks and the latter from those intended for the carriage of liquid foam for fire extinguishing or fresh water or boiler feed water may be waived when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to **Ch 6, Sec 1**, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
- the structural test is carried out with a head increased by 1 m with respect to **Ch 11, Sec 3**.

2.1.3

Spaces intended for the carriage of flammable liquids are to be separated from accommodation and service spaces by means of a cofferdam.

2.1.4

Cofferdams are only required between fuel oil double bottoms and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides.
Where a corner to corner situation occurs, tanks are not be considered to be adjacent.

Adjacent tanks not separated by cofferdams are to have adequate dimensions to ensure easy inspection.

3. Double bottoms

3.1 General

3.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1
A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

3.1.2

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1
Where a double bottom is required to be fitted, its depth is to satisfy the provisions of ***Ch 3, Sec 6, [6]*** *and the inner bottom is to be continued out to the ship side in such a manner as to protect the bottom to the turn of the bilge.*

3.1.3

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1
Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend in depth more than necessary. A well extending to the outer bottom, may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with ***[3.1].***

3.1.4

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1
A double bottom need not be fitted in way of water-tight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not, in the opinion of the Society, thereby impaired.

4. Compartment forward of the collision bulkhead

4.1 General

4.1.1

The fore peak and other compartments located forward of the collision bulkhead may not be arranged for the carriage of fuel oil or other flammable products.

5. Minimum bow height

5.1 General

5.1.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(1))
The bow height F_b, defined as the vertical distance at the forward perpendicular between the waterline corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side, is to be not less than:

$$F_b=(6075(L_{LL}/100)-1875(L_{LL}/100)^2+200(L_{LL}/100)^3)\times(2.08+0.609C_B-1.603C_{wf}-0.0129(L/T_1))$$

where:

F_b : *Calculated minimum bow height, in mm*

T_1 : *Draught at 85 % of the least moulded depth, in m*

C_{wf} : *Waterplane area coefficient forward of* $L_{LL}/2$:

$$C_{wf} = \frac{A_{wf}}{\frac{L_{LL}}{2}B}$$

A_{wf} : *Waterplane area forward of* $L_{LL}/2$ *at draught* T_1, *in* m^2.

For ships to which timber freeboards are assigned, the summer freeboard (and not the timber summer freeboard) is to be assumed when applying the formula above.

5.1.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39.(2))
Where the bow height required in paragraph ***[5.1.1]*** *is obtained by sheer, the sheer is to extend for at least 15 % of the length of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least 0.07 L abaft the forward perpendicular, and is to be enclosed as defined* ***Ch 9, Sec 4.***

5.1.3

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(3))
Ships which, to suit exceptional operational requirements, cannot meet the requirements in ***[5.1.1]*** *and* ***[5.1.2]*** *will be considered by the Society on a case by case basis.*

5.1.4

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(4, a))
The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than 0.15 L, but greater than 0.07 L, provided that the forecastle height is not less than one half of standard height of superstructure between 0.07 L and the forward perpendicular.

5.1.5

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 39(4, b))
Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows:

a) *Where the freeboard deck has sheer extending from abaft 0.15 L, by a parabolic curve having its origin at 0.15 L abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (as illustrated in* ***Fig 1****). However, if the value of the height denoted ht in* ***Fig 1*** *is smaller than the value of the height denoted* h_b *then* h_t *may be replaced by* h_b *in the available bow height, where:*

$$h_t = Z_b\left(\frac{0.15L}{x_b}\right)^2 - Z_t$$

Z_b : *As defined in* ***Fig 1***

Z_t : *As defined in* ***Fig 1***

h_f : *Half standard height of superstructure*

b) *Where the freeboard deck has sheer extending for less than 0.15 L or has no sheer, by a line from the forecastle deck at side at 0.07 L extended parallel to the base line to the forward perpendicular (as illustrated in* ***Fig 2****).*

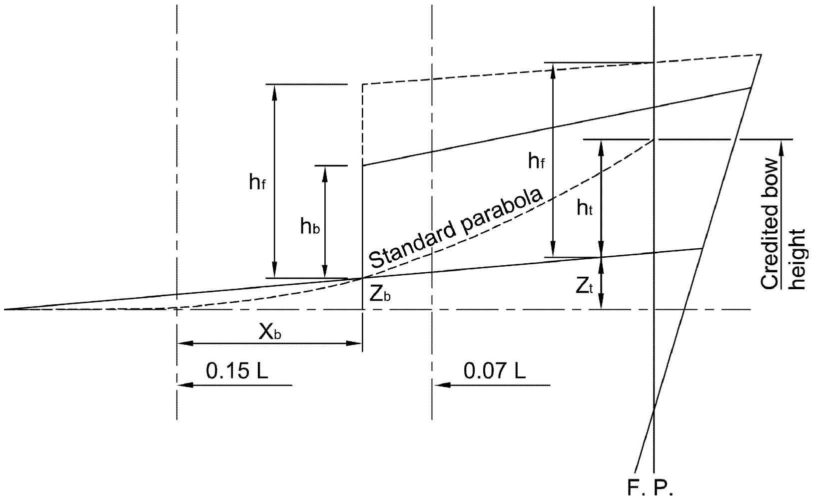


Fig 1: Credited bow height where the freeboard deck has sheer extending from abaft 0.15*L*

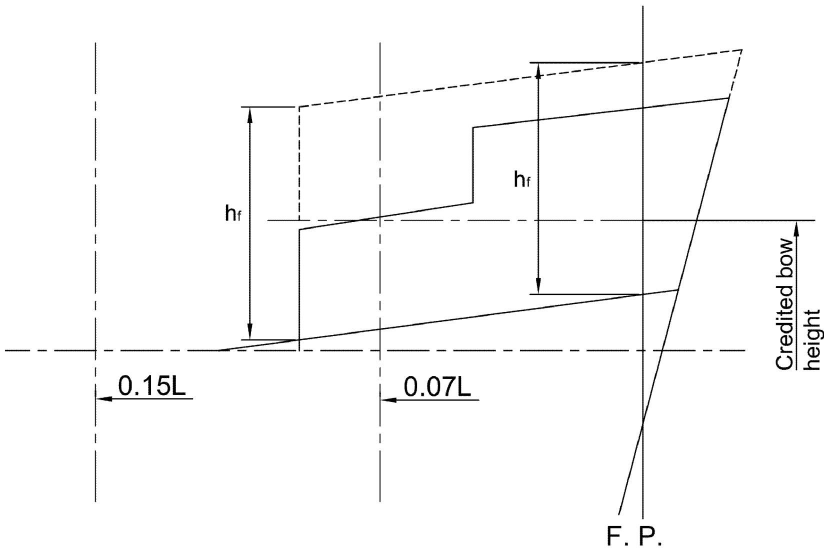


Fig 2: Credited bow height where the freeboard deck has sheer extending for less than 0.15*L*

6. Shaft tunnels

6.1 General

6.1.1

Shaft tunnels are to be watertight.

7. Watertight ventilators and trunks

7.1 General

7.1.1

Ref. SOLAS Ch. II-1, Part B, Reg. 19.1
Watertight ventilators and trunks are to be carried at least up to the freeboard deck.

8. Fuel oil tanks

8.1 General

8.1.1

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2
The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

8.1.2

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2
As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A.
Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.
Where such tanks are situated within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint of less than 60 °C.

8.1.3

Ref. SOLAS Ch. II-2, Part B, Reg. 4.2
Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.
Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.
Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

8.1.4

Where a compartment intended for goods or coal is situated in proximity of a heated liquid container, suitable thermal insulation is to be provided.

Section 3 – ACCESS ARRANGEMENT

1. General

1.0 Application

1.0.1

This section applies to ships of 20,000 gross tonnage and over.

1.1 Means of access to cargo and other spaces

1.1.1

Ref. SOLAS Reg.II-1/3-6 .2.1 (Resolution MSC.151(78))
Each space is to be provided with means of access to enable, throughout the life of a ship, overall and close-up inspections and thickness measurements of the ship's structures. Such means of access are to comply with ***[1.3]*** *and* ***[2].***

1.1.2

Ref. SOLAS Reg.II-1/3-6 .2.2 (Resolution MSC.151(78))
Where a permanent means of access may be susceptible to damage during normal cargo loading and unloading operations or where it is impracticable to fit permanent means of access, the Administration may allow, in lieu thereof, the provision of movable or portable means of access, as specified in ***[2]****, provided that the means of attaching, rigging, suspending or supporting the portable means of access forms a permanent part of the ship's structure. All portable equipment are to be capable of being readily erected or deployed by ship's personnel.*

1.1.3

Ref. SOLAS Reg.II-1/3-6 .2.3 (Resolution MSC.151(78))
The construction and materials of all means of access and their attachment to the ship's structure are to be to the satisfaction of the Society.

1.2 Safe access to cargo holds, ballast tanks and other spaces

1.2.1

Ref. SOLAS Reg.II-1/3-6 .3.1 (Resolution MSC.151(78)) and IACS UI SC191
Safe access to cargo holds, cofferdams, ballast tanks and other spaces in the cargo area are to be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom spaces or to forward ballast tanks may be from a pump-room, deep cofferdam, pipe tunnel, cargo hold, double hull space or similar compartment not intended for the carriage of oil or hazardous cargoes.
Access to a double side skin space may be either from a topside tank or double bottom tank or from both.

1.2.2

Ref. SOLAS Reg.II-1/3-6 .3.2 (Resolution MSC.151(78))
Tanks, and subdivisions of tanks, having a length of 35 m or more, are to be fitted with at least two access hatchways and ladders, as far apart as practicable.
Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.
When a tank is subdivided by one or more swash bulkheads or similar obstructions which do not allow ready means of access to the other parts of the tank, at least two hatchways and ladders are to be fitted.

1.2.3

Ref. SOLAS Reg.II-1/3-6 .3.3 (Resolution MSC.151(78))
Each cargo hold is to be provided with at least two means of access as far apart as practicable. In general, these accesses are to be arranged diagonally, for example one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side.

1.3 General technical specifications

1.3.1

Ref. SOLAS Reg.II-1/3-6 .5.1 (Resolution MSC.151(78)) and IACS UI SC191
For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm × 600 mm, with corner radii up to 100 mm maximum.
In such a case where as a consequence of structural analysis the stress is to be reduced around the opening, it is considered appropriate to take measures to increase the clear opening, e.g. 600 × 800 with 300 mm radii, in which a clear opening of 600 × 600 mm with corner radii up to 100 mm maximum fits.
When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming. Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

1.3.2

Ref. SOLAS Reg.II-1/3-6 .5.2 (Resolution MSC.151(78)) and IACS UI SC191
For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is to be not less than 600 mm × 800 mm with corner radii of 300 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.
*Subject to verification of easy evacuation of injured person on a stretcher the vertical opening 850 mm × 620 mm with wider upper half than 600 mm, while the lower half may be less than 600 mm with the overall height not less than 850 mm is considered acceptable alternative to the opening of 600 mm × 800 mm with corner radii of 300 mm (see **Fig 1**).*

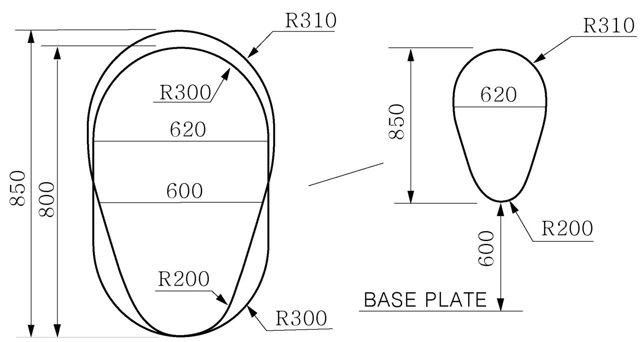


Fig 1: Alternative vertical opening

2. Technical provisions for means of access

2.1 Definitions

Ref. IMO Technical Provisions, 2 (Resolution MSC.158(78))

2.1.1 Rung

Rung means the step of vertical ladder or step on the vertical surface.

2.1.2 Tread

Tread means the step of inclined ladder, or step for the vertical access opening.

2.1.3 Flight of a ladder

*Flight of an inclined ladder means the actual stringer length of an inclined ladder.
For vertical ladders, it is the distance between the platforms.*

2.1.4 Stringer

Stringer means:

1) *the frame of a ladder; or*
2) *the stiffened horizontal plating structure fitted on side shell, transverse bulkheads and/or longitudinal bulkheads in the space. For the purpose of ballast tanks of less than 5 m width forming double side spaces, the horizontal plating structure is credited as a stringer and a longitudinal permanent means of access, if it provides a continuous passage of 600 mm or more in width past frames or stiffeners on the side shell or longitudinal bulkhead. Openings in stringer plating utilized as permanent means of access are to be arranged with guard rails or grid covers to provide safe passage on the stringer or safe access to each transverse web.*

2.1.5 Vertical ladder

Vertical ladder means a ladder of which the inclined angle is 70º and over up to 90º. Vertical ladder is to be not skewed by more than 2º.

2.1.6 Overhead obstructions

Overhead obstructions mean the deck or stringer structure including stiffeners above the means of access.

2.1.7 Distance below deck head

Distance below deck head means the distance below the plating.

2.1.8 Cross deck

Cross deck means the transverse area of main deck which is located inboard and between hatch coamings.

2.2 Permanent means of access

2.2.1

Ref. IMO Technical Provisions, 3.1 & 3.2 (Resolution MSC.158(78))
*Structural members, except those in double bottom spaces, are to be provided with a permanent means of access to the extent as specified in **[2.7]** to **[2.13]**.*
Permanent means of access are, as far as possible, to be integral to the structure of the ships , thus ensuring that they are robust and at the same time contributing to the overall strength of the structure, of the ship.

2.2.2

Ref. IMO Technical Provisions, 3.3 (Resolution MSC.158(78)) and IACS UI SC191
Elevated passageways forming sections of a permanent means of access, where fitted, are to have a minimum clear width of 600 mm, except for going around vertical webs where the minimum clear width

may be reduced to 450 mm, and to have guard rails over the open side of their entire length. For stand alone passageways guard rails are to be fitted on both sides of these structures.
Sloping structure providing part of the access and that are sloped by 5 or more degrees from horizontal plane when a ship is in upright position at even-keel, is to be of a non-skid construction.
Guard rails are to be 1000 mm in height and consist of a rail and intermediate bar 500 mm in height and of substantial construction. Stanchions are to be not more than 3 m apart.

2.2.3

Ref. IMO Technical Provisions, 3.4 (Resolution MSC.158(78))
Access to permanent means of access and vertical openings from the ship's bottom are to be provided by means of easily accessible passageways, ladders or treads. Treads are to be provided with lateral support for the foot. Where the rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to the surface is to be at least 150 mm. Where vertical manholes are fitted higher than 600 mm above the walking level, access is to be facilitated by means of treads and hand grips with platform landings on both sides.

2.3 Construction of ladders

2.3.1 General

Ref. IMO Technical Provisions, 3.5 (Resolution MSC.158(78))
Permanent inclined ladders are to be inclined at an angle of less than 70°. There are to have no obstructions within 750 mm of the face of the inclined ladder, except that in way of an opening this clearance may be reduced to 600 mm. Resting platforms of adequate dimensions are normally to be provided at a maximum of 6 m vertical height. Ladders and handrails are to be constructed of steel or equivalent material of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay is to be such that vibration is reduced to a practical minimum. In cargo holds, ladders are to be designed and arranged so that cargo handling difficulties are not increased and the risk of damage from cargo handling gear is minimized.

2.3.2 Inclined ladders

Ref. IMO Technical Provisions, 3.6 (Resolution MSC.158(78))
The width of inclined ladders between stringers is to be not less than 400 mm. The treads are to be equally spaced at a distance apart, measured vertically, of between 200 mm and 300 mm. When steel is used, the treads are to be formed of two square bars of not less than 22 mm by 22 mm in section, fitted to form a horizontal step with the edges pointing upward. The treads are to be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders are to be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

2.3.3 Vertical or spiral ladders

Ref. IMO Technical Provisions, 3.7 (Resolution MSC.158(78))
For vertical ladders or spiral ladders, the width and construction are to be in accordance with international or national standards.

2.4 Access through openings

2.4.1 Access through horizontal openings, hatches or manholes

Ref. IMO Technical Provisions, 3.10 (Resolution MSC.158(78))
For access through horizontal openings, hatches or manholes, the minimum clear opening is to be not less than 600 mm × 600 mm. When access to a cargo hold is arranged through the cargo hatch, the top of the ladder is to be placed as close as possible to the hatch coaming.
Access hatch coamings having a height greater than 900 mm are also to have steps on the outside in conjunction with the ladder.

2.4.2 Access through vertical openings, or manholes

Ref. IMO Technical Provisions, 3.11 (Resolution MSC.158(78))
For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is to be not less than 600 mm × 800 mm at a height of not more than 600 mm from the passage unless gratings or other foot holds are provided.

2.5 Access ladders to cargo holds and other spaces

2.5.1 General

Ref. IMO Technical Provisions, 3.13.1 & 3.13.2 (Resolution MSC.158(78))
Access ladders to cargo holds and other spaces are to be:

a) where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is not more than 6 m, either a vertical ladder or an inclined ladder.
b) where the vertical distance between the upper surface of adjacent decks or between deck and the bottom of the cargo space is more than 6 m, an inclined ladder or series of inclined ladders at one end of the cargo hold, except the uppermost 2.5 m of a cargo space measured clear of overhead obstructions and the lowest 6 m may have vertical ladders, provided that the vertical extent of the inclined ladder or ladders connecting the vertical ladders is not less than 2.5 m.

2.5.2

Ref. IMO Technical Provisions, 3.13.2 (Resolution MSC.158(78))
The second means of access at the other end of the cargo hold may be formed of a series of staggered vertical ladders, which have to comprise one or more ladder linking platforms spaced not more than 6 m apart vertically and displaced to one side of the ladder. Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder. The uppermost, entrance section, of the ladder directly exposed to a cargo hold is to be vertical for a distance of 2.5 m measured clear of overhead obstructions and connected to a ladder-linking platform.

2.5.3

Ref. IMO Technical Provisions, 3.13.3 (Resolution MSC.158(78))
A vertical ladder may be used as a means of access to topside tanks, where the vertical distance is 6 m or less between the deck and the longitudinal means of access in the tank or the stringer or the bottom of the space immediately below the entrance. The uppermost, entrance section from deck, of the vertical ladder of the tank is to be vertical for a distance of 2.5 m measured clear of the overhead obstructions and comprises a ladder linking platform unless landing on the longitudinal means of access, the stringer or the bottom within the vertical distance, it should be displaced to one side of a vertical ladder.

2.5.4

Ref. IMO Technical Provisions, 3.13.4 (Resolution MSC.158(78))
Unless allowed in ***[2.5.3]****, an inclined ladder or combination of ladders are to be used for access to a tank or a space where the vertical distance is greater than 6 m between the deck and a stringer immediately below the entrance, between stringers, or between the deck or a stringer and the bottom of the space immediately below the entrance.*

2.5.5

Ref. IMO Technical Provisions, 3.13.5 (Resolution MSC.158(78))
In case of ***[2.5.4]****, the uppermost, entrance section from deck, of the ladder is to be vertical for a distance of 2.5 m clear of the overhead obstructions and connected to a landing platform and continued with an inclined ladder. The flights of inclined ladders are to be not more than 9 m in actual length and the vertical height is normally to be not more than 6 m. The lowermost section of the ladders may be vertical for a vertical distance of not less than 2.5 m.*

2.5.6

Ref. IMO Technical Provisions, 3.13.6 (Resolution MSC.158(78))
In double side skin spaces of less than 2.5 m width, the access to the space may be by means of vertical ladders that comprises one or more ladder linking platforms spaced not more than 6 m apart vertically and displace to one side of the ladder.
Adjacent sections of ladder are to be laterally offset from each other by at least the width of the ladder.

2.5.7

Ref. IMO Technical Provisions, 3.13.7 (Resolution MSC.158(78))
A spiral ladder is considered acceptable as an alternative for inclined ladders. In this regard, the uppermost 2.5 m can continue to be comprised of the spiral ladder and need not change over to vertical ladders.

2.6 Access ladders to tanks

2.6.1

Ref. IMO Technical Provisions, 3.14 (Resolution MSC.158(78))
The uppermost, entrance section from deck, of the vertical ladder providing access to a tank should be vertical for a distance of 2.5 m measured clear of the overhead obstructions and comprises a ladder linking platform. It should be displaced to one side of a vertical ladder. The vertical ladder can be between 1.6 m and 3 m below deck structure if it lands on a longitudinal or athwartship permanent means of access fitted within that range.

2.7 Access to underdeck structure of cargo holds

2.7.1

Ref. IMO Technical Provisions, Tab 2, 1.1 (Resolution MSC.158(78))
Permanent means of access are to be fitted to provide access to the overhead structure at both sides of the cross deck and in the vicinity of the centerline.
Each means of access is to be accessible from the cargo hold access or directly from the main deck and installed at a minimum of 1.6 m to a maximum of 3 m below the deck.

2.7.2

Ref. IMO Technical Provisions, Tab 2, 1.2 (Resolution MSC.158(78))
An athwartship permanent means of access fitted on the transverse bulkhead at a minimum 1.6 m to a maximum 3 m below the cross-deck head is accepted as equivalent to ***[2.7.1].***

2.7.3

Ref. IMO Technical Provisions, Tab 2, 1.3 (Resolution MSC.158(78))
Access to the permanent means of access to overhead structure of the cross deck may also be via the upper stool.

2.7.4

Ref. IMO Technical Provisions, Tab 2, 1.4 (Resolution MSC.158(78)) and IACS UI SC191
Ships having transverse bulkheads with full upper stools, i.e. stools with a full extension between top side tanks and between hatch end beams, with access from the main deck which allows monitoring of all framing and plates from inside, do not require permanent means of access of the cross deck.

2.7.5

Ref. IMO Technical Provisions, Tab 2, 1.5 (Resolution MSC.158(78))
Alternatively, movable means of access may be utilized for access to the overhead structure of cross

deck if its vertical distance is 17 m or less above the tank top.

2.8 Access to double side skin tanks in double side bulk carriers

2.8.1

Ref. IMO Technical Provisions, Tab 2, 2.8 & Tab 1, 2.1 (Resolution MSC.158(78))
For double side spaces above the upper knuckle point of the bilge hopper sections, permanent means of access are to be provided in accordance with the following requirements:

a) where the vertical distance between horizontal uppermost stringer and deck head is 6 m or more, one continuous longitudinal permanent means of access is to be provided for the full length of the tank with a means to allow passing through transverse webs installed at a minimum of 1.6 m to a maximum of 3 m below the deck head with a vertical access ladder at each end of the tank;

b) continuous longitudinal permanent means of access, which are integrated in the structure, at a vertical distance not exceeding 6 m apart; and

c) plated stringers are to be, as far as possible, in alignment with horizontal girders of transverse bulkheads.

2.9 Access to vertical structures of cargo holds in single side bulk carriers

2.9.1

Ref. IMO Technical Provisions, Tab 2, 1.6 (Resolution MSC.158(78))
Permanent means of vertical access are to be provided in all cargo holds and built into the structure to allow for an inspection of a minimum of 25 % of the total number of hold frames port and starboard equally distributed throughout the hold including at each end in way of transverse bulkheads. But in no circumstance is this arrangement to be less than 3 permanent means of vertical access fitted to each side (fore and aft ends of hold and mid-span).
Permanent means of vertical access fitted between two adjacent hold frames is counted for an access for the inspection of both hold frames. A means of portable access may be used to gain access over the sloping plating of lower hopper ballast tanks.

2.9.2

Ref. IMO Technical Provisions, Tab 2, 1.7 (Resolution MSC.158(78))
In addition, portable or movable means of access are to be utilized for access to the remaining hold frames up to their upper brackets and transverse bulkheads.

2.9.3

Ref. IMO Technical Provisions, Tab 2, 1.8 (Resolution MSC.158(78))
Portable or movable means of access may be utilized for access to hold frames up to their upper bracket in place of the permanent means required in ***[2.9.1]****. These means of access are to be carried on board the ship and readily available for use.*

2.9.4

Ref. IMO Technical Provisions, Tab 2, 1.9 (Resolution MSC.158(78))

The width of vertical ladders for access to hold frames is to be at least 300 mm, measured between stringers.

2.9.5

Ref. IMO Technical Provisions, Tab 2, 1.10 (Resolution MSC.158(78))
A single vertical ladder over 6 m in length is acceptable for the inspection of the hold side frames in a single skin construction.

2.10 Access to vertical structures of cargo holds in double side bulk carriers

2.10.1

Ref. IMO Technical Provisions, Tab 2, 1.11 (Resolution MSC.158(78))
For double side skin construction no vertical ladders for the inspection of the cargo hold surfaces are required. Inspection of this structure should be provided from within the double hull space.

2.11 Access to top side ballast tanks in single side bulk carriers

2.11.1

Ref. IMO Technical Provisions, Tab 2, 2.1 (Resolution MSC.158(78))
For each topside tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.6 m to a maximum of 3 m below deck with a vertical access ladder in the vicinity of each access to that tank.

2.11.2

Ref. IMO Technical Provisions, Tab 2, 2.2 (Resolution MSC.158(78))
If no access holes are provided through the transverse webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

2.11.3

Ref. IMO Technical Provisions, Tab 2, 2.3 (Resolution MSC.158(78))
Three permanent means of access, fitted at the end bay and middle bay of each tank, are to be provided spanning from tank base up to the intersection of the sloping plate with the hatch side girder. The existing longitudinal structure, if fitted on the sloping plate in the space may be used as part of this means of access.

2.11.4

Ref. IMO Technical Provisions, Tab 2, 2.4 (Resolution MSC.158(78))
For topside tanks of which the height is less than 6 m, alternative or a portable means may be utilized in lieu of the permanent means of access.

2.12 Access to bilge hopper ballast tanks

2.12.1

Ref. IMO Technical Provisions, Tab 2, 2.5 (Resolution MSC.158(78)) and IACS UI SC191
For each bilge hopper tank of which the height is 6 m and over, one longitudinal continuous permanent means of access is to be provided along the side shell webs and installed at a minimum of 1.2 m below the top of the clear opening of the web ring with a vertical access ladder in the vicinity of each access to the tank.
An access ladder between the longitudinal continuous permanent means of access and the bottom of the space is to be provided at each end of the tank.
Alternatively, the longitudinal continuous permanent means of access can be located through the upper web plating above the clear opening of the web ring, at a minimum of 1.6 m below the deck head, when this arrangement facilitates more suitable inspection of identified structurally critical areas. An enlarged longitudinal frame, of at least 600 mm clear width canbeusedforthepurposeofthewalkway.
For double side skin bulk carriers the longitudinal continuous permanent means of access may be installed within 6 m from the knuckle point of the bilge, if used in combination with alternative methods to gain access to the knuckle point.

2.12.2

Ref. IMO Technical Provisions, Tab 2, 2.6 (to Resolution MSC.158(78))
If no access holes are provided through the transverse ring webs within 600 mm of the tank base and the web frame rings have a web height greater than 1 m in way of side shell and sloping plating, then step rungs/grab rails are to be provided to allow safe access over each transverse web frame ring.

2.12.3

Ref. IMO Technical Provisions, Tab 2, 2.7 (Resolution MSC.158(78))
For bilge hopper tanks of which the height is less than 6 m, alternative or a portable means may be utilized in lieu of the permanent means of access. Such means of access are to be demonstrated that they can be deployed and made readily available in the areas where needed.

2.13 Access to fore peak tanks

2.13.1

Ref. IMO Technical Provisions, Tab 2, 2.9 (Resolution MSC.158(78))
For fore peak tanks with a depth of 6 m or more at the centreline of the collision bulkhead, a suitable means of access is to be provided for access to critical areas such as the underdeck structure, stringers, collision bulkhead and side shell structure.

2.13.2

Ref. IMO Technical Provisions, Tab 2, 2.9.1 (Resolution MSC.158(78))
Stringers of less than 6 m in vertical distance from the deck head or a stringer immediately above are considered to provide suitable access in combination with portable means of access.

2.13.3

Ref. IMO Technical Provisions, Tab 2, 2.9.2 (Resolution MSC.158(78))
In case the vertical distance between the deck head and stringers, stringers or the lowest stringer and the tank bottom is 6 m or more, alternative means of access are to be provided.

3. Shaft tunnels

3.1 General

3.1.1

Tunnels are to be large enough to ensure easy access to shafting.

3.1.2

Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with **Ch 2, Sec 1, [6]**, and an escape trunk which can also act as watertight ventilator is to be fitted up to the subdivision deck, for tunnels greater than 7 m in length.

4. Access to steering gear compartment

4.1 General

4.1.1

The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

4.1.2

Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided.
These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage. ⚓

Chapter 3

Structural Design Principles

Section 1 - MATERIAL

1. General

1.1 Standard of material

1.1.1

The requirements in this Section are intended for ships of welded construction using steels having characteristics complying with the Society Rules for Materials.

1.1.2

Materials with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1

Materials are to be tested in compliance with the applicable requirements of Society Rules for Materials.

1.3 Manufacturing processes

1.3.1

The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice defined in IACS UR W and the applicable requirements of Society Rules for Materials. In particular:

- parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2. Hull structural steel

2.1 General

2.1.1

Table 1 gives the mechanical characteristics of steels currently used in the construction of ships.

Table 1: Mechanical properties of hull steels

Steel grades for plates with $t \leq 100$ mm	Minimum yield stress R_{eH}, in N/mm^2	Ultimate tensile strength R_m, in N/mm^2
A-B-D-E	235	400 - 520
AH32-DH32-EH32-FH32	315	440 - 570
AH36-DH36-EH36-FH36	355	490 - 630
AH40-DH40-EH40-FH40	390	510 - 660

2.1.2

Where higher strength steels are to be used for hull construction, the drawings showing the scope and locations of the used place together with the type and scantlings are to be submitted for the approval of the Society.

2.1.3

Higher strength steels other than those indicated in **Table 1** are considered by the Society on a case by case basis.

2.1.4

When steels with a minimum guaranteed yield stress R_{eH} other than 235 $\mathrm{N/mm^2}$ are used on a ship, hull scantlings are to be determined by taking into account the matrial factor k defined in **[2.2].**

2.1.5

It is required to keep on board a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in **Table 1** are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available on board together with the above plan.

2.2 Material factor k

2.2.1

Unless otherwise specified, the material factor k of normal and higher strength steel for scantling purposes is to be taken as defined in **Table 2**, as a function of the minimum yield stress R_{eH}.
For intermediate values of R_{eH}, k may be obtained by linear interpolation.
Steels with a yield stress greater than 390 $\mathrm{N/mm^2}$ are considered by the Society on a case by case basis.

Table 2: Material factor k

Minimum yield stress R_{eH}, in $\mathrm{N/mm^2}$	k
235	1.0
315	0.78
355	0.72
390	0.68

2.3 Grades of steel

2.3.1

Steel materials in the various strength members are not to be of lower grade than those corresponding to classes I, II and III, as given in **Table 3** for the material classes and grades given in **Table 4-1,** while additional requirements for ships with length (L) exceeding 150 m and 250 m, BC-A and BC-B ships are given in **Table 4-2** to **Table 4-4.**
For strength members not mentioned in **Table 4-1** to **Table 4-4**, grade A/AH may be used.

Table 3 : Material grade requirements for classes I, II and III

Class	I		II		III	
As-built thickness (mm)	NSS	HSS	NSS	HSS	NSS	HSS
$t \le 15$	A	AH	A	AH	A	AH
$15 < t \le 20$	A	AH	A	AH	B	AH
$20 < t \le 25$	A	AH	B	AH	D	DH
$25 < t \le 30$	A	AH	D	DH	D	DH
$30 < t \le 35$	B	AH	D	DH	E	EH
$35 < t \le 40$	B	AH	D	DH	E	EH
$40 < t \le 50$	D	DH	E	EH	E	EH
Notes NSS : Normal strength steel, HSS : Higher strength steel						

Table 4 : (void)

Table 4-1: Material Classes and Grades for ships in general

SECONDARY:		
A1	Longitudinal bulkhead strakes, other than that belonging to the Primary category	- Class I within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
A2	Deck plating exposed to weather, other than that belonging to the Primary or Special category	
A3	Side plating	
PRIMARY:		
B1	Bottom plating, including keel plate	- Class II within 0.4 *L* amidships - Grade A/AH outside 0.4 *L* amidships
B2	Strength deck plating, excluding that belonging to the Special category	
B3	Continuous longitudinal members above strength deck, excluding hatch coamings.	
B4	Uppermost strake in longitudinal bulkhead	
B5	Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	
SPECIAL:		
C1	Sheer strake at strength deck (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
C2	Stringer plate in strength deck (1)	
C3	Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships (1)	
C5	Strength deck plating at corners of cargo hatch openings	- Class III within 0.6 *L* amidships - Class II within rest of cargo region
C6	Bilge strake in ships with double bottom over the full breadth and length less than 150 m (1)	- Class II within 0.6 *L* amidships - Class I outside 0.6 *L* amidships
C7	Bilge strake in other ships (1)	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships
C8	Longitudinal hatch coamings of length greater than 0.15L	- Class III within 0.4 *L* amidships - Class II outside 0.4 *L* amidships - Class I outside 0.6 *L* amidships - Not to be less than Grade D/DH
C9	End brackets and deck house transition of longitudinal cargo hatch coamings (2)	

(1) Single strakes required to be of Class III within 0.4 *L* amidships are to have breadths not less than 800+5 *L* (mm), and need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.
(2) Applicable to bulk carriers having the longitudinal hatch coaming of length greater than 0.15 *L*.

Table 4-2: Minimum material grades for ships with ship's length (*L*) exceeding 150 m and single strength deck

Structural member category	Material Grade
Longitudinal strength members of strength deck plating	Grade B/AH within 0.4 L amidships
Continuous longitudinal strength members above strength deck	Grade B/AH within 0.4 L amidships
Single side strakes for ships without inner continuous longitudinal bulkheads between bottom and the strength deck	Grade B/AH within cargo region

Table 4-3: Minimum Material Grades for ships with ship's length (*L*) exceeding 250 m

Structural member category	Material Grade
Shear strake at strength deck(1)	Grade E/EH within 0.4 L amidships
Stringer plate in strength deck(1)	Grade E/EH within 0.4 L amidships
Bilge strake (1)	Grade D/DH within 0.4 L amidships
(1) Single strakes required to be of Class III within 0.4 L amidships are to have breadths not less than 800+5 L (mm), and need not be greatert han 1800 (mm), unless limited by the geometry of the ship's design	

Table 4-4: Minimum material grades for BC-A and BC-B ships

Structural member category	Material Grade
Lower bracket of ordinary side frame(1),(2)	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125 l above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate(2)	Grade D/DH
(1) The term "lower bracket" means webs of lower brackets and webs of the lower part of side frames up to the point 0.125 l above the intersection of side shell and bilge hopper sloping plate or inner bottom plate. (2) The span of the side frame, l, is defined as the distance between the supporting structure (See **Ch 3, Sec 6, Fig 19**)	

2.3.2

Plating materials for stern frames, rudders, rudder horns and shaft brackets are in general not to be of lower grades than corresponding to class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders) class III is to be applied.

2.3.3

Bedplates of seats for propulsion and auxiliary engines inserted in the inner bottom within 0.6 L amidships are to be of class I. In other cases, the steel is to be at least of grade A/AH.

2.3.4 (void)

2.3.5

The steel grade is to correspond to the as-built thickness.

2.3.6

Steel grades of plates or sections of as-built thickness greater than the limiting thicknesses in **Table 3** are considered by the Society on a case by case basis.

2.3.7

In specific cases, such as **[2.3.8]**, with regard to stress distribution along the hull girder, the classes required within 0.4 L amidships may be extended beyond that zone, on a case by case basis.

2.3.8

The material classes required for the strength deck plating, the sheerstrake and the upper strake of longitudinal bulkheads within 0.4 L amidships are to be maintained for an adequate length across the poop front and at the ends of the bridge, where fitted.

2.3.9

Rolled products used for welded attachments of length greater than 0.15 L on outside of hull plating, such as gutter bars, are to be of the same grade as that used for the hull plating in way.

2.3.10

In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case by case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to prevent the risk of lamellar tearing (Z type steel).

2.3.11 (void)

2.4 Structures exposed to low air temperature

2.4.1

The application of steels for ships designed to operate in area with low air temperatures is to comply with **[2.4.2]** to **[2.4.6].**

2.4.2

For ships intended to operate in areas with low air temperatures (below and including −20 °C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D , to be taken as defined in **[2.4.3].**

2.4.3

The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean : Statistical mean over observation period (at least 20 years).

Average : Average during one day and night.

Lowest : Lowest during year.

Fig 1 illustrates the temperature definition for Arctic waters.
For seasonally restricted service the lowest value within the period of operation applies.

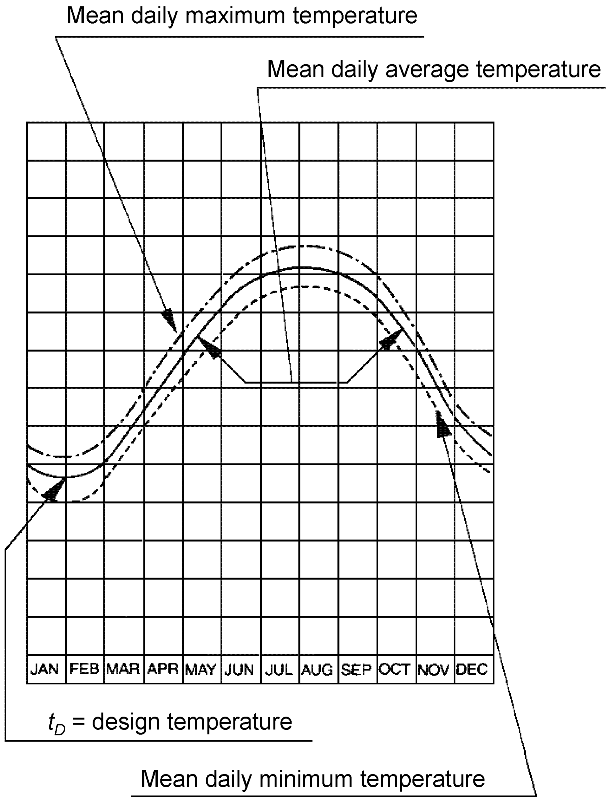


Fig 1: Commonly used definitions of temperatures

2.4.4

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes I, II and III as given in **Table 5** depending on the categories of structural members (SECONDARY, PRIMARY and SPECIAL).
For non-exposed structures and structures below the lowest ballast water line, see **[2.3]**

2.4.5

The material grade requirements for hull members of each class depending on thickness and design temperature are defined in **Table 6**, **Table 7** and **Table 8**. For design temperatures t_D < -55 °C, materials are to be specially considered by the Society.

2.4.6

Single strakes required to be of class III or of grade E/EH and FH are to have breadths not less than the values, in m, given by the following formula, but need not to be greater than 1.8 m:

$b = 0.005\,L + 0.8$

Table 5: Application of material classes and grades – Structures exposed at low temperature

Structural member category	Material class	
	Within 0.4 L amidship	Outside 0.4 L amidship
SECONDARY		
Deck plating exposed to weather, in general	I	I
Side plating above BWL		
Transverse bulkheads above BWL		
PRIMARY		
Strength deck plating(1)	II	I
Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings		
Longitudinal bulkhead above BWL		
Top wing tank bulkhead above BWL		
SPECIAL		
Sheer strake at strength deck(2)	III	II
Stringer plate in strength deck(2)		
Deck strake at longitudinal bulkhead(3)		
Continuous longitudinal hatch coamings(4)		

Notes:
(1) Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.
(2) Not to be less than grade E/EH within 0.4 L amidships in ships with length exceeding 250 m.
(3) In ships with a breadth exceeding 70 m at least three deck strakes to be class III.
(4) Not to be less than grade D/DH.

Table 6: Material grade requirements for class I at low temperature

As-built thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \le 10$	A	AH	B	AH	D	DH	D	DH
$10 < t \le 15$	B	AH	D	DH	D	DH	D	DH
$15 < t \le 20$	B	AH	D	DH	D	DH	E	EH
$20 < t \le 25$	D	DH	D	DH	D	DH	E	EH
$25 < t \le 30$	D	DH	D	DH	E	EH	E	EH
$30 < t \le 35$	D	DH	D	DH	E	EH	E	EH
$35 < t \le 45$	D	DH	E	EH	E	EH	-	FH
$45 < t \le 50$	E	EH	E	EH	-	FH	-	FH

Note: ”NSS” and “HSS” mean, respectively “Normal Strength Steel” and “Higher Strength Steel”

Table 7: Material grade requirements for class II at low temperature

As-built thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	D	DH	E	EH	E	EH	-	FH
$30 < t \leq 40$	E	EH	E	EH	-	FH	-	FH
$40 < t \leq 45$	E	EH	-	FH	-	FH	-	-
$45 < t \leq 50$	E	EH	-	FH	-	FH	-	-

Note: "NSS" and "HSS" mean, respectively "Normal Strength Steel" and "Higher Strength Steel"

Table 8: Material grade requirements for class III at low temperature

As-built thickness (mm)	-20 / -25 °C		-26 / -35 °C		-36 / -45 °C		-45 / -55 °C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	D	DH	E	EH	E	EH	-	FH
$20 < t \leq 25$	E	EH	E	EH	-	FH	-	FH
$25 < t \leq 30$	E	EH	E	EH	-	FH	-	FH
$30 < t \leq 40$	E	EH	-	FH	-	FH	-	-
$40 < t \leq 45$	E	EH	-	FH	-	FH	-	-
$45 < t \leq 50$	-	FH	-	FH	-	-	-	-

Note: "NSS" and "HSS" mean, respectively "Normal Strength Steel" and "Higher Strength Steel"

3. Steels for forging and casting

3.1 General

3.1.1

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of the Society Rules for Materials.

3.1.2

Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case by case basis.

3.1.3

The steels used are to be tested in accordance with the applicable requirements of the Society Rules for Materials.

3.2 Steels for forging

3.2.1

Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case by case basis.
In such case, compliance with the applicable requirements of the Society Rules for Materials, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1

Cast parts intended for stems, sternframes, rudders, parts of steering gear and deck machinery in general may be made of C and C-Mn weldable steels, having specified minimum tensile strength $R_m = 400$ N/mm^2 or 440 N/mm^2, in accordance with the applicable requirements of the Society Rules for Materials.

3.3.2

The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case by case basis.
The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

3.3.3

Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to surface and volumetric non-destructive examination to check their internal structure.

4. Aluminium alloy structures

4.1 General

4.1.1

The characteristics of aluminium alloys are to comply with the requirements of the Society Rules for Materials. Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used.

4.1.2

In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are to be agreed by the Society.

4.1.3

Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70,000 N/mm^2 and the Poisson's ratio equal to 0.33.

4.2 Extruded plating

4.2.1

Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2

In general, the application is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case by case basis.

4.2.3

Extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4

Connections between extruded plating and primary members are to be given special attention.

4.3 Mechanical properties of weld joints

4.3.1

Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition O or H111) or by heat treatment (series 6000).

4.3.2

The as-welded properties of aluminium alloys of series 5000 are in general those of condition O or H111. Higher mechanical characteristics may be taken into account, provided they are duly justified.

4.3.3

The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

4.4 Material factor k

4.4.1

The material factor k for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{\lim}}$$

where:

$R'_{\lim}$: Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0.2}$, in $\mathrm{N/mm^2}$, but not to be taken greater than 70 % of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in $\mathrm{N/mm^2}$

$R'_{p0.2} = \eta_1 R_{p0.2}$

$R'_m = \eta_2 R_m$

$R_{p0.2}$: Minimum guaranteed yield stress, in $\mathrm{N/mm^2}$, of the parent metal in delivery condition

R_m : Minimum guaranteed tensile strength, in $\mathrm{N/mm^2}$, of the parent metal in delivery condition

η_1, η_2 : Specified in **Table 9.**

4.4.2

In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

Table 9: Aluminium alloys for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition O or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition O or H111)	$R'_{p0.2} / R_{p0.2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) (1)	$R'_{p0.2} / R_{p0.2}$	0.6

Notes:
(1) : When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β defined in **Table 10**
$R'_{p0.2}$: Minimum guaranteed yield stress, in N/mm^2, of material in welded condition
R'_m : Minimum guaranteed tensile strength, in N/mm^2, of material in welded condition

Table 10: Aluminium alloys – Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness, in mm	β
6005 A (Open sections)	T5 or T6	$t \leq 6$	0.45
		$t > 6$	0.40
6005 A (Closed sections)	T5 or T6	All	0.50
6061 (Sections)	T6	All	0.53
6082 (Sections)	T6	All	0.45

5. Other materials and products

5.1 General

5.1.1

Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of the Society Rules for Materials.

5.1.2

The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case by case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

5.1.3

Materials used in welding processes are to comply with the applicable requirements of the Society Rules for Materials.

5.2 Iron cast parts

5.2.1

As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2

Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type will be considered by the Society on a case by case basis.

Section 2 - NET SCANTLING APPROACH

Symbols

t_{as_built} : As-built Thickness: the actual thickness, in mm, provided at the newbuilding stage, including $t_{voluntary\_addition}$, if any.

t_C : Corrosion Addition Thickness: as defined in **Ch 3**, **Sec 3**, in mm.

$t_{gross\_offered}$: Gross Thickness Offered: the actual gross (full) thickness, in mm, provided at the newbuilding stage, excluding $t_{voluntary\_addition}$, the owner's extra margin for corrosion wastage, if any.

$t_{gross\_required}$: Gross Thickness Required: the gross (full) thickness, in mm, obtained by adding t_C to the Net Thickness Required.

$t_{net\_offered}$: Net Thickness Offered: the net thickness, in mm, obtained by subtracting t_C from the Gross Thickness Offered

$t_{net\_required}$: Net Thickness Required: the net thickness, in mm, as required by the Rules that satisfy all the structural strength requirements, rounded to the closest half millimetre.

$t_{voluntary\_addition}$: Thickness for Voluntary Addition: the thickness, in mm, voluntarily added as the owner's extra margin for corrosion wastage in addition to t_C.

1. General philosophy

1.1

1.1.1

Net Scantling Approach is to clearly specify the "net scantling" that is to be maintained right from the newbuilding stage throughout the ship's design life to satisfy the structural strength requirements. This approach clearly separates the net thickness from the thickness added for corrosion that is likely to occur during the ship-in-operation phase.

2. Application criteria

2.1 General

2.1.1

The scantlings obtained by applying the criteria specified in this Rule are net scantlings as specified in **[3.1]** to **[3.3]**; i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion and voluntarily added thickness such as the owner's extra margin, if any. The following gross offered scantlings are exceptions; i.e. they already include additions for corrosion but without voluntarily added values such as the owner's extra margin:

- scantlings of superstructures and deckhouses, according to **Ch 9**, **Sec 4**
- scantlings of rudder structures, according to **Ch 10**, **Sec 1**
- scantlings of massive pieces made of steel forgings, steel castings.

2.1.2

The required strength characteristics are:

- thickness, for plating including that which constitutes primary supporting members
- section modulus, shear area, moments of inertia and local thickness for ordinary stiffeners and, as the

case may be, primary supporting members

- section modulus, moments of inertia and first moment for the hull girder.

2.1.3

The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in **Ch 3**, **Sec 3** to the net scantlings. The thickness for voluntary addition is to be added as an extra.

3. Net scantling approach

3.1 Net scantling definition

3.1.1 Required thickness

The gross thickness required, $t_{gross\_required}$, is not less than the gross thickness which is obtained by adding the corrosion addition t_C as defined in **Ch 3**, **Sec 3** to net thickness required, as follows:

$$t_{gross\_required} = t_{net\_required} + t_C$$

3.1.2 Offered thickness

The gross thickness offered, $t_{gross\_offered}$, is the gross thickness provided at the newbuilding stage, which is obtained by deducting the thickness for voluntary addition from the as-built thickness, as follows:

$$t_{gross\_offered} = t_{as\_built} - t_{voluntary\_addition}$$

3.1.3 Net thickness for plate

Net thickness offered, $t_{net\_offered}$, is obtained by subtracting t_C from the gross thickness offered, as follows:

$$t_{net\_offered} = t_{gross\_offered} - t_C = t_{as\_built} - t_{voluntary\_addition} - t_C$$

3.1.4 Net section modulus for stiffener

The net transverse section scantling is to be obtained by deducting t_C from the gross thickness offered of the elements which constitute the stiffener profile as shown in **Fig 1**.
For bulb profiles, an equivalent angle profile, as specified in **Ch 3**, **Sec 6, [4.1.1],** may be considered.
The net strength characteristics are to be calculated for the net transverse section.
In assessing the net strength characteristics of stiffeners reflecting the hull girder stress and stress due to local bending of the local structure such as double bottom structure, the section modulus of hull girder or rigidity of structure is obtained by deducting $0.5\,t_C$ from the gross thickness offered of the related elements.
Shadow area is corrosion addition.
For attached plate, the half of the considered corrosion addition specified in **3.2** is deducted from both sides of the attached plate.

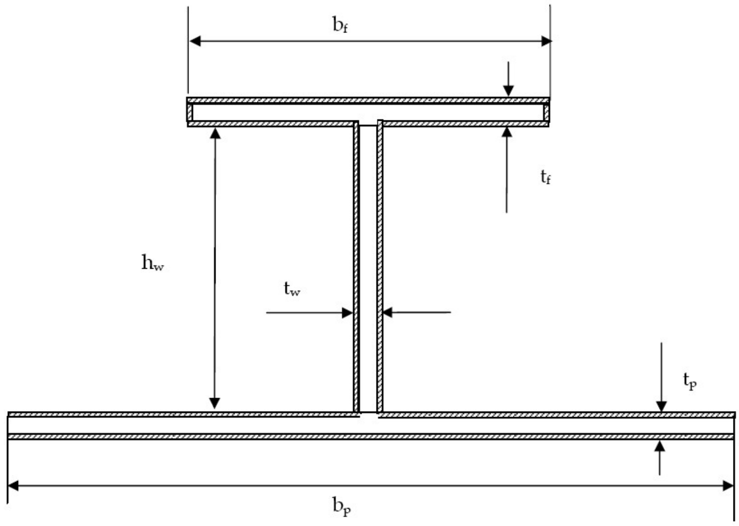


Fig 1: Net scantling of stiffener

3.2 Considered net scantling

3.2.1 Yielding check of the hull girder

The net thickness of structural members to be considered for the yielding check of the hull girder, according to **Ch 5**, **Sec 1**, is to be obtained by deducting 0.5 t_C from the gross thickness offered.

3.2.2 Global stress such as stress due to hull girder bending moment and shear force

The net thickness of structural members to be considered for stress due to hull girder bending moment and shear force according to **Ch 5**, **Sec 1**, is to be obtained by deducting 0.5 t_C from the gross thickness offered.

3.2.3 Buckling check of the hull girder

The net thickness of structural members to be considered for the buckling check, according to **Ch 6**, **Sec 3**, is to be obtained by deducting t_C from the gross thickness offered.

3.2.4 Ultimate strength check of the hull girder

The net thickness of structural members to be considered for the ultimate strength check of the hull girder, according to **Ch 5**, **Sec 2**, is to be obtained by deducting 0.5 t_C from the gross thickness offered.

3.2.5 Direct strength analysis

The net thickness of plating which constitutes primary supporting members to be checked stresses according to **Ch 7** is to be obtained by deducting 0.5 t_C from the gross thickness offered.
The net thickness of plating members to be considered for the buckling check according to **Ch 6**, **Sec 3,** using the stresses obtained from direct strength analysis, is to be obtained by deducting t_C from the gross thickness offered.

3.2.6 Fatigue check

The net thickness of structural members to be checked for fatigue according to **Ch 8** is to be obtained by deducting 0.5 t_C from the gross thickness offered.

3.2.7 Check of primary supporting members for ships less than 150 m in length *L*

The net thickness of plating which constitutes primary supporting members for ships less than 150 m in length L, to be checked according to **Ch 6**, **Sec 4, [2]**, is to be obtained by deducting t_c from the gross thickness.

3.3 Available information on structural drawings

3.3.1

The structural drawings are to indicate for each structural element the gross scantling and the renewal thickness as specified in **Ch 13**, **Sec 2**.
If thickness for voluntary addition is included in the as-built thicknesses, this is to be clearly mentioned and identified on the drawings.

Section 3 – CORROSION ADDITIONS

Symbols

t_C : Total corrosion addition, in mm, defined in **[1.2]**

t_{C1}, t_{C2} : Corrosion addition, in mm, on one side of the considered structural member, defined in **Table 1**

$t_{reserve}$: Reserve thickness, in mm, defined in **Ch 13**, **Sec 2** and taken equal to:

$t_{reserve} = 0.5$

1. Corrosion additions

1.1 General

1.1.1

The values of the corrosion additions specified in this section are to be applied in relation with the relevant protective coatings required by **Sec 5**.
For materials different from carbon steel, special consideration is to be given to the corrosion addition.

1.2 Corrosion addition determination

1.2.1 Corrosion additions for steel

The corrosion addition for each of the two sides of a structural member, t_{C1} or t_{C2}, is specified in **Table 1**. The total corrosion addition t_C, in mm, for both sides of the structural member is obtained by the following formula:

$$t_C = Roundup_{0.5}(t_{C1} + t_{C2}) + t_{reserve}$$

For an internal member within a given compartment, the total corrosion addition t_C is obtained from the following formula:

$$t_C = Roundup_{0.5}(2t_{C1}) + t_{reserve}$$

where t_{C1} is the value specified in **Table 1** for one side exposure to that compartment.
When a structural member is affected by more than one value of corrosion addition (e.g. a plate in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the severest value of corrosion addition applicable to the member.
In addition, the total corrosion addition t_C is not to be taken less than 2 mm, except for web and face plate of ordinary stiffeners.

1.2.2 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_C is to be taken equal to 0.

Table 1: Corrosion addition on one side of structural members

<table>
<tr><th rowspan="2">Compartment Type</th><th rowspan="2" colspan="2">Structural member</th><th colspan="2">Corrosion addition, t_{C1} or t_{C2} in mm</th></tr>
<tr><th>BC-A or BC-B ships with $L \geq 150$ m</th><th>Other</th></tr>
<tr><td rowspan="4">Ballast water tank(2)</td><td rowspan="2">Face plate of primary members</td><td>Within 3 m below the top of tank(3)</td><td colspan="2">2.0</td></tr>
<tr><td>Elsewhere</td><td colspan="2">1.5</td></tr>
<tr><td rowspan="2">Other members</td><td>Within 3 m below the top of tank(3)</td><td colspan="2">1.7</td></tr>
<tr><td>Elsewhere</td><td colspan="2">1.2</td></tr>
<tr><td rowspan="10">Dry bulk cargo hold(1)</td><td rowspan="3">Transverse bulkhead</td><td>Upper part(4)</td><td>2.4</td><td>1.0</td></tr>
<tr><td>Lower stool: sloping plate, vertical plate and top plate</td><td>5.2</td><td>2.6</td></tr>
<tr><td>Other parts</td><td>3.0</td><td>1.5</td></tr>
<tr><td rowspan="5">Other members</td><td>Upper part(4)</td><td rowspan="2">1.8</td><td rowspan="2">1.0</td></tr>
<tr><td>Webs and flanges of the upper end brackets of side frames of single side bulk carriers</td></tr>
<tr><td>Webs and flanges of lower brackets of side frames of single side bulk carriers</td><td>2.2</td><td>1.2</td></tr>
<tr><td>Other parts</td><td>2.0</td><td>1.2</td></tr>
<tr><td>Continuous wooden ceiling</td><td>2.0</td><td>1.2</td></tr>
<tr><td rowspan="2">Sloped plating of hopper tank, inner bottom plating</td><td>No continuous wooden ceiling</td><td>3.7</td><td>2.4</td></tr>
<tr><td>Exposed to atmosphere</td><td colspan="2">Horizontal member and weather deck(5)</td><td colspan="2">1.7</td></tr>
<tr><td></td><td colspan="2">Non horizontal member</td><td colspan="2">1.0</td></tr>
<tr><td colspan="3">Exposed to sea water(7)</td><td colspan="2">1.0</td></tr>
<tr><td colspan="3">Fuel oil tanks and lubricating oil tanks(2)</td><td colspan="2">0.7</td></tr>
<tr><td colspan="3">Fresh water tanks</td><td colspan="2">0.7</td></tr>
<tr><td>Void spaces(6)</td><td colspan="2">Spaces not normally accessed, e.g. access only through bolted manholes openings, pipe tunnels, etc.</td><td colspan="2">0.7</td></tr>
<tr><td>Dry spaces</td><td colspan="2">Internal of deck houses, machinery spaces, stores spaces, pump rooms, steering spaces, etc.</td><td colspan="2">0.5</td></tr>
<tr><td colspan="3">Other compartments than above</td><td colspan="2">0.5</td></tr>
</table>

Notes
(1) Dry bulk cargo hold includes holds, intended for the carriage of dry bulk cargoes, which may carry water ballast.
(2) The corrosion addition of a plating between water ballast and heated fuel oil tanks is to be increased by 0.7 mm.
(3) This is only applicable to ballast tanks with weather deck as the tank top.
(4) Upper part of the cargo holds corresponds to an area above the connection between the top side and the inner hull or side shell. If there is no top side, the upper part corresponds to the upper one third of the cargo hold height.
(5) Horizontal member means a member making an angle up to 20° as regard as a horizontal line.
(6) The corrosion addition on the outer shell plating in way of pipe tunnel is to be considered as water ballast tank.
(7) Outer side shell between normal ballast draught and scantling draught is to be increased by 0.5 mm.

Section 4 - LIMIT STATES

1. General

1.1 General principle

1.1.1

The structural strength assessments indicated in **Table 1** are covered by the requirements of the present Rules.

Table 1: Structural strength assessment

		Yielding check	Buckling check	Ultimate strength check	Fatigue check
Local Structures	Ordinary stiffeners	√	√	√[1]	√[2]
	Plating subjected to lateral pressure	√	√	√[3]	—
Primary supporting members		√	√	√	√[2]
Hull girder		√	√[4]	√	—

Note: √ indicates that the structural assessment is to be carried out.
(1) The ultimate strength check of stiffeners is included in the buckling check of stiffeners.
(2) The fatigue check of stiffeners and primary supporting members is the fatigue check of connection details of these members.
(3) The ultimate strength check of plating is included in the yielding check formula of plating.
(4) The buckling check of stiffeners and plating taking part in hull girder strength is performed against stress due to hull girder bending moment and hull girder shear force.

1.1.2

Strength of hull structures in flooded condition is to be assessed.

1.2 Limit states

1.2.1 Serviceability limit state

Serviceability limit state, which concerns the normal use, includes:

- local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members
- unacceptable deformations which affect the efficient use and appearance of structural members or the functioning of equipment.

1.2.2 Ultimate limit state

Ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations
- instability of the whole structure or part of it.

1.2.3 Fatigue limit state

Fatigue limit state relate to the possibility of failure due to cyclic loads.

1.2.4 Accidental limit state

Accidental limit state considers the flooding of any one cargo hold without progression of the flooding to the other compartments and includes:

- the maximum load-carrying capacity of hull girder
- the maximum load-carrying capacity of double bottom structure
- the maximum load-carrying capacity of bulkhead structure

Accidental single failure of one structural member of any one cargo hold is considered in the assessment of the ultimate strength of the entire stiffened panel.

2. Strength criteria

2.1 Serviceability limit states

2.1.1 Hull girder

For the yielding check of the hull girder, the stress corresponds to a load at 10^{-8} probability level.

2.1.2 Plating

For the yielding check and buckling check of platings constituting a primary supporting member, the stress corresponds to a load at 10^{-8} probability level.

2.1.3 Ordinary stiffener

For the yielding check of an ordinary stiffener, the stress corresponds to a load at 10^{-8} probability level.

2.2 Ultimate limit states

2.2.1 Hull girder

The ultimate strength of the hull girder is to withstand the maximum vertical longitudinal bending moment obtained by multiplying the partial safety factor and the vertical longitudinal bending moment at 10^{-8} probability level.

2.2.2 Plating

The ultimate strength of the plating between ordinary stiffeners and primary supporting members is to withstand the load at 10^{-8} probability level.

2.2.3 Ordinary stiffener

The ultimate strength of the ordinary stiffener is to withstand the load at 10^{-8} probability level.

2.3 Fatigue limit state

2.3.1 Structural details

The fatigue life of representative structural details such as connections of ordinary stiffeners and primary supporting members is obtained from reference pressures at 10^{-4}.

2.4 Accidental limit state

2.4.1 Hull girder

Longitudinal strength of hull girder in cargo hold flooded condition is to be assessed in accordance with **Ch 5, Sec 2.**

2.4.2 Double bottom structure

Double bottom structure in cargo hold flooded condition is to be assessed in accordance with **Ch 6**, **Sec 4**

2.4.3 Bulkhead structure

Bulkhead structure in cargo hold flooded condition is to be assessed in accordance with **Ch 6**, **Sec 1**, **Sec 2** and **Sec 3.**

3. Strength check against impact loads

3.1 General

3.1.1

Structural response against impact loads such as forward bottom slamming, bow flare slamming and grab falling depends on the loaded area, magnitude of loads and structural grillage.

3.1.2

The ultimate strength of structural members that constitute the grillage, i.e. platings between ordinary stiffeners and primary supporting members and ordinary stiffeners with attached plating, is to withstand the maximum impact loads acting on them.

Section 5 – CORROSION PROTECTION

1. General

1.1 Structures to be protected

1.1.1

All seawater ballast tanks, cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with **[1.2]**, **[1.3]** and **[1.4]** respectively.

1.1.2

Void double side skin spaces in cargo length area for vessels having a length (L_{LL}) of not less than 150 m are to be coated in accordance with **[1.2]**.

1.1.3

Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of fuel oil.

1.1.4

Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

1.2 Protection of seawater ballast tanks and void double side skin spaces

1.2.1

All dedicated seawater ballast tanks anywhere on the ship (excluding ballast hold) for vessels having a length (L) of not less than 90 m and void double side skin spaces in the cargo length area for vessels having a length (L_{LL}) of not less than 150 m are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent, applied in accordance with the manufacturer's recommendation.
The coatings are to be of a light colour, i.e. a colour easily distinguishable from rust which facilitates inspection.
Where appropriate, sacrificial anodes, fitted in accordance with **[2]**, may also be used.

1.2.2

For ships contracted for construction on or after the date of IMO adoption of the amended SOLAS regulation II-1/3-2, by which an IMO "Performance standard for protective coatings for ballast tanks and void spaces" will be made mandatory, the coatings of internal spaces subject to the amended SOLAS regulation are to satisfy the requirements of the IMO performance standard.
Consistent with IMO Resolution A.798(19) and IACS UI SC 122, the selection of the coating system, including coating selection, specification, and inspection plan, are to be agreed between the shipbuilder, coating system supplier and the owner, in consultation with the Society, prior to commencement of construction. The specification for the coating system for these spaces is to be documented and this documentation is to be verified by the Society and is to be in full compliance with the coating performance standard.
The shipbuilder is to demonstrate that the selected coating system with associated surface preparation and application methods is compatible with the manufacturing processes and methods.
The shipbuilder is to demonstrate that the coating inspectors have proper qualification as required by the IMO standard.
The attending surveyor of the Society will not verify the application of the coatings but will review the reports of the coating inspectors to verify that the specified shipyard coating procedures have been followed.

1.3 Protection of cargo hold spaces

1.3.1 Coating

It is the responsibility of the shipbuilder and of the owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

1.3.2 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.
The side and transverse bulkhead areas to be coated are specified in **[1.3.3]** and **[1.3.4]** respectively.

1.3.3 Side areas to be coated

The areas to be coated are the internal surfaces of:

- the inner side plating
- the internal surfaces of the topside tank sloping plates
- the internal surfaces of the hopper tank sloping plates for a distance of 300 mm below the frame end bracket for single side bulk carriers or below the hopper tank upper end for double side bulk carriers.

These areas are shown in **Fig 1**.

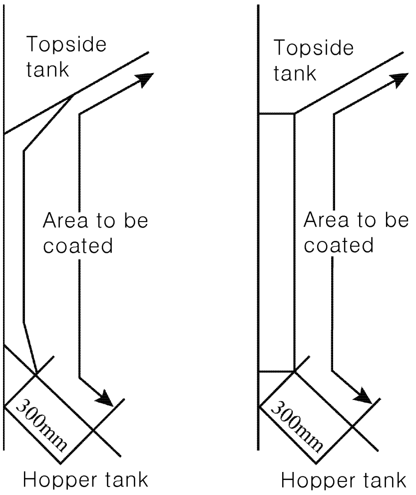


Fig 1: Side areas to be coated

1.3.4 Transverse bulkhead areas to be coated

The areas of transverse bulkheads to be coated are all the areas located above an horizontal level located at a distance of 300 mm below the frame end bracket for single side bulk carriers or below the hopper tank upper end for double side bulk carriers.

1.4 Protection of ballast hold spaces

1.4.1 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of ballast holds are to have an effective protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

2. Sacrificial anodes

2.1 General

2.1.1

Anodes are to have steel cores and are to be fitted sufficiently rigid by the anode support designed so that they retain the anode even when it is wasted.
The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.1.2

The supports at each end of an anode may not be attached to separate items which are likely to move independently.

2.1.3

Where anode inserts or supports are welded to the structure, the welds are to be smoothly.

3. Protection of inner bottom by ceiling

3.1 General

3.1.1

Ceiling on the inner bottom, if any, is to comply with **[3.2]** and **[3.3]**.

3.2 Arrangement

3.2.1

Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

3.2.2

Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

3.2.3

Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

3.2.4

The shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

3.3 Scantlings

3.3.1

The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case by case basis.

Section 6 – Structural Arrangement Principles

Symbols

For symbols not defined in this Section, refer to the list defined in **Ch 1, Sec 4**.

b_h : Breadth, in m, of cargo hatch opening

ℓ_b : Length, in m, of the free edge of the end bracket

1. Application

The requirements of this section apply to the cargo hold area. For other areas, the requirements of **Ch 9, Sec 1** to **Ch 9, Sec 4** are to be applied.

2. General principles

2.1 Definition

2.1.1 Primary frame spacing

Primary frame spacing, in m, is defined as the distance between the primary supporting members.

2.1.2 Secondary frame spacing

Secondary frame spacing, in m, is defined as the distance between ordinary stiffeners.

2.2 Structural continuity

2.2.1 General

The reduction in scantling from the midship part to the end parts is to be effected as gradually as practicable.
Attention is to be paid to the structural continuity in way of changes in the framing system, at the connections of primary supporting members or ordinary stiffeners and in way of the ends of the fore and aft parts and machinery space and in way of the ends of superstructures.

2.2.2 Longitudinal members

Longitudinal members are to be so arranged as to maintain the continuity of strength.
Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously for a sufficient distance towards the end of ship.
In particular, the continuity of the longitudinal bulkheads, including vertical and horizontal primary supporting members, extended over the cargo hold area is to be ensured beyond the cargo hold area. Scarfing brackets are a possible means.

2.2.3 Primary supporting members

Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength.
Abrupt changes in height or cross section are to be avoided.

2.2.4 Ordinary stiffeners

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members.

2.2.5 Platings

A change in plating thickness in as-built is not to exceed 50 % of thicker plate thickness for load carrying direction. The butt weld preparation is to be in accordance with the requirements of **Ch 11**, **Sec 2**, **[2.2]**.

2.2.6 Stress concentrations

Where stress concentration may occur in way of structural discontinuity, sufficient consideration is to be paid to reduce the stress concentration and adequate compensation and reinforcements are to be provided.
Openings are to be avoided, as far as practicable, in way of highly stressed areas.
Where openings are arranged, the shape of openings is to be such that the stress concentration remains within acceptable limits.
Openings are to be well rounded with smooth edges.
Weld joints are to be properly shifted from places where the stress may highly concentrate.

2.3 Connections with higher tensile steel

2.3.1 Connections with higher tensile steel

Where steels of different strengths are mixed in a hull structure, due consideration is to be given to the stress in the lower tensile steel adjacent to higher tensile steel.
Where stiffeners of lower tensile steel are supported by primary supporting members of higher tensile steel, due consideration is to be given to the stiffness of primary supporting members and scantlings to avoid excessive stress in the stiffeners due to the deformation of primary supporting members.
Where higher tensile steel is used at deck structures and bottom structure, longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, etc., are to be made of the same higher tensile steel. The same requirement is applicable for non continuous longitudinal stiffeners welded on the web of a primary member contributing to the hull girder longitudinal strength as hatch coamings, stringers and girders.

3. Plating

3.1 Structural continuity of plating

3.1.1 Insert plate

Where a local increase in plating thickness is generally to be achieved to through insert plates, an insert plate is to be made of the materials of a quality (yield & grade) at least equal to that of the plates on which they are welded.

4. Ordinary stiffener

4.1 Profile of stiffeners

4.1.1 Stiffener profile with a bulb section

A bulb section may be taken as equivalent to a built-up section. The dimensions of the equivalent angle section are to be obtained, in mm, from the following formulae.

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha\left(t'_w + \frac{h'_w}{6.7} - 2\right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

where:

h'_w, t'_w : Height and net thickness of a bulb section, in mm, as shown in **Fig 1.**

α : Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \le 120$$

$$\alpha = 1.0 \quad \text{for } h'_w > 120$$

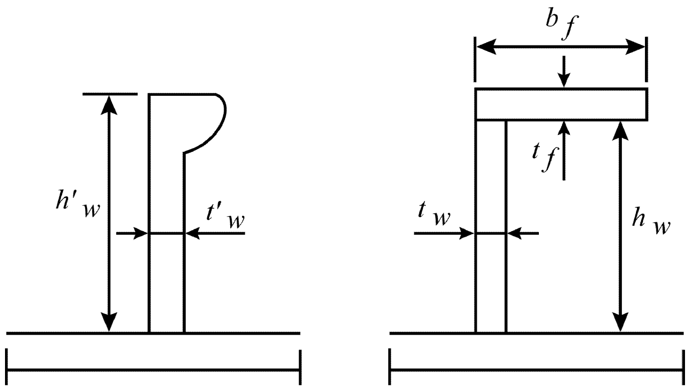


Fig 1: Dimensions of stiffeners

4.2 Span of ordinary stiffeners

4.2.1 Ordinary stiffener

The span ℓ of ordinary stiffeners is to be measured as shown in **Fig 2** For curved stiffeners, the span is measured along the chord.

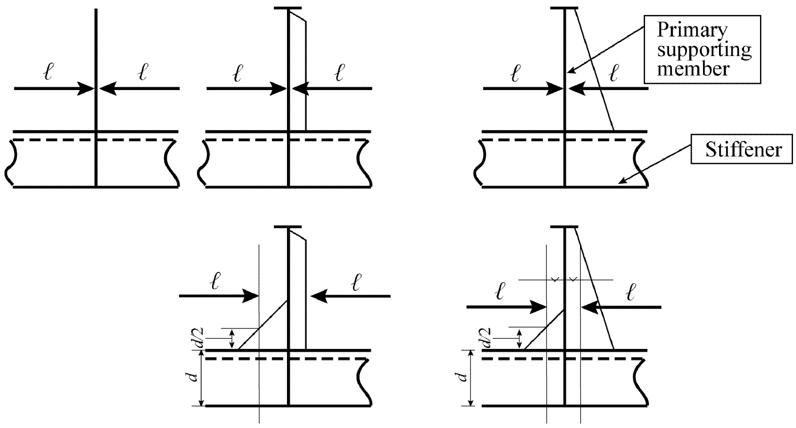


Fig 2: Span of ordinary stiffeners

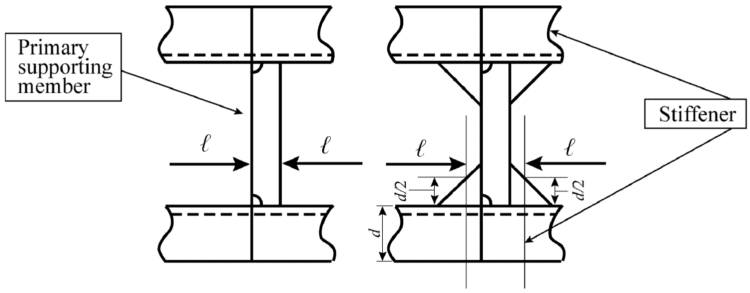


Fig 3: Span of ordinary stiffeners within a double hull

4.2.2 Ordinary stiffener within a double hull

The span ℓ of ordinary stiffeners fitted inside a double hull, i.e. when the web of the primary supporting members is connected with the inner hull and the outer shell acting as its flanges, is to be measured as shown in **Fig 3**.

4.2.3 Ordinary stiffeners supported by struts

The arrangement of ordinary stiffeners supported by struts is not allowed for ships over 120 m in length.
The span ℓ of ordinary stiffeners supported by one strut fitted at mid distance of the primary supporting members is to be taken as 0.7 ℓ_2.
In case where two struts are fitted between primary supporting members, the span ℓ of ordinary stiffeners is to be taken as the greater of 1.4 ℓ_1 and 0.7 ℓ_2.
ℓ_1 and ℓ_2 are the spans defined in **Figs 4** and **5**.

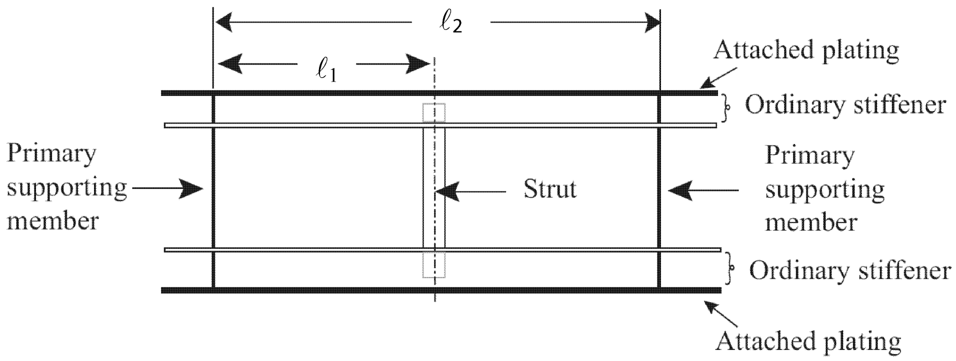


Fig 4: Span of ordinary stiffeners with one strut

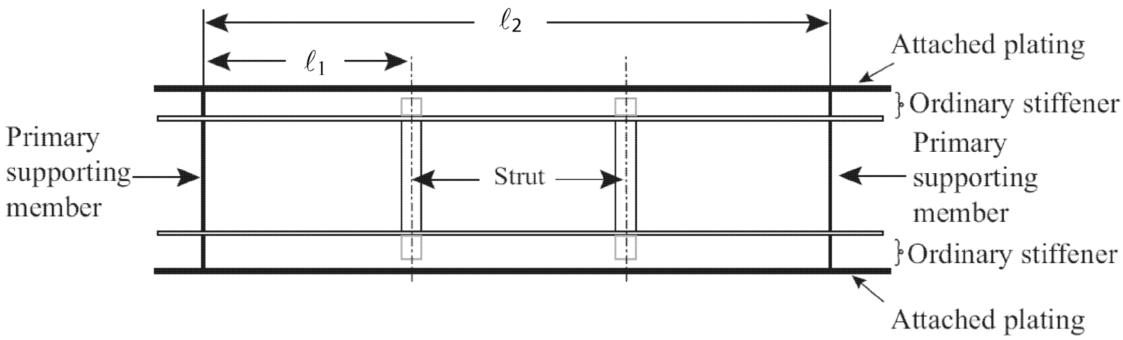


Fig 5: Span of ordinary stiffeners with two struts

4.3 Attached plating

4.3.1 Effective breadth for yielding check

The effective width b_p of the attached plating to be considered in the actual net section modulus for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the ordinary stiffener:

  $b_p = 0.2\ell$, or

  $b_p = s$

  whichever is lesser.
- where the plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):

  $b_p = 0.5s$

  $b_p = 0.1\ell$

  whichever is lesser.

4.3.2 Effective width for buckling check

The effective width of the attached plating of ordinary stiffeners for checking the buckling of ordinary stiffeners is defined in **Ch 6**, **Sec 3**, **[5]**.

4.4 Geometric property of ordinary stiffeners

4.4.1 General

Geometric properties of stiffeners such as moment of inertia, section modulus, shear sectional area, slenderness ratio of web plating, etc., are to be calculated based on the net thickness as defined in **Ch 3, Sec 2.**

4.4.2 Stiffener not perpendicular to the attached plating

The actual stiffener's net section modulus is to be calculated about an axis parallel to the attached plating.
Where the stiffener is not perpendicular to the attached plating, the actual net section modulus can be obtained, in cm^3, from the following formula:

$$w = w_0 \sin\alpha$$

where:

w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the attached plating

α : Angle, in degrees, between the stiffener web and the attached plating, as shown in **Fig 6**, but not to be taken less than 50.

The correction is to be applied when α is between 50 and 75 degrees.

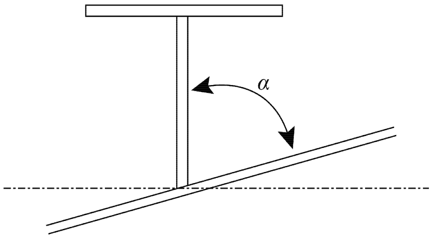


Fig 6: Angle between stiffener web and attached plating

Where the angle between the web plate of stiffener and the attached plating is less than 50 degrees, tripping bracket is to be fitted at suitable spacing. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 degrees, the face plate of the stiffener is to be fitted on the side of open bevel, as shown in **Fig 7.**

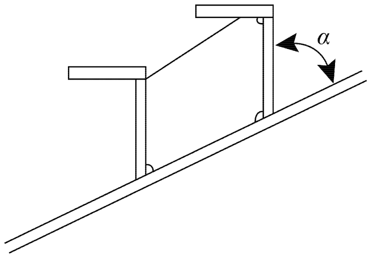


Fig 7: Orientation of stiffener when the angle is less than 50 degrees

4.5 End connections of ordinary stiffeners

4.5.1 General

Where ordinary stiffeners are to be continuous through primary supporting members, they are to be properly connected to the web plating so as to ensure proper transmission of loads. Some sample connections are shown in **Fig 8** to **Fig 11**.

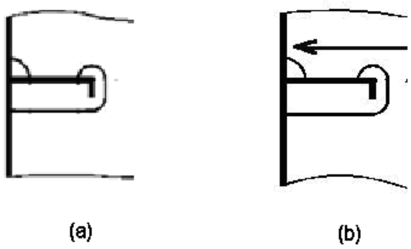


Fig 8: (a) Connection without collar plate and
(b) Connection with stiffener at side of longitudinal

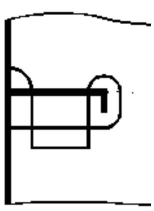


Fig 9: Connection with collar plate

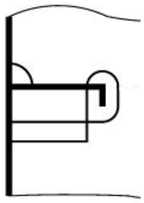


Fig 10: Connection with one large collar plate

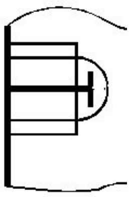


Fig 11: Connection with two large collar plates

4.5.2 Structural continuity of stiffeners

Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure structural continuity. In this case, the net section modulus and net sectional area of the brackets are to be not less than those of the ordinary stiffener.
The minimum net thickness of brackets is to be not less than that required for web plate of ordinary stiffeners.
The brackets are to be flanged or stiffened by a welded face plate where:

- the net thickness of the bracket, in mm, is less than 15 ℓ_b, where ℓ_b is the length, in m, of the free edge of the end bracket or brackets; or
- the longer arm of the bracket is greater than 800 mm.

The net sectional area, in cm^2, of the flanged edge or faceplate is to be at least equal to 10 ℓ_b.

4.5.3 End connections

End connection of stiffeners is to be sufficiently supported by the primary supporting members. Generally, a stiffener or a bracket to support the ordinary stiffener is to be provided.
Where slots for penetration of stiffeners are reinforced with collars, they are to be of the same materials as the primary supporting members.
Brackets or stiffeners to support the ordinary stiffeners are to be of sufficient sectional area and moment of inertia with respect to structural continuity, and are to have appropriate shape with respect to fatigue strength. If brackets or stiffeners to support the ordinary stiffeners are not fitted, or special slot configurations considering the fatigue strength are provided, fatigue strength assessment for slots are required by the Society.

5. Primary supporting members

5.1 General

5.1.1

Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

5.1.2

Where arrangements of primary supporting members are ensured adequate based on the results of FE analysis, fatigue assessment and ultimate strength assessment, primary supporting members are to be arranged in accordance with the result of such assessment.

5.2.1

Webs of primary supporting members are to be stiffened where the height, in mm, is greater than 100 t, where t is the net web thickness, in mm, of the primary supporting member.
In general, the web stiffeners of primary supporting members are to be spaced not more than 110 t.
The net thickness of web stiffeners and brackets are not to be less than the minimum net thickness of the primary members on which they are fitted.
Additional stiffeners are to be fitted in way of end brackets, at the connection with cross ties, etc. of transverse primary supporting members where shearing stress and/or compressive stress is expected to be high. These parts are not to have holes. Cut outs for penetration of ordinary stiffeners in these parts are to be reinforced with collar plates.
Depth of stiffener is to be more than 1/12 of stiffener length.

5.2.2

Tripping brackets (see **Fig 12**) welded to the face plate are generally to be fitted:

- at every fourth spacing of ordinary stiffeners, without exceeding 4 m.
- at the toe of end brackets
- at rounded face plates
- in way of concentrated loads
- near the change of section.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.
Where the face plate of the primary supporting member exceeds 180 mm on either side of the web, tripping bracket is to support the face plate as well.

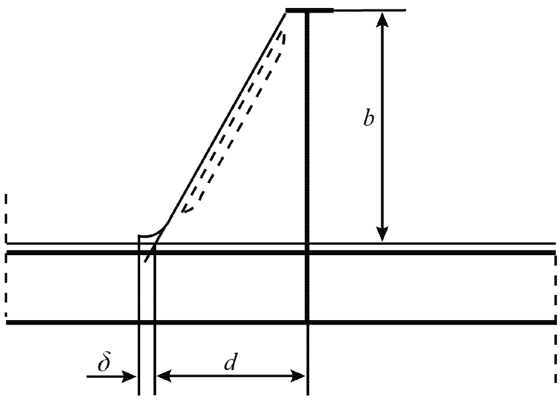


Fig 12: Primary supproting member: web stiffener in way of ordinary stiffener

5.2.3

The width of face plate of the primary supporting member except ring shape such as transverse ring in bilge hopper tanks and top side tank is to be not less than one tenth of the depth of the web, where tripping brackets are spaced as specified in **[5.2.2].**

5.2.4

The arm length of tripping brackets is to be not less than the greater of the following values, in m:

$$d = 0.38b$$

$$d = 0.85\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in **Fig 12**

s_t : Spacing, in m, of tripping brackets

t : Net thickness, in mm, of tripping brackets.

5.2.5

Tripping brackets with a net thickness, in mm, less than 10 ℓ_b are to be flanged or stiffened by a welded face plate.
The net sectional area, in cm^2, of the flanged edge or the face plate is to be not less than 7 ℓ_b, where ℓ_b is the length, in m, of the free edge of the bracket.
Where the height or breadth of tripping brackets is greater than 3 m, an additional stiffener is to be fitted parallel to the bracket free edge.

5.3 Span of primary supporting members

5.3.1 Definitions

The span ℓ, in m, of a primary supporting member without end bracket is to be taken as the length of the member between supports.
The span ℓ, in m, of a primary supporting member with end brackets is taken between points where the depth of the bracket is equal to half the depth of the primary supporting member as shown in **Fig 13(a)**.
However, in case of curved brackets where the face plate of the member is continuous along the face of the bracket, as shown in **Fig 13(b)**, the span is taken between points where the depth of the bracket is equal to one quarter the depth of the primary supporting member.

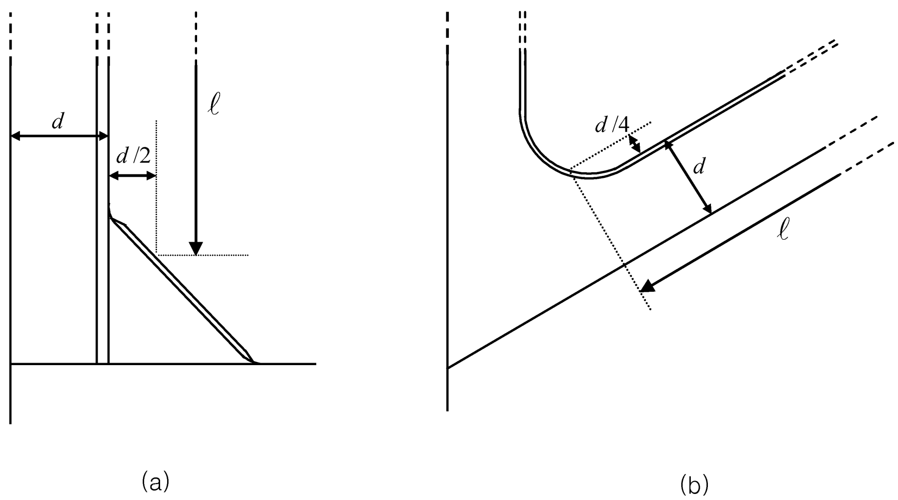


Fig 13 : Span of primary support member

5.4 Effective breadth of primary supporting member

5.4.1 General

The effective breadth of the attached plating of a primary supporting member to be considered in the actual net section modulus for the yielding check is to be taken as the mean spacing between adjacent primary supporting members.

5.5 Geometric properties

5.5.1 General

Geometric properties of primary supporting members such as moment of inertia, section modulus, shear sectional area, slenderness ratio of web plating, etc., are to be calculated based on the net thickness as specified in **Ch 3, Sec 2.**

5.6 Bracketed end connection

5.6.1 General

Where the ends of the primary supporting members are connected to bulkheads, inner bottom, etc., the end connections of all primary supporting members are to be balanced by effective supporting members on the opposite side of bulkheads, inner bottoms, etc..
Tripping brackets are to be provided on the web plate of the primary supporting members at the inner edge of end brackets and connection parts of the other primary supporting members and also at the proper intervals to support the primary supporting members effectively.

5.6.2 Dimensions of brackets

Arm length of bracket is generally not to be less than one-eighth of span length of the primary member, unless otherwise specified. Arm lengths of brackets at both ends are to be equal, as far as practicable.
The height of end brackets is to be not less than that of the primary supporting member. The net thickness of the end bracket web is not to be less than that of the web plate of the primary supporting member.
The scantlings of end brackets are to be such that the section modulus of the primary supporting member with end brackets is not less than that of the primary supporting member at mid-span point.
The width, in mm, of the face plate of end brackets is to be not less than $50(\ell_b+1)$.
Moreover, the net thickness of the face plate is to be not less than that of the bracket web.
Stiffening of end brackets is to be designed such that it provides adequate buckling web stability.
The following prescriptions are to be applied:

- where the length ℓ_b is greater than 1.5 m, the web of the bracket is to be stiffened
- the net sectional area, in cm^2, of web stiffeners is to be not less than $16.5\,\ell$, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted to prevent lateral buckling of web stiffeners. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

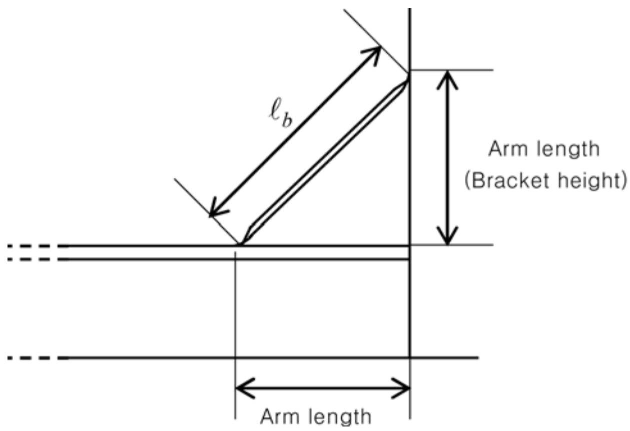


Fig 14: Dimension of brackets

5.7 Cut-outs and holes

5.7.1

Cut-outs for the passage of ordinary stiffeners are to be as small as possible and well rounded with smooth edges.
The depth of cut-outs is to be not greater than 50 % of the depth of the primary supporting member.

5.7.2

Where openings such as lightening holes are cut in primary supporting members, they are to be equidistant from the face plate and corners of cut-outs and, in general, their height is to be not greater than 20 % of the web height.
Where lightening holes with free edges are provided, the dimensions and locations of lightening holes are generally to be as shown in **Fig 15.**

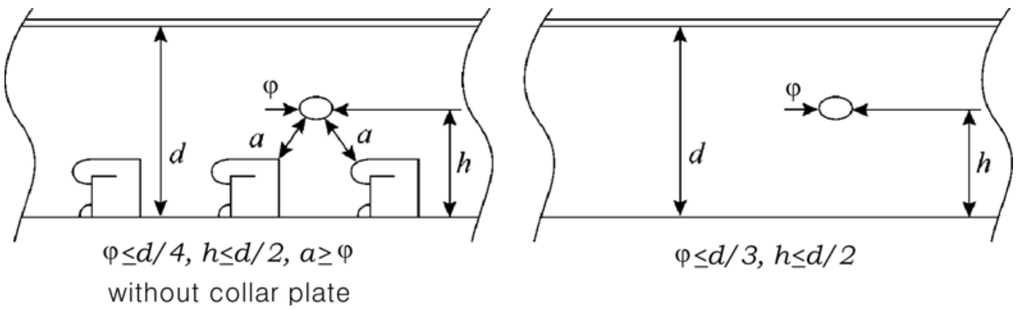


Fig 15: Location and dimensions of lightening holes

Where lightening holes are cut in the brackets, the distance from the circumference of the hole to the free flange of brackets is not to be less than the diameter of the lightening hole.

5.7.3

Openings are not be fitted in way of toes of end brackets.

5.7.4

At the mid-part within 0.5 times of the span of primary supporting members, the length of openings is to be not greater than the distance between adjacent openings.
At the ends of the span, the length of openings is to be not greater than 25 % of the distance between adjacent openings.

5.7.5

In the case of large openings in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.
This may be carried out by assigning an equivalent net shear sectional area to the primary supporting member obtained, in cm^2, according from the following formula:

$$A_{sh} = \frac{A_{sh1}}{1 + \frac{0.0032\ell^2 A_{sh1}}{I_1}} + \frac{A_{sh2}}{1 + \frac{0.0032\ell^2 A_{sh2}}{I_2}}$$

where (see **Fig 16**):

I_1, I_2 : Net moments of inertia, in cm^4, of deep webs(1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

A_{sh1}, A_{sh2}: Net shear sectional areas, in cm^2, of deep webs(1) and (2), respectively, taking account of the web height reduction by the depth of the cut out for the passage of the ordinary stiffeners, if any

ℓ : Span, in cm, of deep webs (1) and (2).

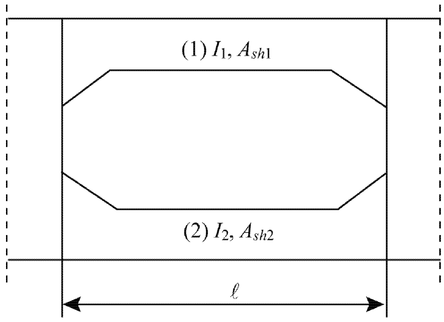


Fig 16: Large openings in the web of primary supporting members

6. Double bottom

6.1 General

Ref. SOLAS Ch. II-1, Part B, Reg. 12-1
A double bottom is to be fitted extending from the collision bulkhead to the afterpeak bulkhead.

6.1.2 Framing system

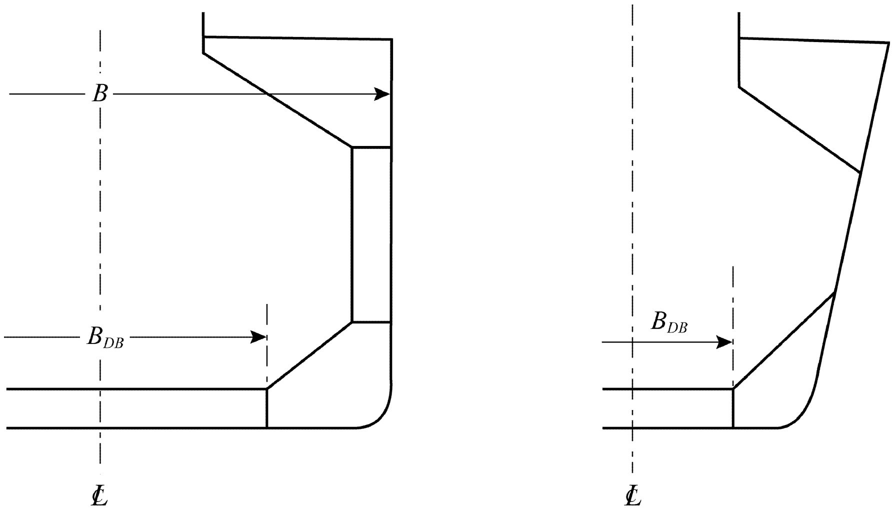
For ships greater than 120 m in length, the bottom, the double bottom and the sloped bulkheads of hopper tanks are to be of longitudinal system of frame arrangement at least within the cargo hold area. The spacing of the floors and bottom girders is not only governed by frame spaces but requirement in absolute value, in metres, is also indicated in **[6.3.3]** and **[6.4.1].**

6.1.3 Height of double bottom

Unless otherwise specified, the height of double bottom is not to be less than $B/20$ or 2 m whichever is the lesser.
Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors.
Where this is impossible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle are to be arranged.

6.1.4 Dimensions of double bottom

The breadth of double bottom is taken as shown in **Fig 17.**



Ships with inclined sides

Fig 17: Breadth of double bottom

6.1.5 Docking

The bottom is to have sufficient strength to withstand the loads resulting from the dry-docking of the ship.
Where docking brackets are provided between solid floors and connecting the centreline girder to the bottom shell plating, the docking brackets are to be connected to the adjacent bottom longitudinals.

6.1.6 Continuity of strength

Where the framing system changes from longitudinal to transverse, special attention is to be paid to the continuity of strength by means of additional girders or floors. Where this variation occurs within 0.6 L amidships, the inner bottom is generally to be maintained continuous by means of inclined plating.
Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the floors.
The actual net thickness and the yield stress of the lower strake of the sloped bulkhead of hopper tanks, if any, are not to be less than these ones of the inner bottom with which the connection is made.

6.1.7 Reinforcement

The bottom is to be locally stiffened where concentrated loads are envisaged such as under the main engine and thrust seat.
Girders and floors are to be fitted under each line of pillars, toes of end brackets of bulkhead stiffeners and slant plate of lower stool of bulkhead. In case girders and floors are not fitted, suitable reinforcement is to be provided by means of additional primary supporting members or supporting brackets.
When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be required for this purpose.

6.1.8 Manholes and lightening holes

Manholes and lightening holes are to be provided in floors and girders to ensure accessibility and ventilation as a rule.
The number of manholes in tank tops is to be kept to the minimum compatible with securing free ventilation and ready access to all parts of the double bottom.
Manholes may not be cut in the girders and floors below the heels of pillars.

6.1.9 Air holes and drain holes

Air and drain holes are to be provided in floors and girders.
Air holes are to be cut as near to the inner bottom and draining holes as near to the bottom shell as

practicable.
Air holes and drain holes are to be designed to aid full ballast water and sediment removal to allow for effective ballast water exchange.

6.1.10 Drainage of tank top

Effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend for more than one-half depth of the height of double bottom

6.1.11 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the bottom plating.

6.1.12 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders generally spaced, no more than 3 m apart.
The structures in way of the floors are to ensure sufficient continuity of the latter.

6.2 Keel

6.2.1

The width of the keel is to be not less than the value obtained, in m, from the following formula:

$$b = 0.8 + L/200$$

6.3 Girders

6.3.1 Centre girder

The centre girder is to extend within the cargo hold area and is to extend forward and aft as far as practicable, and structural continuity thereof to be continuous within the full length of the ship.
Where double bottom compartments are used for the carriage of fuel oil, fresh water or ballast water, the centre girder is to be watertight, except for the case such as narrow tanks at the end parts or when other watertight girders are provided within 0.25 B from the centreline, etc.

6.3.2 Side girders

The side girders are to extend within the parallel part of cargo hold area and are to extend forward and aft of cargo hold area as far as practicable.

6.3.3 Spacing

The spacing of adjacent girders is generally to be not greater than 4.6 m or 5 times the spacing of bottom or inner bottom ordinary stiffeners, whichever is the smaller. Greater spacing may be accepted depending on the result of the analysis carried out according to **Ch 7.**

6.4 Floors

6.4.1 Spacing

The spacing of floors is generally to be not greater than 3.5 m or 4 frame spaces as specified by the designer, whichever is the smaller. Greater spacing may be accepted depending on the result of the analysis carried out according to **Ch 7.**

6.4.2 Floors in way of transverse bulkheads

Where transverse bulkhead is provided with lower stool, solid floors are to be fitted in line with both sides of lower stool. Where transverse bulkhead is not provided with lower stool, solid floors are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead or in line of plane transverse bulkhead.

6.4.3 Web stiffeners

Floors are to be provided with web stiffeners in way of longitudinal ordinary stiffeners. Where the web stiffeners are not provided, fatigue strength assessment for the cut out and connection of longitudinal stiffener is to be carried out.

6.5 Bilge strake and bilge keel

6.5.1 Bilge strake

Where some of the longitudinal stiffeners at the bilge part are omitted, longitudinal stiffeners are to be provided as near to the turns of bilge as practicable.

6.5.2 Bilge keel

Bilge keels are not be welded directly to the shell plating. An intermediate flat is required on the shell plating. The ends of the bilge keel are to be sniped as shown in **Fig 18** or rounded with large radius. The ends are to be located in way of transverse bilge stiffeners inside the shell plating and the ends of intermediate flat are not to be located at the block joints.
The bilge keel and the intermediate flat are to be made of steel with the same yield stress as the one of the bilge strake. The bilge keel with a length greater than 0.15 L is to be made with the same grade of steel as the one of bilge strake.
The net thickness of the intermediate flat is to be equal to that of the bilge strake. However, this thickness may generally not be greater than 15 mm.
Scallops in the bilge keels are to be avoided.

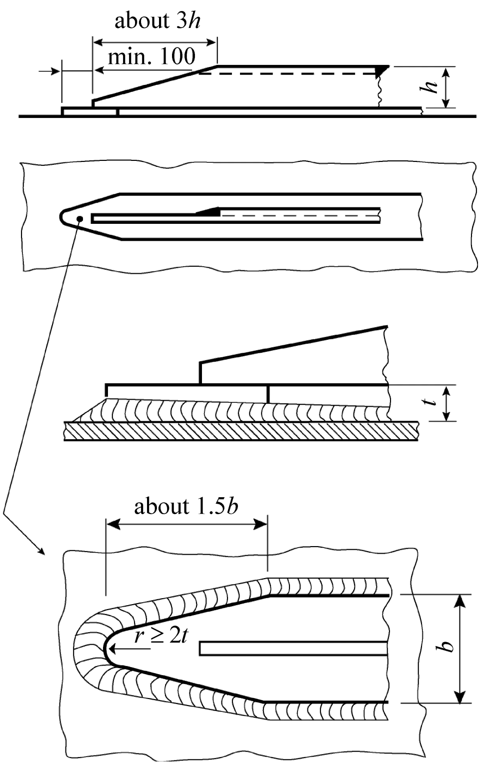


Fig 18: Example of bilge keel arrangement

7. Double Side structure

7.1 Application

7.1.1

The requirement of this article applies to longitudinally or transversely framed side structure.
The transversely framed side structures are built with transverse frames possibly supported by horizontal side girders.
The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by vertical primary supporting members.
The side within the hopper and topside tanks is, in general, to be longitudinally framed. It may be transversely framed when this is accepted for the double bottom and the deck according to **[6.1.2]** and **[9.1.1]**, respectively.

7.2 Design principles

7.2.1

Where the double side space is void, the structural members bounding this space are to be structurally designed as a water ballast tank according to **Ch 6.** In such case the corresponding air pipe is considered as extending 0.76 m above the freeboard deck at side.
For corrosion addition, the space is still considered as void space.

7.3 Structural arrangement

7.3.1 General

Double side structures are to be thoroughly stiffened by providing web frames and side stringers within the double hull.
Continuity of the inner side structures, including stringers, is to be ensured within and beyond the cargo area. Scarfing brackets are a possible means.

7.3.2 Primary supporting member spacing

For transverse framing system, the spacing of transverse side primary supporting members is, in general, to be not greater than 3 frame spaces.
Greater spacing may be accepted depending on the results of the analysis carried out according to **Ch 7** for the primary supporting members in the cargo holds.
The vertical distance between horizontal primary members of the double side is not to exceed 6 m, unless the appropriate structural members complying with the requirements for safe access are provided.

7.3.3 Primary supporting member fitting

Transverse side primary supporting members are to be fitted in line with web frames in topside and hopper tanks. However where it is not practicable for top side web frames, large brackets are to be fitted in the topside space in line with double side web frames
Transverse bulkheads in double side space are to be arranged in line with the cargo hold transverse bulkheads.
Vertical primary supporting members are to be fitted in way of hatch end beams.
Unless otherwise specified, horizontal side girders are to be fitted aft of the collision bulkhead up to 0.2 L aft of the fore end, in line with fore peak girders.

7.3.4 Transverse ordinary stiffeners

The transverse ordinary stiffeners of the shell and the inner side are to be continuous or fitted with bracket end connections within the height of the double side. The transverse ordinary stiffeners are to be effectively connected to stringers. At their upper and lower ends, opposing shell and inner side transverse ordinary stiffeners and supporting stringer plates are to be connected by brackets.

7.3.5 Longitudinal ordinary stiffeners

The longitudinal side shell and inner side ordinary stiffeners, where fitted, are to be continuous within the length of the parallel part of cargo hold area and are to be fitted with brackets in way of transverse bulkheads aligned with cargo hold bulkheads. They are to be effectively connected to transverse web frames of the double side structure. For the side longitudinal and ordinary stiffeners of inner skin out of parallel part of cargo hold area, special attention is to be paid for a structural continuity.

7.3.6 Sheer strake

The width of the sheer strake is to be not less than the value obtained, in m, from the following formula:

$$b = 0.715 + 0.425L/100$$

The sheer strake may be either welded to the stringer plate or rounded.
If the shear strake is rounded, its radius, in mm, is to be not less than 17 t_s, where t_s is the net thickness, in mm, of the sheer strake.
The fillet weld at the connection of the welded sheer strake and deck plate may be either full penetration or deep penetration weld.
The upper edge of the welded sheer strake is to be rounded smooth and free of notches. Fixtures such as bulwarks, eye plates are not to be directly welded on the upper edge of sheer strake, except in fore and aft parts.
Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thicknesses of the sheer strake.
The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures at the ends of the ship is to be carefully designed so as to avoid any discontinuities.

7.3.7 Plating connection

At the locations where the inner hull plating and the inner bottom plating are connected, attention is to be paid to the structural arrangement so as not to cause stress concentration.
Knuckles of the inner side are to be adequately stiffened by ordinary stiffeners or equivalent means, fitted in line with the knuckle.
The connections of hopper tank plating with inner hull and with inner bottom are to be supported by a primary supporting member.

7.4 Longitudinally framed double side

7.4.1 General

Adequate continuity of strength is to be ensured in way of breaks or changes in the width of the double side.

7.5 Transversely framed double side

7.5.1 General

Transverse frames of side and inner side may be connected by means of struts. Struts are generally to be connected to transverse frames by means of vertical brackets.

8. Single side structure

8.1 Application

8.1.1

This article applies to the single side structure with transverse framing.

If single side structure is supported by transverse or longitudinal primary supporting members, the requirements in **[7]** above apply to these primary supporting members as regarded to ones in double side skin.

8.2 General arrangement

8.2.1

Side frames are to be arranged at every frame space.
If air pipes are passing through the cargo hold, they are to be protected by appropriate measures to avoid a mechanical damage.

8.3 Side frames

8.3.1 General

Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.
The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than r ,in mm, given by:

$$r = \frac{0.4 b_f^2}{t_f + t_C}$$

where:

t_C : Corrosion addition, in mm, specified in **Ch 3**, **Sec 3**

b_f and t_f : Flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.
The dimensions of side frames are defined in **Fig 19.**

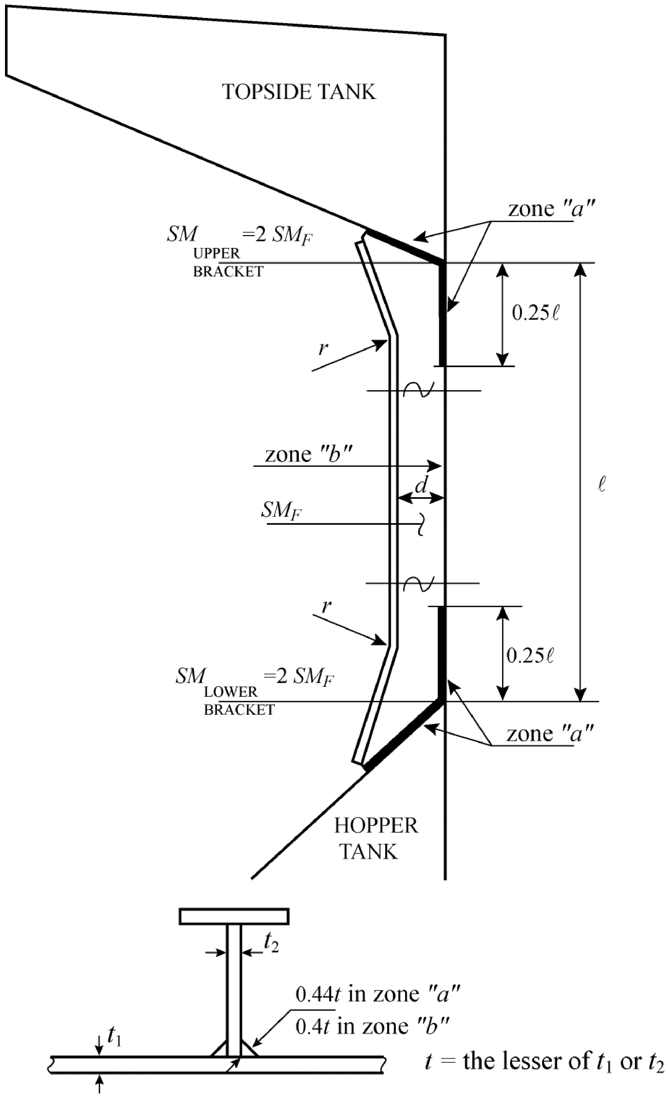


Fig 19: Dimensions of side frames

8.4 Upper and lower brackets

8.4.1

The face plates or flange of the brackets is to be sniped at both ends.
Brackets are to be arranged with soft toes.
The as-built thickness of the brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

8.4.2

The dimensions (in particular the height and length) of the lower brackets and upper brackets are to be not less than those shown in **Fig 20.**

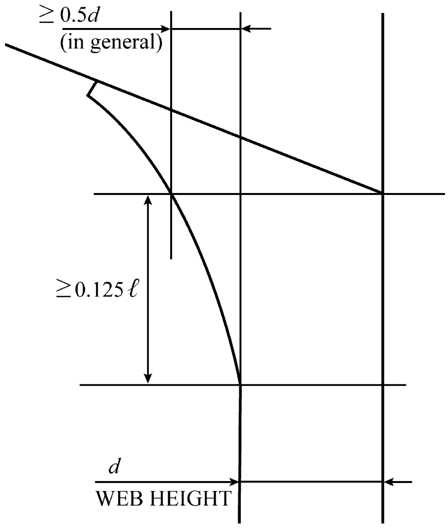


Fig 20: Dimensions of lower and upper brackets

8.5 Tripping brackets

8.5.1

In way of the foremost hold and in the holds of BC-A ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in **Fig 21.**
The as-built thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.
Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

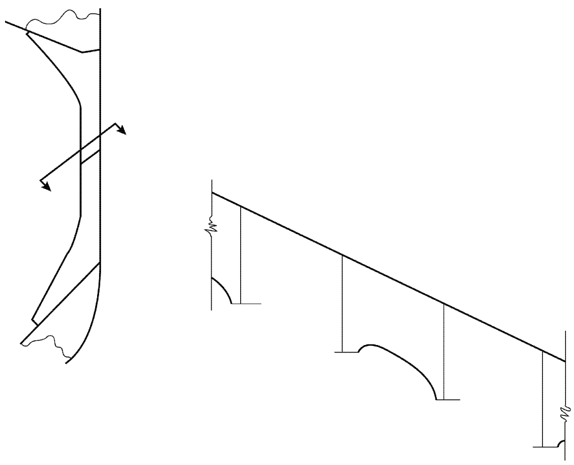


Fig 21: Tripping brackets to be fitted in way of foremost hold

8.6 Support structure

8.6.1

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in **Fig 22.** The brackets are to be stiffened against buckling according to **[5.6.2].**

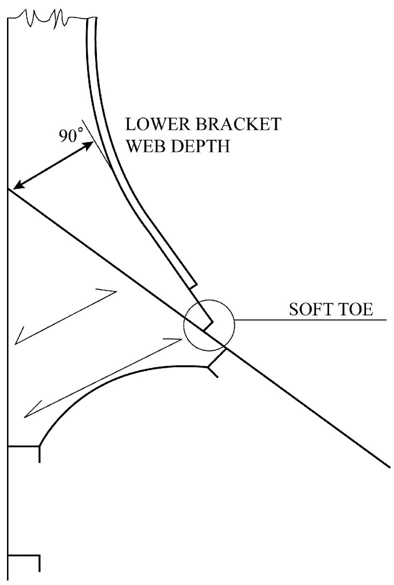


Fig 22: Example of support structure for lower end

9. Deck structure

9.1 Application

9.1.1

The deck outside the line of hatches and the topside tank sloping plates are to be longitudinally framed. Within the line of hatches, other arrangement than longitudinal framing may be considered provided that adequate structural continuity is ensured.

9.2 General arrangement

9.2.1

The spacing of web frames in topside tanks is generally to be not greater than 6 frame spaces.
Greater spacing may be accepted by the Society, on a case-by-case basis, depending on the results of the analysis carried out according to **Ch 7.**

9.2.2

The deck supporting structure is to be made of ordinary stiffeners longitudinally or transversely arranged, supported by primary supporting members.

9.2.3 Deck between hatches

Inside the line of openings, a transverse structure is to be generally adopted for the cross deck structures, beams are to be adequately supported by girders and extended up to the second longitudinal from the hatch side girders towards the bulwark. Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.
Smooth connection of the strength deck at side with the deck between hatches is to be ensured by a plate of intermediate thickness.

9.2.4 Topside tank structures

Topside tank structures are to extend as far as possible within the machinery space and are to be adequately tapered.
Where a double side primary supporting member is fitted outside the plane of the topside tank web

frame, a large bracket is to be fitted in line with.

9.2.5 Stringer plate

The width of the stringer plate is to be not less than the value obtained, in m, from the following formula:

$$b = 0.35 + 0.5L/100$$

Rounded stringer plate, where adopted, are to have a radius complying with the requirements in **[7.3.6].**

9.2.6

Adequate continuity of strength by providing proper overlapping of structures and adequate scarphing members is to be ensured in way of:

- stepped strength deck
- changes in the framing system

9.2.7

Deck supporting structures under deck machinery, cranes, king post and equipment such as towing equipment, mooring equipment, etc., are to be adequately stiffened.

9.2.8

Pillars or other supporting structures are to be generally fitted under heavy concentrated loads.

9.2.9

A suitable stiffening arrangement is considered in way of the ends and corners of deckhouses and partial superstructures.

9.2.10 Connection of hatch end beams with deck structures

The connection of hatch end beams with deck structures is to be properly ensured by fitting inside the topside tanks additional web frames or brackets.

9.2.11 Construction of deck plating

Hatchways or other openings on decks are to have rounded corners, and compensation is to be suitably provided.

9.3 Longitudinally framed deck

9.3.1 General

Deck longitudinals within the parallel part of cargo hold area except within the line of hatch openings are to be continuous in way of deck transverses and transverse bulkheads. For the deck longitudinals out of parallel part of cargo hold area, other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.
Connections at ends of longitudinal stiffeners are to ensure a sufficient strength to bending and shear.

9.4 Transversely framed deck

9.4.1 General

Where the deck structure is transversely framed, deck beams or deck transverse stiffeners are to be fitted at each frame.

Transverse beams or deck transverse stiffeners are to be connected to side structure or frames by brackets.

9.5 Hatch supporting structures

9.5.1

Hatch side girders and hatch end beams of reinforced scantlings are to be fitted in way of cargo hold openings.

9.5.2

The connection of hatch end beams to web frames is to be ensured. Hatch end beams are to be aligned with transverse web frames in topside tanks.

9.5.3

Clear of openings, adequate continuity of strength of longitudinal hatch coamings is to be ensured by under deck girders.
At hatchway corners, deck girders or their extension parts provided under deck in line with hatch coamings and hatch end beams are to be effectively connected so as to maintain the continuity in strength.

9.5.4

For ships with holds designed for loading/discharging by grabs and having the additional class notation GRAB[X], wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of top side tank plates)/hatch end beams in cargo hold and upper portion of hatch coamings.

9.6 Openings in the strength deck

9.6.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the breaks of effective superstructures. Openings are to be cut as far as practicable from hatchway corners, hatch side coamings and side shell platings.

9.6.2 Small opening location

Openings are generally to be cut outside the limits as shown in **Fig 23** in dashed area, defined by:

- the bent area of a rounded sheer strake, if any, or the side shell
- $e = 0.25(B-b)$ from the edge of opening
- $c = 0.07\ell + 0.1b$ or $0.25b$, whichever is greater

where:

b : Width, in m, of the hatchway considered, measured in the transverse direction. (see **Fig 23**)

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction. (see **Fig 23**).

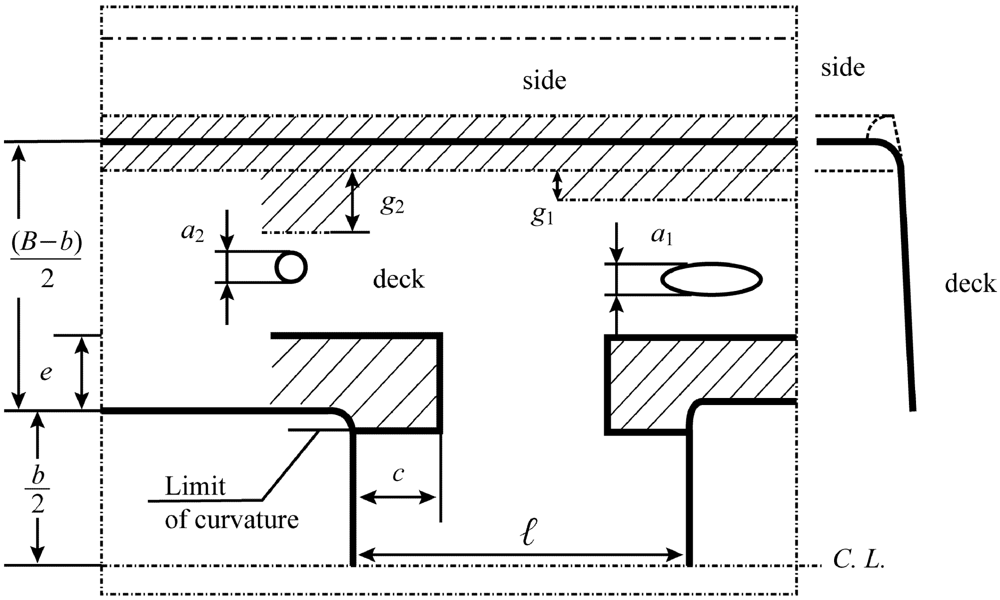


Fig 23: Position of openings in strength deck

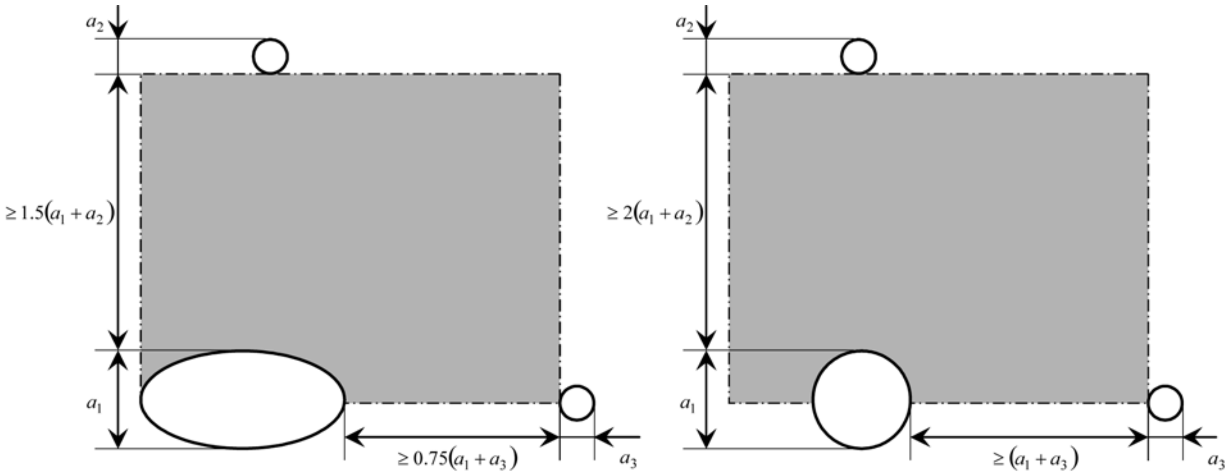


Fig 24: Elliptical and circular openings in strength deck

Moreover the transverse distance between these limits and openings or between openings together is not to be less than the followings:

- Transverse distance between the above limits and openings or between hatchways and openings as shown in **Fig 23**:

  $g_2 = 2a_2$ for circular openings

  $g_1 = a_1$ for elliptical openings

- Transverse distance between openings as shown in **Fig 24**:

  $2(a_1 + a_2)$ for circular openings

  $1.5(a_1 + a_2)$ for elliptical openings

where

a_1 : Transverse dimension of elliptical openings, or diameter of circular openings, as the case may be

a_2 : Transverse dimension of elliptical openings, or diameter of circular openings, as the case may be

a_3 : Longitudinal dimension of elliptical openings, or diameter of circular openings, as the case may be

- Longitudinal distance between openings is not to be less than the followings:

$(a_1 + a_3)$ for circular openings

$0.75(a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one.

If the opening arrangements do not comply with these requirements, the longitudinal strength assessment in accordance with **Ch 5** is to be carried out by subtracting such opening areas.

9.6.3 Corner of hatchways

For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to the formula given after, are generally to be fitted in way of corners where the plating cut-out has a circular profile.
The radius of circular corners is to be not less than 5 % of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming.
Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.
For hatchways located within the cargo area, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is to be obtained, in mm, from the following formula:

$$t_{INS} = (0.8 + 0.4\ell / b)\, t$$

without being taken less than t or greater than 1.6t

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction (see **Fig 23**)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see **Fig 23**)

t : Actual net thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60 % greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.
Where insert plates are required, the arrangement is shown in **Fig 25**, in which d_1, d_2, d_3 and d_4 are to be greater than the ordinary stiffener spacing.
For hatchways located outside the cargo area, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case by case basis.
For ships having length L of 150 m or above, the corner radius, the thickness and the extent of insert plate may be determined by the results of a direct strengt hassessment according to **Ch 7, Sec 2** and **Sec 3**, including buckling check and fatigue strength assessment of hatch corners according to **Ch 8, Sec 5.**

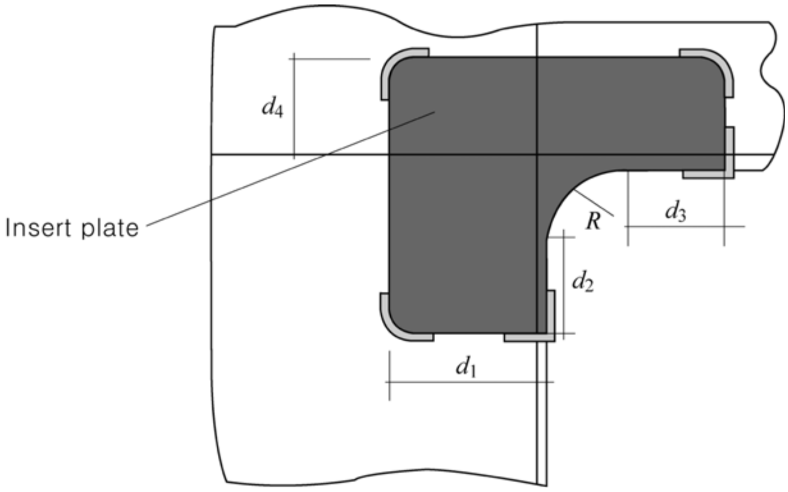


Fig 25: Hatch corner insert plate

10. Bulkhead structure

10.1 Application

10.1.1

The requirements of this article apply to longitudinal and transverse bulkhead structures which may be plane or corrugated.

10.1.2 Plane bulkheads

Plane bulkheads may be horizontally or vertically stiffened.
Horizontally framed bulkheads are made of horizontal ordinary stiffeners supported by vertical primary supporting members.
Vertically framed bulkheads are made of vertical ordinary stiffeners which may be supported by horizontal girders.

10.2 General

10.2.1

The web height of vertical primary supporting members of bulkheads may be gradually tapered from bottom to deck.

10.2.2

The net thickness of the after peak bulkhead plating in way of the stern tube is to be increased by at least 60 % of other part of after peak bulkhead plating

10.3 Plane bulkheads

10.3.1 General

Where a bulkhead does not extend up to the uppermost continuous deck, suitable strengthening is to be provided in the extension of the bulkhead.
Bulkheads are to be stiffened in way of the deck girders.
The bulkhead stiffener webs of hopper and topside tank watertight bulkheads are required to be aligned with the webs of longitudinal stiffeners of sloping plates of inner hull.
A primary supporting member is to be provided in way of any vertical knuckle in longitudinal

bulkheads. The distance between the knuckle and the primary supporting member is to be taken not greater than 70 mm. When the knuckle is not vertical, it is to be adequately stiffened by ordinary stiffeners or equivalent means, fitted in line with the knuckle.
Plate floors are to be fitted in the double bottom in line with the plate transverse bulkhead.

10.3.2 End connection of ordinary stiffeners

The crossing of ordinary stiffeners through a watertight bulkhead is to be watertight.
In general, end connections of ordinary stiffeners are to be bracketed. If bracketed end connections cannot be applied due to hull lines, etc., they are to be terminated on transverse headers between adjacent longitudinal or if not possible, sniped ends may be accepted, provided the scantling of ordinary stiffeners and corresponding plating are modified accordingly.

10.3.3 Sniped end of ordinary stiffener

Sniped ends are not allowed on bulkheads subject to hydrostatic pressure. Where sniped ordinary stiffeners are fitted, the snipe angle is not to be greater than 30 degrees, and their ends are to be extended as far as practicable to the boundary of the bulkhead.

10.3.4 Bracketed ordinary stiffeners

Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in **Figs 26** and **27**, are to be not less than the following values, in mm:

- for arm length a:
  - brackets of horizontal stiffeners and bottom bracket of vertical stiffeners:

    $a = 100\ell$
  - upper bracket of vertical stiffeners:

    $a = 80\ell$
- for arm length b,thegreaterof

  $b = 80\{(w+20)/t\}^{0.5}$ and

  $b = \alpha p s \ell / t$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm^3, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m^2, calculated at mid-span

α : Coefficient equal to:

α = 4.9 for tank bulkheads

α = 3.6 for watertight bulkheads.

The connection between the stiffener and the bracket is to be such that the net section modulus of the connection is not less than that of the stiffener.

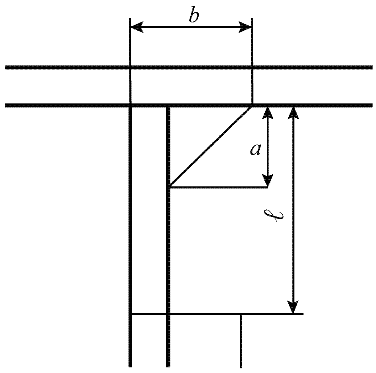


Fig 26: Bracket at upper end of ordinary stiffener on plane bulkhead

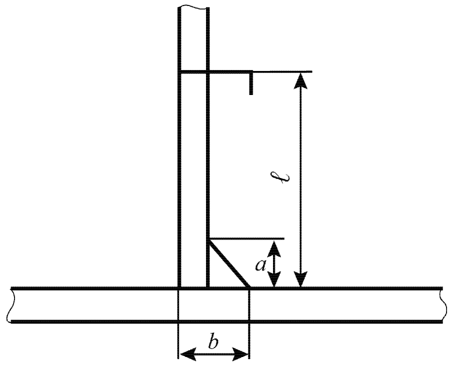


Fig 27: Bracket at lower end of ordinary stiffener on plane bulkhead

10.4 Corrugated bulkheads

10.4.1 General

For ships of 190 m of length L and above, the transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For ships less than 190 m in length L, corrugations may extend from inner bottom to deck provided the global strength of hull structures are satisfactorily proved for ships having ship length L of 150 m and above by DSA as required by **Ch 7** of the Rules

10.4.2 Construction

The main dimensions a, R, c, d, t, φ and s_C of corrugated bulkheads are defined in **Fig 28**.
The bending radius is not to be less than the following values, in mm:

$$R = 3.0t$$

where :

t : As-built thickness, in mm, of the corrugated plate.

The corrugation angle φ shown in **Fig 28** is to be not less than 55°.
When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

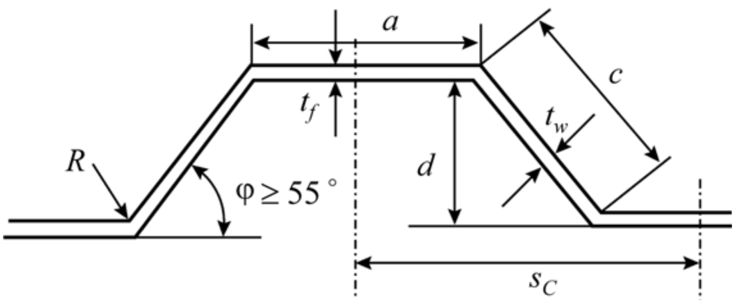


Fig 28: Dimensions of a corrugated bulkhead

10.4.3 Actual section modulus of corrugations

The net section modulus of a corrugation may be obtained, in cm^3, from the following formula:

$$w = \left[\frac{d(3at_f + ct_w)}{6} \right] 10^{-3}$$

where:

t_f, t_w : Net thickness of the plating of the corrugation, in mm, shown in **Fig 28**

d, a, c : Dimensions of the corrugation, in mm, shown in **Fig 28.**

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm^3, from the following formula:

$$w = 0.5\, a\, t_f\, d \cdot 10^{-3}$$

10.4.4 Span of corrugations

The span ℓ_C of the corrugations is to be taken as the distance shown in **Fig 29**.
For the definition of ℓ_C, the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, in general
- 2 times the depth of corrugation, for rectangular stool

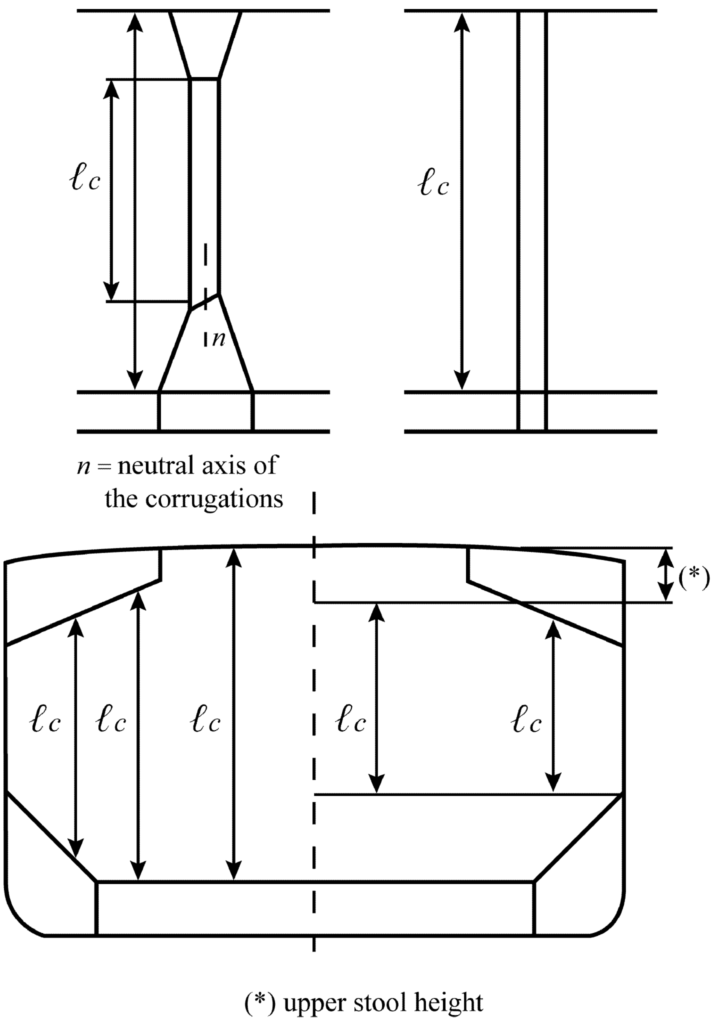


Fig 29: Span of the corrugations

10.4.5 Structural arrangements

The strength continuity of corrugated bulkheads is to be ensured at the ends of corrugations.
Where corrugated bulkheads are cut in way of primary supporting members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.
Where vertically corrugated transverse bulkheads or longitudinal bulkheads are welded on the inner bottom plate, floors or girders are to be fitted in way of flanges of corrugations, respectively.
In general, the first vertical corrugation connected to the boundary structures is to have a width not smaller than typical width of corrugation flange.

10.4.6 Bulkhead stools

Plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.
Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams, as the case may be.

10.4.7 Lower stool

The lower stool, when fitted, is to have a height in general not less than 3 times the depth of the corrugations. The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool.
The distance d from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with **Fig 30**.
The stool bottom is to be installed in line with double bottom floors or girders as the case may be, and is to have a width not less than 2.5 times the mean depth of the corrugation.
The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors as the case may be, for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.
Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration weld.

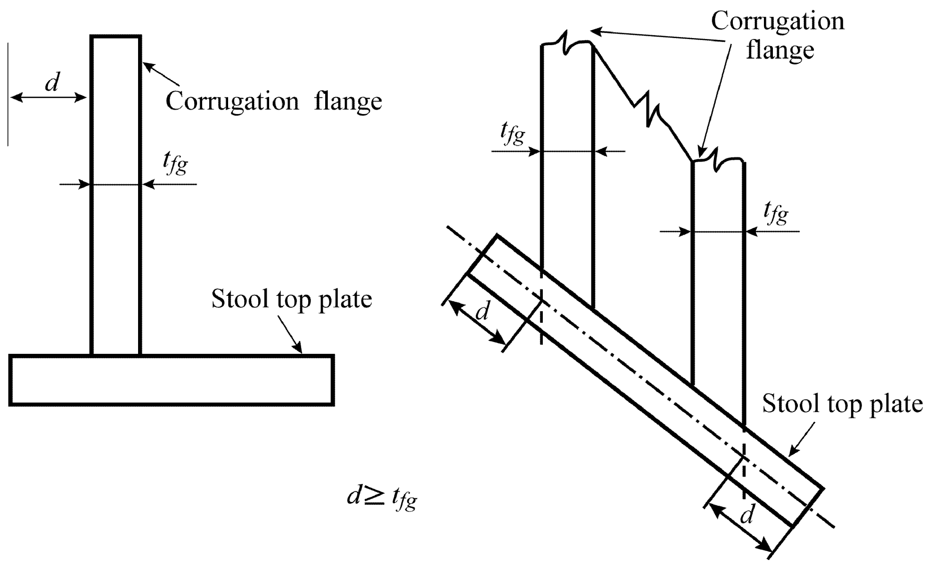


Fig 30: Permitted distance, *d*, from the edge of the stool top plate to the surface of the corrugation flange

10.4.8 Upper stool

The upper stool, when fitted, is to have a height in general between two and three times the depth of corrugations. Rectangular stools are to have a height in general equal to twice the depth of corrugations,

measured from the deck level and at the hatch side girder.
The upper stool of transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams.
The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools is to have a width not less than twice the depth of corrugations.
The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.
The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members as the case may be, for effective support of the corrugated bulkhead.
Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.4.9 Alignment

At deck, if no upper stool is fitted, two transverse or longitudinal reinforced beams as the case may be, are to be fitted in line with the corrugation flanges.
At bottom, if no lower stool is fitted, the corrugation flanges are to be in line with the supporting floors or girders.
The weld of corrugations and floors or girders to the inner bottom plating are to be full penetration ones.
The cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors or girders are to be connected to each other by suitably designed shear plates.
Stool side plating is to be aligned with the corrugation flanges. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures as longitudinals or similar, to provide appropriate load transmission between these stiffening members.
Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

10.4.10 Effective width of the compression flange

The effective width of the corrugation flange in compression to be considered for the strength check of the bulkhead is to be obtained, in m, from the following formula:

$$b_{ef} = C_E a$$

where:

C_E : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for} \quad \beta > 1.25$$

$$C_E = 1.0 \quad \text{for} \quad \beta \le 1.25$$

β : Coefficient to be taken equal to:

$$\beta = 10^3 \frac{a}{t_f} \sqrt{\frac{R_{eH}}{E}}$$

a : Width, in m, of the corrugation flange (see **Fig 28**)

t_f : Net flange thickness, in mm.

10.4.11 Effective shedder plates

Effective shedder plates are those which:

- are not knuckled
- are welded to the corrugations and the lower stool top plate according to **Ch 11**

- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating
- have thickness not less than 75 % of that required for the corrugation flanges
- have material properties not less than those required for the flanges.

10.4.12 Effective gusset plates

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in **[10.4.11],**
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool top plate, corrugations and shedder plates according to **Ch 11,**
- have thickness and material properties not less than those required for the flanges.

10.4.13 (void)

Fig 31: (void)
Fig 32: (void)
Fig 33: (void)
Fig 34: (void)
Fig 35: (void)

10.4.14 (void)

10.4.15 (void)

10.5 Non-tight bulkheads

10.5.1 Non-tight bulkheads not acting as pillars

Non-tight bulkheads not acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- 0.9 m, for transverse bulkheads
- two frame spacings, with a maximum of 1.5 m, for longitudinal bulkheads.

  The depth of bulkhead stiffener is not to be less than 1/12 of stiffener length. The net thickness of bulkhead stiffener is not to be less than the minimum thickness required for the considered bulkhead Plate.

Non-tight bulkheads acting as pillars are to be provided with bulkhead stiffeners with a maximum spacing equal to:

- two frame spacings, when the frame spacing does not exceed 0.75 m,
- one frame spacing, when the frame spacing is greater than 0.75 m.

Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness or 1/12 of stiffener length, whichever is the smaller, is to comply with the applicable requirements in **Ch 6, Sec 2**, for the load being supported.
In the case of non-tight bulkheads supporting longitudinally framed decks, vertical girders are to be provided in way of deck transverse.

10.6 Watertight bulkheads of trunks and tunnels

10.6.1

Ref. SOLAS Ch. II-1, Part B, Reg. 19.1
Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

11. Pillars

11.1 General

11.1.1

Pillars are to be fitted, as far as practicable, in the same vertical line. If not possible, effective means are to be provided for transmitting their loads to the supports below.

11.1.2

Pillars are to be provided in line with the double bottom girder or as close thereto as practicable, and the structure above and under the pillars is to be of sufficient strength to provide effective distribution of the load. Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

11.1.3

Pillars provided in tanks are to be of solid or open section type. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

11.1.4 Connections

Heads and heels of pillars are to be secured by thick doubling plates and brackets as necessary. Where the pillars are likely to be subjected to tensile loads such as those in tanks, the head and heel of pillars are to be efficiently secured to withstand the tensile loads and the doubling plates replaced by insert plate.
In general, the net thickness of doubling plates is to be not less than 1.5 times the net thickness of the pillar.
Pillars are to be attached at their heads and heels by continuous welding. ⚓

Chapter 4

Design Loads

Appendix 3 Standard Loading Conditions for Fatigue Assessment

Section 1 – GENERAL

1. General

1.1

1.1.1

The equivalent design wave (EDW) method is used to set the design loads which include lateral loads normal to plating and hull girder loads in still water and in waves.

1.1.2

External hydrostatic pressure and internal static pressure due to cargo and ballast are considered as lateral loads in still water. External hydrodynamic pressure and internal inertial pressure due to cargo and ballast are considered as lateral loads in waves.

1.1.3

Still water vertical shear force and bending moment, wave-induced vertical shear force and bending moment and wave-induced horizontal bending moment are considered as the hull girder loads.

1.1.4

The stresses due to the lateral loads in waves and the hull girder loads in waves are to be combined using load combination factors determined for each equivalent design wave.

Section 2 - SHIP MOTIONS AND ACCELERATIONS

Symbols

For symbols not defined in this Section, refer to **Ch 1**, **Sec 4.**

a_0 : Acceleration parameter, taken equal to:

$$a_0 = f_p(1.58 - 0.47C_B)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

T_R : Roll period, in s, defined in **[2.1.1]**

θ : Single roll amplitude, in deg, defined in **[2.1.1]**

T : Pitch period, in s, defined in **[2.2.1]**

Φ : Single pitch amplitude, in deg, defined in **[2.2.1]**

f_p : Coefficient corresponding to the probability level, taken equal to:

$f_p = 1.0$ for strength assessments corresponding to the probability level of 10^{-8}

$f_p = 0.5$ for strength assessments corresponding to the probability level of 10^{-4}

1. General

1.1

1.1.1

Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to trough amplitudes.

1.1.2

As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship's characteristics and intended service. In general, the values of ship motions and accelerations to be determined are those which can be reached with a probability level of 10^{-8} or 10^{-4}. In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2. Ship absolute motions and accelerations

2.1 Roll

2.1.1

The roll period T_R, in s, and the single roll amplitude θ , in deg, are given by:

$$T_R = \frac{2.3k_r}{\sqrt{GM}}$$

$$\theta = \frac{9000(1.25 - 0.025T_R)f_p k_b}{(B + 75)\pi}$$

where:

k_b : Coefficient taken equal to:

k_b =1.2 for ships without bilge keel

k_b =1.0 for ships with bilge keel

k_r : Roll radius of gyration, in m, in the considered loading condition. When k_r is not known, the values indicated in **Table 1** may be assumed.

GM : Metacentric height, in m, in the considered loading condition. When GM is not known, the values indicated in **Table 1** may be assumed.

Table 1: Values of k_r and GM

Loading condition		k_r	GM
Full load condition	Alternate or homogeneous loading	0.35 B	0.12 B
	Steel coil loading	0.42 B	0.24 B
Normal ballast condition		0.45 B	0.33 B
Heavy ballast condition		0.40 B	0.25 B

2.2 Pitch

2.2.1

The pitch period T_P, in s, and the single pitch amplitude Φ, in deg, are given by:

$$T_P = \sqrt{\frac{2\pi\lambda}{g}}$$

$$\Phi = f_p \frac{960}{L} \sqrt[4]{\frac{V}{C_B}}$$

where:

$$\lambda = 0.6\left(1 + \frac{T_{LC}}{T_S}\right)L$$

2.3 Heave

2.3.1

The vertical acceleration due to heave, in m/s^2, is given by:

$$a_{heave} = a_0 g$$

2.4 Sway

2.4.1

The transverse acceleration due to sway, in m/s^2, is given by:

$$a_{sway} = 0.3 a_0 g$$

2.5 Surge

2.5.1

The longitudinal acceleration due to surge, in m/s^2, is given by:

$$a_{surge} = 0.2 a_0 g$$

3. Ship relative accelerations

3.1 General

3.1.1

At any point, the accelerations in X, Y and Z directions are the acceleration components which result from the ship absolute motions and accelerations defined in **[2.1]** to **[2.5].**

3.2 Accelerations

3.2.1

The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the following formulae:

- In longitudinal direction:

$$a_X = C_{XG} g \sin \Phi + C_{XS} a_{surge} + C_{XP} a_{pitch\,x}$$

- In transverse direction:

$$a_Y = C_{YG} g \sin \theta + C_{YS} a_{sway} + C_{YR} a_{roll\,y}$$

- In vertical direction:

$$a_Z = C_{ZH} a_{heave} + C_{ZR} a_{roll\,z} + C_{ZP} a_{pitch\,z}$$

where:

C_{XG}, C_{XS}, C_{XP}, C_{YG}, C_{YS}, C_{YR}, C_{ZH}, C_{ZR} and C_{ZP} : Load combination factors defined in **Ch 4**, **Sec 4**, **[2.2]**

a_{pitchx} : Longitudinal acceleration due to pitch, in m/s^2

$$a_{pitch\,x} = \Phi \frac{\pi}{180} \left(\frac{2\pi}{T_P} \right)^2 R$$

a_{rolly} : Transverse acceleration due to roll, in m/s^2

$$a_{roll\,y} = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_R} \right)^2 R$$

a_{rollz} : Vertical acceleration due to roll, in m/s^2

$$a_{roll\,z} = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_R} \right)^2 y$$

a_{pitchz} : Vertical acceleration due to pitch, in m/s^2

$$a_{pitch\,z} = \Phi \frac{\pi}{180} \left(\frac{2\pi}{T_P} \right)^2 \left| (x - 0.45L) \right|$$

where $\left| (x - 0.45L) \right|$ is to be taken not less than $0.2\,L$

R = $z - \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2} \right)$

x, y, z : X, Y and Z co-ordinates, in m, of any point considered with respect to the reference co-ordinate system defined in **Ch 1, Sec 4**

Section 3 – HULL GIRDER LOADS

Symbols

For symbols not defined in this Section, refer to **Ch 1**, **Sec 4**.

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system

f_p : Coefficient corresponding to the probability, defined in **Ch 4**, **Sec 2**.

1. General

1.1 Sign conventions of bending moments and shear forces

1.1.1

Absolute values are to be taken for bending moments and shear forces introduced in this Section. The sign of bending moments and shear forces is to be considered according to **Sec 4**, **Table 3**. The sign conventions of vertical bending moments, horizontal bending moments and shear forces at any ship transverse section are as shown in **Fig 1**, namely:

- the vertical bending moments M_{SW} and M_{WV} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and are negative in the opposite case (sagging bending moment)
- the horizontal bending moment M_{WH} is positive when it induces tensile stresses in the starboard and is negative in the opposite case.
- the vertical shear forces Q_{SW}, Q_{WV} are positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration, and is negative in the opposite case.

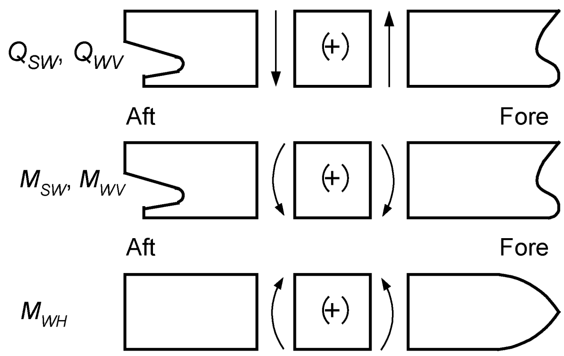


Fig 1: Sign conventions for shear forces Q_{SW}, Q_{WV} and bending moments M_{SW}, M_{WV} and M_{WH}

2. Still water loads

2.1 General

2.1.1

In general the vertical still water bending moment and the shear force of the individual loading condition is to be applied. The shipbuilder has to submit for each of the loading condition defined in **Ch 4, Sec 7** a longitudinal strength calculation.

The values of still water vertical bending moment and shear force are to be treated as the upper limits with respect to hull girder strength.

In general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the M_{SW} and Q_{SW} calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

2.1.2 Partially filled ballast tanks in ballast loading conditions

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full, and
- for BC-A and BC-B ships, longitudinal strength of hull girder in flooded condition according to **Ch 5**, **Sec 1**, **[2.1.3]** is complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival, and where required by **[2.1.1]**, any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

2.1.3 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirement in **[2.1.2]** applies to the peak tanks only.

2.1.4 Sequential ballast water exchange

Requirements of **[2.1.2]** and **[2.1.3]** are not applicable to ballast water exchange using the sequential method.

2.2 Still water bending moment

2.2.1

The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions, as defined in **[2.1.1]**. Greater values may be considered if defined by the Designer.

2.2.2

If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in **Fig 2** may be considered.
In **Fig 2**, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{SW,H} = 175CL^2B(C_B + 0.7)10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SW,S} = 175CL^2B(C_B + 0.7)10^{-3} - M_{WV,S}$$

where $M_{WV,H}$ and $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in **[3.1].**

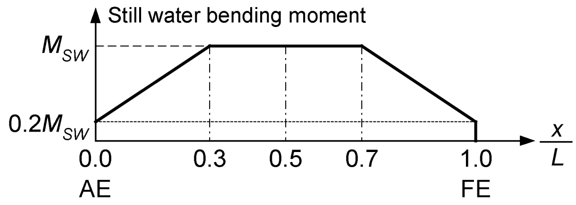


Fig 2: Preliminary still water bending moment distribution

2.3 Still water shear force

2.3.1

The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions, as defined in **[2.1.1]**. Greater values may be considered if defined by the Designer.

2.4 Still water bending moment and still water shear force in flooded condition

2.4.1

The still water bending moments $M_{SW,F}$, in hogging and sagging conditions, and the still water shear force $Q_{SW,F}$, in flooded condition are to be determined for the flooding scenario considering each cargo hold individually flooded up to the equilibrium waterline.
This means that double side spaces may not be considered flooded, and the cargo holds may not be considered completely flooded, but only up to the equilibrium waterline.

2.4.2

To calculate the weight of ingressed water, the following assumptions are to be made:

a) The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.

b) Appropriate permeabilities and bulk densities are to be used for any cargo carried. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m^3 is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m^3 is to be used. In this respect, "permeability" for solid bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of the cargo, to the gross volume of the bulk cargo.

For packed cargo conditions (such as steel mill products), the actual density of the cargo should be used with a permeability of zero.

2.4.3

To quantify the effects of ingressed water on the hull girder still water bending moments and still water shear forces, specific calculations are to be carried out. The loading conditions on which the design of the ship has been based are to be considered and, for each of them, the cargo holds are to be considered as being individually flooded up to the equilibrium waterline. The still water bending moments and still water shear forces are therefore to be calculated for any combination of considered loading conditions and flooded cargo holds.

3. Wave loads

3.1 Vertical wave bending moments

3.1.1 Intact condition

The vertical wave bending moments in intact condition at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:
  $M_{WV,H} = 190 F_M f_p C L^2 B C_B 10^{-3}$
- sagging conditions:
  $M_{WV,S} = 110 F_M f_p C L^2 B (C_B + 0.7) 10^{-3}$

where:

F_M : Distribution factor defined in **Table 1** (see also **Fig 3**).

Table 1: Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0.4L$	$2.5\frac{x}{L}$
$0.4L \le x \le 0.65L$	1.0
$0.65L \le x < L$	$2.86\left(1-\frac{x}{L}\right)$

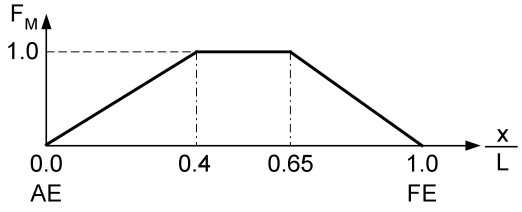


Fig 3: Distribution factor F_M

3.1.2 Flooded condition

The vertical wave bending moments in flooded condition at any hull transverse section are obtained, in kN.m, from the following formula:

$$M_{WV,F} = 0.8 M_{WV}$$

where M_{WV} is defined in **[3.1.1]**.

3.1.3 Harbour condition

The vertical wave bending moments in harbour condition at any hull transverse section are obtained, in kN.m, from the following formula:

$$M_{WV,P} = 0.4 M_{WV}$$

where M_{WV} is defined in **[3.1.1]**.

3.2 Vertical wave shear force

3.2.1 Intact condition

The vertical wave shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{WV} = 30 F_Q f_p CLB(C_B + 0.7)10^{-2}$$

where:

F_Q : Distribution factor defined in **Table 2** for positive and negative shear forces (see also **Fig 4**).

Table 2: Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0.2L$	$4.6A\frac{x}{L}$	$4.6\frac{x}{L}$
$0.2L \le x \le 0.3L$	$0.92A$	0.92
$0.3L < x < 0.4L$	$(9.2A-7)\left(0.4-\frac{x}{L}\right)+0.7$	$2.2\left(0.4-\frac{x}{L}\right)+0.7$
$0.4L \le x \le 0.6L$	0.7	0.7
$0.6L < x < 0.7L$	$3\left(\frac{x}{L}-0.6\right)+0.7$	$(10A-7)\left(\frac{x}{L}-0.6\right)+0.7$
$0.7L \le x \le 0.85L$	1	A
$0.85L < x \le L$	$6.67\left(1-\frac{x}{L}\right)$	$6.67A\left(1-\frac{x}{L}\right)$
Note : $A = \frac{190C_B}{110(C_B+0.7)}$		

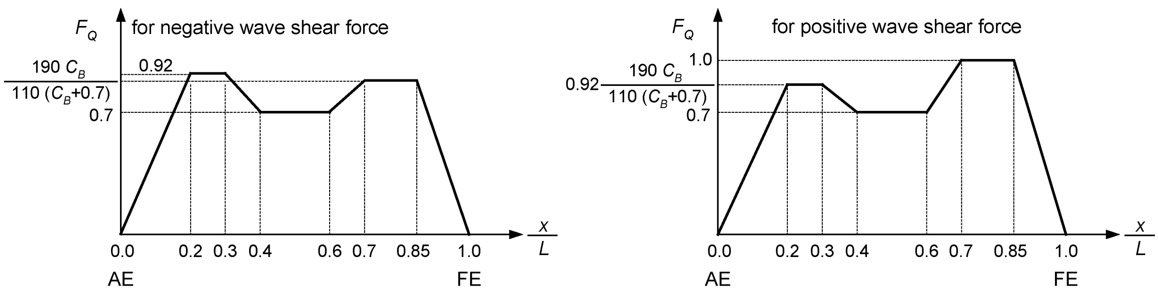


Fig 4: Distribution factor F_Q

3.2.2 Flooded condition

The vertical wave shear force in flooded condition at any hull transverse section are obtained, in kN, from the following formula:

$$Q_{WV,F} = 0.8 Q_{WV}$$

where Q_{WV} is defined in **[3.2.1]**.

3.2.3 Harbour condition

The vertical wave shear force in harbour condition at any hull transverse section are obtained, in kN, from the following formula:

$$Q_{WV,P} = 0.4Q_{WV}$$

where Q_{WV} is defined in **[3.2.1].**

3.3 Horizontal wave bending moment

3.3.1

The horizontal wave bending moment at any hull transverse section, in kN.m, is given by:

$$M_{WH} = (0.3 + \frac{L}{2000}) F_M f_p C L^2 T_{LC} C_B$$

where F_M is the distribution factor defined in **[3.1.1].**

3.4 Wave torsional moment

3.4.1

The wave torsional moment at any hull transverse section, in kN.m, is given by:

$$M_{WT} = f_p (|M_{WT1}| + |M_{WT2}|)$$

where:

$$M_{WT1} = 0.4 \cdot C \sqrt{\frac{L}{T}} \cdot B^2 D \cdot C_B \cdot F_{T1}$$

$$M_{WT2} = 0.22 CLB^2 C_B \cdot F_{T2}$$

F_{T1}, F_{T2} : Distribution factors, defined as follows:

$$F_{T1} = \sin\left(\frac{2\pi x}{L}\right)$$

$$F_{T2} = \sin^2\left(\frac{\pi x}{L}\right)$$

Section 4 - LOAD CASES

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

a_{surge}, a_{pitchx}, a_{sway}, a_{rolly}, a_{heave}, a_{rollz}, a_{pitchz} : Components of accelerations, defined in **Ch 4, Sec 2.**

1. General

1.1 Application

1.1.1

The load cases described in this section are those to be used for:

- the local strength analysis of plating and ordinary stiffeners and primary supporting members according to the applicable requirements of **Ch 6**, **Sec 1**, **Ch 6**, **Sec 2** and **Ch 6**, **Sec 4** respectively,
- the direct strength analysis of structural members, according to the applicable requirements of **Ch 7**,
- the fatigue check of structural details, according to the applicable requirements of **Ch 8**.

1.1.2

For the local strength analysis and for the direct strength analysis, the load cases are the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2 described in **[2].**

1.2 Equivalent design wave

1.2.1

Regular waves that generate response values equivalent to the long-term response values of the load components considered being predominant to the structural members are set as Equivalent Design Waves (EDWs). They consist of:

- regular waves when the vertical wave bending moment becomes maximum in head sea (EDW "H")
- regular waves when the vertical wave bending moment becomes maximum in following sea (EDW "F")
- regular waves when the roll motion becomes maximum (EDW "R")
- regular waves when the hydrodynamic pressure at the waterline becomes maximum (EDW "P")

The definitions of wave crest and wave trough in the EDW "H" and EDW "F" are given in **Fig 1**. The definitions of weather side down and weather side up for the EDW "R" and EDW "P" are given in **Fig 2.**

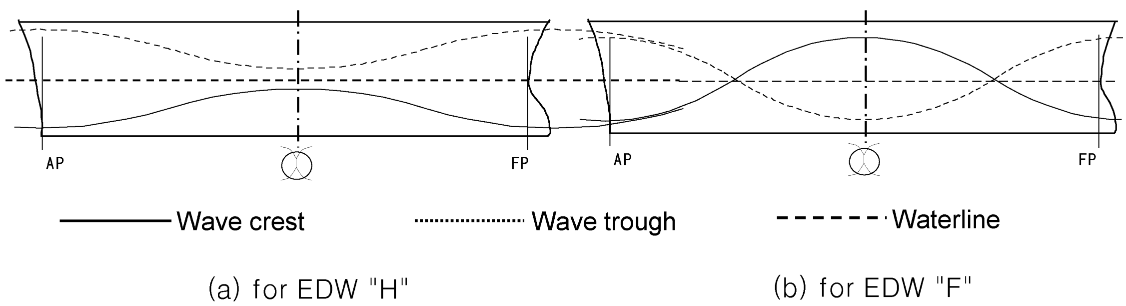


Fig 1: Definition of wave crest and wave trough for EDWs "H" and "F"

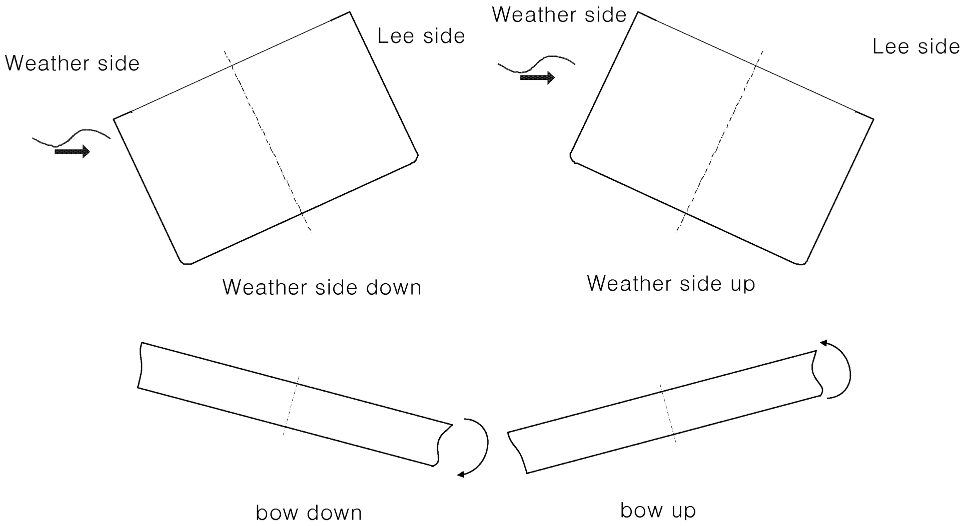


Fig 2: Definitions of ship motion

2. Load cases

2.1 General

2.1.1

The load cases corresponding to the Equivalent Design Waves (EDWs) are defined in **Table 1**. The corresponding hull girder loads and motions of the ship are indicated in **Table 2**. If the ship structure or the ship loading condition is not symmetrical with respect to the centreline plane of ship, the load cases (R1, R2, P1 and P2) corresponding to the beam conditions in which the encounter wave comes from the starboard (in this case the starboard is the weather side), should be also included in the structural strength assessment.

Table 1: Definition of load cases

Load case	H1	H2	F1	F2	R1	R2	P1	P2
EDW	"H"		"F"		"R"		"P"	
Heading	Head		Follow		Beam (Port: weather side)		Beam (Port: weather side)	
Effect	Max. Bending Moment		Max. Bending Moment		Max. Roll		Max. Ext. Pressure	
	Sagging	Hogging	Sagging	Hogging	(+)	(-)	(+)	(-)

Table 2: Reference hull girder loads and motions of ship

Load case	H1	H2	F1	F2	R1	R2	P1	P2
Vert. BM & SF	Yes		Yes		-		Yes	
Hor. BM	-		-		Yes		-	
Heave	Down	Up	-	-	Down	Up	Down	Up
Pitch	Bow down	Bow up	-	-	-	-	-	-
Roll	-	-	-	-	Stbd up	Stbd down	Stbd up	Stbd down
Surge	Stern	Bow	-	-	-	-	-	-
Sway	-	-	-	-	-	-	Port	Stbd

2.2 Load combination factors

2.2.1

The hull girder loads and the acceleration components to be considered in each load case H1, H2, F1, F2, R1, R2, P1 and P2 are to be obtained by multiplying the reference value of each component by the relevant load combination factor LCF defined in **Table 3**.

2.2.2

The still water vertical bending moment is to be added to the hull girder loads in waves, calculated with load combination factors.

2.2.3

The internal loads are the sum of static pressures or forces induced by the weights carried, including those carried on decks, and of inertial pressures or forces induced by the accelerations on these weights and calculated with load combination factors.

Table 3: Load combination factors LCF

	LCF	H1	H2	F1	F2	R1	R2	P1	P2
M_{WV}	C_{WV}	-1	1	-1	1	0	0	$0.4-\frac{T_{LC}}{T_S}$	$\frac{T_{LC}}{T_S}-0.4$
Q_{WV}	C_{QW}(1)	-1	1	-1	1	0	0	$0.4-\frac{T_{LC}}{T_S}$	$\frac{T_{LC}}{T_S}-0.4$
M_{WH}	C_{WH}	0	0	0	0	$1.2-\frac{T_{LC}}{T_S}$	$\frac{T_{LC}}{T_S}-1.2$	0	0
a_{surge}	C_{XS}	-0.8	0.8	0	0	0	0	0	0
a_{pitchx}	C_{XP}	1	-1	0	0	0	0	0	0
$gsinF$	C_{XG}	1	-1	0	0	0	0	0	0
a_{sway}	C_{YS}	0	0	0	0	0	0	1	-1
a_{rolly}	C_{YR}	0	0	0	0	1	-1	0.3	-0.3
$gsinq$	C_{YG}	0	0	0	0	1	-1	0.3	-0.3
a_{heave}	C_{ZH}	$0.6\frac{T_{LC}}{T_S}$	$-0.6\frac{T_{LC}}{T_S}$	0	0	$\frac{\sqrt{L}}{40}$	$-\frac{\sqrt{L}}{40}$	1	-1
a_{rollz}	C_{ZR}	0	0	0	0	1	-1	0.3	-0.3
a_{pitchz}	C_{ZP}	1	-1	0	0	0	0	0	0

(1) The LCF for C_{QW} is only used for the aft part of midship section. The inverse value of it should be used for the forward part of the midship section.

Section 5 - EXTERNAL PRESSURES

Symbols

For symbols not defined in this Section, refer to **Ch 1**, **Sec 4**.

L_2 : Rule length L, but to be taken not greater than 300 m

C : Wave coefficient, as defined in **Ch 1**, **Sec 4**, **[2.3.1]**

λ : Wave length, in m, corresponding to the load case, defined in **[1.3.1]**, **[1.4.1]**, and **[1.5.1]**

f_p : Coefficient corresponding to the probability, defined in **Ch 4**, **Sec 2**

T_{LCi} : Draught in the considered cross section, in m, in the considered loading condition

B_i : Moulded breadth at the waterline, in m, in the considered cross section

x, y, z : X, Y and Z co-ordinates, in m, of the load point with respect to the reference co-ordinate system defined in **Ch 1, Sec 4.**

1. External sea pressures on side shell and bottom

1.1 General

1.1.1

The total pressure p at any point of the hull, in kN/m^2, to be obtained from the following formula is not to be negative:

$$p = p_S + p_W$$

Where:

p_S : Hydrostatic pressure defined in **[1.2]**

p_W : Wave pressure equal to the hydrodynamic pressure defined in **[1.3]**, **[1.4]** or **[1.5]**, as the case may be, and corrected according to **[1.6]**

1.2 Hydrostatic pressure

1.2.1

The hydrostatic pressure p_S at any point of the hull, in kN/m^2, corresponding to the draught in still water is obtained, for each loading condition, from the formulae in **Table 1** (see also **Fig 1**).

Table 1: Hydrostatic pressure p_S

Location	Hydrostatic pressure, p_S, in kN/m^2
Points at and below the waterline ($z \le T_{LCi}$)	$\rho g(T_{LCi} - z)$
Points above the waterline ($z > T_{LCi}$)	0

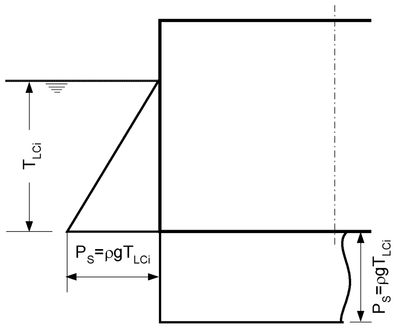


Fig 1: Hydrostatic pressure p_S

1.3 Hydrodynamic pressures for load cases H1, H2, F1 and F2

1.3.1

The hydrodynamic pressures p_H and p_F, for load cases H1, H2, F1 and F2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from **Table 2.**
The distribution of pressure p_{F2} is schematically given in **Fig 2**.

Table 2: Hydrodynamic pressures for load cases H1, H2, F1 and F2

Load case	Hydrodynamic pressure, in kN/m^2
H1	$p_{H1} = -k_\ell k_p p_{HF}$
H2	$p_{H2} = k_\ell k_p p_{HF}$
F1	$p_{F1} = -p_{HF}$
F2	$p_{F2} = p_{HF}$

where:

$p_{HF} = 3 f_p f_{nl} C \sqrt{\frac{L+\lambda-125}{L}} \left(\frac{z}{T_{LCi}} + \frac{|2y|}{B_i} + 1 \right)$; with $\frac{|2y|}{B_i} \le 1.0$ and z is to be taken not greater than T_{LCi}

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

f_{nl} = 0.9 for the probability level of 10^{-8}

f_{nl} = 1.0 for the probability level of 10^{-4}

k_ℓ : Amplitude coefficient in the longitudinal direction of the ship, taken equal to:

$$k_\ell = 1 + \frac{12}{C_B}\left(1 - \sqrt{\frac{|2y|}{B}}\right)\left|\frac{x}{L} - 0.5\right|^3 \quad \text{for } 0.0 \le x/L \le 0.5$$

$$k_\ell = 1 + \frac{6}{C_B}\left(3 - \frac{|4y|}{B}\right)\left|\frac{x}{L} - 0.5\right|^3 \quad \text{for } 0.5 \le x/L \le 1.0$$

k_p : Phase coefficient in the longitudinal direction of the ship, taken equal to:

$k_p = \left(1.25 - \frac{T_{LC}}{T_S}\right)\cos\left(\frac{2\pi|x-0.5L|}{L}\right) - \frac{T_{LC}}{T_S} + 0.25$, for local strength analysis in conditions other than full load condition, for direct strength analysis and for fatigue strength assessments

k_p = -1.0, for local strength analysis in full load condition

λ : Wave length, in m, taken equal to:

$$\lambda = 0.6\left(1+\frac{T_{LC}}{T_S}\right)L$$ for load cases H1 and H2

$$\lambda = 0.6\left(1+\frac{2}{3}\frac{T_{LC}}{T_S}\right)L$$ for load cases F1 and F2

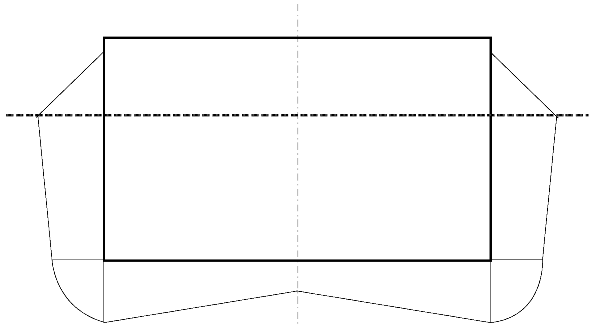


Fig 2: Distribution of hydrodynamic pressure p_{F2} at midship

1.4 Hydrodynamic pressures for load cases R1 and R2

1.4.1

The hydrodynamic pressures p_R, for load cases R1 and R2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from the following formulae. The distribution of pressure p_{R1} is schematically given in **Fig 3**.

$$p_{R1} = f_{nl}\left(10y\sin\theta + 0.88 f_p C\sqrt{\frac{L+\lambda-125}{L}}\left(\frac{|2y|}{B}+1\right)\right)$$

$$p_{R2} = -p_{R1}$$

where:

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

f_{nl} = 0.8 for the probability level of 10^{-8}

f_{nl} = 1.0 for the probability level of 10^{-4}

$\lambda = \frac{g}{2\pi}T_R^2$

y : Y co-ordinate of the load point, in m, taken positive on the portside.

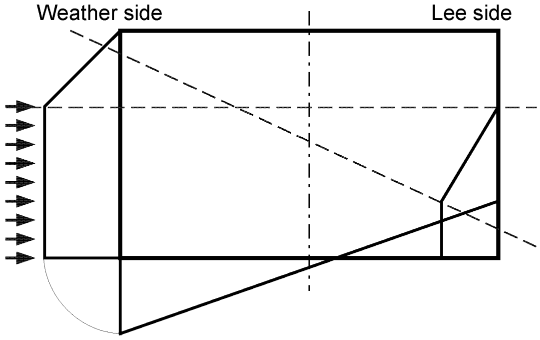


Fig 3: Distribution of hydrodynamic pressure p_{R1} at midship

1.5 Hydrodynamic pressures for load cases P1 and P2

1.5.1

The hydrodynamic pressures p_P, for the load cases P1 and P2, at any point of the hull below the waterline are to be obtained, in kN/m^2, from **Table 3**. The distribution of pressure p_{P1} is schematically given in **Fig 4.**

Table 3: Hydrodynamic pressures for load cases P1 and P2

Load case	Hydrodynamic pressure, in kN/m^2	
	weather side	lee side
P1	$p_{P1} = p_P$	$p_{P1} = p_P/3$
P2	$p_{P2} = -p_P$	$p_{P2} = -p_P/3$

where:

$$p_P = 4.5 f_p f_{nl} C \sqrt{\frac{L+\lambda-125}{L}} \left(2\frac{|z|}{T_{LCi}} + 3\frac{|2y|}{B}\right)$$

f_{nl} : Coefficient considering nonlinear effect, taken equal to:

$f_{nl} = 0.65$ for the probability level of 10^{-8}

$f_{nl} = 1.0$ for the probability level of 10^{-4}

$$\lambda = \left(0.2 + 0.4\frac{T_{LC}}{T_S}\right)L$$

y : Y co-ordinate of the load point, in m, as defined in **[1.4.1]**

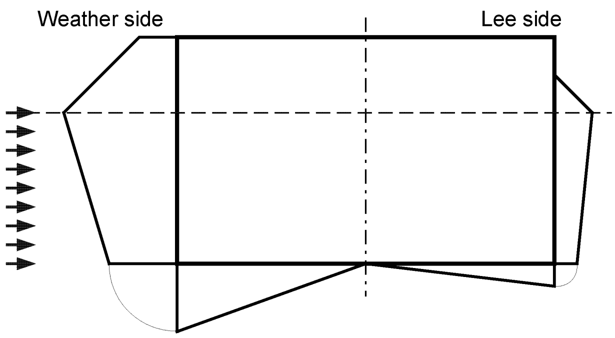


Fig 4: Distribution of hydrodynamic pressure p_{P1} at midship

1.6 Correction to hydrodynamic pressures

1.6.1

For the positive hydrodynamic pressure at the waterline (in load cases H1, H2, F2, R1, R2 and P1), the hydrodynamic pressure $P_{W,C}$ at the side above waterline is given (see **Fig 5**), in kN/m^2, by:

- $p_{W,C} = p_{W,WL} + \rho g (T_{LCi} - z)$ for $T_{LCi} \le z \le h_W + T_{LCi}$
- $p_{W,C} = 0$ for $z \ge h_W + T_{LCi}$

where:

$p_{W,WL}$: positive hydrodynamic pressure at the waterline for the considered load case

$$h_W = \frac{p_{W,WL}}{\rho g}$$

1.6.2

For the negative hydrodynamic pressure at the waterline (in load cases H1, H2, F1, R1, R2, and P2), the hydrodynamic pressure $P_{W,C}$, under the waterline is given (see **Fig 5**), in kN/m^2, by:
$p_{W,C} = p_W$, without being taken less than $\rho g(z - T_{LCi})$

where

p_W : Negative hydrodynamic pressure under the waterline for the considered load case

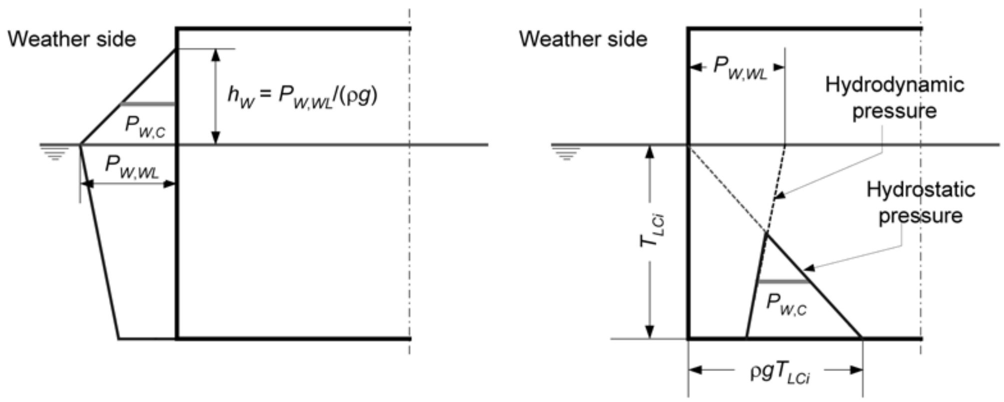


Fig 5: Correction to hydrodynamic pressure

2. External pressures on exposed decks

2.1 General

2.1.1

The external pressures on exposed decks are to be applied for the local scantling check of the structures on exposed deck but not applied for fatigue strength assessment.
If a breakwater is fitted on the exposed deck, no reduction in the external pressures defined in **[2.2]** and **[2.3]** is allowed for the area of the exposed deck located aft of the breakwater.

2.2 Load cases H1, H2, F1 and F2

2.2.1

The external pressure p_D, for load cases H1, H2, F1 and F2, at any point of an exposed deck is to be obtained, in kN/m^2, from the following formula:

$$p_D = \varphi p_W$$

where:

p_W : Pressure obtained from the formulae in **Table 4**

φ : Coefficient defined in **Table 5**.

Table 4: Pressures on exposed decks for H1, H2, F1 and F2

Location	Pressure p_W, in $\mathrm{kN/m^2}$	
	$L_{LL} \geq 100$ m	$L_{LL} < 100$ m
$0 \leq x_{LL}/L_{LL} \leq 0.75$	34.3	$14.9 + 0.195\,L_{LL}$
$0.75 < x_{LL}/L_{LL} < 1$	$34.3+(14.8+a(L_{LL}-100))\left(4\frac{x_{LL}}{L_{LL}}-3\right)$	$12.2+\frac{L_{LL}}{9}\left(5\frac{x_{LL}}{L_{LL}}-2\right)+3.6\frac{x_{LL}}{L_{LL}}$

where:
a : Coefficient taken equal to:
$a = 0.0726$ for Type B freeboard ships
$a = 0.356$ for Type B-60 or Type B-100 freeboard ships.
x_{LL} : X coordinate of the load point measured from the aft end of the freeboard length L_{LL}.

Table 5: Coefficient for pressure on exposed decks

Exposed deck location	φ
Freeboard deck	1.00
Superstructure deck, including forecastle deck	0.75
1st tier of deckhouse	0.56
2nd tier of deckhouse	0.42
3rd tier of deckhouse	0.32
4th tier of deckhouse	0.25
5th tier of deckhouse	0.20
6th tier of deckhouse	0.15
7th tier of deckhouse and above	0.10

2.3 Load cases R1, R2, P1 and P2

2.3.1

The external pressure p_D, for load cases R1, R2, P1 and P2, at any point of an exposed deck is to be obtained, in $\mathrm{kN/m^2}$, from the following formula:

$$p_D = 0.4\varphi p_W$$

where:

p_W : Hydrodynamic pressure at side of the exposed deck for the load cases P1, P2 , R1 and R2, in $\mathrm{kN/m^2}$, can be determined by **[1.6]** at the z co-ordinate. p_W is to be taken greater one of the hydrodynamic pressures $p_{W,C}$ at both sides of the exposed deck (portside and starboard), and is not to be taken less than zero.

φ : Coefficient defined in **Table 5**.

2.4 Load carried on exposed deck

2.4.1 Pressure due to distributed load

If a distributed load is carried on an exposed deck, the static pressure p_S corresponding to this load is to be defined by the Designer and, in general, is not to be taken less than 10 kN/m^2.
The total pressure p due to this load is to be considered not simultaneously to the pressures defined in **[2.2]** and **[2.3]**. It is to be taken equal, in kN/m^2, to the greater value obtained from the following formulae:

$$p = p_S + p_W$$

$$p = p_D$$

where:

p_S : Static pressure due to the distributed load carried, if any

p_W : Dynamic pressure due to the distributed load carried, in kN/m^2, taken equal to:

$$p_W = \frac{a_Z}{g} p_S$$

a_Z : Vertical acceleration at the centre of gravity of the distributed load carried for the load case considered, in m/s^2, obtained by the formulae defined in **Ch 4, Sec 2, [3.2]**

p_D : Pressure for the exposed deck, for the load case considered, as defined in **[2.2.1]** and **[2.3.1].**

2.4.2 Concentrated forces due to unit load

If a unit load is carried on an exposed deck, the static and dynamic forces due to the unit load carried are considered.
The total force F due to this load is to be considered not simultaneously to the pressures defined in **[2.2]** and **[2.3]**. It is to be taken, in kN, equal to value obtained from the following formula:

$$F = F_S + F_W$$

where:

F_S : Static force due to the unit load carried, in kN, taken equal to:

$$F_S = m_U g$$

F_W : Dynamic force due to unit load carried, in kN, taken equal to:

$$F_W = m_U a_Z$$

m_U : Mass of the unit load carried, in t

a_Z : Vertical acceleration at the centre of gravity of the unit load carried for the load case considered, in m/s^2, obtained by the formulae defined in **Ch 4, Sec 2, [3.2].**

3. External pressures on superstructure and deckhouses

3.1 Exposed decks

3.1.1

External pressures on exposed decks of superstructures and deckhouses are to be obtained according to **[2]**.

3.2 Exposed wheel house tops

3.2.1

The lateral pressure for exposed wheel house tops, in kN/m^2, is not to be taken less than:

$p = 12.5$

3.3 Sides of superstructures

3.3.1

The lateral pressure for sides of superstructures, in kN/m^2, is to be obtained from the following formula:

$$p_{SI} = 2.1 C f_p c_F (C_B + 0.7) \frac{20}{10 + z - T}$$

f_p : Probability factor, taken equal to:

$f_P = 1.0$ for plate panels

$f_P = 0.75$ for ordinary stiffeners and primary supporting members

c_F : Distribution factor according to **Table 6.**

Table 6: Distribution factor c_F

Location	c_F
$0 \le \frac{x}{L} < 0.2$	$1.0 + \frac{5}{C_B}\left(0.2 - \frac{x}{L}\right)$, without taking $\frac{x}{L}$ less than 0.1
$\frac{x}{L} \ge 0.2$	1.0

3.4 End bulkheads of superstructure and deckhouse walls

3.4.1

The lateral pressure, in kN/m^2, for determining the scantlings is to be obtained from the greater of the following formulae:

$$p_A = nc[bC - (z - T)]$$

$$p_A = p_{A\min}$$

where:

n : Coefficient defined in **Table 7**, depending on the tier level.

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the depth D is to be measured. However, where the actual distance ($D-T$) exceeds the minimum non-corrected tabular freeboard according to ILLC as amended by at least one standard superstructure height as defined in **Ch1, Sec4, [3.18.1],** this tier may be defined as the 2nd tier and the tier above as the 3rd tier

c : Coefficient taken equal to:

$$c = 0.3 + 0.7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is not to be taken less than 1.0

b_1 : Breadth of deckhouse at the position considered

B_1 : Actual maximum breadth of ship on the exposed weather deck at the position considered. b_1/B_1 is not to be taken less than 0.25

b : Coefficient defined in **Table 8**

x : X co-ordinate, in m, of the calculation point for the bulkhead considered. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each, and x is to be taken as the X co-ordinate of the centre of each part considered.

z : Z co-ordinate, in m, of the midpoint of stiffener span, or to the middle of the plate field

ℓ : Span, in m, to be taken as the superstructure height or deckhouse height respectively, and not less than 2.0 m

$p_{A\min}$: Minimum lateral pressure, in kN/m^2, defined in **Table 9**.

Table 7: Coefficient *n*

Type of bulkhead	Location	n
Unprotected front	Lowest tier	$20 + \frac{L_2}{12}$
	Second tier	$10 + \frac{L_2}{12}$
	Third tier and above	$5 + \frac{L_2}{15}$
Protected front	All tiers	$5 + \frac{L_2}{15}$
Sides	All tiers	$5 + \frac{L_2}{15}$
Aft end	Abaft amidships	$7 + \frac{L_2}{100} - 8\frac{x}{L_2}$
	Forward of amidships	$5 + \frac{L_2}{100} - 4\frac{x}{L_2}$

Table 8: Coefficient *b*

Location of bulkhead	b
$\frac{x}{L} < 0.45$	$1.0 + \left(\frac{\frac{x}{L} - 0.45}{C_B + 0.2} \right)^2$
$\frac{x}{L} \geq 0.45$	$1.0 + 1.5 \left(\frac{\frac{x}{L} - 0.45}{C_B + 0.2} \right)^2$
Where: C_B : Block coefficient with $0.6 \leq C_B \leq 0.8$. When determining scantlings of aft ends forward of amidships, C_B need not be taken lessthan 0.8.	

Table 9: Minimum lateral pressure $p_{A\min}$

L	$P_{A\min}$ (kN/m^2)	
	Lowest tier of unprotected fronts	Elsewhere(1)
$90 < L \leq 250$	$25 + \frac{L}{10}$	$12.5 + \frac{L}{20}$
$L > 250$	50	25
(1) For the 4th tier and above, $P_{A\min}$ is to be taken equal to 12.5 kN/m^2.		

4. Pressure in bow area

4.1

4.1.1

The bow pressure, in kN/m^2, to be considered for the reinforcement of the bow flare area is to be obtained from the following formula:

$$p_{FB} = K(p_S + p_W)$$

where:

p_S, p_W : Hydrostatic pressure and maximum hydrodynamic pressures among load cases H, F, R and P, calculated in normal ballast condition at T_B

K : Coefficient taken equal to:

$$K = \frac{c_{FL}\left(0.2V + 0.6\sqrt{L}\right)^2}{42C(C_B + 0.7)\left(1 + \frac{20}{C_B}\left(\frac{x}{L} - 0.7\right)^2\right)}(10 + z - T_B)$$

to be taken not less than 1.0

c_{FL} : Coefficient taken equal to:

$c_{FL} = 0.8$ in general

$c_{FL} = \dfrac{0.4}{1.2 - 1.09\sin\alpha}$ where the flare angle α is greater than 40°

Where, the flare angle α at the load calculation point is to be measured in plane of the frame between a vertical line and the tangent to the side shell plating. (see **Fig 6**)

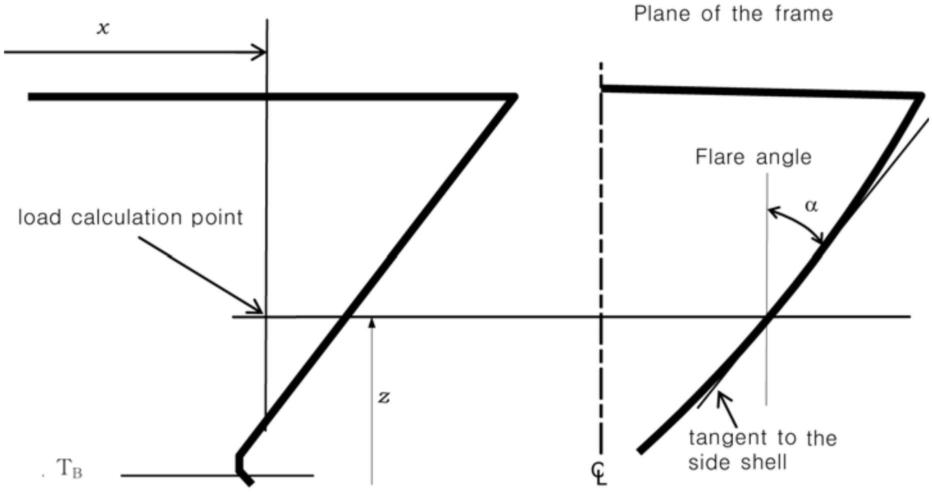


Fig 6 : The definition of the flare angle

4.2 Design bottom slamming pressure

4.2.1

The bottom slamming pressure, in kN/m², to be considered for the reinforcement of the flat bottom forward is to be obtained from the following formula:

$p_{SL} = 162 c_1 c_{SL} \sqrt{L}$ for $L \le 150$ m

$p_{SL} = 1984 c_1 c_{SL} (1.3 - 0.002L)$ for $L > 150$ m

where:

c_1 : Coefficient taken equal to:

$c_1 = 3.6 - 6.5\left(\dfrac{T_{BFP}}{L}\right)^{0.2}$, to be taken not greater than 1.0

T_{BFP} : Smallest design ballast draught, in m, defined at forward perpendicular for normal ballast conditions. Where the sequential method for ballast water exchange is intended to be ap plied, T_{BFP} is to be considered for the sequence of exchange.

c_{SL} : Distribution factor taken equal to(see **Fig 7**):

$c_{SL} = 0$ for $\dfrac{x}{L} \le 0.5$

$c_{SL} = \dfrac{\frac{x}{L} - 0.5}{c_2}$ for $0.5 < \dfrac{x}{L} \le 0.5 + c_2$

$c_{SL} = 1.0$ for $0.5 + c_2 < \dfrac{x}{L} \le 0.65 + c_2$

$$c_{SL} = 0.5\left(1+\frac{1-\frac{x}{L}}{0.35-c_2}\right) \qquad \text{for } \frac{x}{L} > 0.65+c_2$$

c_2 : Coefficient taken equal to:

$c_2 = 0.33C_B + \frac{L}{2500}$, to be taken not greater than 0.35.

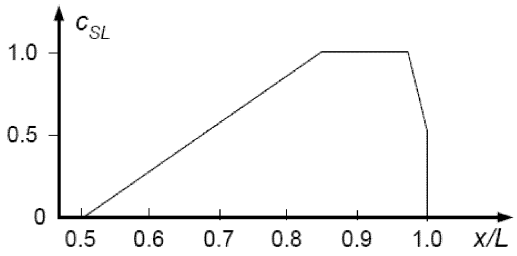


Fig 7: Distribution Factor c_{SL}

4.2.2

It is the Master's responsibility to observe, among others, the weather conditions and the draught at forward perpendicular during water ballast exchange operations, in particular when the forward draught during these operations is less than T_{BFP}.
The above requirement and the draught T_{BFP} is to be clearly indicated in the operating manuals.

5. External pressures on hatch covers

5.1 General

5.1.1

If a specific load is carried on a hatch cover, the pressure is to be obtained according to **[2.4]**.

5.2 Wave pressure

5.2.1

The pressure at any point of the hatch cover is to be obtained according to **[2.2.1]**, considering φ equal to 1.0.
However, when the hatchway is located at least one superstructure standard height, as defined in **Ch 1, Sec 4, [3.18],** higher than the freeboard deck, the pressure p_W may be taken equal to 34.3 kN/m^2.

Section 6 – INTERNAL PRESSURES AND FORCES

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4**.

ρ_C : Density of the dry bulk cargo, in t/m^3, taken equal to:

- the value given in **Table 1** for ships having a length L of 150 m and above
- the maximum density from the loading manual for ships having a length L less than 150 m

Table 1: Density of dry bulk cargo

Type of loading	Density	
	BC-A, BC-B	BC-C
Cargo hold loaded up to the upper deck	max(M_H/V_H, 1.0)	1.0
Cargo hold not loaded up to the upper deck	3.0(1)	-
(1) Except otherwise specified by the designer.		

ρ_L : Density of internal liquid, in t/m^3, taken equal to 1.025 when internal liquid is ballast water

M_H : The actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t

V_H : Volume, in m^3, of cargo hold excluding the volume enclosed by hatch coaming

K_C : Coefficient taken equal to:

$K_C = \cos^2\alpha + (1-\sin\psi)\sin^2\alpha$ for inner bottom, hopper tank, transverse and longitudinal bulkheads, lower stool, vertical upper stool, inner side and side shell:

$K_C = 0$ for top side tank, upper deck and sloped upper stool:

a : Angle, in deg, between panel considered and the horizontal plane

ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); in the absence of more precise evaluation, the following values may be taken:

ψ = 30° in general

ψ = 35° for iron ore

ψ = 25° for cement

h_C : Vertical distance, in m, from the inner bottom to the upper surface of bulk cargo, as defined in **[1.1.1]** or **[1.1.2]**

h_{DB} : Height, in m, of the double bottom in the centreline

h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom

z_{TOP} : Z co-ordinate, in m, of the top of the tank, in upright condition

z_{BO} : Z co-ordinate, in m, of the top of the overflow pipe

a_X : Longitudinal acceleration at the centre of gravity of the hold or tank considered, in m/s^2, obtained by the formulae defined in **Ch 4, Sec 2, [3.2]**

a_Y : Transverse acceleration at the centre of gravity of the hold or tank considered, in m/s^2, obtained by the formulae defined in **Ch 4, Sec 2, [3.2]**

a_Z : Vertical acceleration at the centre of gravity of the hold or tank considered, in m/s^2, obtained by the formulae defined in **Ch 4, Sec 2, [3.2]**

B_H : Mean breadth of the cargo hold, in m

b_{IB} : Breadth of inner bottom, in m, as defined on **Fig 2**

D_1 : Distance, in m, from the base line to the freeboard deck at side amidships

s_C : Spacing of corrugations, in m; see **Ch 3, Sec 6, Fig 28**

x, y, z : X, Y and Z co-ordinates, in m, of the load point with respect to the reference co-ordinate system defined in **Ch 1, Sec 4**. y is to be taken positive on the weather side

x_G, y_G, z_G: X, Y and Z co-ordinates, in m, of the centre of gravity of the hold or tank considered with respect to the reference co-ordinate system defined in **Ch 1, Sec 4**

d_{AP} : Distance from the top of air pipe to the top of compartment, in m, taken equal to:

$d_{AP} = z_{BO} - z_{TOP}$

1. Lateral pressure due to dry bulk cargo

1.1 Dry bulk cargo upper surface

1.1.1

When the dry bulk cargo density is such that the cargo hold is loaded to the top of hatch coaming, the upper surface of the dry bulk cargo is an equivalent horizontal surface to be determined in considering the same loaded cargo volume in the considered hold bounded by the side shell or inner hull, as the case may be.
For holds of cylindrical shape, the equivalent horizontal surface of the dry bulk cargo may be taken at a distance h_C, in m, above the inner bottom obtained from the following formula (see **Fig 1**):

$$h_C = h_{HPU} + h_0$$

where:

$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{\ell_H}$$

h_{HPU} : Vertical distance, in m, between inner bottom and lower intersection of top side tank and side shell or inner side, as the case may be, as defined in **Fig 1**

S_0 : Shaded area, in m^2, above the lower intersection of top side tank and side shell or inner side, as the case may be, and up to the upper deck level, as defined in **Fig 1**

V_{HC} : Volume, in m^3, enclosed by the hatch coaming.

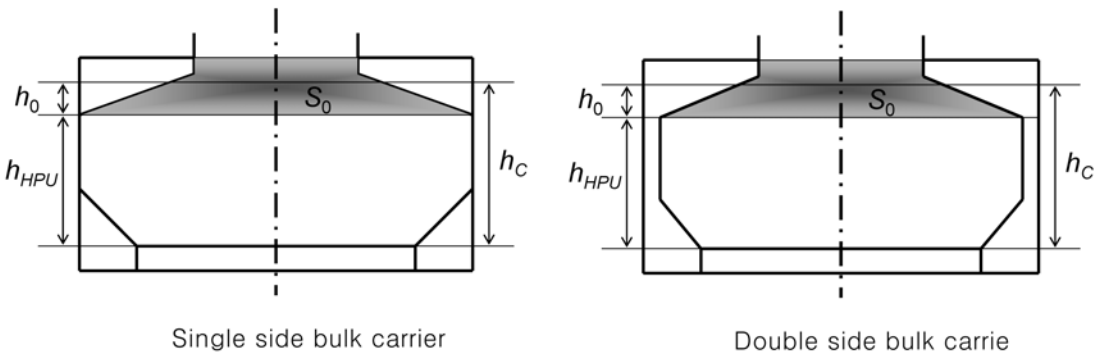


Fig 1: Definitions of h_C ,h_0, h_{HPU} and S_0

1.1.2

When the dry bulk cargo density is such that the cargo hold is not loaded up to the upper deck, the upper surface of the dry bulk cargo is considered as having a plane surface of width $B_H/2$ in the centreline and inclined parts with an angle equal to half the angle of repose ($\psi/2$) at sides, and is to be determined in considering the same loaded cargo volume in the considered hold, taken equal to M/ρ_C.
For holds of cylindrical shape, the upper surface of the dry bulk cargo may be taken at a distance h_C, in m, above the inner bottom obtained from the following formula (see **Fig 2**):

$$h_C = h_{HPL} + h_1 + h_2$$

where:

h_{HPL} : Vertical distance, in m, between inner bottom and upper intersection of hopper tank and inner side, as defined in **Fig 2**. h_{HPL} is to be taken equal to 0 if there is no hopper tank.

h_1 : Vertical distance, in m, obtained from the following formula, see **Fig 2**.

$$h_1 = \frac{M}{\rho_C \cdot B_H \ell_H} - \frac{B_H + b_{IB}}{2B_H} h_{HPL} - \frac{3}{16} B_H \tan\frac{\psi}{2} + \frac{V_{TS}}{B_H \ell_H}$$

M : Mass, in t, of the bulk cargo to be considered, as defined in **Ch 4 Sec 7**

V_{TS} : Total volume, in m^3, of transverse stools at bottom of transverse bulk heads within the concerned cargo hold length ℓ_H. This volume excludes the part of hopper tank passing through the transverse bulkhead.

h_2 : Bulk cargo upper surface, in m, depending on y, given by:

$$h_2 = \frac{B_H}{4}\tan\frac{\psi}{2}, \qquad \text{if } 0 \le |y| \le \frac{B_H}{4}$$

$$h_2 = \left(\frac{B_H}{2} - |y|\right)\tan\frac{\psi}{2}, \qquad \text{if } \frac{B_H}{4} \le |y| \le \frac{B_H}{2}$$

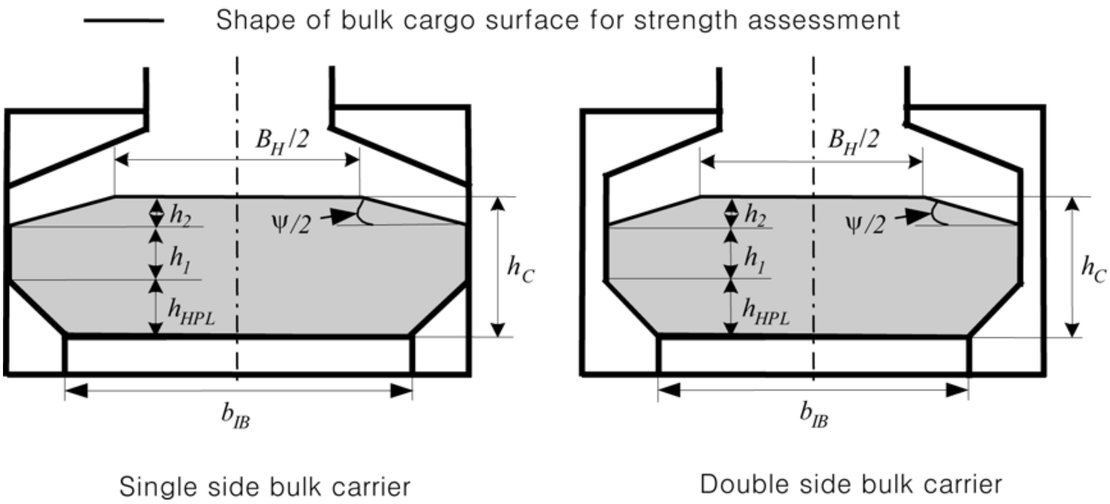


Fig 2: Definitions of h_C, h_1, h_2 and h_{HPL}

For holds of non-cylindrical shape, and in case of prescriptive rule requirements, the upper surface of the bulk cargo may be taken at the upper deck level with a density of dry bulk cargo equal to M/V_H.

1.2 Dry bulk cargo pressure in still water

1.2.1

The dry bulk cargo pressure in still water p_{CS}, in kN/m², is given by:

$$p_{CS} = \rho_C g K_C (h_C + h_{DB} - z)$$

1.3 Inertial pressure due to dry bulk cargo

1.3.1

The inertial pressure induced by dry bulk cargo p_{CW}, in kN/m², for each load case is given by the following formulae.

- for load case H: $p_{CW} = \rho_C [0.25 a_X (x - x_G) + K_C a_Z (h_C + h_{DB} - z)]$
- for load case F: $p_{CW} = 0$
- for load cases R and P: $p_{CW} = \rho_C [0.25 a_Y (y - y_G) + K_C a_Z (h_C + h_{DB} - z)]$

$(x\text{-}x_G)$ is to be taken as $0.25\,\ell_H$ in the load case H1 or $-0.25\,\ell_H$ in the load case H2 for local strength by **Ch 6** and fatigue check for longitudinal stiffeners by **Ch 8.**
The total pressure (p_{CS} + p_{CW}) is not to be negative.

1.4 Shear load due to dry bulk cargo

1.4.1

In order to evaluate the total force in the vertical direction, shear load due to dry bulk cargo acting along sloping plates in way of bilge hopper tank and lower stool is to be considered.
The shear load due to dry bulk cargo acting along the sloping members in still water $p_{CS\text{-}S}$ (positive down to inner bottom plating), in kN/m², is given by:

$$p_{CS-S} = \rho_C g \frac{(1 - K_C)(h_C + h_{DB} - z)}{\tan\alpha}$$

The shear load due to dry bulk cargo acting along the sloping members in waves $p_{CW\text{-}S}$ (positive down to inner bottom plating), in kN/m², is given by:

- for load cases H, R and P: $p_{CW-S} = \rho_C a_Z \dfrac{(1 - K_C)(h_C + h_{DB} - z)}{\tan\alpha}$
- for load case F: $p_{CW-S} = 0$

1.4.2

In order to evaluate the total force in the longitudinal and transverse directions, shear load due to dry bulk cargo in way of inner bottom plating is to be considered.
The shear load due to dry bulk cargo in the longitudinal direction in waves $p_{CW\text{-}S}$ (positive forward), in kN/m², is given by:

- for load case H: $p_{CW\text{-}S} = 0.75 \rho_C a_X h_C$
- for load cases F, R and P: $p_{CW\text{-}S} = 0$

The shear load due to dry bulk cargo in the transverse direction in waves $p_{CW\text{-}S}$ (positive weather side), in kN/m², is given by:

- for load cases R and P: $p_{CW\text{-}S} = 0.75 \rho_C a_Y h_C$
- for load cases H and F: $p_{CW\text{-}S} = 0$

2. Lateral pressure due to liquid

2.1 Pressure due to liquid in still water

2.1.1

The liquid pressure in still water p_{BS}, in kN/m^2, is given by the greater of the following values:

$$p_{BS} = \rho_L g(z_{TOP} - z + 0.5 d_{AP})$$

$$p_{BS} = \rho_L g(z_{TOP} - z) + 100 P_{PV}$$

where:

P_{PV} : Setting pressure, in bar, of safety valves to be considered if any

For local strength assessments, the static pressure p_{BS} is to be taken not less than 25 kN/m^2.

2.1.2

When checking ballast water exchange operations by means of the flow through method, the static pressure p_B for local strength assessments and direct strength analysis by **Ch 7** is to be not less than:

$$p_{BS} = \rho_L g(z_{TOP} - z + d_{AP}) + 25$$

Additional calculation may be required where piping or pumping arrangements may lead to a higher pressure.

2.1.3

For fatigue strength assessment, the liquid pressure in still water p_{BS}, in kN/m^2, is given by the following formula.

$$p_{BS} = \rho_L g(z_{TOP} - z)$$

If the p_{BS} is negative, p_{BS} is to be taken equal to 0.
Where the considered load point is located in the fuel oil, other oils or fresh water tanks, liquids are assumed to be fulfilled up to the half height of the tanks and z_{TOP} is taken to the Z coordinate of the liquid surface at the upright condition.

2.2 Inertial pressure due to liquid

2.2.1

The inertial pressure due to liquid p_{BW}, in kN/m^2, for each load case is given as follows. When checking ballast water exchange operations by means of the flow through method, the inertial pressure due to ballast water is not to be considered for local strength assessments and direct strength analysis.

- for load case H: $p_{BW} = r_L[a_Z(z_{TOP} - z) + a_X(x - x_B)]$

  $(x - x_B)$ is to be taken as $0.75\,\ell_H$ in the load case H1 or $-0.75\,\ell_H$ in the load case H2 for local strength by **Ch 6** and fatigue check for longitudinal stiffeners by **Ch 8**
- for load case F: $p_{BW} = 0$
- for load cases R and P: $p_{BW} = r_L[a_Z(z_B - z) + a_Y(y - y_B)]$

where:

x_B : X co-ordinate, in m, of the aft end of the tank when the bow side is downward, or of the fore end of the tank when the bow side is upward, as defined in **Fig 3**

y_B : Y co-ordinate, in m, of the tank top located at the most lee side when the weather side is downward, or of the most weather side when the weather side is upward, as defined in **Fig 3**

z_B : Z co-ordinate of the following point:

- for completely filled spaces: the tank top
- for ballast hold: the top of the hatch coaming

The reference point B is defined as the upper most point after rotation by the angle φ between the vertical axis and the global acceleration vector $\overrightarrow{A_G}$ shown in **Fig 3**. φ is obtained from the following formulae:

- load cases H1 and H2:

$$\varphi = \tan^{-1}\left(\frac{|a_X|}{g\cos\Phi + a_Z}\right)$$

- load cases R1(P1) and R2(P2):

$$\varphi = \tan^{-1}\left(\frac{|a_Y|}{g\cos\theta + a_Z}\right)$$

where:

θ : Single roll amplitude, in deg, defined in **Ch 4, Sec 2, [2.1.1]**

Φ : Single pitch amplitude, in deg, defined in **Ch 4, Sec 2, [2.2.1]**

The total pressure (p_{BS}+p_{BW}) is not to be negative.

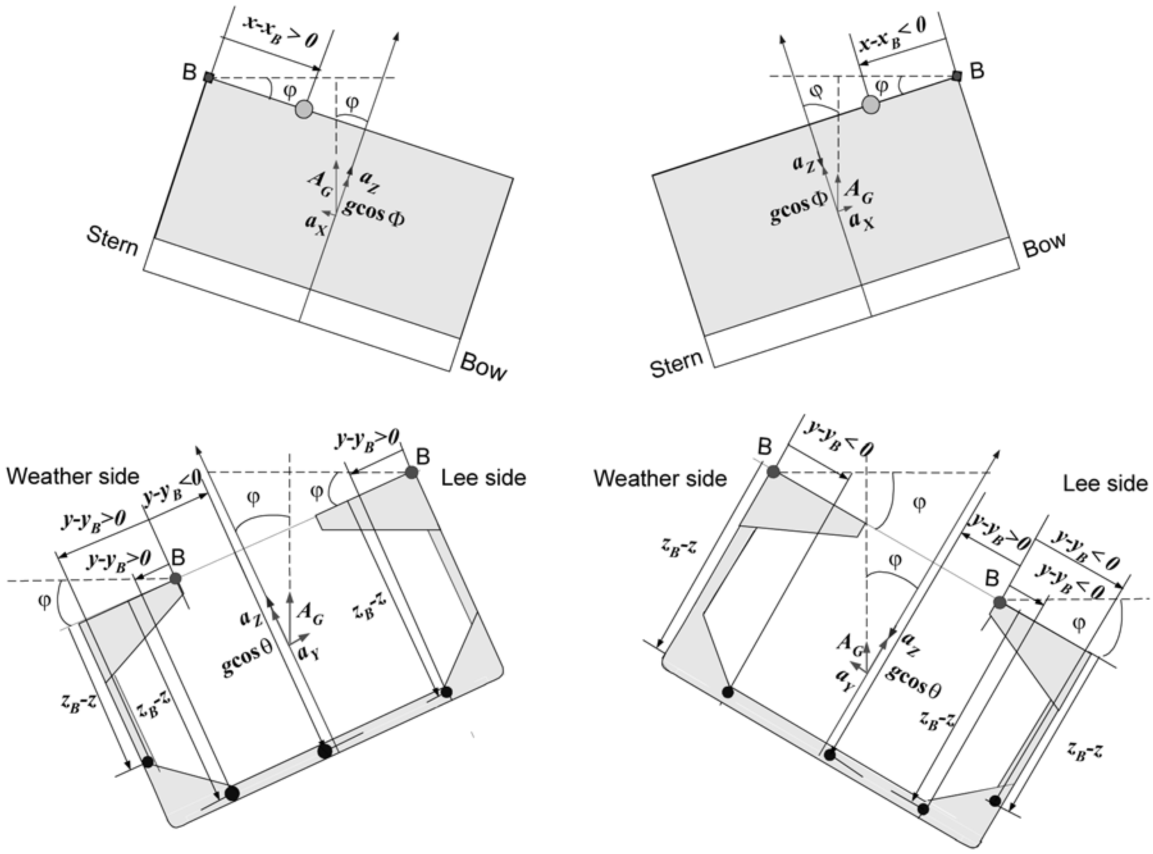


Fig 3: Definition of x_B and y_B

3. Lateral pressures and forces in flooded condition

3.1 Application

3.1.1

The lateral pressures to be considered in flooded condition are indicated in:

- **[3.2]** in general cases
- **[3.3]** for the particular case of transverse corrugated bulkheads
- **[3.4]** for the particular case of double bottom

3.2 General

3.2.1

The pressure p_F to be considered as acting on plating (excluding bottom and side shell plating) which constitute boundaries of compartments not intended to carry liquids is to be obtained, in $\mathrm{kN/m^2}$, from the following formula:

$$p_F = \rho g\left(1 + 0.6\frac{a_Z}{g}\right)(z_F - z)$$, without being less than gd_0

where:

z_F : Z co-ordinate, in m, of the freeboard deck at side in way of the transverse section considered. Where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the freeboard deck; in this case, the Society may require transient conditions to be taken into account

d_0 : Distance, in m, to be taken equal to:

$d_0 = 0.02\,L$ for $90\text{ m} \le L < 120\text{ m}$

$d_0 = 2.4$ for $L \ge 120\text{ m}$

3.3 Transverse vertically corrugated watertight bulkheads

3.3.1 Application

Each cargo hold is to be considered individually flooded.

3.3.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of those induced by cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered.
The most severe combinations of cargo induced loads and flooding loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions,

considering the individual flooding of both loaded and empty holds.
For the purpose of this item, homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling ratio, evaluated for each hold, does not exceed 1.20, to be corrected for different cargo densities.
Non-homogeneous part loading conditions associated with multiport loading and unloading operations for homogeneous loading conditions need not be considered according to these requirements.
The specified design load limits for the cargo holds are to be represented by loading conditions defined

by the Designer in the loading manual.
For the purpose of this item, holds carrying packed cargoes are to be considered as empty.
Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m^3, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the upper deck level at centreline.

3.3.3 Flooding level

The flooding level z_F is the distance, in m, measured vertically from the base line with the ship in the upright position, and equal to:

- in general:
  - *D1* for the foremost transverse corrugated bulkhead
  - 0.9 *D1* for other bulkheads;

where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions, the following values may be assumed:
  - 0.95 *D1* for the foremost transverse corrugated bulkhead
  - 0.85 *D1* for other bulkheads
- for ships less than 50000 *t* deadweight with type B freeboard:
  - 0.95 *D1* for the foremost transverse corrugated bulkhead
  - 0.85 *D1* for other bulkheads;

where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions, the following values may be assumed:
  - 0.9 *D1* for the foremost transverse corrugated bulkhead
  - 0.8 *D1* for other bulkheads.

3.3.4 Pressures and forces on a corrugation in non-flooded bulk cargo loaded holds

At each point of the bulkhead, the pressure is to be obtained, in kN/m^2, from the following formula:

$$p_B = \rho_C g(h_C + h_{DB} - z)\tan^2\left(45 - \frac{\psi}{2}\right)$$

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_B = \rho_C g s_C \frac{(h_C - h_{LS})^2}{2}\tan^2\left(45 - \frac{\psi}{2}\right)$$

3.3.5 Pressures and forces on a corrugation in flooded bulk cargo loaded holds

Two cases are to be considered, depending on the values of z_F and h_C (see **[3.3.3]** and **[1.1]**):

- First case, when $z_F \geq h_C + h_{DB}$

  At each point of the bulkhead located at a distance between z_F and $h_C + h_{DB}$ from the base line, the pressure, in kN/m^2, is to be obtained from the following formula:

$$p_{B,F} = \rho g(z_F - z)$$

  At each point of the bulkhead located at a distance lower than hC+hDB from the base line, the pressure, in kN/m^2, is to be obtained from the following formula:

$$p_{B,F} = \rho g(z_F - z) + [\rho_C - \rho(1 - perm)]g(h_C + h_{DB} - z)\tan^2\left(45 - \frac{\psi}{2}\right)$$

  where perm is the permeability of cargo, to be taken as 0.3 for iron ore, coal cargoes and cement.

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_{B,F} = s_C\left[\rho g\frac{(z_F - h_C - h_{DB})^2}{2} + \frac{\rho g(z_F - h_C - h_{DB}) + (p_{B,F})_{LE}}{2}(h_C - h_{LS})\right]$$

where $(p_{B,F})_{LE}$ is the pressure $p_{B,F}$, in $\mathrm{kN/m^2}$, calculated at the lower edge of the corrugation.

- Second case, when $z_F < h_C + h_{DB}$

At each point of the bulkhead located at a distance between z_F and $h_C + h_{DB}$ from the base line, the pressure is to be obtained, in $\mathrm{kN/m^2}$, from the following formula:

$$p_{B,F} = \rho_C g(h_C + h_{DB} - z)\tan^2\left(45 - \frac{\psi}{2}\right)$$

At each point of the bulkhead located at a distance lower than z_F from the base line, the pressure is to be obtained, in $\mathrm{kN/m^2}$, from the following formula:

$$p_{B,F} = \rho g(z_F - z) + [\rho_C(h_C + h_{DB} - z) - \rho(1 - perm)(z_F - z)]g\tan^2\left(45 - \frac{\psi}{2}\right)$$

where perm is the permeability of cargo, to be taken as 0.3 for iron ore, coal cargoes and cement. The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_{B,F} = s_C\left[\rho_C g\frac{(h_C + h_{DB} - z_F)^2}{2}\tan^2\left(45 - \frac{\psi}{2}\right)\right] + s_C\left[\frac{\rho_C g(h_C + h_{DB} - z_F)\tan^2\left(45 - \frac{\psi}{2}\right) + (p_{B,F})_{LE}}{2}(z_F - h_{DB} - h_{LS})\right]$$

where $(p_{B,F})_{LE}$ is the pressure $p_{B,F}$, in $\mathrm{kN/m^2}$, calculated at the lower edge of the corrugation.

3.3.6 Pressures and forces on a corrugation in flooded empty holds

At each point of the bulkhead, the still water pressure induced by the flooding to be considered is to be obtained, in $\mathrm{kN/m^2}$, from the following formula:

$$p_F = \rho g(z_F - z)$$

The force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F_F = s_C \rho g\frac{(z_F - h_{DB} - h_{LS})^2}{2}$$

3.3.7 Resultant pressures and forces

Resultant pressures and forces to be calculated for homogeneous and non-homogeneous loading conditions are to be obtained according to the following formulae:

- Homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure to be considered for the scantlings of the bulkhead is to be obtained, in $\mathrm{kN/m^2}$, from the following formula:

$$p = p_{B,F} - 0.8p_B$$

The resultant force acting on a corrugation is to be obtained, in kN, from the following formula:

$$F = F_{B,F} - 0.8F_B$$

where:

p_B : Pressure in the non-flooded holds, in kN/m^2, to be obtained as specified in **[3.3.4]**

$p_{B,F}$: Pressure in the flooded holds, in kN/m^2, to be obtained as specified in **[3.3.5]**

$F_{B,F}$: Force acting on a corrugation in the flooded holds, in kN, to be obtained as specified in **[3.3.5].**

F_B : Force acting on a corrugation in non-flooded holds, in kN, to be obtained as specified in **[3.3.4].**

- Non-homogeneous loading conditions

At each point of the bulkhead structures, the resultant pressure to be considered for the scantlings of the bulkhead is to be obtained, in kN/m^2, by the following formula:

$$p = p_{B,F}$$

The resultant force acting on a corrugation is to be obtained, in kN, by the following formula:

$$F = F_{B,F}$$

where:

$p_{B,F}$: Pressure in the flooded holds kN/m^2, to be obtained as specified in **[3.3.5]**

$F_{B,F}$: Force acting on a corrugation in the flooded holds kN/m^2, to be obtained as specified in **[3.3.5].**

3.4 Double bottom

3.4.1 Application

Each cargo hold is to be considered individually flooded.

3.4.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.
The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions
- non-homogeneous loading conditions
- packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

3.4.3 Flooding level

The flooding level z_F is the distance, in m, measured vertically from the base line with the ship in the upright position, and equal to:

- for ships less than 50000 t deadweight with type B freeboard:
- 0.95 D_1 for the foremost hold
- 0.85 D_1 for other holds;

- for other ships:
- D_1 for the foremost hold
- 0.9 D_1 for other holds;

4. Testing lateral pressure

4.1 Still water pressures

4.1.1

The total pressure to be considered as acting on plates and stiffeners subject to tank testing is obtained, in kN/m^2, from the following formula:

$$p_{ST} = 10(z_{ST} - z)$$

where:

z_{ST} : Testing load height, in m, as defined in **Table 2.**

Table 2: Testing load height

Compartment or structure to be tested	Testing load height, in m
Double bottom tanks	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{ml}$
Hopper side tanks, topside tanks, double side tanks, fore and after peaks used as tank, cofferdams	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{TOP} + 2.4$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{TOP} + 2.4$ $z_{ST} = z_{TOP} + 10\,p_{PV}$
Ballast hold	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_h + 0.9$
Fore and aft peak not used as tank	The greater of the following: $z_{ST} = z_F$ $z_{ST} = z_{ml}$
Watertight doors below freeboard deck	$z_{ST} = z_{fd}$
Chain locker (if aft of collision bulkhead)	$z_{ST} = z_{TOP}$
Independent tanks	The greater of the following: $z_{ST} = z_{TOP} + d_{AP}$ $z_{ST} = z_{TOP} + 0.9$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure

where:
z_{ml} : Z co-ordinate, in m, of the margin line.
z_h : Z co-ordinate, in m, of the top of hatch.
z_F : As defined in [3.2.1].
z_{fd} : Z co-ordinate, in m, of the freeboard deck.
p_{PV} : Setting pressure, in bar, of safety valves.

Section 7 - LOADING CONDITIONS

Symbols

M_H : The actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in t

M_{Full} : The cargo mass in a cargo hold corresponding to cargo with virtual density (homogenous mass / hold cubic capacity, minimum 1.0 t/m^3) filled to the top of the hatch coaming, in t.

$$M_{Full} = V_{Full} \cdot \max(M_H / V_H, 1.0)$$

M_{Full} is in no case to be less than M_H

M_{HD} : The maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draught, in t

V_{Full} : Volume, in m^3, of the cargo hold including the volume enclosed by the hatch coaming

V_H : Volume, in m^3, defined in **Ch4**, **Sec6**

T_{HB} : Deepest ballast draught, in m.

1. Application

1.1 Ships having a length *L* less than 150 m

1.1.1

The severest loading conditions from the loading manual, midship section drawing or otherwise specified by the Designer are to be considered for the longitudinal strength according to **Ch 5, Sec 1** and for the local strength check of plating, ordinary stiffeners and primary supporting members according to **Ch 6.**

1.2 Ships having a length *L* of 150 m and above

1.2.1

The requirements in **[2]** to **[4]** are applicable to ships having a length L of 150 m and above.

1.2.2

These requirements are not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted. It is not intended to replace in any way the required loading manual/instrument.

1.2.3

The maximum loading condition draught is to be taken as the moulded summer load line draught.

1.2.4

The loading conditions listed in **[2]** are to be applied for the check of longitudinal strength as required by **Ch 5, Sec 1**, the check of local strength by **Ch 6**, the direct strength analysis by **Ch 7**, for capacity and disposition of ballast tanks and stability purposes. The loading conditions listed in **[3]** are to be applied for the check of local strength. The loading conditions listed in **[4]** are to be applied for direct strength analysis.

1.2.5

In operation, a bulk carrier may be loaded differently from the design loading conditions specified in the loading manual, provided longitudinal and local strength as defined in the loading manual and onboard loading instrument and applicable stability requirements are not exceeded.

2. General

2.1 Design loading conditions - General

2.1.1

For the determination of the maximum cargo mass in cargo holds, the condition corresponding to the ship being loaded at maximum draught with 50% of consumables is to be considered.

2.1.2 BC-C

Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100 % full at maximum draught with all ballast tanks empty.

2.1.3 BC-B

As required for BC-C, plus:
Homogeneous cargo loaded condition with cargo density 3.0 t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all cargo holds at maximum draught with all ballast tanks empty.
In cases where the cargo density applied for this design loading condition is less than 3.0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated with the additional service feature **{maximum cargo density x.y** t/m^3**}.**

2.1.4 BC-A

As required for **BC-B**, plus:
At least one cargo loaded condition with specified holds empty, with cargo density 3.0 t/m^3, and the same filling ratio (cargo mass/hold cubic capacity) in all loaded cargo holds at maximum draught with all ballast tanks empty.
The combination of specified empty holds is to be indicated with the additional service feature **{holds a, b, ... may be empty}**.
In such cases where the design cargo density applied is less than 3.0 t/m^3, the maximum density of the cargo that the ship is allowed to carry is to be indicated within the additional service feature **{holds a, b, ... maybe empty with maximum cargo density x.y** t/m^3**}**.

2.2 Applicable ballast conditions

2.2.1 Ballast tank capacity and disposition

All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements.

Normal ballast condition
Normal ballast condition is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in **Ch 4, Sec 3** are to be complied with
- any cargo hold or holds adapted for the carriage of water ballast at sea are to be empty
- the propeller is to be fully immersed, and
- the trim is to be by the stern and is not to exceed 0.015 L_{BP}.

In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.

Heavy ballast condition
Heavy ballast condition is a ballast (no cargo) condition where:

- the ballast tanks may be full, partially full or empty. Where ballast tanks are partially full, the conditions in **Ch 4, Sec 3** are to be complied with
- at least one cargo hold adapted for carriage of water ballast at sea is to be full
- the propeller immersion *I/D* is to be at least 60 %, where:

  I = Distance from propeller centerline to the waterline

  D = Propeller diameter
- the trim is to be by the stern and is not to exceed 0.015 L_{BP}
- the moulded forward draught in the heavy ballast condition is not to be less than the smaller of 0.03 L_{BP} or 8 m.

2.2.2 Strength requirements

All bulk carriers are to meet the following strength requirements:

Normal ballast condition:

- the structures of bottom forward are to be strengthened in accordance with the Rules against slamming for the condition of **[2.2.1]** for normal ballast condition at the lightest forward draught,
- the longitudinal strength requirements according to **Ch 4, Sec 3** are to be met for the condition of **[2.2.1]** for normal ballast condition, and
- in addition, the longitudinal strength requirements according to **Ch 4, Sec 3** are to be met with all ballast tanks 100 % full.

Heavy ballast condition:

- the longitudinal strength requirements according to **Ch 4, Sec 3** are to be met for the condition of **[2.2.1]** for heavy ballast condition
- in addition, the longitudinal strength requirements according to **Ch 4, Sec 3** are to be met with all ballast tanks 100 % full and one cargo hold adapted and designated for the carriage of water ballast at sea, where provided, 100 % full, and
- where more than one hold is adapted and designated for the carriage of water ballast at sea, it will not be required that two or more holds be assumed 100 % full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

2.3.1

Unless otherwise specified, each of the design loading conditions defined in **[2.1]** and **[2.2]** is to be investigated for the arrival and departure conditions as defined as follows:

- Departure condition : with bunker tanks not less than 95 % full and other consumables 100 %
- Arrival condition : with 10 % of consumables

3. Design loading conditions for local strength

3.1 Definitions

3.1.1

The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks.

3.2 Applicable general conditions

3.2.1

Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.

3.2.2

Any cargo hold is to be capable of carrying minimum 50 % of M_H, with all double bottom tanks in way of the cargo hold being empty, at maximum draught.

3.2.3

Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught.

3.3 Additional conditions applicable except when additional service feature {no MP} is assigned

3.3.1

Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67 % of maximum draught.

3.3.2

Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83 % of maximum draught.

3.3.3

Any two adjacent cargo holds are to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67 % of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast, if applicable.

3.3.4

Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75 % of maximum draught.

3.4 Additional conditions applicable for BC-A only

3.4.1

Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty.

3.4.2

Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying M_{HD} plus 10 % of M_H, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom being empty in way of the cargo hold, at maximum draught.
In operation the maximum allowable cargo mass shall be limited to M_{HD}.

3.4.3

Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10% of M_H in each hold in addition to the maximum cargo load according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught.
In operation the maximum allowable mass shall be limited to the maximum cargo load according to the design loading conditions.

3.5 Additional conditions applicable for ballast hold(s) only

3.5.1

Cargo holds, which are designed as ballast water holds, are to be capable of being 100 % full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100 % full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty.

3.6 Additional conditions applicable during loading and unloading in harbour only

3.6.1

Any single cargo hold is to be capable of holding the maximum allowable seagoing mass at 67 % of maximum draught, in harbour condition.

3.6.2

Any two adjacent cargo holds are to be capable of carrying M_{Full}, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100 % full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67 % of maximum draught, in harbour condition.

3.6.3

At reduced draught during loading and unloading in harbour, the maximum allowable mass in a cargo hold may be increased by 15 % of the maximum mass allowed at the maximum draught in sea-going condition, but shall not exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

3.7 Hold mass curves

3.7.1

Based on the design loading criteria for local strength, as given in **[3.2]** to **[3.6]** except **[3.5.1]**, hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught in sea-going condition as well as during loading and unloading in harbour. Hold mass curves are to be calculated according to **Ch 4, App 1.**

3.7.2

At other draughts than those specified in the design loading conditions, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught.
Hold mass curves for each single hold, as well as for any two adjacent holds, are to be included in the loading manual and the loading instrument.

4. Design loading conditions for direct strength analysis

4.1 Loading patterns

4.1.1

The loading patterns applicable to types of bulk carriers with various service feature notations are summarized in **Table 1,** which are to be considered in direct strength analysis in accordance with **[2]** and **[3].**

Table 1: Applicable loading patterns according to additional service features

No.	Loading pattern	Ref.	BC-			BC-,(no MP)		
			A	B	C	A	B	C
1	Full load in homogeneous condition	**3.2.1**	x	x	x	x	x	x
2	Slack load	**3.2.2**	x	x	x	x	x	x
3	Deepest ballast	**3.2.3**	x	x	x	x	x	x
4	Multiport -1	**3.3.1**	x	x	x			
5	Multiport -2	**3.3.2**	x	x	x			
6	Multiport -3	**3.3.3**	x	x	x			
7	Multiport -4	**3.3.4**	x	x	x			
8	Alternate load	**3.4.1** & **.2**	x			x		
9	Alternate block load	**3.4.3**	x			x		
10	Heavy ballast	**3.5.1**	x	x	x	x	x	x
11	Harbour condition -1	**3.6.1**				x	x	x
12	Harbour condition -2	**3.6.2**				x	x	x

4.1.2

Other loading conditions from the loading manual, which are not covered in **Table 1**, if any, are also to be considered.

4.2 Still water bending moment and shear force

4.2.1

Load cases defined in **Sec 4** are to be considered for each loading pattern given in **Table 1.** The still water vertical bending moment provided in **Table 2** and the still water vertical shear force provided in **Table 3** are to be used for each combination of loading pattern and load case.

4.2.2

If one loading condition in the loading manual has a still water vertical bending moment more severe than the value in **Table 2** for the corresponding loading pattern, the value in **Table 2** for this loading pattern is to be replaced with the value from the loading manual.

4.3 Application

4.3.1

The minimum required loading conditions for direct strength analysis, including vertical shear force analysis, are defined in **Ch 4, App 2.**

4.3.2

The standard loading conditions for fatigue assessment are defined in **Ch 4, App 3.**

Table 2: Vertical still water bending moment

<table>
<tr><td colspan="2" rowspan="4"></td><td colspan="5">Loading pattern</td></tr>
<tr><td rowspan="3">Full load in homogeneous condition</td><td>Slack load</td><td>Multiport</td><td rowspan="3">Heavy ballast (Ballast hold)</td><td rowspan="3">Harbour condition</td></tr>
<tr><td>Alternate load</td><td>Alternate block load</td></tr>
<tr><td>Normal ballast</td><td>Deepest ballast</td></tr>
<tr><td rowspan="13">load case</td><td>H1</td><td>0.5 $M_{SW,S}$</td><td>0</td><td>$M_{SW,S}$</td><td>$M_{SW,S}$</td><td rowspan="10">---</td></tr>
<tr><td>H2</td><td>0.5 $M_{SW,H}$</td><td>$M_{SW,H}$</td><td>$M_{SW,H}$</td><td>0</td></tr>
<tr><td>F1</td><td>0.5 $M_{SW,S}$</td><td>0</td><td>$M_{SW,S}$</td><td>$M_{SW,S}$</td></tr>
<tr><td>F2</td><td>0.5 $M_{SW,H}$</td><td>$M_{SW,H}$</td><td>$M_{SW,H}$</td><td>0</td></tr>
<tr><td rowspan="2">R1</td><td>0.5 $M_{SW,S}$</td><td>0</td><td>$M_{SW,S}$</td><td>$M_{SW,S}$</td></tr>
<tr><td>0.5 $M_{SW,H}$</td><td>$M_{SW,H}$</td><td>$M_{SW,H}$</td><td>0</td></tr>
<tr><td rowspan="2">R2</td><td>0.5 $M_{SW,S}$</td><td>0</td><td>$M_{SW,S}$</td><td>$M_{SW,S}$</td></tr>
<tr><td>0.5 $M_{SW,H}$</td><td>$M_{SW,H}$</td><td>$M_{SW,H}$</td><td>0</td></tr>
<tr><td>P1</td><td>0.5 $M_{SW,S}$</td><td>0</td><td>$M_{SW,S}$</td><td>$M_{SW,S}$</td></tr>
<tr><td>P2</td><td>0.5 $M_{SW,H}$</td><td>$M_{SW,H}$</td><td>$M_{SW,H}$</td><td>0</td></tr>
<tr><td rowspan="2">Static</td><td colspan="4" rowspan="2">---</td><td>$M_{SW,P,S}$</td></tr>
<tr><td>$M_{SW,P,H}$</td></tr>
</table>

where:

$M_{SW,H}$: Allowable still water vertical bending moment in hogging condition for seagoing condition

$M_{SW,S}$: Allowable still water vertical bending moment in sagging condition for seagoing condition

$M_{SW,P,H}$: Allowable still water vertical bending moment in hogging condition for harbour condition

$M_{SW,P,S}$: Allowable still water vertical bending moment in sagging condition for harbour condition

Table 3: Vertical still water shear force

		Loading pattern				
		Full load in homogeneous condition	Alternate load (BC-A)	Multiport (BC-B and BC-C)	Heavy ballast (Ballast hold)	Heavy ballast (Except for ballast hold)
Load case	H1	---	Q_{SW}	Q_{SW}	Q_{SW}	---
	H2	---	Q_{SW}	Q_{SW}	Q_{SW}	---
	F1	---	Q_{SW}	Q_{SW}	Q_{SW}	---
	F2	---	Q_{SW}	Q_{SW}	Q_{SW}	---

where:
Q_{SW} : Allowable still water shear force at the position of the considered transverse bulkhead

Section 8 - LOADING MANUAL AND LOADING INSTRUMENT

1. General

1.1 All ships

1.1.1

An approved loading manual is to be supplied on board for all ships.
In addition, an approved loading instrument is to be supplied for all ships.
The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.
An approved loading instrument may not replace an approved loading manual.

1.2 Ships equal to or greater than 150 m in length *L*

1.2.1

BC-A, BC-B, and BC-C ships are to be provided with an approved loading manual and an approved computer-based loading instrument, in accordance with the applicable requirements of this Section.
A guidance for loading and unloading sequences is given in **[5].**

2. Loading manual

2.1 Definitions

2.1.1 All ships

A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force. The conditions specified in the ballast water exchanging procedure and dry docking procedure are to be included in the loading manual.
- the results of the calculations of still water bending moments and shear forces
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

2.1.2 Ships equal to or greater than 150 m in length *L*

In addition to **[2.1.1]**, for BC-A, BC- and BC-C ships, the loading manual is also to describe:

- envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition according to **Ch 5, Sec 1**
- the cargo hold(s) or combination of cargo holds that might be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual
- maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position
- maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions
- maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes
- maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual
- maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.2 Conditions of approval

2.2.1 All ships

The approved loading manual is to be based on the final data of the ship. The manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based.
In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

2.2.2 Ships equal to or greater than 150 m in length *L*

In addition to **[2.2.1]**, for BC-A, BC-B and BC-C ships, the following loading conditions, subdivided into departure and arrival conditions as appropriate, are also to be included in the loading manual:

- homogeneous light and heavy cargo loading conditions at maximum draught
- alternate light and heavy cargo loading conditions at maximum draught, where applicable
- ballast conditions. For ships having ballast holds adjacent to topside wing, hopper and double bottom tanks, it shall be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty
- short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers
- multiple port loading / unloading conditions
- deck cargo conditions, where applicable
- typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading / unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to loading rate and the deballasting capability. **Table 1** contains, as guidance only, an example of a Loading Sequence Summary Form
- typical sequences for change of ballast at sea, where applicable.

2.3 Language

2.3.1

The loading manual is to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

3. Loading instrument

3.1 Definitions

3.1.1 All ships

A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces, in any load or ballast condition, do not exceed the specified permissible values.

3.1.2 Ships equal to or greater than 150 m in length *L*

For BC-A, BC-B and BC-C ships, the loading instrument is an approved digital system as defined in **[3.1.1]**. In addition to **[3.1.1]**, it is also to ascertain as applicable that:

- the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position
- the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean

draught in way of these holds
- the still water bending moment and shear forces in the hold flooded conditions do not exceed the specified permissible values.

3.2 Conditions of approval

3.2.1 All ships

The loading instrument is subject to approval, which is to include:
- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

3.2.2 Ships equal to or greater than 150 m in length *L*

In addition, for BC-A, BC-B and BC-C ships, the approval is also to include, asapplicable:
- acceptance of hull girder bending moment limits for all read-out points
- acceptance of hull girder shear force limits for all read-out points
- acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught
- acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

3.2.3

In the case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

3.2.4

An operational manual is always to be provided for the loading instrument.
The operation manual and the instrument output are to be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

3.2.5

The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

4. Annual and class renewal survey

4.1 General

4.1.1

At each annual and class renewal survey, it is to be checked that the approved loading manual is available on board.

4.1.2

The loading instrument is to be checked for accuracy at regular intervals by the ship's Master by applying test loading conditions.

4.1.3

At each class renewal survey this checking is to be done in the presence of the Surveyor.

5. Guidance for loading/unloading sequences

5.1 General

5.1.1

The typical loading/unloading sequences shall be developed paying due attention to the loading/unloading rate, the ballasting/deballasting capacity and the applicable strength limitations.

5.1.2

The shipbuilder will be required to prepare and submit for approval typical loading and unloading sequences.

5.1.3

The typical loading sequences as relevant should include:

- alternate light and heavy cargo load condition
- homogeneous light and heavy cargo load condition
- short voyage condition where the ship is loaded to maximum draught but with limited bunkers
- multiple port loading/unloading condition
- deck cargo condition
- block loading.

5.1.4

The loading/unloading sequences may be port specific or typical.

5.1.5

The sequence is to be built up step by step from commencement of cargo loading to reaching full dead-weight capacity. Each time the loading equipment changes position to a new hold defines a step. Each step is to be documented and submitted to the Society. In addition to longitudinal strength, the local strength of each hold is to be considered.

5.1.6

For each loading condition a summary of all steps is to be included. This summary is to highlight the essential information for each step such as:

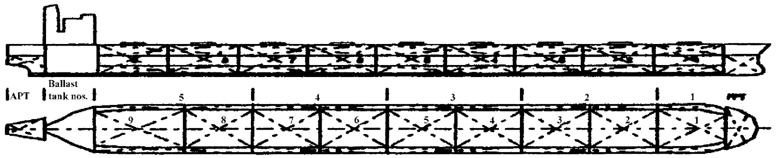
- how much cargo is filled in each hold during the different steps,
- how much ballast is discharged from each ballast tank during the different steps,
- the maximum still water bending moment and shear at the end of each step,
- the ship’s trim and draught at the end of each step.

Table 1: Guidance on Typical loading Sequence Summary Form

LOADING/UNLOADING SEQUENCE SUMMARY FORM

Vessel name	Voyage No.	Condition	Yard	Id. Number

Port (specific or typical) :		Condition at commencement of loading/discharging	
Total mass of cargo to be loaded/discharged :		Condition at end of loading/discharging	
Dock water density (t/m3) :		Maximum Loading/discharging rate :	Average Loading/discharging rate :
Number of loaders/dischargers :		Maximum Ballasting/Deballasting rate :	Average Ballasting/Deballasting rate :



Hold No.			7	6	5	4	3	2	1
Volume of Hold, Vh(m³)									
Height of hold, h(m)									

Note : During each pour it has to be controlled that allowable limits for hull girder shear force, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow for ballasting/deballasting in order to keep actual values within limits.

Hold content at commencement of loading/discharging

Cargo mass									
Density (t/m³)									
Grade									

Ballasting contents at commencement of loading/discharging

Wings or peaks	APT	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	FPT
Upper									
Lower/Peaks									

Commencement of loading/discharging (sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

CARGO OPERATIONS

Pour No. / Grade	Hold	Hold	Hold 7	Hold 6	Hold 5	Hold 4	Hold 3	Hold 2	Hold 1
1									
2									
3									
4									
5									
6									
7									
8									

BALLASTING OPERATIONS

	APT	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	No. B.T.	FPT
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									
Upper									
Lower/Peak									

Values at end of pour (from harbour to sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

Total cargo onboard (t) : Remaining cargo to be loaded (t) : Total amount of bunkers onboard (t) :

Draft Survey n-1									
Draft Survey n									

Upper									
Lower/Peak									
Upper									
Lower/Peak									

Hold content at end of loading/discharging

Cargo mass									

Total mass loaded /discharged (t)		

Ballasting contents at end of loading/discharging

Wings or peaks	APT	Ball.no.5	Ball.no.4	Hold no.6	Ball.no.3	Hold no.4	Ball.no.2	Ball.no.1	FPT
Upper									
Lower/Peaks									

Values at end of loading/discharging (sea)

Taft (m)	Trim (m)	Tfwd (m)	Maximum S.F.(%)	Maximum B.M.(%)

Maximum occuring values among all conditions above

Net load on Double Bottom									tons/m²
Net load in two adjacent holds									tons

Net load on double bottom = (Mh/V) * h·T (t/m²)
where : Mh = Mass in hold + mass in DB (t)
V = Total volume of hold (m³)
h = height of hold from inner bottom to top of coaming (m)
T = draught (m)

Approved by : ____________________

Date : ____________________

Appendix 1 - HOLD MASS CURVES

Symbols

h : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline, in m.

h_a : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the aft cargo hold in a block loading, in m.

h_f : Vertical distance from the top of inner bottom plating to the lowest point of the upper deck plating at the ship's centreline of the fore cargo hold in a block loading, in m.

M_H : As defined in **Ch 4, Sec 7**

M_{Full} : As defined in **Ch 4, Sec 7**

M_{HD} : As defined in **Ch 4, Sec 7**

M_D : The maximum cargo mass given for each cargo hold, in t

M_{BLK} : The maximum cargo mass in a cargo hold according to the block loading condition in the loading manual, in t

T_{HB} : As defined in **Ch 4, Sec 7**

T_i : Draught in loading condition No. i, at mid-hold position of cargo hold length ℓ_H, in m

V_H : As defined in **Ch 4, Sec 6**

V_f and V_a: Volume of the forward and after cargo hold excluding volume of the hatchway part, in m^3

$T_{\min}$: 0.75 T_S or draught in ballast conditions with the two adjacent cargo holds empty, which ever is greater, in m.

Σ : The sum of masses of two adjacent cargo holds

1. General

1.1 Application

1.1.1

The requirements of this Appendix apply to ships of 150 m in length L and above.

1.1.2

This Appendix describes the procedure to be used for determination of:

- the maximum and minimum mass of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold
- the maximum and minimum mass of cargo in any two adjacent holds as a function of the mean draught in way of these holds.

1.1.3

Results of these calculations are to be included in the reviewed loading manual which has also to indicate the maximum permissible mass of cargo at scantling draught in each hold or in any two adjacent holds, as obtained from the design review.

1.1.4

The following notice on referring to the maximum permissible and the minimum required mass of cargo is to be described in loading manual.

Where ship engages in a service to carry such hot coils or heavy cargoes that have some adverse effect on the local strength of the double bottom and that the loading is not described as cargo in loading manual, the maximum permissible and the minimum required mass of cargo are to be considered specially.

2. Maximum and minimum masses of cargo in each hold

2.1 Maximum permissible mass and minimum required masses of single cargo hold in seagoing condition

2.1.1 General

The cargo mass curves of single cargo hold in seagoing condition are defined in **[2.1.2]** to **[2.1.5].** However if the ship structure is checked for more severe loading conditions than the ones considered in **Ch 4, Sec 7, [3.7.1],** the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

2.1.2 BC-A ship not having {No MP} assigned

- For loaded holds

  The maximum permissible mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(T_S - T_i)}{h}$$

  However, $W_{max}(T_i)$ is no case to be greater than M_{HD}.

  The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \qquad \text{for } T_i \le 0.83T_S$$

$$W_{min}(T_i) = 1.025V_H \frac{(T_i - 0.83T_S)}{h} \qquad \text{for } T_S \ge T_i > 0.83T_S$$

- For empty holds which can be empty at the maximum draught

  The maximum permissible mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{max}(T_i) = M_{Full} \qquad \text{for } T_S \ge T_i \ge 0.67T_S$$

$$W_{max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_S - T_i)}{h} \qquad \text{for } T_i < 0.67T_S$$

  The minimum required mass ($W_{min}(T_i)$) is obtained, in t, by the following formula:

$$W_{min}(T_i) = 0 \qquad \text{for } T_i \le T_S$$

Examples for mass curve of loaded cargo hold and cargo hold which can be empty at the maximum draught for BC-A ships not having {No MP} assigned are shown in **Fig 1.**

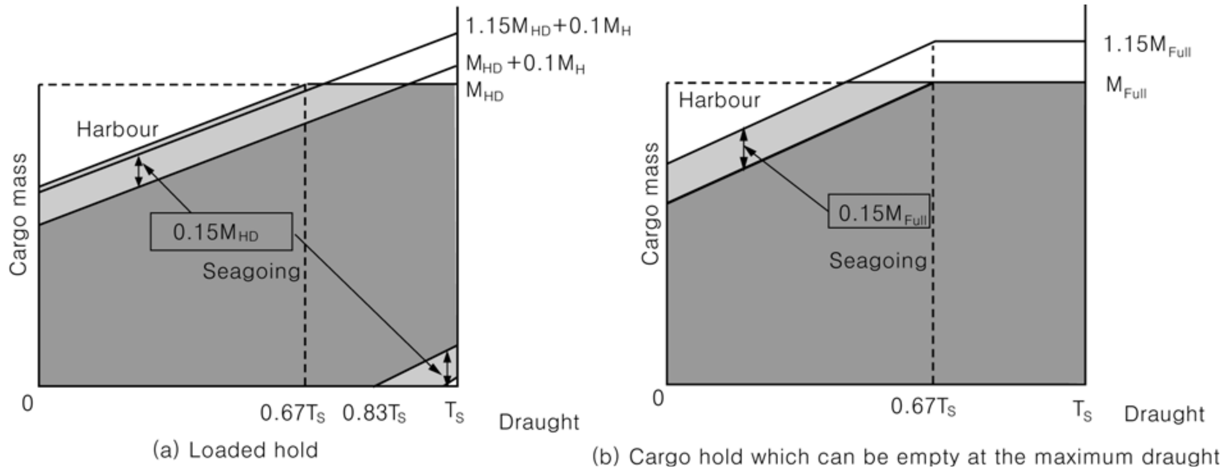


Fig 1: Example of mass curve for BC-A ships not having {No MP} assigned

2.1.3 BC-A ship having {No MP} assigned

- For loaded holds

  The maximum permissible mass ($W_{max}(T_i)$) at various draughts (T_i) is the same specified in **[2.1.2].** The minimum required mass ($W_{min}(T_i)$) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for} \quad T_i \le T_{HB}$$

$$W_{min}(T_i) = 1.025 V_H \frac{(T_i - T_{HB})}{h} \quad \text{for} \quad T_S \ge T_i > T_{HB} \quad \text{or}$$

$$W_{min}(T_i) = 0.5 M_H - 1.025 V_H \frac{(T_S - T_i)}{h} \ge 0 \quad \text{for} \quad T_S \ge T_i$$

- For empty hold which can be empty at the maximum draught

  The maximum permissible mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{max}(T_i) = M_{Full} - 1.025 V_H \frac{(T_S - T_i)}{h}$$

  The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for} \quad T_i \le T_S$$

  Examples for mass curve of cargo hold for BC-A ships, having {No MP} assigned are shown in **Fig 2.**

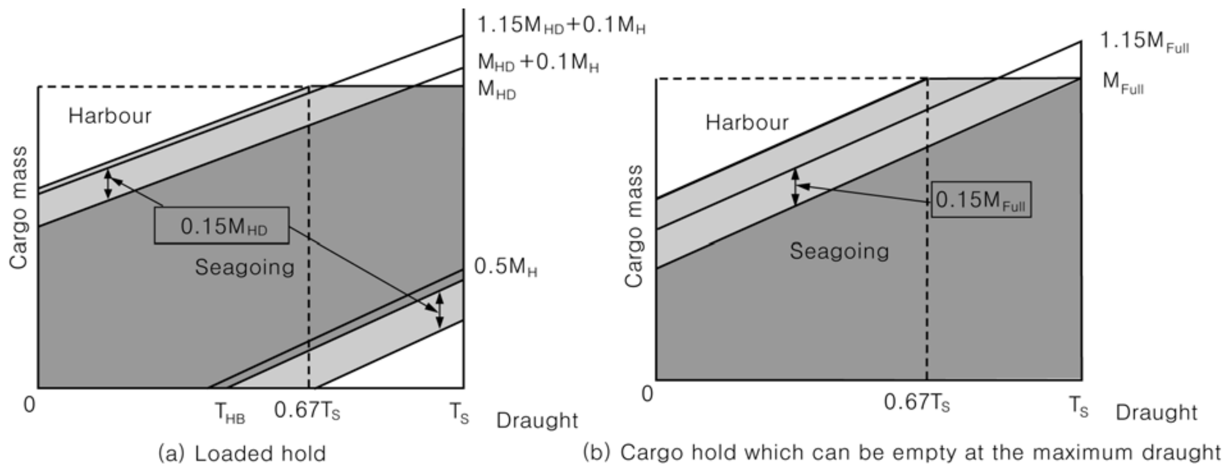


Fig 2: Example of mass curve for BC-A ships having {No MP} assigned

2.1.4 BC-B and BC-C ships not having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{max}(T_i) = M_{Full} \qquad \text{for } T_S \geq T_i \geq 0.67T_S$$

$$W_{max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67T_S - T_i)}{h} \qquad \text{for } T_i < 0.67T_S$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \qquad \text{for } T_i \leq 0.83T_S$$

$$W_{min}(T_i) = 1.025V_H \frac{(T_i - 0.83T_S)}{h} \qquad \text{for } T_S \geq T_i > 0.83T_S$$

Example for mass curve of cargo hold for BC-B and BC-C ships is shown in **Fig 3.**

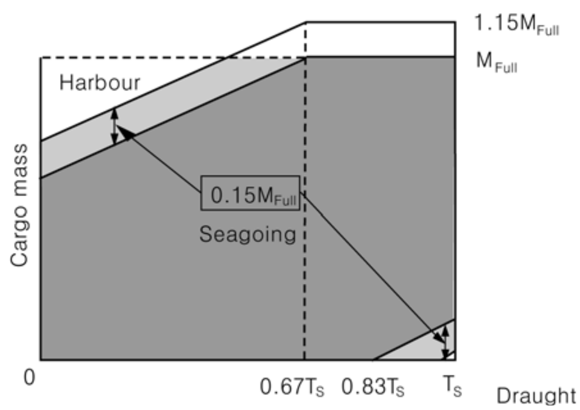


Fig 3: Example of mass curve for BC-B and BC-C ships not having {No MP} assigned

2.1.5 BC-B and BC-C ships having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(T_S - T_i)}{h}$$

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$W_{\min}(T_i) = 0$ for $T_i \le T_{HB}$

$W_{\min}(T_i) = 1.025V_H \dfrac{(T_i - T_{HB})}{h}$ for $T_S \ge T_i > T_{HB}$ or

$W_{\min}(T_i) = 0.5M_H - 1.025V_H \dfrac{(T_S - T_i)}{h}$ for $T_S \ge T_i$

$W_{\min}(T_i) \ge 0.0$

Example for mass curve of cargo hold for BC-B or BC-C ships with {No MP} is shown in **Fig 4.**

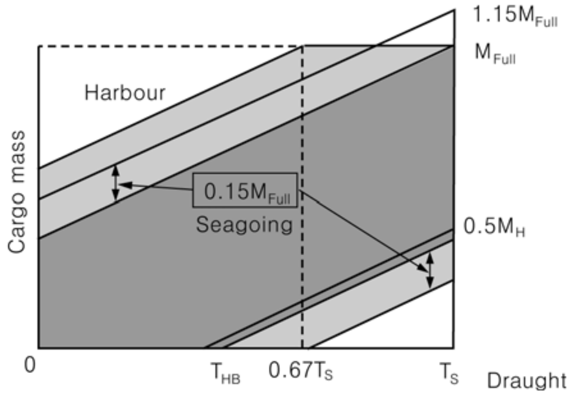


Fig 4: Example of mass curve for BC-B and BC-C ships having {No MP} assigned

2.2 Maximum permissible mass and minimum required masses of single cargo hold in harbour condition

2.2.1 General

The cargo mass curves of single cargo hold in harbour condition are defined in **[2.2.2]**. However if the ship structure is checked for more severe loading conditions than ones considered in **Ch 4, Sec 7, [3.7.1],** the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

2.2.2 All ships

The maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15 % of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

2.2.3 BC-A ship not having {No MP} assigned

The maximum permissible mass ($W_{\max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in **[2.1.2]**:

For loaded hold

$W_{max}(T_i) = M_{HD}$ for $T_i \geq 0.67T_S$

$W_{max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \dfrac{0.67T_S - T_i}{h}$ for $T_i < 0.67T_S$

2.2.4 BC-A ship having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in **[2.1.3]**:

For empty hold which can be empty at the maximum draught

$W_{max}(T_i) = M_{Full}$ for $T_S \geq T_i \geq 0.67T_S$

$W_{max}(T_i) = M_{Full} - 1.025V_H \dfrac{(0.67T_S - T_i)}{h}$ for $T_i < 0.67T_S$

2.2.5 BC-B and BC-C ships having {No MP} assigned

The maximum permissible mass $W_{max}(T_i)$ at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in **[2.2.2]**:

$W_{max}(T_i) = M_{Full}$ for $T_S \geq T_i \geq 0.67T_S$

$W_{max}(T_i) = M_{Full} - 1.025V_H \dfrac{(0.67T_S - T_i)}{h}$ for $T_i < 0.67T_S$

3. Maximum and minimum masses of cargo of two adjacent holds

3.1 Maximum permissible mass and minimum required masses of two adjacent holds in seagoing condition

3.1.1 General

The cargo mass curves of two adjacent cargo holds in seagoing condition are defined in **[3.1.2]** and **[3.1.3]**. However if the ship structure is checked for more severe loading conditions than ones considered in **Ch 4, Sec 7, [3.7.1],** the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

3.1.2 BC-A ships with "Block loading" and not having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the greater of the following formulae:

$$W_{max}(T_i) = \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_s - T_i)$$

or

$$W_{max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_s - T_i)$$

However, $W_{max}(T_i)$ is no case to be greater than ΣM_{BLK}.

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$W_{min}(T_i) = 0$ for $T_i \leq 0.75T_S$

$$W_{min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0.75T_S) \quad \text{for} \quad T_S \geq T_i > 0.75T_S$$

3.1.2 bis BC-A ships with "Block loading" and having {No MP} assigned

The maximum permissible mass $W_{max}(T_i)$ at various draughts T_i is obtained, in t, by the following formula:

$$W_{max}(T_i) = \sum(M_{BLK} + 0.1M_H) - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_s - T_i)$$

However, $W_{max}(T_i)$ is no case to be greater than M_{BLK}.

The minimum required cargo mass $W_{min}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for} \quad T_i \leq T_{HB}$$

$$W_{min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{HB}) \quad \text{for} \quad T_S \geq T_i > T_{HB}$$

Examples for mass curve of cargo hold for BC-A with block loading ships are shown in **Fig 5**.

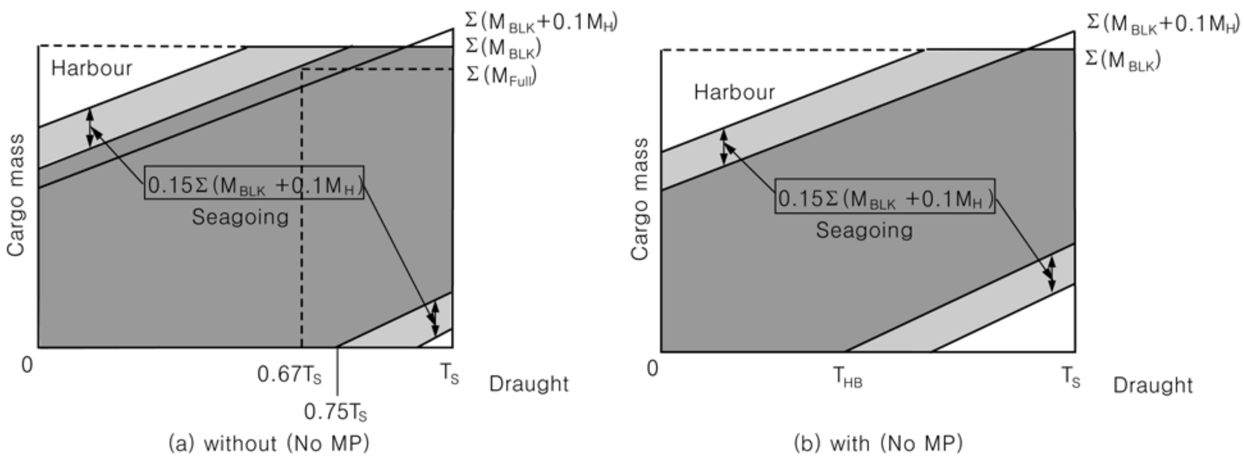


Fig 5: Example of mass curve for BC-A ships with "Block loading"

3.1.3 (void)

3.1.4 BC-A ships without "Block loading" and BC-B, BC-C ships, not having {No MP} assigned

The maximum permissible mass $W_{max}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{max}(T_i) = \sum M_{Full} \quad \text{for} \quad T_S \geq T_i \geq 0.67T_S$$

$$W_{max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_S - T_i) \quad \text{for} \quad T_i < 0.67T_S$$

The minimum required cargo mass $W_{min}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for} \quad T_i \le 0.75T_S$$

$$W_{min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - 0.75T_S) \quad \text{for} \quad T_S \ge T_i > 0.75T_S$$

3.1.5 BC-A ships without "Block loading" and BC-B, BC-C ships, having {No MP} assigned

The maximum permissible mass $W_{max}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_S - T_i) \quad \text{for} \quad T_i < T_S$$

The minimum required cargo mass $W_{min}(T_i)$ at various draughts T_i is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for} \quad T_i \le T_{HB}$$

$$W_{min}(T_i) = 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(T_i - T_{HB}) \quad \text{for} \quad T_S \ge T_i > T_{HB}$$

Examples for mass curve of cargo hold for BC-A without block loading and BC-B or BC-C are shown in **Fig 6.**

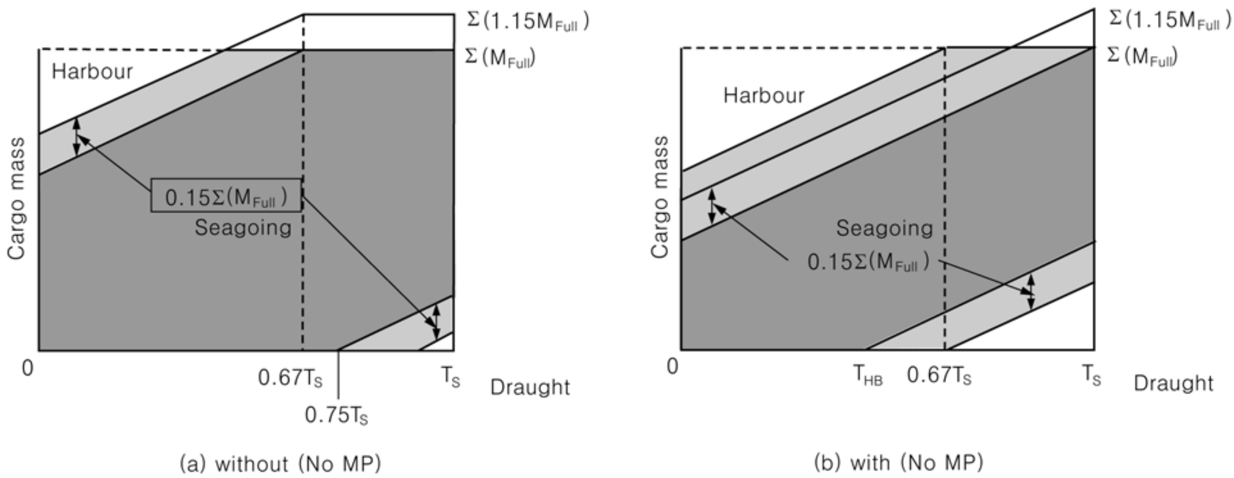


Fig 6: Example of mass curve for BC A-ship without block loading and BC-B or BC-C ships

3.2 Maximum permissible mass and minimum required masses of two adjacent cargo holds in harbour condition

3.2.1 General

The cargo mass curves of two adjacent cargo holds in harbour condition are defined in **[3.2.2]**. However if the ship structure is checked for more severe loading conditions than ones considered in **Ch 4, Sec 7, [3.7.1],** the minimum required cargo mass and the maximum allowable cargo mass can be based on those corresponding loading conditions.

3.2.2 All ships

The maximum permissible cargo mass and minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15 % of the maximum permissible mass at the maximum draught for the cargo hold in seagoing condition. However, maximum permissible mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

3.2.3 BC-A ships with “Block loading” and having {No MP} assigned

The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in **[3.1.2 bis]**:

$$W_{max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_S - T_i)$$

$$W_{max}(T_i) \le \sum M_{BLK}$$

3.2.4 BC-A ships without “Block loading” and BC-B, BC-C ships, having {No MP} assigned

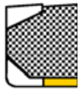
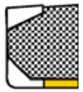
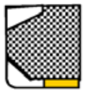
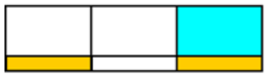
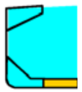
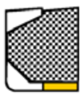
The maximum permissible mass ($W_{max}(T_i)$) at various draughts T_i in harbour condition is also to be checked by the following formulae in addition to the requirements in **[3.1.5]:**

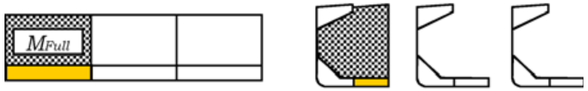
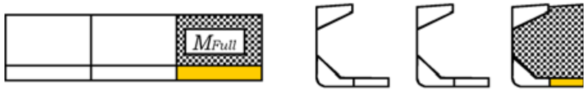
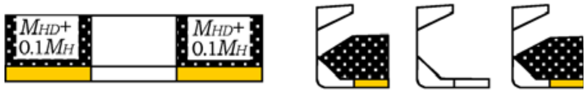
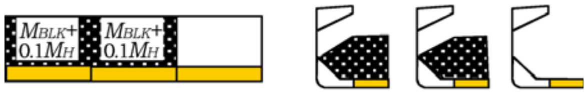
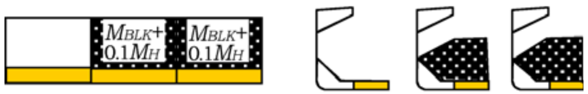
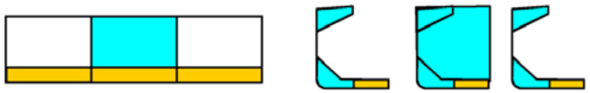
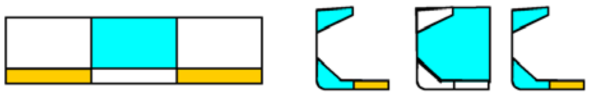
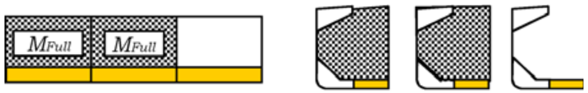
$$W_{max}(T_i) = \sum M_{Full} \qquad \text{for} \quad T_S \ge T_i \ge 0.67T_S$$

$$W_{max}(T_i) = \sum M_{Full} - 1.025\left(\frac{V_f}{h_f} + \frac{V_a}{h_a}\right)(0.67T_S - T_i) \qquad \text{for} \quad T_i < 0.67T_S$$

Appendix 2 - Standard Loading Condition for Direct Strength Analysis

Table 1: Bending moment analysis applicable to empty hold in alternate condition of BC-A (mid-hold is empty hold)

No.	Description[a]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave) / Still water vertical bending moment[b]				Remarks (see below)
1	Full Load ([2.1.3])	T_S					P1				1), 2)
							0.5 $M_{SW,S}$				
2	Full Load ([3.2.1])	T_S					P1				1), 3)
							0.5 $M_{SW,S}$				
3	Slack Load ([3.2.2])	T_S					P1				3)
							0				
4	Slack Load ([3.2.2])	T_S					P1				3)
							0				
5	Deepest Ballast [3.2.3])	T_{HB}					R1	R1	P1		4), 5)
							$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$		
6	Multi Port-3 ([3.3.3])	0.67 T_S					H1				3), 6)
							$M_{SW,S}$				
7	Multi Port-3 ([3.3.3])	0.67 T_S					H1				3), 6)
							$M_{SW,S}$				

No.	Description[a)]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) / Still water vertical bending moment[b)]				Remarks (see below)
8	Multi Port-4 ([3.3.4])	0.75 T_S		F2	P1			3), 6)
				$M_{SW,H}$	$M_{SW,S}$			
9	Multi Port-4 ([3.3.4])	0.75 T_S		F2	P1			3), 6)
				$M_{SW,H}$	$M_{SW,S}$			
10	Alternate Load ([3.4.1])	T_S		F2	P1			2)
				$M_{SW,H}$	0			
11	Alt-Block Load ([3.4.3])	T_S		H1	F2	P1		2), 8), 9), 10)
				$M_{SW,S}$	$M_{SW,H}$	$M_{SW,S}$		
12	Alt-Block Load ([3.4.3])	T_S		H1	F2	P1		2), 8), 9), 10)
				$M_{SW,S}$	$M_{SW,H}$	$M_{SW,S}$		
13	Heavy Ballast ([3.5.1])	T_{HB}(min)		H1	R1	R1		11),12)
				$M_{SW,S}$	0	$M_{SW,S}$		
14	Heavy Ballast	T_{HB}(min)		R1	R1			11), 12), 13)
				0	$M_{SW,S}$			
15	Harbour Condition-2 ([3.6.2])	0.67 T_S		---	---			3), 14), 15)
				$M_{SW,P,H}$	$M_{SW,P,S}$			

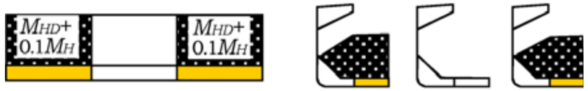
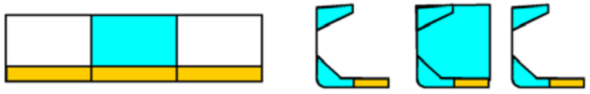
No.	Description[a)]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave)				Remarks (see below)
							Still water vertical bending moment[b)]				
16	Harbour Condition-2 ([3.6.2])	0.67 T_S					---	---			3), 14), 15)
							$M_{SW,P,H}$	$M_{SW,P,S}$			

a) Referred paragraph number corresponds to loading pattern prescribed in **Ch 4, Sec 7.**
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively
$M_{SW,P,H}$, $M_{SW,P,S}$: Allowable still water vertical bending moment for harbour condition, hogging or sagging respectively

Remarks

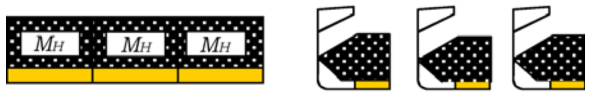
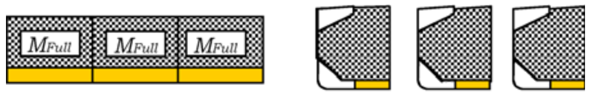
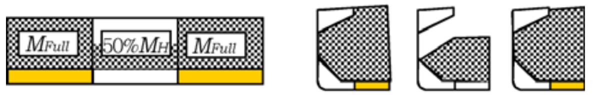
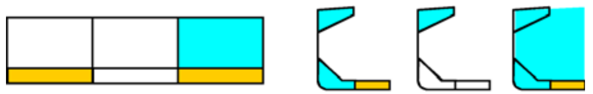
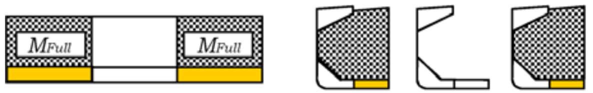
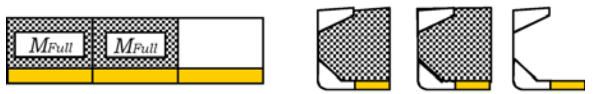
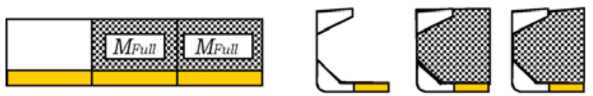
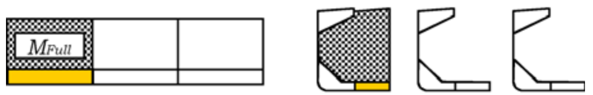
1) Single loading pattern in M_{Full} with cargo density of 3.0 t/m^3 can be analyzed in lieu of these two loading patterns.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) M_H/V_H or 1.0 t/m^3, whichever is greater, is to be used as cargo density for calculation of dry cargo pressure.
4) In case of no ballast hold, normal ballast condition with assuming $M_{SW,S} = 0$ is to be analyzed.
5) Position of ballast hold is to be adjusted as appropriate.
6) This condition is not required when {no MP} notation is assigned.
7) For vertical shear force analysis, maximum shear force ($Q_{SW} + Q_{WV}$) with reduced vertical bending moment (0.8 M_{SW} + 0.65 $C_{WV}M_{WV}$) is to be considered.
8) This condition is only required when such a condition is prepared in the loading manual.
9) "M_{BLK}" is maximum cargo mass according to the design loading condition in the loading manual.
10) Actual still water vertical bending moment, as given in the loading manual, may be used in stead of design value.
11) This condition is to be considered for the empty hold which is assigned as ballast hold if any.
12) Minimum draught among heavy ballast conditions is to be used in principle.
13) This condition is not required when such a condition is explicitly prohibited in the loading manual.
14) This condition is to be analyzed when {noMP} notation is assigned.
15) External sea pressures and internal pressures can be considered as static.

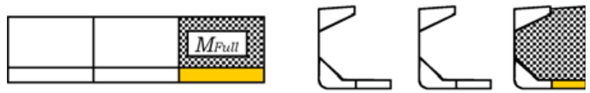
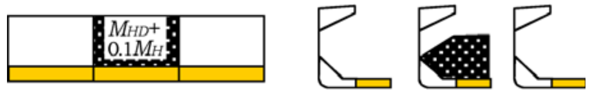
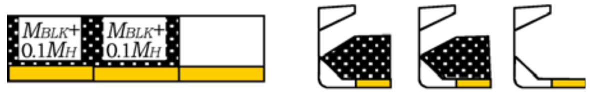
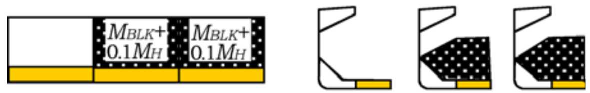
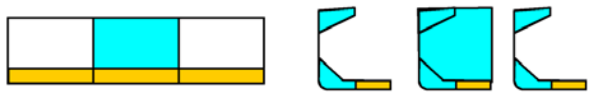
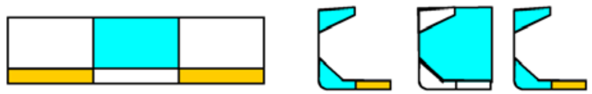
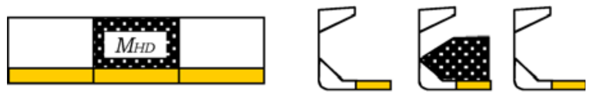
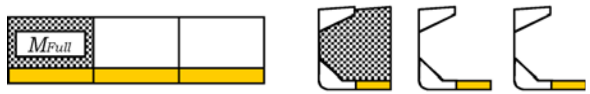
Table 2: Shear force analysis applicable to empty hold of BC-A (mid-hold is empty hold)

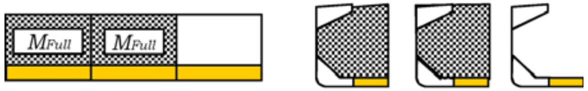
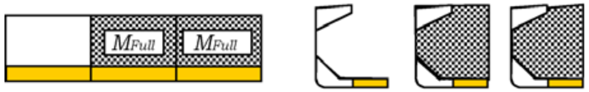
No.	Description[a]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) / Still water vertical bending moment[b] / Still water shear force				Remarks (see Table 1 above)
10SF	Alternate Load ([3.4.1])	T_S		F2				2), 7)
				0.8 $M_{SW,H}$				
				Q_{SW}				
13SF	Heavy Ballast ([3.5.1])	T_{HB}(min)		H1				7), 11), 12)
				0.8 $M_{SW,S}$				
				Q_{SW}				

a) Referred paragraph number corresponds to loading pattern prescribed in **Ch 4, Sec 7.**
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively

Table 3: Bending moment analysis applicable to loaded hold in alternate condition of BC-A (mid-hold is loaded hold)

No.	Description[a]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) / Still water vertical bending moment[b]				Remarks (see below)
1	Full Load ([2.1.3])	T_S		P1				1), 2)
				0.5 $M_{SW,S}$				
2	Full Load ([3.2.1])	T_S		P1				1), 3)
				0.5 $M_{SW,S}$				
3	Slack Load ([3.2.2])	T_S		P1				3)
				0				
4	Deepest Ballast ([3.2.3])	T_{HB}		R1	R1	P1		4), 5)
				$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$		
5	Multi Port-2 ([3.3.2])	0.83 T_S		F2	P1			3), 6)
				$M_{SW,H}$	$M_{SW,S}$			
6	Multi Port-3 ([3.3.3])	0.67 T_S		P1				3), 6)
				$M_{SW,S}$				
7	Multi Port-3 ([3.3.3])	0.67 T_S		P1				3), 6)
				$M_{SW,S}$				
8	Multi Port-4 ([3.3.4])	0.75 T_S		F2	R1	R1	P1	3), 6)
				$M_{SW,H}$	$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$	

No.	Description[a)]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave)				Remarks (see below)
							Still water vertical bending moment[b)]				
9	Multi Port-4 ([3.3.4])	0.75 T_S					F2	R1	R1	P1	3), 6)
							$M_{SW,H}$	$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$	
10	Alternate Load ([3.4.2])	T_S					F2	P1			2)
							$M_{SW,H}$	0			
11	Alt-Block Load ([3.4.3])	T_S					H1	F2	P1		2), 8), 9), 10)
							$M_{SW,S}$	$M_{SW,H}$	$M_{SW,S}$		
12	Alt-Block Load ([3.4.3])	T_S					H1	F2	P1		2), 8), 9), 10)
							$M_{SW,S}$	$M_{SW,H}$	$M_{SW,S}$		
13	Heavy Ballast ([3.5.1])	T_{HB}(min)					H1	R1	R1		11),12)
							$M_{SW,S}$	0	$M_{SW,S}$		
14	Heavy Ballast	T_{HB}(min)					R1	R1			11), 12), 13)
							0	$M_{SW,S}$			
15	Harbour Condition-1 ([3.6.1])	0.67 T_S					---	---			2), 15)
							$M_{SW,P,H}$	$M_{SW,P,S}$			
16	Harbour Condition-1 ([3.6.1])	0.67 T_S					---	---			3), 14), 15)
							$M_{SW,P,H}$	$M_{SW,P,S}$			

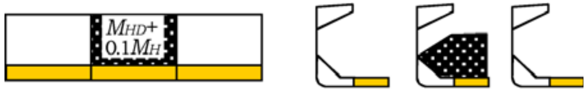
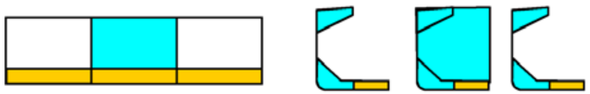
No.	Description[a)]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) Still water vertical bending moment[b)]				Remarks (see below)
17	Harbour Condition-1 ([3.6.1])	0.67 T_S		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)
18	Harbour Condition-2 ([3.6.2])	0.67 T_S		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)
19	Harbour Condition-2 ([3.6.2])	0.67 T_S		--- $M_{SW,P,H}$	--- $M_{SW,P,S}$			3), 14), 15)

a) Referred paragraph number corresponds to loading pattern prescribed in **Ch 4, Sec 7.**
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively
$M_{SW,P,H}$, $M_{SW,P,S}$: Allowable still water vertical bending moment for harbour condition, hogging or sagging respectively

Remarks

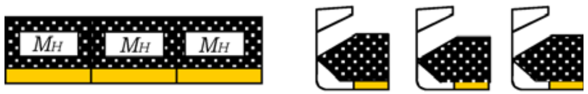
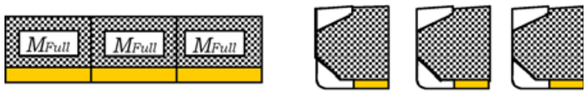
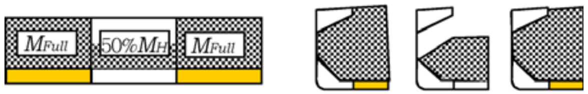
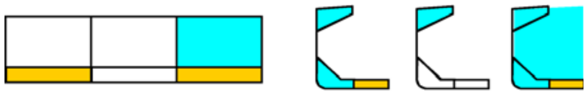
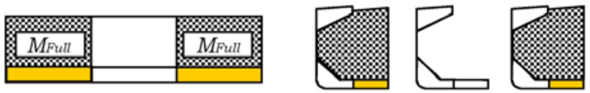
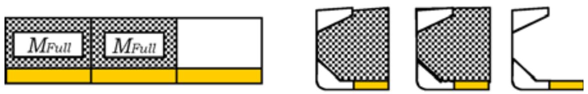
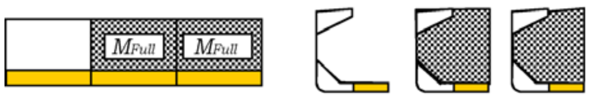
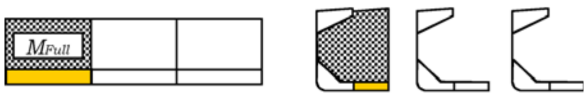
1) Single loading pattern in M_{Full} with cargo density of 3.0 t/m^3 can be analyzed in lieu of these two loading patterns.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) M_H/V_H or 1.0 t/m^3, whichever is greater, is to be used as cargo density for calculation of dry cargo pressure.
4) In case of no ballast hold, normal ballast condition with assuming $M_{SW,S}=0$ is to be analyzed.
5) Position of ballast hold is to be adjusted as appropriate.
6) This condition is not required when {no MP} notation is assigned.
7) For vertical shear force analysis, maximum shear force ($Q_{SW}+Q_{WV}$) with reduced vertical bending moment ($0.8\ M_{SW}+0.65\ C_{WV}M_{WV}$) is to be considered.
8) This condition is only required when such a condition is prepared in the loading manual.
9) "M_{BLK}" is maximum cargo mass according to the design loading condition in the loading manual.
10) Actual still water vertical bending moment, as given in the loading manual, may be used in stead of design value.
11) This condition is to be considered for the empty hold which is assigned as ballast hold if any.
12) Minimum draught among heavy ballast conditions is to be used in principle.
13) This condition is not required when such a condition is explicitly prohibited in the loading manual.
14) This condition is to be analyzed when {noMP} notation is assigned.
15) External sea pressures and internal pressures can be considered as static.

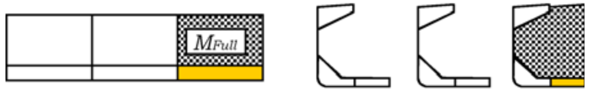
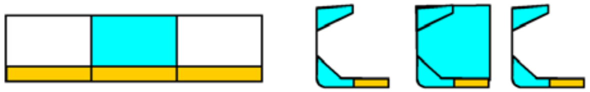
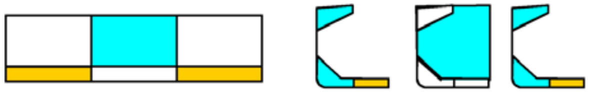
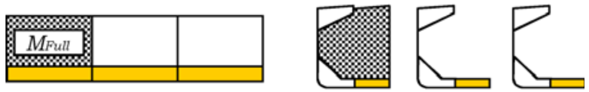
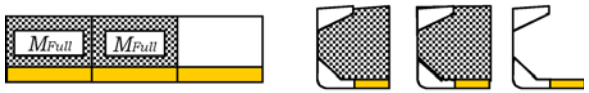
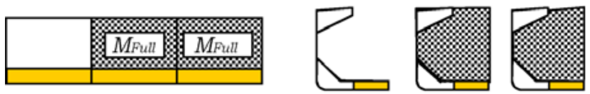
Table 4: Shear force analysis applicable to loaded hold of BC-A (mid-hold is loaded hold)

No.	Description[a)]	Draught	Loading Pattern (Aft, Mid, Fore)	Load Case (Design Wave) / Still water vertical bending moment[b)] / Still water shear force				Remarks (see Table 3 above)
10SF	Alternate Load ([3.4.2])	T_S		F2				2), 7)
				0.8 $M_{SW,H}$				
				Q_{SW}				
13SF	Heavy Ballast ([3.5.1])	T_{HB}(min)		H1				7), 11), 12)
				0.8 $M_{SW,S}$				
				Q_{SW}				

a) Referred paragraph number corresponds to loading pattern prescribed in **Ch 4, Sec 7.**
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively

Table 5: Bending moment analysis applicable to BC-B and BC-C

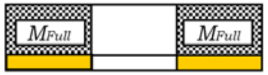
No.	Description[a)]	Draught	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave) / Still water vertical bending moment[b)]				Remarks (see below)
1	Full Load ([2.1.3])	T_S		P1				1), 2), 3)
				0.5 $M_{SW,S}$				
2	Full Load ([3.2.1])	T_S		P1				2), 4)
				0.5 $M_{SW,S}$				
3	Slack Load ([3.2.2])	T_S		P1				4)
				0				
4	Deepest Ballast ([3.2.3])	T_{HB}		R1	R1	P1	F2	5), 6), 14)
				$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$	$M_{SW,H}$	
5	Multi Port-2 ([3.3.2])	0.83 T_S		F2	P1			4), 7)
				$M_{SW,H}$	$M_{SW,S}$			
6	Multi Port-3 ([3.3.3])	0.67 T_S		P1				4), 7)
				$M_{SW,S}$				
7	Multi Port-3 ([3.3.3])	0.67 T_S		P1				4), 7)
				$M_{SW,S}$				
8	Multi Port-4 ([3.3.4])	0.75 T_S		F2	R1	R1	P1	4), 7)
				$M_{SW,H}$	$M_{SW,H}$	$M_{SW,S}$	$M_{SW,S}$	

No.	Description[a)]	Draught	Loading Pattern	Aft	Mid	Fore	Load Case (Design Wave) Still water vertical bending moment[b)]				Remarks (see below)
9	Multi Port-4 ([3.3.4])	0.75 T_S					F2 $M_{SW,H}$	R1 $M_{SW,H}$	R1 $M_{SW,S}$	P1 $M_{SW,S}$	4), 7)
10	Heavy Ballast ([3.5.1])	T_{HB}(min)					H1 $M_{SW,S}$	R1 0	R1 $M_{SW,S}$		9), 10)
11	Heavy Ballast	T_{HB}(min)					R1 0	R1 $M_{SW,S}$			9), 10), 11)
12	Harbour Condition-1 ([3.6.1])	0.67 T_S					--- $M_{S,P}$(+)	--- $M_{S,P}$(-)			4), 12),13)
13	Harbour Condition-1 ([3.6.1])	0.67 T_S					--- $M_{S,P}$(+)	--- $M_{S,P}$(-)			4), 12), 13)
14	Harbour Condition-2 ([3.6.2])	0.67 T_S					--- $M_{S,P}$(+)	--- $M_{S,P}$(-)			4), 12), 13)
15	Harbour Condition-2 ([3.6.2])	0.67 T_S					--- $M_{S,P}$(+)	--- $M_{S,P}$(-)			4), 12), 13)

a) Referred paragraph number corresponds to loading pattern prescribed in **Ch 4, Sec 7.**
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively
$M_{SW,P,H}$, $M_{SW,P,S}$: Allowable still water vertical bending moment for harbour condition, hogging or sagging respectively
Remarks

1) Applicable to BC-B only.
2) For BC-B single loading pattern in M_{Full} with cargo density of 3.0 t/m^3 can be analyzed in lieu of these two loading patterns.
3) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
4) M_H / V_H or 1.0 t/m^3, which ever is greater, is to be used as cargo density for calculation of dry cargo pressure.
5) In case of no ballast hold, normal ballast condition with assuming $M_{SW,S} = 0$ is to be analyzed.
6) Position of ballast hold is to be adjusted as appropriate.
7) This condition is not required when {no MP} notation is assigned.
8) For vertical shear force analysis, maximum shear force ($Q_{SW} + Q_{WV}$) with reduced vertical bending moment (0.8 M_{SW} + 0.65 $C_{WV} M_{WV}$) is to be considered.
9) This condition is to be considered for the cargo hold which is assigned as ballast hold if any.
10) Minimum draught among heavy ballast conditions is to be used in principle.
11) This condition is not required when such a condition is explicitly prohibited in the loading manual.
12) This condition is to be analyzed when {no MP} notation is assigned.
13) External sea pressures and internal pressures can be considered as static.
14) Load case F2 is to be analyzed when {no MP} notation is assigned.

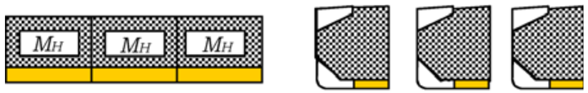
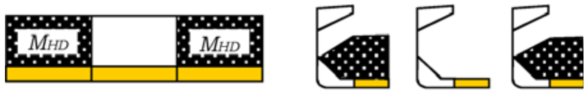
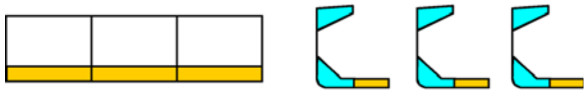
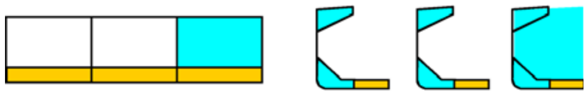
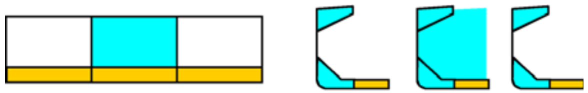
Table 6: Shear force analysis applicable to BC-B and BC-C

No.	Description[a)]	Draught	Loading Pattern	Aft / Mid / Fore	Load Case (Design Wave) Still water vertical bending moment[b)] Still water shear force				Remarks (see Table 5 above)
5SF	Multi Port-2 ([3.3.2])	0.83 T_S			F2				4), 7), 8)
					0.8 $M_{SW,H}$				
					Q_{SW}				
10SF	Heavy Ballast ([3.5.1])	T_{HB}(min)			H1				8), 9), 10)
					0.8 $M_{SW,S}$				
					Q_{SW}				

a) Referred paragraph number corresponds to loading pattern prescribed in **Ch 4, Sec 7.**
b) $M_{SW,H}$, $M_{SW,S}$: Allowable still water vertical bending moment for seagoing condition, hogging or sagging respectively

Appendix 3 - Standard Loading Condition for fatigue assessment

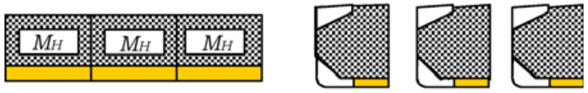
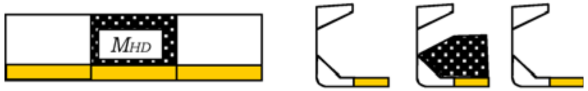
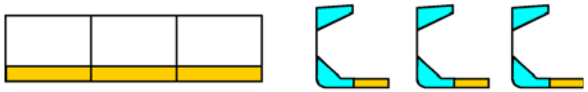
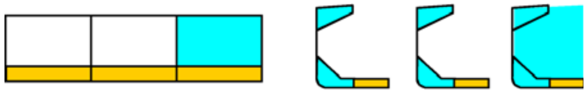
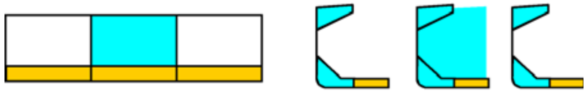
Table 1: Fatigue Assessment applicable to empty hold in alternate condition of BC-A (mid-hold is empty hold)

No.	Description	Draught[a)]	Loading Pattern Aft Mid Fore	Load Case (Design Wave)				Still water vertical bending moment[b)]	Remarks (see below)
1	Full Load	T		H1	F1	R1	P1	$M_{S(1)}$	1)
				H2	F2	R2	P2		
2	Alternate Load	T		H1	F1	R1	P1	$M_{S(2)}$	2)
				H2	F2	R2	P2		
3	Normal Ballast	T_{NB}		H1	F1	R1	P1	$M_{S(3)}$	
				H2	F2	R2	P2		
4	Heavy Ballast	T_{HB}		H1	F1	R1	P1	$M_{S(4)}$	3)
				H2	F2	R2	P2		
				H1	F1	R1	P1	$M_{S(4)}$	4)
				H2	F2	R2	P2		

a) T : Moulded draught, T_{NB} : Draught at normal ballast condition, T_{HB} : Draught at heavy ballast condition
b) $M_{S(1)}$, $M_{S(2)}$, $M_{S(3)}$, $M_{S(4)}$: Still water vertical bending moment as defined in **[3.2.2]** of **Ch 8, Sec 3**

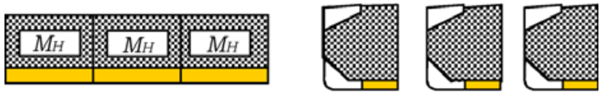
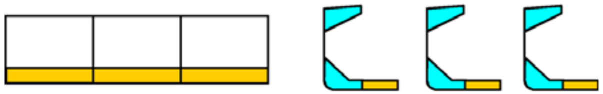
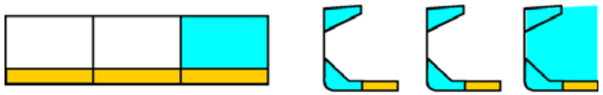
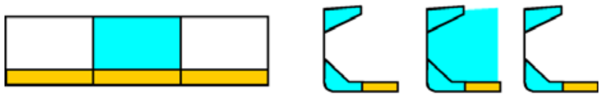
Remarks
1) M_H / V_H is to be used as cargo density for calculation of dry cargo pressure.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) This condition is to be applied only for the empty hold which is not assigned as ballast hold. Position of ballast hold is to be adjusted as appropriate.
4) This condition is to be applied only for the empty hold which is assigned as ballast hold.

Table 2: Fatigue Assessment applicable to loaded hold in alternate condition of BC-A (mid-hold is loaded hold)

No.	Description	Draught[a)]	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave)				Still water vertical bending moment[b)]	Remarks (see below)
1	Full Load	T		H1	F1	R1	P1	$M_{S(1)}$	1)
				H2	F2	R2	P2		
2	Alternate Load	T		H1	F1	R1	P1	$M_{S(2)}$	2)
				H2	F2	R2	P2		
3	Normal Ballast	T_{NB}		H1	F1	R1	P1	$M_{S(3)}$	
				H2	F2	R2	P2		
4	Heavy Ballast	T_{HB}		H1	F1	R1	P1	$M_{S(4)}$	3)
				H2	F2	R2	P2		
				H1	F1	R1	P1	$M_{S(4)}$	4)
				H2	F2	R2	P2		

a) T : Moulded draught, T_{NB} : Draught at normal ballast condition, T_{HB} : Draught at heavy ballast condition
b) $M_{S(1)}$, $M_{S(2)}$, $M_{S(3)}$, $M_{S(4)}$: Still water vertical bending moment as defined in **[3.2.2]** of **Ch 8, Sec 3**
Remarks
1) M_H / V_H is to be used as cargo density for calculation of dry cargo pressure.
2) Cargo density 3.0 t/m^3 is to be used for calculation of dry cargo pressure in principle.
3) This condition is to be applied only for the empty hold which is not assigned as ballast hold. Position of ballast hold is to be adjusted as appropriate.
4) This condition is to be applied only for the empty hold which is assigned as ballast hold.

Table 3: Fatigue Assessment applicable to BC-B, BC-C

No.	Description	Draught[a)]	Loading Pattern / Aft / Mid / Fore	Load Case (Design Wave)				Still water vertical bending moment[b)]	Remarks (see below)
1	Full Load	T		H1	F1	R1	P1	$M_{S(1)}$	1)
				H2	F2	R2	P2		
2	Normal Ballast	T_{NB}		H1	F1	R1	P1	$M_{S(3)}$	
				H2	F2	R2	P2		
3	Heavy Ballast	T_{HB}		H1	F1	R1	P1	$M_{S(4)}$	2)
				H2	F2	R2	P2		
				H1	F1	R1	P1	$M_{S(4)}$	3)
				H2	F2	R2	P2		

a) T : Moulded draught, T_{NB} : Draught at normal ballast condition, T_{HB} : Draught at heavy ballast condition

b) $M_{S(1)}$, $M_{S(2)}$, $M_{S(3)}$, $M_{S(4)}$: Still water vertical bending moment as defined in **[3.2.2]** of **Ch 8, Sec 3**

Remarks

1) M_H / V_H is to be used as cargo density for calculation of dry cargo pressure.

2) This condition is to be applied only for the mid-hold which is not assigned as ballast hold. Position of ballast hold is to be adjusted as appropriate.

3) This condition is to be applied only for the mid-hold which is assigned as ballast hold. ⚓

Chapter 5

Hull Girder Strength

Section 1 – Yielding check

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

M_{SW} : Design still water bending moment in intact condition, in kN.m, at the hull transverse section considered, defined in **Ch 4, Sec 3, [2.2]**:

$M_{SW} = M_{SW,H}$ in hogging conditions

$M_{SW} = M_{SW,S}$ in sagging conditions

M_{WV} : Vertical wave bending moment in intact condition, in kN.m, at the hull transverse section considered, defined in **Ch 4, Sec 3, [3.1]**

$M_{SW,F}$: Still water bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, to be calculated according to **Ch 4, Sec 3**

$M_{WV,F}$: Vertical wave bending moment, in kN.m, in flooded conditions, at the hull transverse section under consideration, to be calculated according to **Ch 4, Sec 3**

$M_{WV,P}$: Vertical wave bending moment, in kN.m, in harbour conditions, at the hull transverse section under consideration, to be calculated according to **Ch 4, Sec 3**

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in **Ch 4, Sec 3, [3.3]**

Q_{SW} : Design still water shear force in intact condition, in kN, at the hull transverse section considered, defined in **Ch 4, Sec 3, [2.3]**

Q_{WV} : Vertical wave shear force in intact condition, in kN, at the hull transverse section considered, defined in **Ch 4, Sec 3, [3.2]**

$Q_{SW,F}$: Still water shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be calculated according to **Ch 4, Sec 3**

$Q_{WV,F}$: Vertical wave shear force, in kN, in flooded conditions, at the hull transverse section under consideration, to be calculated according to **Ch 4, Sec 3**

$Q_{WV,P}$: Vertical wave shear force, in kN, in harbour conditions, at the hull transverse section under consideration, to be calculated according to **Ch 4, Sec 3**

k : Material factor, as defined in **Ch 1, Sec 4, [2.2.1]**

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in **[1.2]**, with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**

V_D : Vertical distance, in m, defined in **[1.4.2]**

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to **[1.5]**

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to **[1.5]**

S : Net first moment, in m^3, of the hull transverse section, to be calculated according to **[1.6]**

Z_A : Net section modulus, in m^3,at any point of the hull transverse section, to be calculated according **[1.4.1]**

Z_{AB}, Z_{AD}: Net section moduli, in m^3, at bottom and deck, respectively, to be calculated according to **[1.4.2]**

C : Wave parameter defined in **Ch 1, Sec 4, [2.3.1]**

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm^2, defined in **[3.1.1]**

$\tau_{1,ALL}$: Allowable shear stress, in N/mm^2, defined in **[3.2.1]**

ρ : Sea water density, taken equal to 1.025 t/m^3.

1. Strength characteristics of the hull girder transverse sections

1.1 General

1.1.1

This Article specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in **[2]** to **[5]**, in association with the hull girder loads specified in **Ch 4, Sec 3.**

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below and including the strength deck defined in **[1.3]**, taking into account the requirements in **[1.2.2]** to **[1.2.9]**.
These members are to be considered as having (see also **Ch 3, Sec 2**) net offered scantlings based on gross offered thickness reduced by 0.5 t_C, when the hull girder strength characteristics are used for:

- the hull girder yielding check according to **[2]** to **[5]**
- the ultimate strength check in **Ch 5, Sec 2**
- the calculation of the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members according to **Ch 6.**

1.2.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.3 Longitudinal ordinary stiffeners or girders welded above the strength deck

Longitudinal ordinary stiffeners or girders welded above the strength deck (including the deck of any trunk fitted as specified in **[1.2.2]**) are to be included in the hull girder transverse sections.

1.2.4 Longitudinal girders between hatchways, supported by longitudinal bulkheads

Where longitudinal girders, effectively supported by longitudinal bulkheads, are fitted between hatchways, the sectional area of these longitudinal girders are to be included in the hull girder transverse.

1.2.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations are not to be included in the hull girder transverse sections.

1.2.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a

Young's modulus E equal to 2.06×10^5 N/mm^2, the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$$A_{SE} = \frac{E}{2.06 \cdot 10^5} A_M$$

where:

A_M : Sectional area, in m^2, of the member under consideration.

1.2.7 Large openings

Large openings are:

- elliptical openings exceeding 2.5 m in length or 1.2 m in breadth
- circular openings exceeding 0.9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.8 Small openings

Smaller openings than those in **[1.2.7]** in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \leq 0.06 (B - \Sigma b)$$

where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in **Fig 1**

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in **Fig 1.**

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0.25 h_w, without being greater than 75 mm, where h_w is the web height, in mm.
Otherwise, the excess is to be deducted from the sectional area or compensated.

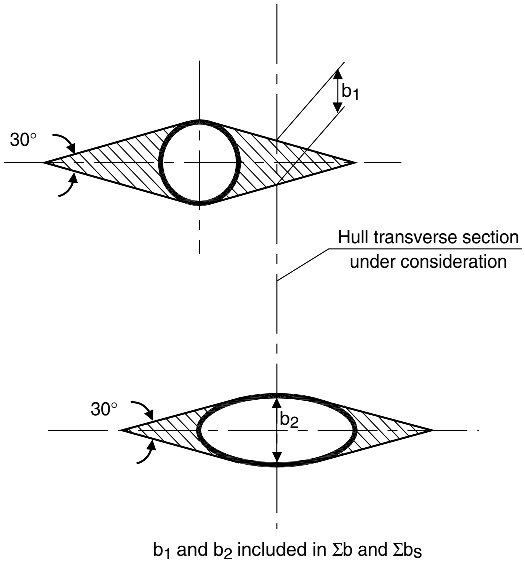


Fig 1: Calculation of Σb and Σb_S

1.3 Strength deck

1.3.1

The strength deck is, in general, the uppermost continuous deck.
In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.3.2

A superstructure extending at least $0.15\,L$ within $0.4\,L$ amidships may generally be considered as contributing to the longitudinal strength.
For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, to evaluate their percentage of participation to the longitudinal strength.

1.4 Section modulus

1.4.1

The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

1.4.2

The section moduli at bottom and at deck are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

V_D : Vertical distance, in m, taken equal to:

- in general:

  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck at side, defined in **[1.3]**, with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in **[1.2.2]**:

  $$V_D = (z_T - N)\left(0.9 + 0.2\frac{y_T}{B}\right) \geq z_D - N$$

  where:

  y_T, z_T: Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**; y_T and z_T are to be measured for the point which maximises the value of V_D

- if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, as specified in **[1.2.3]**, V_D is to be obtained from the formula given above for continuous trunks and hatch coamings. In this case, y_T and z_T are the Y and Z co-ordinates, in m, of the top of the longitudinal stiffeners or girders with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4].**

1.5 Moments of inertia

1.5.1

The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in **[1.2].**

1.6 First moment

1.6.1

The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in **[1.2]** located above the z level.

2. Hull girder stresses

2.1 Normal stresses

2.1.1 General

The normal stresses in a member made in material other than steel with a Young's modulus E equal to 2.06×10^5 N/mm^2, included in the hull girder transverse sections as specified in **[1.2.6]**, are obtained from the following formula:

$$\sigma_1 = \frac{E}{2.06\cdot10^5}\sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm^2, in the member under consideration, calculated according to **[2.1.2]** and **[2.1.3]** considering this member as having the steel equivalent sectional area A_{SE} defined in **[1.2.6].**

2.1.2 Normal stresses induced by vertical bending moments

The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section, located below z_{VD}, where $z_{VD} = V_D + N$:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A} 10^{-3}$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}} 10^{-3}$$

- at deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^{-3}$$

2.1.3 Normal stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to BC-A or BC-B ships, in addition to **[2.1.2].**
The normal stresses, in the flooded conditions specified in **Ch 4, Sec 3**, are to be obtained at any point, in N/mm^2, from the following formula:

$$\sigma_1 = \frac{M_{SW,F} + M_{WV,F}}{Z_A} 10^{-3}$$

2.2 Shear stresses

2.2.1 General

The shear stresses induced by vertical shear forces Q_{SW} and Q_{WV} in intact condition and, for BC-A and BC-B ships by vertical shear forces $Q_{SW,F}$ and $Q_{WV,F}$ in flooded condition are normally to be obtained through direct analyses.
When they are combined, vertical shear forces Q_{SW} and Q_{WV} in intact condition are to be taken with the same sign. The same is to be applied also for combination of vertical shear forces $Q_{SW,F}$ and $Q_{WV,F}$ in flooded condition.
The shear force correction ΔQ_C is to be taken into account, in accordance with **[2.2.2]**. The shear force correction need not to be considered at the fore end of foremost hold and aft end of aftermost hold.
As an alternative to this procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} in intact condition and, for BC-A and BC-B ships by the vertical shear forces $Q_{SW,F}$ and $Q_{WV,F}$ in flooded condition may be obtained through the simplified procedure in **[2.2.2]** and **[2.2.3]** respectively.

2.2.2 Simplified calculation of shear stresses induced by vertical shear forces

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm^2, from the following formula:

$$\tau_1 = (Q_{SW} + Q_{WV} - \varepsilon \Delta Q_C) \frac{S}{I_Y t} \delta$$

where:

t : Minimum net thickness, in mm, of side and inner side plating, as applicable according to **Table 1**

δ : Shear distribution coefficient defined in **Table 1**

$\varepsilon = \text{sgn}(Q_{SW})$

ΔQ_C : Shear force correction (see **Fig 2**) at the section considered. The shear force correction is to be considered independently forward and aft of the transverse bulkhead for the hold considered. The shear force correction takes into account, when applicable, the portion of loads transmitted by the double bottom girders to the transverse bulkheads:

- for ships with any non-homogeneous loading conditions, such as alternate hold loading conditions and heavy ballast conditions carrying ballast in hold(s):

  $$\Delta Q_C = \alpha \left| \frac{M}{B_H \ell_H} - \rho T_{LC,mh} \right|$$ for each non-homogenous loading condition

- for other ships and homogenous loading conditions:

  $\Delta Q_C = 0$

$\varphi = 1.38 + 1.55 \frac{\ell_0}{b_0}$, to be taken not greater than 3.7

$$\alpha = g \frac{\ell_0 b_0}{2 + \varphi \frac{\ell_0}{b_0}}$$

ℓ_0, b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold

ℓ_H : Length, in m, of the hold considered, measured between the middle of the transverse corrugated bulkheads depth

B_H : Ship's breadth, in m, measured at the level of inner bottom on the hull transverse section at the middle of the hold considered

M : Mass, in t, in the considered section.

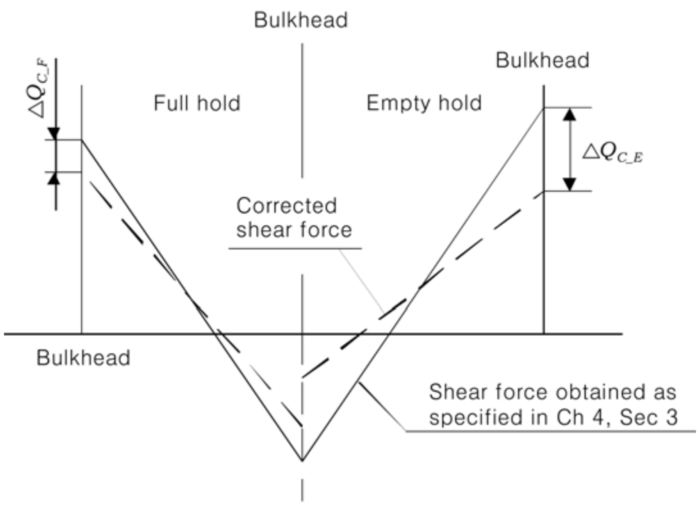
- Adjacent cargo hold is loaded in a non homogenous loading condition for the condition under consideration

  M is to include the total mass in the hold and the mass of water ballast in double bottom tank, bounded by side girders in way of hopper tank plating or longitudinal bulkhead.

- Other cases

  M is the total mass in the hold.

$T_{LC,mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.



ΔQ_{C_F} : shear force correction for the full hold
ΔQ_{C_E} : shear force correction for the empty hold

Fig 1: Shear force correction ΔQ_C

Table 1: Shear stresses induced by vertical shear forces

Ship typology	Location	t, in mm	δ
Single side ship	Sides	t_S	0,5
Double side ship	Sides	t_S	0.5(1-ϕ)
	Inner sides	t_{IS}	0.5ϕ

where:

t_S, t_{IS} : Minimum net thicknesses, in mm, of side and inner side, respectively

t_{SM}, t_{ISM} : Mean net thicknesses, in mm, over all the strakes of side and inner side, respectively. They are calculated as $\Sigma(\ell_i t_i)/\Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the net thickness, in mm, of the ith strake of side and inner side.

ϕ : Coefficient taken equal to: $\phi = 0.275 + 0.25\dfrac{t_{ISM}}{t_{SM}}$

2.2.3 Shear stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to BC-A or BC-B ships, in addition to **[2.2.1]** and **[2.2.2].**
The shear stresses, in the flooded conditions specified in **Ch 4, Sec 3**, are to be obtained at the calculation point, in $\mathrm{N/mm^2}$, from the following formula:

$$\tau_1 = \left(Q_{SW,F} + Q_{WV,F} - \varepsilon\Delta Q_C\right)\frac{S}{I_Y t}\delta$$

$$\varepsilon = \mathrm{sgn}\,(Q_{SW,F})$$

ΔQ_C : Shear force correction, to be calculated according to **[2.2.2]**, where the mass of the ingressed water is to be added to M, and where the draught $T_{LC,mh}$ is to be measured up to the equilibrium waterline.

t : Net thickness, in mm, of the side plating.

3. Checking criteria

3.1 Normal stresses

3.1.1

It is to be checked that the normal stresses s1 calculated according to **[2.1.2]** and, when applicable, **[2.1.3]** are in compliance with the following formula:

$$\sigma_1 \leq \sigma_{1,ALL}$$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm^2, obtained from the following formulae:

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \leq 0.1$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.3\right)^2 \quad \text{for} \quad 0.1 < \frac{x}{L} < 0.3$$

$$\sigma_{1,ALL} = \frac{190}{k} \quad \text{for} \quad 0.3 \leq \frac{x}{L} \leq 0.7$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.7\right)^2 \quad \text{for} \quad 0.7 < \frac{x}{L} < 0.9$$

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \geq 0.9$$

3.2 Shear stresses

3.2.1

It is to be checked that the shear stresses t1 calculated according to **[2.2.1]** or **[2.2.2]** and, when applicable, **[2.2.3]** are in compliance with the following formula:

$$\tau_1 \leq \tau_{1,ALL}$$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm^2:

$$\tau_{1,ALL} = 120/k$$

4. Section modulus and moment of inertia

4.1 General

4.1.1

The requirements in **[4.2]** to **[4.5]** provide the minimum hull net girder section modulus, complying with the checking criteria indicated in **[3]**, and the midship net section moment of inertia required to ensure sufficient hull girder rigidity.

4.1.2

The *k* material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to **[1]**. When material factors for higher strength steels are used, the requirements in **[4.5]** apply.

4.2 Section modulus within 0.4 *L* amidships

4.2.1

The net section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m^3, from the following formula:

- $Z_{R,MIN} = 0.9CL^2B(C_B + 0.7)k10^{-6}$

4.2.2

In addition, the net section moduli Z_{AB} and Z_{AD} within 0.4 L amidships are to be not less than the value obtained, in m^3, from the following formula:

- $Z_R = \frac{M_{SW}+M_{WV}}{\sigma_{1,ALL}}10^{-3}$
- in addition, for BC-A and BC-B ships:

  $Z_R = \frac{M_{SW,F}+M_{WV,F}}{\sigma_{1,ALL}}10^{-3}$

4.2.3

Where the total breadth Σb_S of small openings, as defined in **[1.2.8]**, is deducted from the sectional areas included in the hull girder transverse sections, the values $Z_{R,MIN}$ and Z_R defined in **[4.2.1]** or **[4.2.2]** may be reduced by 3 %.

4.2.4

Scantlings of members contributing to the longitudinal strength (see **[1]**), based on the section modulus requirement in **[4.2.1]**, are to be maintained within 0.4 L amidships.

4.3 Section modulus outside 0.4 *L* amidships

4.3.1

The net section moduli Z_{AB} and Z_{AD} outside 0.4 L amidships are to be not less than the value obtained, in m^3, from the following formula:

- $Z_R = \frac{M_{SW}+M_{WV}}{\sigma_{1,ALL}}10^{-3}$
- in addition, for BC-A and BC-B ships:

  $Z_R = \frac{M_{SW,F}+M_{WV,F}}{\sigma_{1,ALL}}10^{-3}$

4.3.2

Scantlings of members contributing to the hull girder longitudinal strength (see **[1]**) may be gradually reduced, outside 0.4 L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in **Ch 9, Sec 1** or **Ch 9, Sec 2**, respectively.

4.4 Midship section moment of inertia

4.4.1

The net midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m^4, from the following formula:

$$I_{YR} = 3Z'_{R,MIN} L \cdot 10^{-2}$$

where $Z'_{R,MIN}$ is the required net midship section modulus $Z_{R,MIN}$, in m^3, calculated as specified in **[4.2.1]** but assuming $k = 1$.

4.5 Extent of higher strength steel

4.5.1

When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to **[4.2]** or **[4.3]**, the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see **[1]**), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} z_D$$

- below a horizontal line located at a distance V_D (see **[1.4.2]**) above the neutral axis of the hull transverse section (for section modulus a tdeck):

$$V_{HD} = \frac{\sigma_{1D} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} (N + V_D)$$

where:

σ_{1B}, σ_{1D}: Normal stresses, in N/mm^2, at bottom and deck, respectively, calculated according to **[2.1]**

z_D : Z co-ordinate, in m, of the strength deck defined in **[1.3]**, with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**

4.5.2

The higher strength steel is to extend in length at least throughout $0.4L$ amidships where it is required for strength purposes according to the provision of the present Rules.

5. Permissible still water bending moment and shear force

5.1 Permissible still water bending moment and shear force in intact condition

5.1.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in intact condition, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to **[4.2]** and **[4.3]**.
In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.1.2 Permissible still water shear force – Direct calculation

Where the shear stresses are obtained through calculation analyses according to **[2.2.1]**, the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon |Q_T| - Q_{WV}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 120/k$ N/mm² in the most stressed point of the hull net transverse section, taking into account the shear force correction ΔQ_C in accordance with **[2.2.2].**

A lower value of the permissible still water shear force may be considered, if requested by the Shipbuilder.

5.1.3 Permissible still water shear force – Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon \left(\frac{120}{k\delta} \frac{I_Y t}{S} + \Delta Q_C \right) - Q_{WV}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in **Table 1**

t : Minimum net thickness, in mm, of side and inner side plating, as applicable according to **Table 1**

ΔQ_C : Shear force corrections defined in **[2.2.2]**, to be considered independently forward and aft of the transverse bulkhead.

A lower value of the permissible still water shear force may be considered, if requested by the Shipbuilder.

5.2 Permissible still water bending moment and shear force in harbour conditions

5.2.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN.m, from the following formula:

$$M_{P,P} = M_{SW} + M_{WV} - M_{WV,P}$$

A lower value of the permissible still water bending moment in harbour conditions may be considered, if requested by the Shipbuilder.

5.2.2 Permissible still water shear force

The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$$Q_{P,P} = \varepsilon Q_P + Q_{WV} - Q_{WV,P}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to **[5.1.3].**

A lower value of the permissible still water shear force in harbour conditions may be considered, if requested by the Shipbuilder.

5.3 Permissible still water bending moment and shear force in flooded condition

5.3.1 Permissible still water bending moment

The permissible still water bending moment at any hull transverse section in flooded condition, in hogging or sagging conditions, is the value $M_{SW,F}$ considered in the hull girder section modulus calculation according to **[4.2]** and **[4.3].**
In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.3.2 Permissible still water shear force – Direct calculation

Where the shear stresses are obtained through calculation analyses according to [2.2.1], the permissible positive or negative still water shear force in flooded condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{P,F} = \varepsilon |Q_T| - Q_{WV,F}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW,F})$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 120/k\ \mathrm{N/mm^2}$ in the most stressed point of the hull net transverse section, taking into account the shear force correction ΔQ_C in accordance with **[2.2.2].**

5.3.3 Permissible still water shear force – Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in flooded condition at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{P,F} = \varepsilon \left(\frac{120}{k\delta} \frac{I_Y t}{S} + \Delta Q_C \right) - Q_{WV,F}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in **Table 1**

t : Minimum net thickness, in mm, of side and inner side plating, as applicable according to **Table 1**

ΔQ_C : Shear force correction, to be calculated according to **[2.2.2]**, where the mass M is to include the mass of the ingressed water in the hold considered and the draught T_{LC} is to be measured up to the equilibrium waterline.

Section 2 – ULTIMATE STRENGTH CHECK

1. Application

1.1 General

1.1.1

The requirements of this Section apply to ships equal to or greater than 150 m in length L.

2. Hull girder ultimate strength check

2.1 Hull girder loads

2.1.1 Bending moment

The bending moment M in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, in intact, flooded and harbour conditions, from the following formula:

$$M = M_{SW} + \gamma_W M_{WV}$$

where:

$M_{SW}, M_{SW,F}, M_{SW,P}$: Design still water bending moment, in kN.m, in sagging and hogging conditions at the hull transverse section considered, to be calculated respectively in intact (M_{SW}), flooded ($M_{SW,F}$) and harbour ($M_{SW,P}$) conditions

$M_{WV}, M_{WV,F}, M_{WV,P}$: Vertical wave bending moment, in kN.m, in sagging and hogging conditions at the hull transverse section considered, defined in **Ch 4, Sec 3**, respectively in intact (M_{WV}), flooded ($M_{WV,F}$) and harbour ($M_{WV,P}$) conditions

γ_W : Safety factor on wave hull girder bending moments, taken equal to:
$\gamma_W = 1.20$

2.2 Hull girder bending moment

2.2.1 Curve $M-\chi$

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see **Fig 1**).
The curvature χ is positive for hogging condition and negative for sagging condition.
The curve $M-\chi$ is to be obtained through an incremental-iterative procedure, according to the criteria specified in **App 1.**

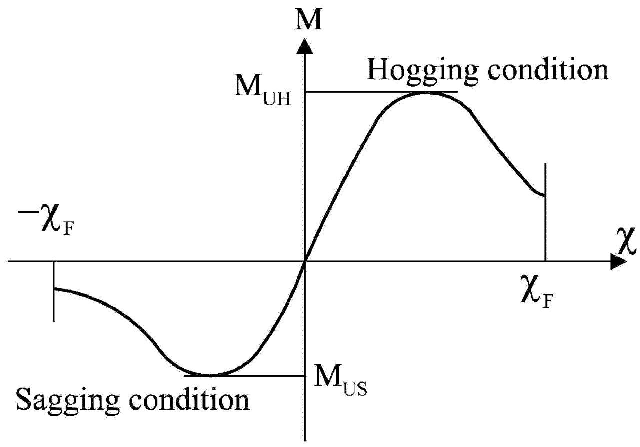


Fig 1: Curve bending moment capacity *M* versus curvature χ

2.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net offered scantlings according to **Ch 3, Sec 2, [3.2.4].**

2.3 Checking criteria

2.3.1

It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$M \le \frac{M_U}{\gamma_R}$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, calculated with net offered scantlings based on gross offered thickness reduced by $0.5\,t_C$, in kN.m:

$M_U = M_{UH}$ in hogging conditions

$M_U = M_{US}$ in sagging conditions

M_{UH} : Ultimate bending moment capacity in hogging conditions, in kN.m, defined in **[2.2.1]**

M_{US} : Ultimate bending moment capacity in sagging conditions, in kN.m, defined in **[2.2.1]**

M : Bending moment, in kN.m, defined in **[2.1.1]** for the ship in intact, flooded and harbour conditions

γ_R : Safety factor taken equal to 1.10

Appendix 1 - HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to **Ch 1, Sec 4.**

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5.1]**

Z_{AB} ,Z_{AD} : Section moduli, in m^3, at bottom and deck, respectively, defined in **Ch 5, Sec 1, [1.4.2].**

R_{eHs} : Minimum yield stress, in N/mm^2, of the material of the considered stiffener.

R_{eHp} : Minimum yield stress, in N/mm^2, of the material of the considered plate.

A_s : Net sectional area, in cm^2, of stiffener, without attached plating

A_p : Net sectional area, in cm^2, of attached plating

1. Hull girder ultimate strength check

1.1 Introduction

1.1.1

This Appendix provides the criteria for obtaining the curve $M-\chi$ and the ultimate longitudinal bending moment capacity M_U that are to be calculated according to the simplified incremental-iterative approach, as specified in **[2.1].**

2. Criteria for the calculation of the curve $M-\chi$

2.1 Simplified method based on a incremental-iterative approach

2.1.1 Procedure

The curve $M-\chi$ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in **Fig 1.**
In this approach, the ultimate hull girder bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in **Fig 1**. The curve is to be obtained through an incremental-iterative approach.
Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.
For each step, the value χ_i is to be obtained by summing an increment of curvature $\triangle\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.
The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve $\sigma-\varepsilon$ of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.
The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship $\sigma-\varepsilon$ is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.
Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.
The main steps of the incremental-iterative approach described above are summarised as follows (see also

Fig 1):

Step 1 Divide the transverse section of hull into stiffened plate elements.

Step 2 Define stress-strain relationships for all elements as shown in **Table 1**

Step 3 Initialize curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (curvature that induces a stress equal to 1 % of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = \frac{0.01\frac{R_{eH}}{E}}{z_D - N}$$

where:

z_D : Z co-ordinate, in m, of strength deck at side, with respect to reference co-ordinate defined in **Ch 1, Sec 4, [4]**

Step 4 Calculate for each element the corresponding strain $\varepsilon_i = \chi(z_i - z_{NA})$ and the corresponding stress σ_i

Step 5 Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:

$\Sigma A_i\sigma_i = \Sigma A_j\sigma_j$ (i-th element is under compression, j-th element under tension)

Step 6 Calculate the corresponding moment by summing the contributions of all elements as:

$M_U = \sum \sigma_{Ui} A_i \left|(z_i - z_{NA\_cur})\right|$

Step 7 Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in $M-\chi$ relationship is less than a negative fixed value, terminate the process and define the peak value of M_U. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to **Step 4.**

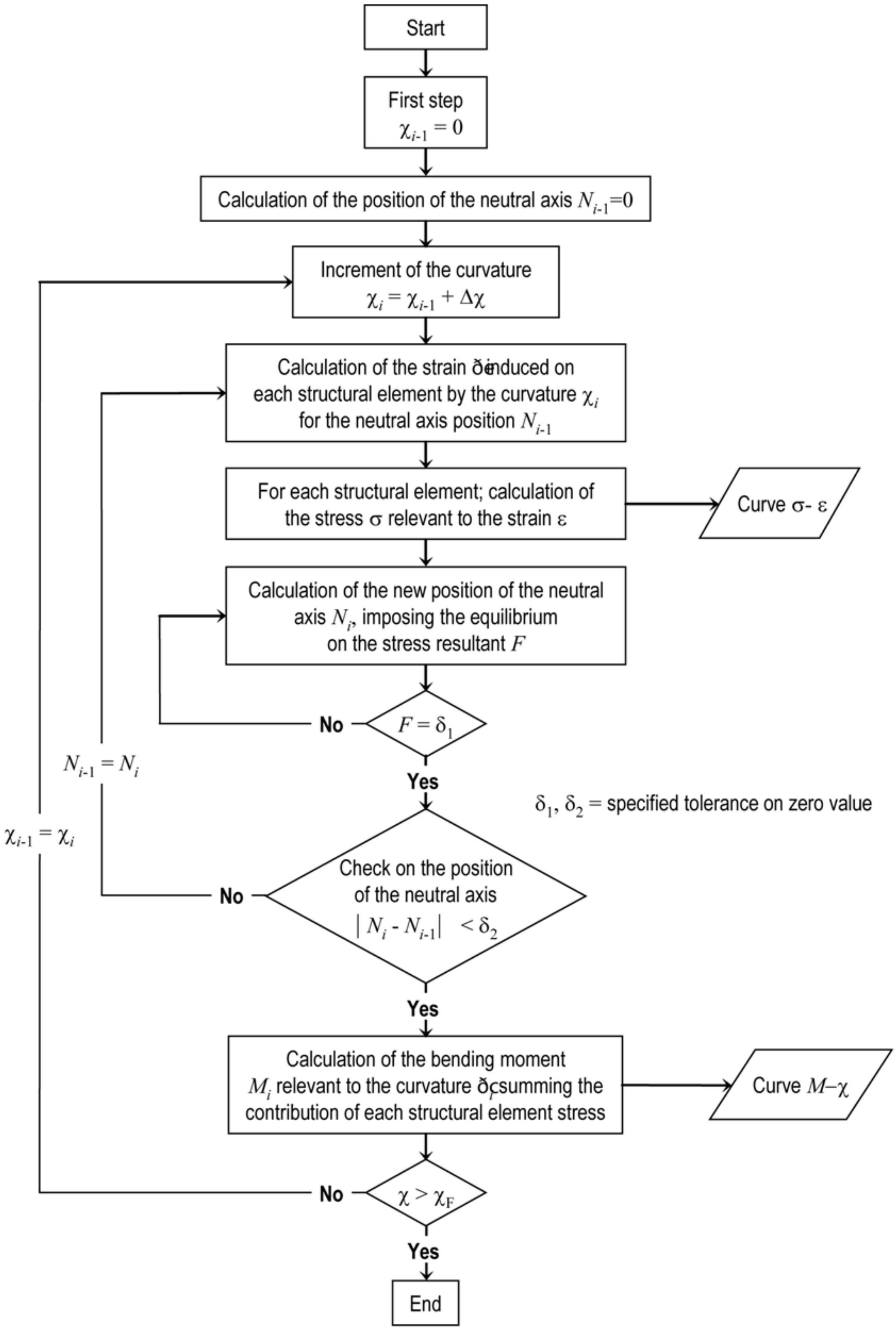


Fig 1: Flow chart of the procedure for the evaluation of the curve $M-\chi$

2.1.2 Assumption

In applying the procedure described in **[2.1.1]**, the following assumptions are generally to be made:

- the ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.

- the hull girder transverse section remains plane during each curvature increment.
- the hull material has an elasto-plastic behaviour.
- the hull girder transverse section is divided into a set of elements, which are considered to act independently.

  These elements are:

  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in **[2.2.1]**
  - hard corners, constituted by plating crossing, whose structural behaviour is described in **[2.2.2].**
- according to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves $\sigma - \varepsilon$ of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in **[2.2]**. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves $\sigma - \varepsilon$.
- The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_Y}{EI_Y}$$

where:

M_Y : the lesser of the values M_{Y1} and M_{Y2}, in kN.m:

$M_{Y1} = 10^3 R_{eH} Z_{AB}$

$M_{Y2} = 10^3 R_{eH} Z_{AD}$

If the value χ_F is not sufficient to evaluate the peaks of the curve $M - \chi$, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.1.3 Modeling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.
Sniped stiffeners are also to be modeled imaginarily, taking account that they doesn't contribute to the hull girder strength.
The structural members are categorized into an ordinary stiffener element, a stiffened plate element or a hard corner element.
The plate panel including web plate of girder or side stringer is idealized into either a stiffened plate element, an attached plate of an ordinary stiffener element or a hard corner element.
The plate panel is categorized into the following two kinds:

- longitudinally stiffened panel of which the longer side is in the longitudinal direction, and
- transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

- Hard corner element

  Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

  The extent of a hard corner element from the point of intersection of the plates is taken equal to 20 t_p on transversely stiffened panel and to $0.5s$ on a longitudinally stiffened panel. (see **Fig 6**)

  where:

  t_p : Gross offered thickness of the plate, in mm

  s : Spacing of the adjacent longitudinal stiffener, in m

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.

- Ordinary stiffener element

The ordinary stiffener constitutes an ordinary stiffener element together with the attached plate.

The attached plate width is in principle:

- equal to the mean spacing of the ordinary stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
- equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened. (See **Fig 6**)

- Stiffened plate element

The plate between ordinary stiffener elements, between an ordinary stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element. (See **Fig 6**)

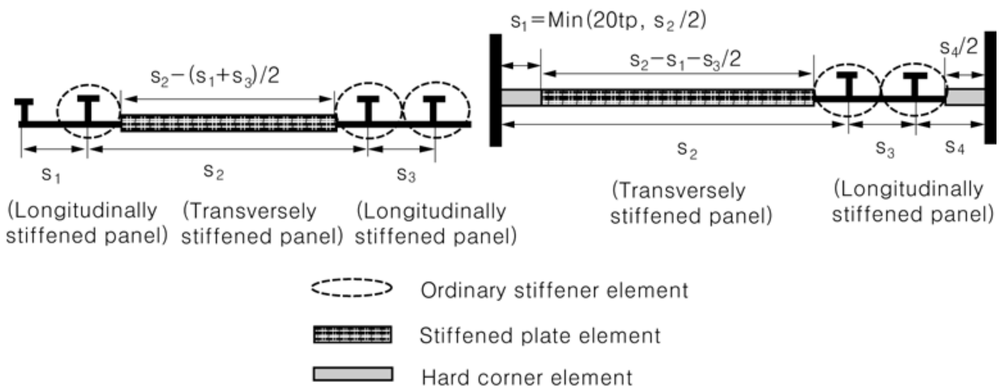


Fig 6: Extension of the breadth of the attached plating and hard corner element

The typical examples of modeling of hull girder section are illustrated in **Figs 7** and **8.**
Notwithstanding the foregoing principle these figures are to be applied to the modeling in the vicinity of upper deck, sheer strake and hatch side girder.

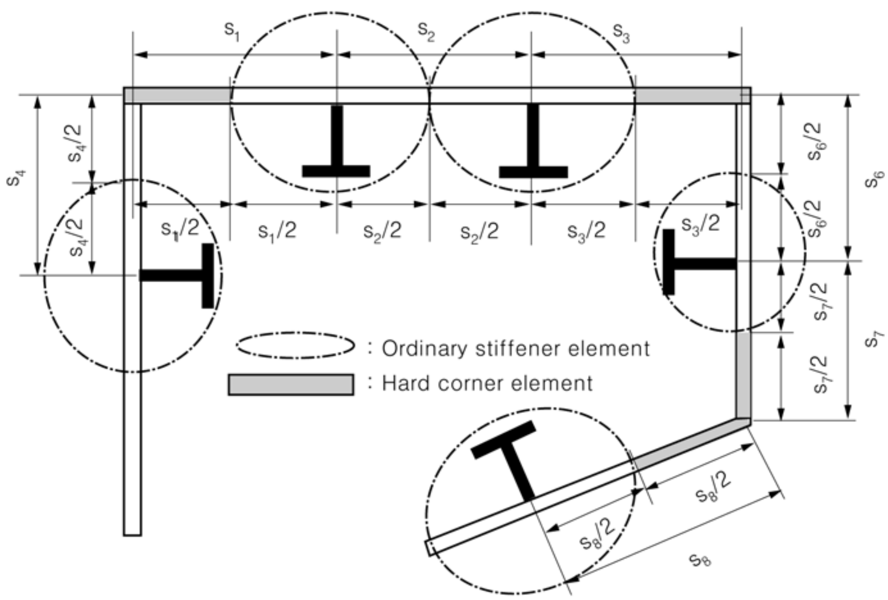


Fig 7: Extension of the breadth of the attached plating and hard corner element

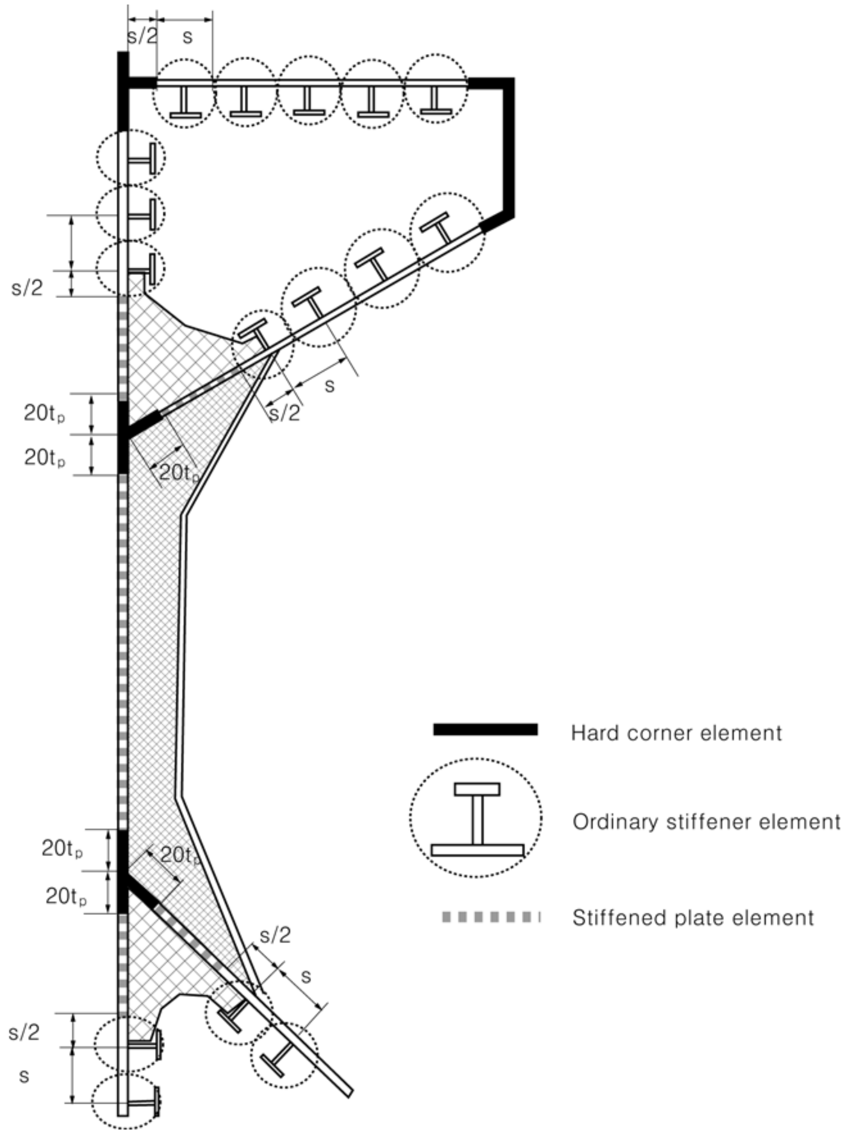


Fig 8: Examples of the configuration of stiffened plate elements, ordinary stiffener elements and hard corner elements on a hull section

(Note)

(1) In case of the knuckle point as shown in **Fig 9**, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to $20\,t_p$ on transversely framed panels and to $0.5\,s$ on longitudinally framed panels from the knuckle point.

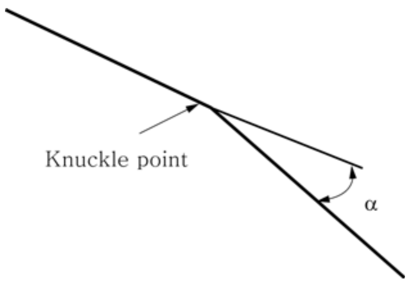


Fig 9: The case of plating with knuckle point

(2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

(3) Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with **Ch 5, Sec 1, [1.2.7], [1.2.8]** and **[1.2.9].**

(4) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation.

$$t = \frac{t_1 s_1 + t_2 s_2}{s}, \qquad R_{eHp} = \frac{R_{eHp1} t_1 s_1 + R_{eHp2} t_2 s_2}{ts}$$

Where,

R_{eHp1}, R_{eHp2}, t_1, t_2, s_1, s_2 and s are shown in **Fig 10.**

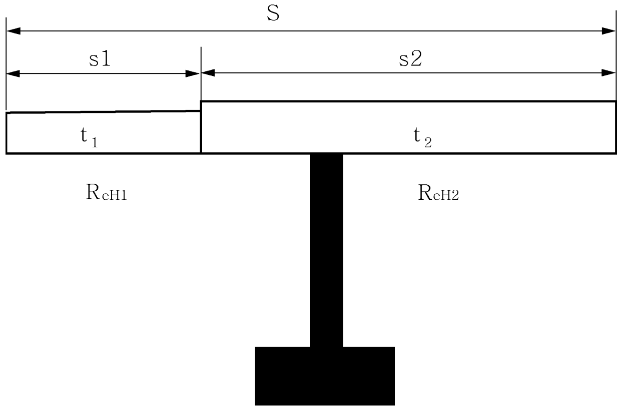


Fig 10: Element with different thickness and yield strength

2.2 Load-end shortening curves $\sigma - \varepsilon$

2.2.1 Stiffened plate element and ordinary stiffener element

Stiffened plate element and ordinary stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in **Table 1.**

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with **[2.2.3]** to **[2.2.7]**, taking into account the non-continuous longitudinal stiffener.

  In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in **Ch 5, Sec 1, [1.2.7]** to **[1.2.9].**

- For stiffened plate element, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as full plate breadth, i.e. to the intersection of other plate or longitudinal stiffener - not from the end of the hard corner element nor from the attached plating of ordinary stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the ordinary stiffener element or between the hard corner elements, as applicable.

Table 1: Modes of failure of stiffened plate element and ordinary stiffener element

Element	Mode of failure	Curve $\sigma-\varepsilon$ defined in
Lengthened stiffened plate element or ordinary stiffener element	Elasto-plastic collapse	[2.2.3]
Shortened ordinary stiffener element	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	[2.2.4] [2.2.5] [2.2.6] [2.2.7]
Shortened stiffened plate element	Plate buckling	[2.2.8]

2.2.2 Hard corner element

The relevant load-end shortening curve $\sigma-\varepsilon$ is to be obtained for lengthened and shortened hard corners according to **[2.2.3].**

2.2.3 Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve $\sigma-\varepsilon$ for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see **Fig 2**):

$$\sigma = \Phi R_{eHA}$$

where:

R_{eHA} : Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula

$$R_{eHA} = \frac{R_{eHp} A_p + R_{eHs} A_s}{A_p + A_s}$$

Φ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \le \varepsilon \le 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

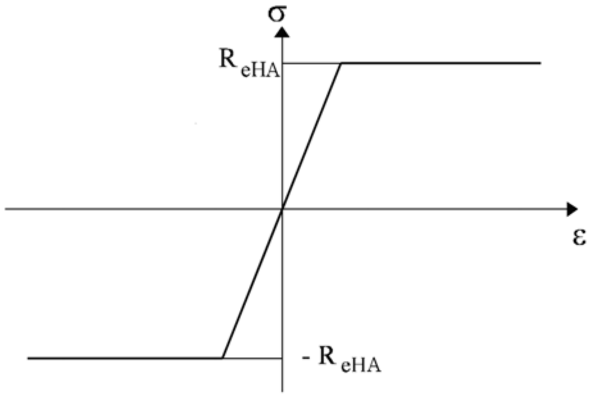


Fig 2: Load-end curve $\sigma-\varepsilon$ for elasto plastic collapse

2.2.4 Beam column buckling

The equation describing the load-end shortening curve $\sigma_{CR1}-\varepsilon$ for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see **Fig 3**):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_s + A_{pE}}{A_s + A_p}$$

where:

Φ : Edge function defined in **[2.2.3]**

σ_{C1} : Critical stress, in N/mm^2, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

R_{eHB} : Equivalent minimum yield stress, in N/mm^2, of the considered element, obtained by the following formula

$$R_{eHB} = \frac{R_{eHB}A_{pE1}l_{pE} + R_{eHs}A_s l_{sE}}{A_{pE1}l_{pE} + A_s l_{sE}}$$

A_{pE1} : Effective area, in cm^2, equal to

$$A_{pE1} = 10\,b_{E1}t_p$$

l_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate

l_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{E1} to the top of the stiffener

ε : Relative strain defined in **[2.2.3]**

σ_{E1} : Euler column buckling stress, in N/mm^2, equal to:

$$\sigma_{E1} = \pi^2 E\frac{I_E}{A_E l^2}10^{-4}$$

I_E : Net moment of inertia of ordinary stiffeners, in cm^4, with attached shell plating of width b_{E1}

b_{E1} : Effective width, in m, of the attached shell plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1.0$$

$b_{E1} = s$ for $\beta_E \le 1.0$

$$\beta_E = 10^3 \frac{s}{t_p} \sqrt{\frac{\varepsilon R_{eHP}}{E}}$$

A_{pE} : Net sectional area, in cm^2, of attached shell plating of width b_E, equal to:

$A_{pE} = 10\, b_E t_p$

b_E : Effective width, in m, of the attached shell plating, equal to:

$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) s$ for $\beta_E > 1.25$

$b_E = s$ for $\beta_E \le 1.25$

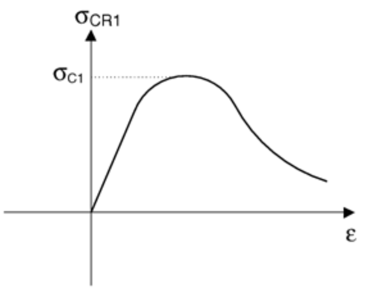


Fig 3: Load-end shortening curve $\sigma_{CR1} - \varepsilon$ for beam column buckling

2.2.5 Torsional buckling

The equation describing the load-end shortening curve $\sigma_{CR2} - \varepsilon$ for the flexural-torsional buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see **Fig 4**).

$$\sigma_{CR2} = \Phi \frac{A_s \sigma_{C2} + A_p \sigma_{CP}}{A_s + A_p}$$

where:

Φ : Edge function defined in **[2.2.3]**

σ_{C2} : Critical stress, in $\mathrm{N/mm^2}$, equal to:

$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon}$ for $\sigma_{E2} \le \frac{R_{eHs}}{2}\varepsilon$

$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E2}}\right)$ for $\sigma_{E2} > \frac{R_{eHs}}{2}\varepsilon$

σ_{E2} : Euler torsional buckling stress, in $\mathrm{N/mm^2}$, defined in **Ch 6, Sec 3, [4.3]**

ε : Relative strain defined in **[2.2.3]**

σ_{CP} : Buckling stress of the attached plating, in $\mathrm{N/mm^2}$, equal to:

$\sigma_{CP} = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) R_{eHp}$ for $\beta_E > 1.25$

$\sigma_{CP} = R_{eHp}$ for $\beta_E \le 1.25$

β_E : Coefficient defined in **[2.2.4]**

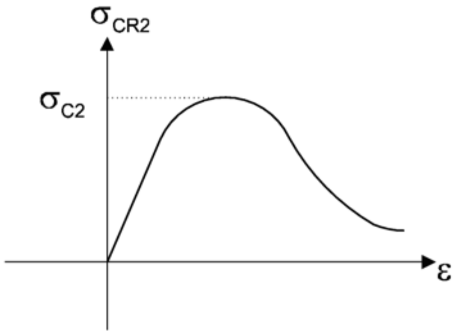


Fig 4: Load-end shortening curve $\sigma_{CR2} - \varepsilon$ for flexural-torsional buckling

2.2.6 Web local buckling of ordinary stiffeners made of flanged profiles

The equation describing the load-end shortening curve $\sigma_{CR3} - \varepsilon$ for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_p R_{eHp} + (h_{we} t_w + b_f t_f) R_{eHs}}{10^3 s t_p + h_w t_w + b_f t_f}$$

where

Φ : Edge function defined in **[2.2.3]**

b_E : Effective width, in m, of the attached shell plating, defined in **[2.2.4]**

h_{we} : Effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \quad \text{for} \quad \beta_w > 1.25$$

$$h_{we} = h_w \quad \text{for} \quad \beta_w \le 1.25$$

$$\beta_w = \frac{h_w}{t_w}\sqrt{\frac{\varepsilon R_{eHs}}{E}}$$

ε : Relative strain defined in **[2.2.3]**

2.2.7 Web local buckling of ordinary stiffeners made of flat bars

The equation describing the load-end shortening curve $\sigma_{CR4} - \varepsilon$ for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see **Fig 5**):

$$\sigma_{CR4} = \Phi \frac{A_P \sigma_{CP} + A_s \sigma_{C4}}{A_p + A_s}$$

where:

Φ : Edge function defined in **[2.2.3]**

σ_{CP} : Buckling stress of the attached plating, in $\mathrm{N/mm^2}$, defined in **[2.2.5]**

σ_{C4} : Critical stress, in $\mathrm{N/mm^2}$, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \le \frac{R_{eHs}}{2}\varepsilon$$

$$\sigma_{C4} = R_{eHs}\left(1 - \frac{R_{eHs}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eHs}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in $\mathrm{N/mm^2}$, equal to:

$$\sigma_{E4} = 160{,}000\left(\frac{t_w}{h_w}\right)^2$$

ε : Relative strain defined in **[2.2.3].**

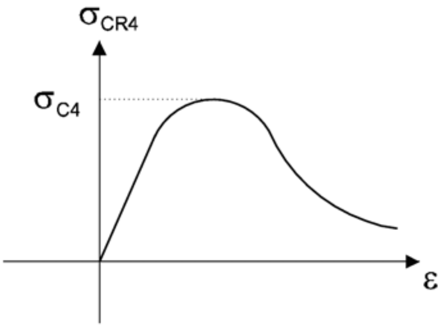


Fig 5: Load-end shortening curve $\sigma_{CR4} - \varepsilon$ for web local buckling

2.2.8 Plate buckling

The equation describing the load-end shortening curve $\sigma_{CR5} - \varepsilon$ for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases} R_{eHp}\Phi \\ \Phi R_{eHp}\left[\dfrac{s}{\ell}\left(\dfrac{2.25}{\beta_E} - \dfrac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \dfrac{s}{\ell}\right)\left(1 + \dfrac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

where:

Φ : Edge function defined in **[2.2.3].**

$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

s : plate breadth, in m, taken as the spacing between the ordinary stiffeners.

ℓ : longer side of the plate, in m. ⚓

Chapter 6

Hull Scantlings

Section 1 - PLATING

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5]**, on gross offered thickness reduced by $0.5\,t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5]**, on gross offered thickness reduced by $0.5\,t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**, in m, of the centre of gravity of the hull net transverse section, defined in **Ch 5, Sec 1, [1.2]**, considering gross offered thickness reduced by $0.5\,t_C$ for all structural members

t : Net thickness, in mm, of a plate panel.

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in **[3.1.2]**

p_F : Pressure, in kN/m^2, in flooded conditions, defined in **[3.1.3]**

p_T : Pressure, in kN/m^2, in testing conditions, defined in **[3.1.4]**

σ_X : Normal stress, in kN/m^2, defined in [3.1.5]

ℓ : Length, in m, of the longer side of the elementary plate panel, measured along the chord

s : Length, in m, of the shorter side of the elementary plate panel, measured along the chord at mid-span of ℓ

c_a : Coefficient of aspect ratio of the plate panel, equal to:

$$c_a = 1.21\sqrt{1+0.33\left(\frac{s}{\ell}\right)^2} - 0.69\frac{s}{\ell}$$, to be taken not greater than 1.0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0.5\frac{s}{r}$$, to be taken not less than 0.4

r : Radius of curvature, in m.

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the strength check of plating subjected to lateral pressure and, for plating contributing to the longitudinal strength, to in-plane hull girder normal stress.
In addition, the buckling check of platings and stiffened panels is to be carried out according to **Ch 6, Sec 3.**

1.2 Net thicknesses

1.2.1

As specified in **Ch 3, Sec 2**, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition.

The gross thicknesses are obtained as specified in **Ch 3, Sec 2, [3].**

1.2.2

The net thickness, in mm, of each plating is given by the greatest of the net thicknesses calculated for each load calculation point, as defined in **[1.5.1]**, representative of the considered plating (see **Table 1**). The geometry to be considered is that of the elementary plate panel related to the load calculation point.

1.3 Pressure combination

1.3.1 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering independently the following cases:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

1.3.2 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

1.4 Elementary plate panel

1.4.1

The elementary plate panel (EPP) is the smallest unstiffened part of plating between stiffeners.

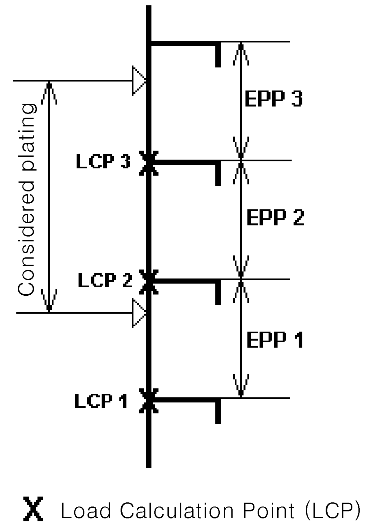
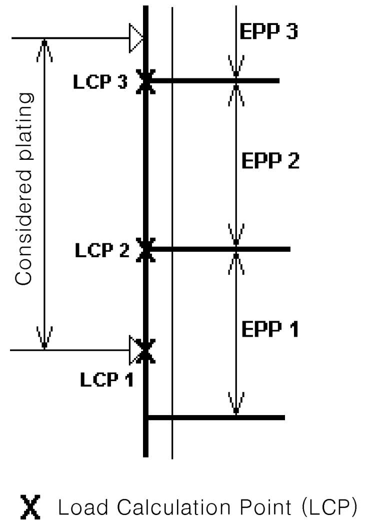
1.5 Load calculation point

1.5.1

Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel (see **Table 1**) or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered, as the case may be
- for transverse framing, at the lower edge of the elementary plate panel or at the lower edge of the strake (see **Table 1**) or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered, as the case may be.

Table 1: Load calculation points

Longitudinally stiffened plating	Transversely stiffened plating
	

2. General requirements

2.1 Corrugated bulkhead

2.1.1

Unless otherwise specified, the net plating thickness of a corrugated bulkhead is to be not less than that obtained for a plate panel with s equal to the greater of a and c, where a and c are defined in **Fig 1.**

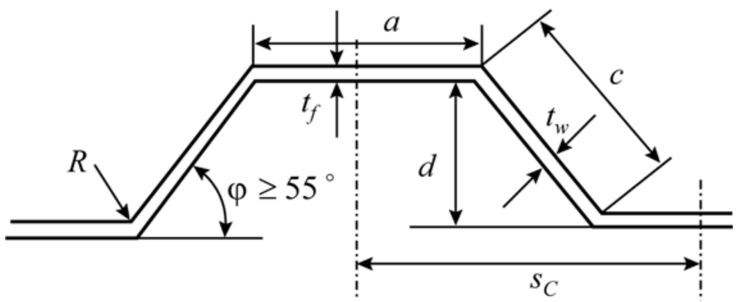


Fig 1: Corrugated bulkhead

2.2 Minimum net thicknesses

2.2.1

The net thickness of plating is to be not less than the values given in **Table 2.**
In addition, in the cargo area, the net thickness of side shell plating, from the normal ballast draught to 0.25 T_S (minimum 2.2 m) above T_S, is to be not less than the value obtained, in mm, from the following formula:

$$t = 28(s + 0.7)\frac{(BT_s)^{0.25}}{\sqrt{R_{eH}}}$$

Table 2: Minimum net thickness of plating

Plating	Minimum net thickness, in mm
Keel	$7.5 + 0.03L$
Bottom, inner bottom	$5.5 + 0.03L$
Weather strength deck and trunk deck, if any	$4.5 + 0.02L$
Side shell, bilge	$0.85L^{1/2}$
Inner side, hopper sloping plate and topside sloping plate	$0.7L^{1/2}$
Transverse and longitudinal watertight bulkheads	$0.6L^{1/2}$
Wash bulkheads	6.5
Accommodation deck	5.0

2.3 Bilge plating

2.3.1

The net thickness of the longitudinally framed bilge plating, in mm, is to be not less than the value obtained from **[3.2].**

2.3.2

The net thickness of the transversely framed bilge plating, in mm, is to be not less than the value obtained from the following formula:

$$t = 0.76\left[(p_S + p_W)s_b\right]^{0.4} R^{0.6} k^{0.5}$$

where :

R : Bilge radius, in m

s_b : Spacing of floors or transverse bilge brackets, in m.

2.3.3

The net thickness of the bilge plating is to be not less than the actual net thicknesses of the adjacent 2 m width bottom or side plating, whichever is the greater.

2.4 Keel plating

2.4.1

The net thickness of the keel plating is to be not less than the actual net thicknesses of the adjacent 2 m width bottom plating.

2.5 Sheerstrake

2.5.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than the actual net thicknesses of the adjacent 2 m width side plating, taking into account higher strength steel corrections if needed.

2.5.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.5.3 Net thickness of the sheerstrake in way of breaks of effective superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of effective superstructures occurring within $0.5\,L$ amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.
This increase in net thickness is not to be less than 40 % of the net thickness of sheerstrake, but need not exceed 4.5 mm.
Where the breaks of superstructures occur outside $0.5\,L$ amidships, the increase in net thickness may be reduced to 30 %, but need not exceed 2.5 mm.

2.5.4 Net thickness of the sheerstrake in way of breaks of non-effective superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of non-effective superstructures occurring within $0.6\,L$ amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.
This increase in net thickness is to be equal to 15 %, but need not exceed 4.5 mm.

2.6 Stringer plate

2.6.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.6.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within $0.5\,L$ amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.
This increase in net thickness is not to be less than 40 % of the net thickness of stringer plate, but need not exceed 4.5 mm.
Where the breaks of superstructures occur outside $0.5\,L$ amidships, the increase in net thickness may be reduced to 30 %, but need not exceed 2.5 mm.

2.6.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within $0.6\,L$ amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.
This increase in net thickness is to be equal to 15 %, but need not exceed 4.5 mm.

2.7 Inner bottom loaded by steel coils on a wooden support

2.7.1 General

The net thickness of inner bottom, bilge hopper sloping plate and inner hull for ships intended to carry steel coils is to comply with **[2.7.2]** to **[2.7.4].**
The provision is determined by assuming **Fig 2** as the standard means of securing steel coils.

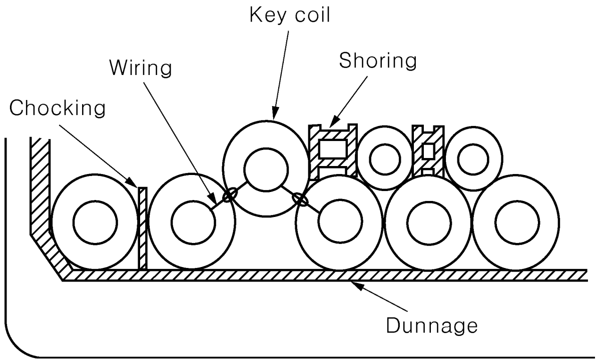


Fig 2: Inner bottom loaded by steel coils

2.7.1 bis1 Accelerations

In order to calculate the accelerations, the following coordinates are to be used for the centre of gravity.

x_{G-sc} = 0.75 ℓ_H forward of aft bulkhead, where the hold of which the mid position is located forward from 0.45 L from A.E.

x_{G-sc} = 0.75 ℓ_H afterward of fore bulkhead, where the hold of which the mid position is located afterward from 0.45 L from A.E.

$$y_{G-sc} = \varepsilon \frac{B_h}{4}$$

$$z_{G-sc} = h_{DB} + \left\{1 + (n_1 - 1)\frac{\sqrt{3}}{2}\right\}\frac{d_{sc}}{2}$$

where:

ε : 1.0 when a port side structural member is considered, or -1.0 when a starboard side structural member is considered.

B_h : breadth in m, at the mid of the hold, of the cargo hold at the level of connection of bilge hopper plate with side shell or inner hull

d_{sc} : diameter of steel coils, in m

h_{DB} : height of inner bottom, in m

ℓ_H : Cargo hold length, in m

Vertical acceleration a_Z, in m/s², are to be calculated by the formulae defined in **Ch 4, Sec 2, [3.2]** and tangential acceleration a_R due to roll, in m/s², is to be calculated by the following formula.

$$a_R = \theta \frac{\pi}{180}\left(\frac{2\pi}{T_R}\right)^2 \sqrt{y_{G\_sc}^{\ 2} + R^2}$$

where:

θ, T_R and R: as defined in **Ch 4, Sec 2, [3.2].**

2.7.2 Inner bottom plating

The net thickness of plating of longitudinally framed inner bottom is to be not less than the value obtained, in mm, from the following formula:

$$t = K_1 \sqrt{\frac{\{g(\cos(C_{ZP}\Phi)\cos(C_{ZR}\theta)) + a_z\}F}{\lambda_P R_Y}}$$

where:

K_1 : Coefficient taken equal to:

$$K_1 = \sqrt{\frac{1.7s\ell K_2 - 0.73s^2K_2^2 - (\ell - \ell')^2}{2\ell'(2s + 2\ell K_2)}}$$

a_Z : Vertical acceleration, in m/s^2, defined in **[2.7.1 bis1]**

Φ : Single pitch amplitude, in deg, defined in **Ch 4, Sec 2, [2.2]**

θ : Single roll amplitude, in deg, defined in **Ch 4, Sec 2, [2.1]**

C_{ZP}, C_{ZR} : Load combination factor defined in **Ch 4, Sec 4, [2.2]**

F : Force, in kg, taken equal to:

$F = K_S \frac{Wn_1n_2}{n_3}$ for $n_2 \le 10$ and $n_3 \le 5$

$F = K_S n_1 W \frac{l}{l_s}$ for $n_2 > 10$ or $n_3 > 5$

λ_P : Coefficient defined in **Table 6**

K_S : Coefficient taken equal to:

K_S = 1.4 when steel coils are lined up in one tier with a key coil

K_S = 1.0 in other cases

W : Mass of one steel coil, in kg

n_1 : Number of tiers of steel coils

n_2 : Number of load points per elementary plate panel (See **Figs 3** and **4**)

When $n_3 \le 5$, n_2 can be obtained from **Table 3** according to the values of n_3 and ℓ/ℓ_s

n_3 : Number of dunnages supporting one steel coil

ℓ_S : Length of a steel coil, in m

K_2 : Coefficient taken equal to:

$$K_2 = -\frac{s}{\ell} + \sqrt{\left(\frac{s}{\ell}\right)^2 + 1.37\left(\frac{\ell}{s}\right)^2\left(1 - \frac{\ell'}{\ell}\right)^2 + 2.33}$$

ℓ' : Distance, in m, between outermost load points per elementary plate panel in ship length (See **Figs 3** and **4**). When $n_2 \le 10$ and $n_3 \le 5$, ℓ' can be obtained from **Table 4** according to the values of ℓ, ℓ_S, n_2 and n_3. When $n_2 > 10$ or $n_3 > 5$, ℓ' is to be taken equal to ℓ.

2.7.3 Bilge hopper sloping plate and inner hull plate

The net thickness of plating of longitudinally framed bilge hopper sloping plate and inner hull is to be not less than the value obtained, in mm, from the following formula:

$$t = K_1 \sqrt{\frac{a_{hopper}F'}{\lambda_P R_y}}$$

where:

K_1 : Coefficient defined in **[2.7.2]**

θ_h : Angle, in deg, between inner bottom plate and bilge hopper sloping plate or inner hull plate

$$a_{hopper} = -C_{YR} a_R \sin\left(\tan^{-1}\left|\frac{y_{G\_sc}}{R}\right| - \theta_h\right) + g\cos(\theta_h - C_{YG}\theta)\cos(C_{XG}\Phi) + C_{YS} a_{sway} \sin\theta_h$$

a_R : tangential acceleration defined in **[2.7.1 bis1].**

a_{sway} : Transverse acceleration due to sway, in m/s^2, defined in **Ch 4, Sec 2, [2.4]**

C_{XG}, C_{YS}, C_{YR}, C_{YG} : Load combination factors defined in **Ch 4, Sec 4, [2.2]**

y_{G_sc} : Centre of gravity in transverse direction, in m, defined in **[2.7.1 bis1]**

R : Coefficient defined in **Ch 4, Sec 2, [3.2.1]**

F' : Force, in kg, taken equal to:

$$F' = \frac{W n_2 C_k}{n_3} \quad \text{for} \quad n_2 \le 10 \text{ and } n_3 \le 5$$

$$F' = C_k W \frac{l}{l_s} \quad \text{for} \quad n_2 > 10 \text{ or } n_3 > 5$$

λ_P : Coefficient defined in Tab 6

W, n_2, n_3, Φ and θ: As defined in [2.7.2]

C_k : Coefficient taken equal to:

C_k = 3.2 when steel coils are lined up two or more tier, or when steel coils are lined up one tier and key coil is located second or third from bilge hopper sloping plate or inner hull plate

C_k = 2.0 for other cases

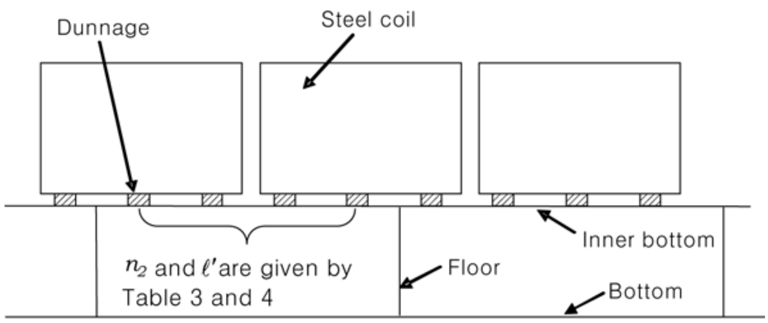


Fig 3: Loading condition of steel coils (example of n_2= 4, n_3= 3)

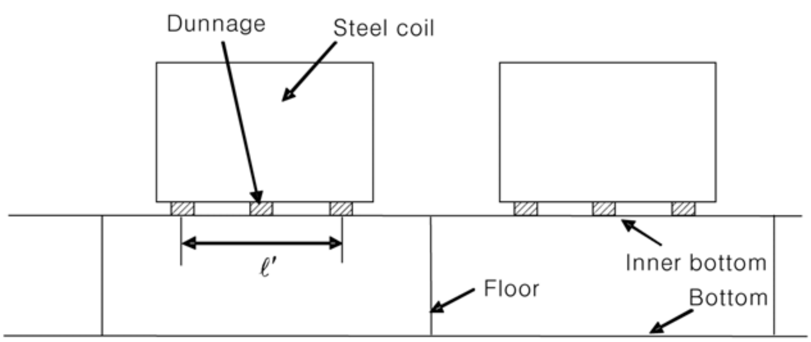


Fig 4: Loading condition of steel coils (Example of n_2= 3, n_3= 3)

2.7.4 (void)

Table 3: Number n_2 of load points per elementary plate panel

n_2	$n_3 = 2$	$n_3 = 3$	$n_3 = 4$	$n_3 = 5$
1	$0 < \frac{\ell}{\ell_S} \leq 0.5$	$0 < \frac{\ell}{\ell_S} \leq 0.33$	$0 < \frac{\ell}{\ell_S} \leq 0.25$	$0 < \frac{\ell}{\ell_S} \leq 0.2$
2	$0.5 < \frac{\ell}{\ell_S} \leq 1.2$	$0.33 < \frac{\ell}{\ell_S} \leq 0.67$	$0.25 < \frac{\ell}{\ell_S} \leq 0.5$	$0.2 < \frac{\ell}{\ell_S} \leq 0.4$
3	$1.2 < \frac{\ell}{\ell_S} \leq 1.7$	$0.67 < \frac{\ell}{\ell_S} \leq 1.2$	$0.5 < \frac{\ell}{\ell_S} \leq 0.75$	$0.4 < \frac{\ell}{\ell_S} \leq 0.6$
4	$1.7 < \frac{\ell}{\ell_S} \leq 2.4$	$1.2 < \frac{\ell}{\ell_S} \leq 1.53$	$0.75 < \frac{\ell}{\ell_S} \leq 1.2$	$0.6 < \frac{\ell}{\ell_S} \leq 0.8$
5	$2.4 < \frac{\ell}{\ell_S} \leq 2.9$	$1.53 < \frac{\ell}{\ell_S} \leq 1.87$	$1.2 < \frac{\ell}{\ell_S} \leq 1.45$	$0.8 < \frac{\ell}{\ell_S} \leq 1.2$
6	$2.9 < \frac{\ell}{\ell_S} \leq 3.6$	$1.87 < \frac{\ell}{\ell_S} \leq 2.4$	$1.45 < \frac{\ell}{\ell_S} \leq 1.7$	$1.2 < \frac{\ell}{\ell_S} \leq 1.4$
7	$3.6 < \frac{\ell}{\ell_S} \leq 4.1$	$2.4 < \frac{\ell}{\ell_S} \leq 2.73$	$1.7 < \frac{\ell}{\ell_S} \leq 1.95$	$1.4 < \frac{\ell}{\ell_S} \leq 1.6$
8	$4.1 < \frac{\ell}{\ell_S} \leq 4.8$	$2.73 < \frac{\ell}{\ell_S} \leq 3.07$	$1.95 < \frac{\ell}{\ell_S} \leq 2.4$	$1.6 < \frac{\ell}{\ell_S} \leq 1.8$
9	$4.8 < \frac{\ell}{\ell_S} \leq 5.3$	$3.07 < \frac{\ell}{\ell_S} \leq 3.6$	$2.4 < \frac{\ell}{\ell_S} \leq 2.65$	$1.8 < \frac{\ell}{\ell_S} \leq 2.0$
10	$5.3 < \frac{\ell}{\ell_S} \leq 6.0$	$3.6 < \frac{\ell}{\ell_S} \leq 3.93$	$2.65 < \frac{\ell}{\ell_S} \leq 2.9$	$2.0 < \frac{\ell}{\ell_S} \leq 2.4$

Table 4: Distance between load points in ship length direction per elementary plate panel of inner bottom

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnage			
2	0.5 ℓ_S	0.33 ℓ_S	0.25 ℓ_S	0.2 ℓ_S
3	1.2 ℓ_S	0.67 ℓ_S	0.50 ℓ_S	0.4 ℓ_S
4	1.7 ℓ_S	1.20 ℓ_S	0.75 ℓ_S	0.6 ℓ_S
5	2.4 ℓ_S	1.53 ℓ_S	1.20 ℓ_S	0.8 ℓ_S
6	2.9 ℓ_S	1.87 ℓ_S	1.45 ℓ_S	1.2 ℓ_S
7	3.6 ℓ_S	2.40 ℓ_S	1.70 ℓ_S	1.4 ℓ_S
8	4.1 ℓ_S	2.73 ℓ_S	1.95 ℓ_S	1.6 ℓ_S
9	4.8 ℓ_S	3.07 ℓ_S	2.40 ℓ_S	1.8 ℓ_S
10	5.3 ℓ_S	3.60 ℓ_S	2.65 ℓ_S	2.0 ℓ_S

3. Strength check of plating subjected to lateral pressure

3.1 Load model

3.1.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it.
The plating which constitutes the boundary of compartments not intended to carry liquid (excluding bottom and side shell plating) is to be subjected to lateral pressure in flooded conditions.
The wave lateral pressures and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in **Ch 4, Sec 4.**

3.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.
Still water pressure p_S includes:

- the hydrostatic pressure, defined in **Ch 4, Sec 5, [1]**
- the still water internal pressure, defined in **Ch 4, Sec 6** for the various types of cargoes and for ballast.

Wave pressure p_W includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in **Ch 4, Sec 5, [1]**
- the inertial pressure, defined in **Ch 4, Sec 6** for the various types of cargoes and for ballast.

3.1.3 Lateral pressure in flooded conditions

The lateral pressure in flooded conditions pF is defined in **Ch 4, Sec 6, [3.2.1].**

3.1.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating

- $p_T = p_{ST}$ otherwise,

where:

p_{ST} : Testing pressure defined in **Ch 4, Sec 6, [4]**

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in **Ch 4, Sec 5, [1]** for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- if the testing is not carried out afloat: p_S = 0

3.1.5 Normal stresses

The normal stress to be considered for the strength check of plating contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained, in N/mm², from the following formula:

$$\sigma_X = \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z - N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z - N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in **Ch 4, Sec 3**

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in **Ch 4, Sec 3**

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in **Table 5**

C_{WV}, C_{WH} : Combination factors defined in **Ch 4, Sec 4, [2.2]** for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in **Table 5**.

Table 5: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	$C_{WH.}$
H1	-			-1	-1	0
H2	1	1	0	-		
F1	-			-1	-1	0
F2	1	1	0	-		
R1	1	0	$1.2 - \frac{T_{LC}}{T_S}$	-1	0	$1.2 - \frac{T_{LC}}{T_S}$
R2	1	0	$\frac{T_{LC}}{T_S} - 1.2$	-1	0	$\frac{T_{LC}}{T_S} - 1.2$
P1	1	$0.4 - \frac{T_{LC}}{T_S}$	0	-1	$0.4 - \frac{T_{LC}}{T_S}$	0
P2	1	$\frac{T_{LC}}{T_S} - 0.4$	0	-1	$\frac{T_{LC}}{T_S} - 0.4$	0

3.2 Plating thickness

3.2.1 Intact conditions

The net thickness of laterally loaded plate panels is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_S + p_W}{\lambda_P R_Y}}$$

where:

λ_P : Coefficient defined in **Table 6**

Table 6: Coefficient λ_P

Plating		Coefficient λ_P
Contributing to the hull girder longitudinal strength	Longitudinally framed plating	$0.95 - 0.45\left\lvert\frac{\sigma_X}{R_Y}\right\rvert$, without being taken greater than 0.9
	Transversely framed plating	$0.95 - 0.90\left\lvert\frac{\sigma_X}{R_Y}\right\rvert$, without being taken greater than 0.9
Not contributing to the hull girder longitudinal strength		0.9

3.2.2 Net thickness under flooded conditions excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds

The plating which constitutes the boundary of compartments not intended to carry liquids (excluding bottom plating and side shell plating), and excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds is to be checked in flooded conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_F}{\alpha \lambda_P R_Y}}$$

where:

λ_P : Coefficient defined in **Table 6**, determined by considering α_X in flooded condition

α : Coefficient taken equal to:

$\alpha = 0.95$ for the plating of collision bulkhead

$\alpha = 1.15$ for the plating of other watertight boundaries of compartments.

3.2.3 Net thickness of corrugation of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

The net plate thickness t, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is to be not less than that obtained from the following formula:

$$t = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

p : Resultant pressure, in kN/m^2, as defined in **Ch 4, Sec 6, [3.3.7]**

s : plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is greater

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different:

- the net thickness of the narrower plating is to be not less than that obtained, in mm, from the following formula:

$$t_N = 14.9s\sqrt{\frac{1.05p}{R_{eH}}}$$

s : plate width, in m, of the narrower plating.

- the net thickness of the wider plating is not to be less than the greater of those obtained, in mm, from the following formulae:

$$t_W = 14.9s\sqrt{\frac{1.05p}{R_{eH}}}$$

$$t_W = \sqrt{\frac{462s^2p}{R_{eH}} - t_{NP}^2}$$

where:

t_{NP} : Actual net thickness of the narrower plating, in mm, to be not taken greater than:

$$t_{NP} = 14.9s\sqrt{\frac{1.05p}{R_{eH}}}$$

s : plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is greater.

The net thickness of the lower part of corrugations is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than 0.15 ℓ_C, where ℓ_C is the span of the corrugations, in m, to be obtained according to **Ch 3, Sec 6, [10.4.4]**. The net thickness is also to comply with the requirements in **[3.2.1], Sec 2, [3.6.1 & 3.6.2]**, and **Sec 3, [6]**.
The net thickness of the middle part of corrugations is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than 0.3 ℓ_C. The net thickness is also to comply with the requirements in **[3.2.1]** and **Sec 2, [3.6.1 & 3.6.2]**.

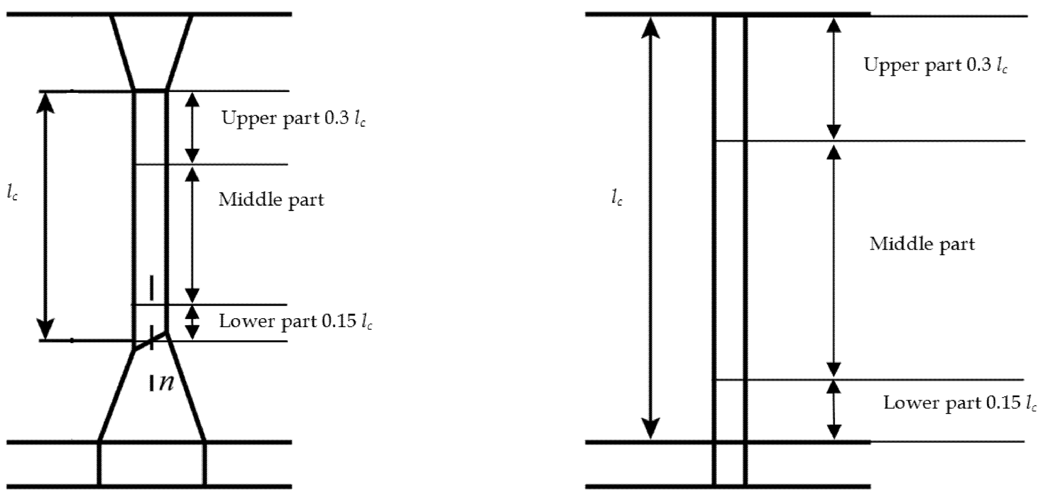


Fig 5: Parts of Corrugation

3.2.3 bis1 Net thickness of lower stool and upper stool

The net thickness and material of the stool top plate of lower stool are to be not less those for the corrugated bulkhead plating above required by **[3.2.3]**.
The net thickness and material of the upper portion of vertical or sloping stool side plating of lower stool within the depth equal to the corrugation flange width from the stool top are to be not less than the flange plate at the lower end of the corrugation required by **[3.2.3]**, as applicable, whichever is the greater.
The net thickness and material of the stool bottom plate of upper stool are to be the same as those of the bulkhead plating required by **[3.2.3]**, as applicable, whichever is the greater.
The net thickness of the lower portion of stool side plating is to not be less than 80 % of the upper part of the bulkhead plating required by **[3.2.3]**, as applicable, whichever is the greater, where the same material is used.
The net thickness of lower stool and upper stool are to be not less than those required by **[3.2.1], [3.2.2]** and **[3.2.4].**

3.2.3 bis 2 Net thickness of supporting floors of corrugated bulkhead

The net thickness and material of the supporting floors and pipe tunnel beams of corrugated bulkhead, when no stool is fitted, are to be not less than those of the corrugation flanges required by **[3.2.3].**
When a lower stool is fitted, the net thickness of supporting floors are to be not less than that of the stool side plating required by the first sentence of **[3.2.2].**

3.2.4 Testing Conditions

The plating of compartments or structures as defined in **Ch 4, Sec 6, [4]** is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_T}{1.05 R_Y}}$$

Section 2 - ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

L_2 : Rule length L, but to be taken not greater than 300 m

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5]**, on gross offered thickness reduced by $0.5\,t_C$ for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5]**, on gross offered thickness reduced by $0.5\,t_C$ for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**, in m, of the centre of gravity of the hull net transverse section defined in **Ch 5, Sec 1, [1.2]**, considering gross offered thickness reduced by $0.5\,t_C$ for all structural members

p_S, p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in **[3.1.2]**

p_F : Pressure, in kN/m^2, in flooded conditions, defined in **[3.1.3]**

p_T : Pressure, in kN/m^2, in testing conditions, defined in **[3.1.4]**

σ_X : Normal stress, in N/mm^2, defined in **[3.1.5]**

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners, measured along the chord between the supporting members, see **Ch 3, Sec 6, [4.2]**

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in **Ch 3, Sec 6, [4.3]**

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in **Ch 3, Sec 6, [4.4]**

A_{sh} : Net shear sectional area, in cm^2, of the stiffener, to be calculated as specified in **Ch 3, Sec 6, [4.4]**

m : Coefficient taken equal to:

m = 10 for vertical stiffeners

m = 12 for other stiffeners

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

$$\tau_a = \frac{R_Y}{\sqrt{3}}$$

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the yielding check of ordinary stiffeners subjected to lateral pressure and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.
The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.
In addition, the buckling check of ordinary stiffeners is to be carried out according to **Ch 6, Sec 3.**

1.2 Net scantlings

1.2.1

As specified in **Ch 3, Sec 2**, all scantlings referred to in this Section are net, i.e. they do not include any corrosion addition.
The gross scantlings are obtained as specified in **Ch 3, Sec 2, [3].**

1.3 Pressure combination

1.3.1 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering independently the following cases:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

1.3.2 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

1.4 Load calculation point

1.4.1 Horizontal stiffeners

Unless otherwise specified, lateral pressure and hull girder stress, if any, are to be calculated at mid-span of the ordinary stiffener considered.

1.4.2 Vertical stiffeners

The lateral pressure p is to be calculated as the maximum between the value obtained at mid-span and the value obtained from the following formula:

- $p = \frac{p_U + p_L}{2}$, when the upper end of the vertical stiffener is below the lowest zero pressure level
- $p = \frac{\ell_1}{\ell}\frac{p_L}{2}$, when the upper end of the vertical stiffener is at or above the lowest zero pressure level (see **Fig 1**)

where:

ℓ_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level

p_U, p_L : Lateral pressures at the upper and lower end of the vertical stiffener span ℓ, respectively.

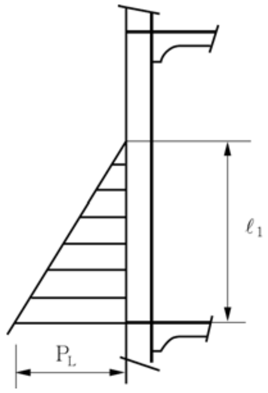


Fig 1: Definition of pressure for vertical stiffeners

2. General requirements

2.1 (void)

2.1.1 (void)

Fig 2: (void)

2.2 Net thickness of web of ordinary stiffeners

2.2.1 Minimum net thickness of webs of ordinary stiffeners other than side frames of single side bulk carriers

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:
- $t = 3.0 + 0.015 L_2$
- 40 % of the net required thickness of the attached plating, to be determined according to **Ch 6, Sec 1**.

2.2.2 Minimum net thickness of side frames of single side bulk carriers

The net thickness of side frame webs within the cargo area, in mm, is to be not less than the value obtained from the following formula:

$$t_{MIN} = 0.75\,\alpha(7 + 0.03L)$$

where:

α : Coefficient taken equal to:

$\alpha = 1.15$ for the frame webs in way of the foremost hold

$\alpha = 1.00$ for the frame webs in way of other holds.

2.2.3 Maximum net thickness of web of ordinary stiffener

The net thickness of the web of ordinary stiffeners, in mm, is to be less than 2 times the net offered thickness of the attached plating.

2.3 Net dimensions of ordinary stiffeners

2.3.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see **Fig 3**) are to comply with the following requirement:

$$\frac{h_W}{t_W} \le 20\sqrt{k}$$

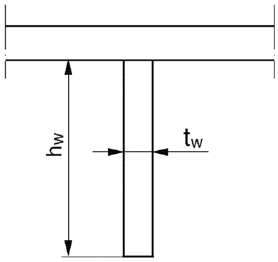


Fig 3: Net dimensions of a flat bar

2.3.2 T-section

The net dimensions of a T-section ordinary stiffener (see **Fig 4**) are to comply with the following requirements:

$$\frac{h_W}{t_W} \le 65\sqrt{k}$$

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

$$b_f t_f \ge \frac{h_W t_W}{6}$$

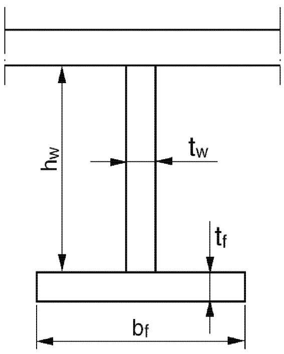


Fig 4: Net dimensions of a T-section

2.3.3 Angle

The net dimensions of an angle ordinary stiffener (see **Fig 5**) are to comply with the following requirements:

$$\frac{h_W}{t_W} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16.5\sqrt{k}$$

$$b_f t_f \ge \frac{h_W t_W}{6}$$

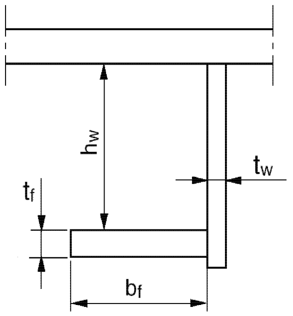


Fig 5: Net dimensions of an angle

2.4 Struts connecting ordinary stiffeners

2.4.1

The net sectional area A_{SR}, in cm^2, and the net moment of inertia I_{SR} about the main axes, in cm^4, of struts connecting ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$A_{SR} = \frac{p_{SR} s \ell}{20}$$

$$I_{SR} = \frac{0.75 s\ell (p_{SR1} + p_{SR2}) A_{ASR}\ \ell_{SR}^2}{47.2 A_{ASR} - s\ell(p_{SR1} + p_{SR2})}$$

where:

p_{SR} : Pressure to be taken equal to the greater of the values obtained, in $\mathrm{kN/m}^2$, from the following formulae:

$$p_{SR} = 0.5(p_{SR1} + p_{SR2})$$

$$p_{SR} = p_{SR3}$$

p_{SR1} : External pressure in way of the strut, in $\mathrm{kN/m}^2$, acting on one side, outside the compartment in which the strut is located

p_{SR2} : External pressure in way of the strut, in $\mathrm{kN/m}^2$, acting on the opposite side, outside the compartment in which the strut is located

p_{SR3} : Internal pressure at mid-span of the strut, in $\mathrm{kN/m}^2$, in the compartment in which the strut is located

ℓ : Span, in m, of ordinary stiffeners connected by the strut (see **Ch 3, Sec 6, [4.2.3]**)

ℓ_{SR} : Length, in m, of the strut

A_{ASR} : Actual net sectional area, in cm^2, of the strut.

2.5 Ordinary stiffeners of inner bottom loaded by steel coils on a wooden support

2.5.1 General

The requirements of this sub-article apply to the ordinary stiffeners located on inner bottom plate, bilge hopper sloping plate and inner hull plate when loaded by steel coils on a wooden support (dunnage), as indicated in **Fig 2** of **Ch 6, Sec 1.**

2.5.2 Ordinary stiffeners located on inner bottom plating

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners located on inner bottom plating are to be not less than the values obtained from the following formulae:

$$w = K_3 \frac{\{g(\cos(C_{ZP}\Phi)\cdot\cos(C_{ZR}\theta)) + a_z\}F}{8\lambda_s R_Y}$$

$$A_{sh} = \frac{5\{g(\cos(C_{ZP}\Phi)\cdot\cos(C_{ZR}\theta)) + a_z\}F}{\tau_a \sin\phi}10^{-3}$$

where:

K_3 : Coefficient defined in **Table 1**. When n_2 is greater than 10, K_3 is to be taken equal to $2\ell/3$

a_Z : Vertical acceleration, in m/s^2, defined in **Ch 6, Sec 1, [2.7.1 bis1]**

Φ : Single pitch amplitude, in deg, defined in **Ch 4, Sec 2, [2.2]**

θ : Single roll amplitude, in deg, defined in **Ch 4, Sec 2, [2.1]**

C_{ZP}, C_{ZR} : Load combination factor defined in **Ch 4, Sec 4, [2.2]**

F : Force, in kg, defined in **Ch 6, Sec 1, [2.7.2]**

λ_S : Coefficient defined in **Table 3**

ϕ : Angle, in deg, defined in **[3.2.3].**

2.5.3 Ordinary stiffeners located on bilge hopper sloping plate or inner hull plate

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are to be not less than the values obtained from the following formulae:

$$w = K_3 \frac{a_{hopper}F'}{8\lambda_S R_Y}$$

$$A_{sh} = \frac{5a_{hopper}F'}{\tau_a \sin\phi}10^{-3}$$

where:

K_3 : Coefficient defined in **Table 1**. When $n_2 > 10$, K_3 is taken equal to $2\ell/3$.

θ : Angle, in deg, between inner bottom plate and bilge hopper sloping plate or inner hull plate

a_{hopper} : Acceleration, in m/s^2, defined in **Ch 6, Sec 1, [2.7.4]**

F' : Force, in kg, defined in **Ch 6, Sec 1, [2.7.3]**

λ_S : Coefficient defined in **Table 3**

ϕ : Angle, in deg, defined in **[3.2.3]**

ℓ' : Distance, in m, between outermost load points per elementary plate panel in ship length

Table 1: Coefficient K_3

n_2	1	2	3	4	5	6	7	8	9	10
K_3	ℓ	$\ell - \frac{\ell'^2}{\ell}$	$\ell - \frac{2\ell'^2}{3\ell}$	$\ell - \frac{5\ell'^2}{9\ell}$	$\ell - \frac{\ell'^2}{2\ell}$	$\ell - \frac{7\ell'^2}{15\ell}$	$\ell - \frac{4\ell'^2}{9\ell}$	$\ell - \frac{3\ell'^2}{7\ell}$	$\ell - \frac{5\ell'^2}{12\ell}$	$\ell - \frac{11\ell'^2}{27\ell}$

2.5.4 (void)

2.6 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

2.6.1

The scantlings of deck ordinary stiffeners are to be determined by direct calculations.

2.6.2

The loads exerted by launching appliance are to correspond to the Safe Working Load of the launching appliance.

2.6.3

The combined stress, in N/mm^2, is not to exceed the smaller of:

$$\frac{100}{235} R_{eH} \quad \text{and} \quad \frac{54}{235} R_m$$

where R_m is the ultimate tensile strength of the stiffener material, in N/mm^2.

3. Yielding check

3.1 Load model

3.1.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of the compartments adjacent to it.
Ordinary stiffeners located on plating which constitutes the boundary of compartments not intended to carry liquids (excluding those on bottom and side shell plating) are to be subjected to the lateral pressure in flooded conditions.
The wave lateral loads and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in **Ch 4, Sec 4.**

3.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.
Still water pressure p_S includes:

- the hydrostatic pressure, defined in **Ch 4, Sec 5, [1]**
- the still water internal pressure, defined in **Ch 4, Sec 6** for the various types of cargoes and for ballast.

Wave pressure p_W includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:

- the hydrodynamic pressure, defined in **Ch 4, Sec 5, [1]**

- the inertial pressure, defined in **Ch 4, Sec 6** for the various types of cargoes and for ballast.

3.1.3 Lateral pressure in flooded conditions

The lateral pressure in flooded conditions p_F is defined in **Ch 4, Sec 6, [3.2.1].**

3.1.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise,

where:

p_{ST} : Testing pressure defined in **Ch 4, Sec 6, [4]**

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in **Ch 4, Sec 5, [1]** for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- if the testing is not carried out afloat: $p_S = 0$

3.1.5 Normal stresses

The normal stress to be considered for the strength check of ordinary stiffeners contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained, in N/mm², from the following formula:

$$\sigma_X = \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z - N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z - N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in **Ch 4, Sec 3**

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in **Ch 4, Sec 3**

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in **Table 2**

C_{WV}, C_{WH}: Combination factors defined in **Ch 4, Sec 4, [2.2]** for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in **Table 2.**

Table 2: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$1.2-\frac{T_{LC}}{T_S}$	-1	0	$1.2-\frac{T_{LC}}{T_S}$
R2	1	0	$\frac{T_{LC}}{T_S}-1.2$	-1	0	$\frac{T_{LC}}{T_S}-1.2$
P1	1	$0.4-\frac{T_{LC}}{T_S}$	0	-1	$0.4-\frac{T_{LC}}{T_S}$	0
P2	1	$\frac{T_{LC}}{T_S}-0.4$	0	-1	$\frac{T_{LC}}{T_S}-0.4$	0

3.2 Strength criteria for single span ordinary stiffeners other than side frames of single side bulk carriers

3.2.1 Boundary conditions

The requirements of this sub-article apply to ordinary stiffeners considered as clamped at both ends. For other boundary conditions, the yielding check is to be considered on a case by case basis.

3.2.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in **[3.2.3]** to **[3.2.7]** is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90 % of the maximum required value.
The same applies for the minimum net shear sectional area.

3.2.3 Net section modulus and net shear sectional area of single span ordinary stiffeners under intact conditions

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{m\lambda_S R_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

where:

λ_S : Coefficient defined in **Table 3.**

ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75 deg.

Table 3: Coefficient λ_S

Ordinary stiffener	Coefficient λ_S
Longitudinal stiffener ccontributing to the hull girder longitudinal strength	$1.2\left(1.0-0.85\left\lvert\frac{\sigma_X}{R_Y}\right\rvert\right)$, without being taken greater than 0.9
Other stiffeners	0.9

3.2.4 Net section modulus of corrugated bulkhead of ballast hold for ships having a length *L* less than 150 m

The net section modulus w, in cm^3, of corrugated bulkhead of ballast hold for ships having a length L less than 150 m subjected to lateral pressure are to be not less than the values obtained from the following formula:

$$w = K\frac{(p_S + p_W)s_C\ell^2}{m\lambda_S R_Y}10^3$$

where:

K : Coefficient given in **Table 4** and **5**, according to the type of end connection. When $d_H < 2.5\,d_0$, both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

s_C : Half pitch length, in m, of the corrugation, defined in **Ch 3, Sec 6, Fig 28**

ℓ : Length, in m, between the supports, as indicated in **Fig 6**

λ_S : Coefficient defined in **Table 3.**

The effective width of the corrugation flange in compression is to be considered according to **Ch 3, Sec 6, [10.4.10]** when the net section modulus of corrugated bulkhead is calculated.

Table 4: Values of *K*, in case $d_H \geq 2.5\,d_0$

Upper end support		
Supported by girders	Welded directly to deck	Welded to stool efficiently supported by ship structure
1.25	1.00	0.83

Table 5: Values of *K*, in case $d_H < 2.5\,d_0$

Section modulus of	Upper end support		
	Supported by girders	Connected to deck	Connected to stool
Corrugated bulkhead	0.83	0.71	0.65
Stool at bottom	0.83	1.25	1.13

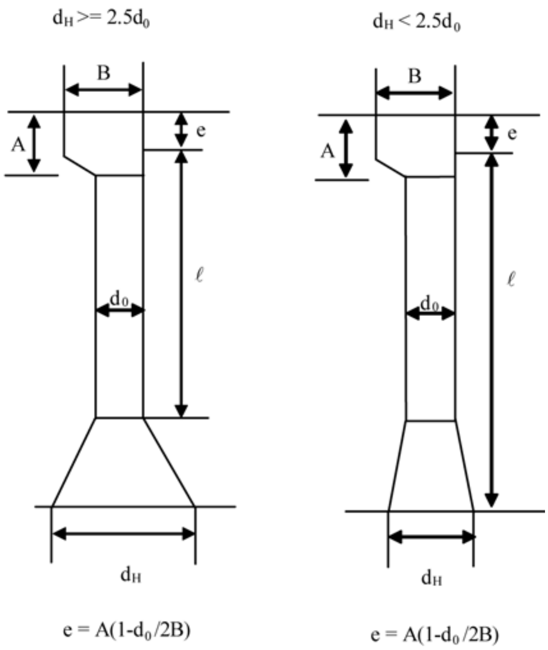


Fig 6: Measurement of ℓ

3.2.5 Net section modulus and net shear sectional area of single span ordinary stiffeners under flooded conditions excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds subjected to flooding are to be not less than the values obtained from the following formulae:

$$w = \frac{p_F s \ell^2}{16 \alpha \lambda_S R_Y} 10^3$$

$$A_{sh} = \frac{5 p_F s \ell}{\alpha \tau_a \sin\phi}$$

where:

λ_S, ϕ : Coefficient and angle defined in **[3.2.3]**, λ_S being determined by considering σ_X in flooded condition.

α : Coefficient taken equal to:

α = 0.95 for the ordinary stiffeners of collision bulkhead,

α = 1.15 for the ordinary stiffeners of other watertight boundaries of compartments.

without taken $\alpha\lambda_S$ greater than 1.0

3.2.6 (void)

3.2.7 Net section modulus and net shear sectional area of single span ordinary stiffeners under testing conditions

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of single span ordinary stiffeners subjected to testing are to be not less than the values obtained from the following formulae:

$$w = \frac{p_T s \ell^2}{1.05 m R_Y} 10^3$$

$$A_{sh} = \frac{5 p_T s \ell}{1.05 \tau_a \sin\phi}$$

where:

ϕ : Angle, in deg, defined in **[3.2.3].**

3.3 Strength criteria for side frames of single side bulk carriers

3.3.1 Net section modulus and net shear sectional area of side frames

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side frames subjected to lateral pressure are to be not less, in the mid-span area, than the values obtained from the following formulae:

$$w = 1.125 \alpha_m \frac{(p_S + p_W) s \ell^2}{m \lambda_S R_Y} 10^3$$

$$A_{sh} = 1.1 \alpha_S \frac{5(p_S + p_W) s \ell}{\tau_a \sin\phi} \left(\frac{\ell - 2\ell_B}{\ell} \right)$$

where:

α_m : Coefficient taken equal to:

α_m = 0.42 for BC-A ships

α_m = 0.36 for other ships

λ_S : Coefficient taken equal to 0.9

ℓ : Side frame span, in m, defined in **Ch 3, Sec 6, Fig 19**, to be taken not less than $0.25D$

α_S : Coefficient taken equal to:

α_S = 1.1 for side frames of holds specified to be empty in BC-A ships

α_S = 1.0 for other side frames

ℓ_B : Lower bracket length, in m, defined in **Fig 7**

p_s, p_w : Still water and wave pressures, in $\mathrm{kN/m}^2$, in intact conditions calculated as defined in **[1.3]** and **[1.4.2].**

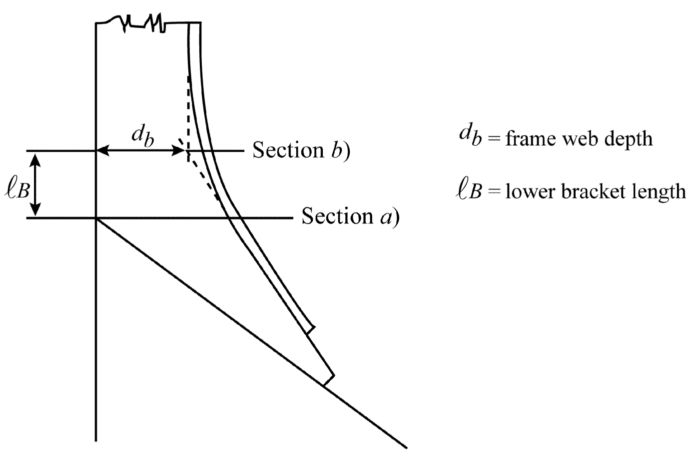


Fig 7: Side frame lower bracket length

In addition, for side frames of holds intended to carry ballast water in heavy ballast condition, the net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, all along the span are to be in accordance with **[3.2.3]**, ℓ being the span of the side frame as defined in **Ch 3, Sec 6, [4.2]**, with consideration to brackets at ends.

3.3.2 Supplementary strength requirements

In addition to **[3.3.1]**, the net moment of inertia, in cm^4, of the 3 side frames located immediately abaft the collision bulkhead is to be not less than the value obtained from the following formula:

$$I = 0.18\frac{(p_S + p_W)\ell^4}{n}$$

where:

ℓ : Side frame span, in m

n : Number of frames from the bulkhead to the frame in question, taken equal to 1, 2 or 3

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of forepeak stringers within the foremost hold.

3.3.3 Lower bracket of side frame

At the level of lower bracket as shown in **Ch 3, Sec 6, Fig 19**, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus w required for the frame mid-span area obtained from **[3.3.1]**.
In addition, for holds intended to carry ballast water in heavy ballast condition, the net section modulus w, in cm^3, at the level of lower bracket is to be not less than twice the greater of the net section moduli obtained from **[3.3.1]** and **[3.2.3].**
The net thickness t_{LB} of the frame lower bracket, in mm, is to be not less than the net thickness of the side frame web plus 1.5 mm.
Moreover, the net thickness t_{LB} of the frame lower bracket is to comply with the following formula:

- for symmetrically flanged frames : $\frac{h_{LB}}{t_{LB}} \le 87\sqrt{k}$
- for asymmetrically flanged frames : $\frac{h_{LB}}{t_{LB}} \le 73\sqrt{k}$

The web depth h_{LB} of lower bracket may be measured from the intersection between the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see **Ch 3, Sec 6, Fig 22**).
For the 3 side frames located immediately abaft the collision bulkhead, whose scantlings are increased according to **[3.3.2]**, when t_{LB} is greater than $1.73\, t_w$, the thickness t_{LB} may be taken as the value t'_{LB} obtained from the following formula:

$$t'_{LB} = \left(t_{LB}^2\, t_W\right)^{1/3}$$

where t_w is the net thickness of the side frame web, in mm, corresponding to A_{sh} determined in accordance to **[3.3.1].**
The flange outstand is not to exceed $12\, k^{0.5}$ times the net flange thickness.

3.3.4 Upper bracket of side frame

At the level of upper bracket as shown in **Ch 3, Sec 6, Fig 19**, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus w required for the frame mid-span area obtained from **[3.3.1]**.
In addition, for holds intended to carry ballast water in heavy ballast condition, the net section modulus w, in cm^3, at the level of upper bracket is not to be less than twice the greater of the net sections

moduli obtained from **[3.2.3]** and **[3.3.1].**
The net thickness t_{UB} of the frame upper bracket, in mm, is to be not less than the net thickness of the side frame web.

3.4 Upper and lower connections of side frames of single side bulk carriers

3.4.1

The section moduli of the:

- side shell and hopper tank longitudinals that support the lower connecting brackets,
- side shell and topside tank longitudinals that support the upper connecting brackets

are to be such that the following relationship is separately satisfied for each lower and upper connecting bracket (see also **Ch 3, Sec 6, Fig 22**):

$$\sum_n w_i d_i \geq \alpha_T \frac{(p_S + p_W)\ell^2 \ell_1^2}{16 R_Y}$$

where:

n : Number of the longitudinal stiffeners of side shell and hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

w_i : Net section modulus, in cm^3, of the i-th longitudinal stiffener of the side shell or hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

d_i : Distance, in m, of the above i-th longitudinal stiffener from the intersection point of the side shell and hopper / topside tank

ℓ_1 : Spacing, in m, of transverse supporting webs in hopper / topside tank, as applicable

R_y : Lowest value of equivalent yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper / topside tanks that support the lower / upper end connecting bracket of the side frame

α_T : Coefficient taken equal to:
α_T = 150 for the longitudinal stiffeners supporting the lower connecting brackets
α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets

ℓ : Side frame span, in m, as defined in **[3.3.1]**

p_s, p_w : Still water and wave pressures as those for the side frame.

3.4.2

The net connection area, A_i, in cm^2, of the bracket to the i-th longitudinal stiffener supporting the bracket is to be obtained from the following formula:

$$A_i = 0.4 \frac{w_i s}{\ell_1^2} \frac{k_{bkt}}{k_{lg,i}}$$

where:

w_i : Net section modulus, in cm^3, of the i-th longitudinal stiffener of the side or sloped bulkheads that support the lower or the upper end connecting bracket of the side frame, as applicable

ℓ_1 : As defined in **[3.4.1]**

k_{bkt} : Material factor for the bracket

$k_{lg,i}$: Material factor for the i-th longitudinal stiffener.
s : Frame spacing, in m

3.5 Strength criteria for multi-span ordinary stiffeners

3.5.1 Checking criteria

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener, calculated according to **[3.5.2]**, are to comply with the formulae in **Table 6.**

Table 6: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Flooded	Testing
Normal stress	$\sigma \le \lambda_S R_Y$	$\sigma \le \alpha\lambda_S R_Y$	$\sigma \le 1.05 R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le \alpha\tau_a$	$\tau \le 1.05\tau_a$
Note 1: λ_S : Coefficient defined in **[3.2.3]** α : Coefficient defined in **[3.2.5]**			

3.5.2 Multi-span ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.6 Scantlings of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

3.6.1 Bending capacity and shear capacity of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds

The bending capacity and the shear capacity of the corrugations of watertight bulkheads between separating cargo holds are to comply with the following formulae:

$$0.5W_{LE} + W_M \ge \frac{M}{0.95R_{eH}}10^3$$

$$\tau \le \frac{R_{eH}}{2}$$

where:

M : Bending moment in a corrugation, to be obtained, in kN.m, from the following formula:

$$M = F\ell_C/8$$

F : Resultant force, in kN, to be calculated according to **Ch 4, Sec 6, [3.3.7]**

ℓ_C : Span of the corrugations, in m, to be obtained according to **[3.6.2]**

W_{LE} : Net section modulus, in cm^3 of one half pitch corrugation, to be calculated at the lower end of the corrugations according to **[3.6.2]**, without being taken greater than the value obtained from the following formula:

$$W_{LE,M} = W_G + \left(\frac{Qh_G - 0.5h_G^2 s_C p_G}{R_{eH}} \right) 10^3$$

W_G : Net section modulus, in cm^3 of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to **[3.6.2]**

Q : Shear force at the lower end of a corrugation, to be obtained, in kN, from the following formula:

$Q = 0.8F$

h_G : Height, in m, of shedders or gusset plates, as applicable (see **Fig 11** to **Fig 15**)

p_G : Resultant pressure, in kN/m^2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to **Ch 4, Sec 6, [3.3.7]**

s_C : Spacing of the corrugations, in m, to be taken according to **Ch 3, Sec 6, Fig 28**

W_M : Net section modulus in cm^3 of one half pitch corrugation, to be calculated at the mid-span of corrugations according to **[3.6.2]** without being taken greater than $1.15\,W_{LE}$

τ : Shear stress in the corrugation, in N/mm^2 to be obtained from the following formula:

$$\tau = 10 \frac{Q}{A_{SH}}$$

A_{sh} : Shear area, in cm^2 calculated according to the followings.

The shear area is to be reduced in order to account for possible non-perpendicular between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by ($\sin\varphi$), φ being the angle between the web and the flange (see **Ch 3, Sec 6, Fig 28**).

The actual net section modulus of corrugations is to be calculated according to **[3.6.2].**

The net section modulus of the corrugations upper part of the bulkhead, as defined in **Sec 1, Fig 5**, is not to be less than 75 % of that of the middle part complying with this requirement and **Sec 1, [3.2.1]**, corrected for different minimum yield stresses.

3.6.2 Net section modulus at the lower end of the corrugations

a) The net section modulus at the lower end of the corrugations (**Fig 11** to **Fig 15**) is to be calculated with the compression flange having an effective flange width b_{ef} not larger than that indicated in **Ch 3, Sec 6, [10.4.10].**

b) Webs not supported by local brackets

Except in case e), if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30 % effective.

c) Effective shedder plates

Provided that effective shedder plates, as defined in **Ch 3, Sec 6, [10.4.11]** are fitted (see **Fig 11** and **Fig 12**), when calculating the section modulus of corrugations at the lower end (cross-sections 1 in **Fig 11** and **Fig 12**), the net area of flange plates may be increased by the value obtained, in cm^2, from the following formula:

$I_{SH} = 2.5a\sqrt{t_f t_{SH}}$ without being taken greater than $2.5\,at_f$,

where:

a : Width, in m, of the corrugation flange (**Ch 3, Sec 6, Fig 28**)

t_{SH} : Net shedder plate thickness, in mm

t_f : Net flange thickness, in mm.

d) Effective gusset plates

Provided that effective gusset plates, as defined in **Ch 3, Sec 6, [10.4.12]**, are fitted (see **Fig 13** to **Fig 15**), when calculating the net section modulus of corrugations at the lower end (cross-sections 1 in **Fig 13** to **Fig 15**), the area of flange plates may be increased by the value obtained, in cm^2, from the following formula:

$$I_G = 7 h_G t_f$$

where:

h_G : Height, in m, of gusset plates (see **Fig 13** to **Fig 15**) to be taken not greater than $(10/7)S_{GU}$

S_{GU} : Width, in m, of gusset plates

t_f : Net flange thickness, in mm

e) Sloping stool top plate

If the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45º with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45º, the effectiveness of the web may be obtained by linear interpolation between 30 % for 0º and 100 % for 45º.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations the net area of flange plates may be increased as specified in d) above. No credit may be given to shedder plates only.

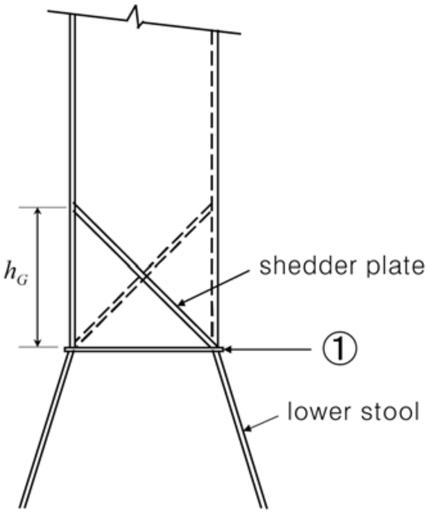


Fig 11: Symmetrical shedder plates

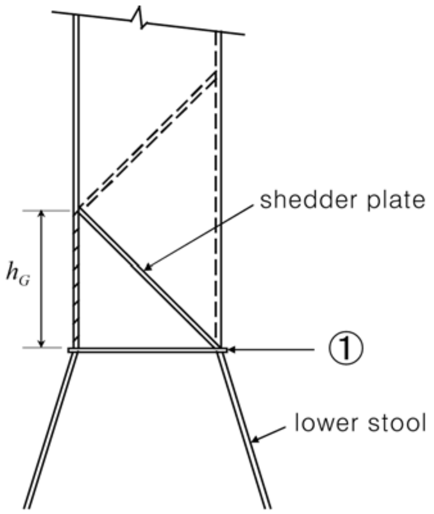


Fig 12: Asymmetrical shedder plates

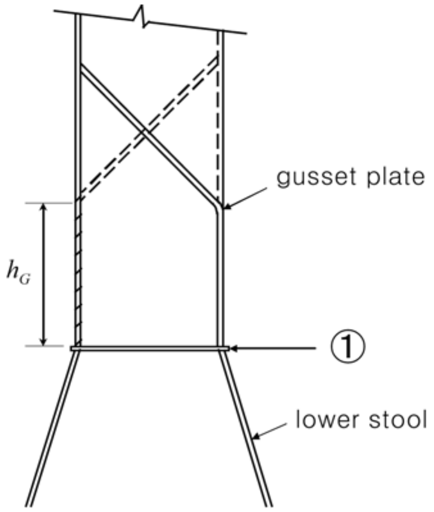


Fig 13: Symmetrical gusset/shedder plates

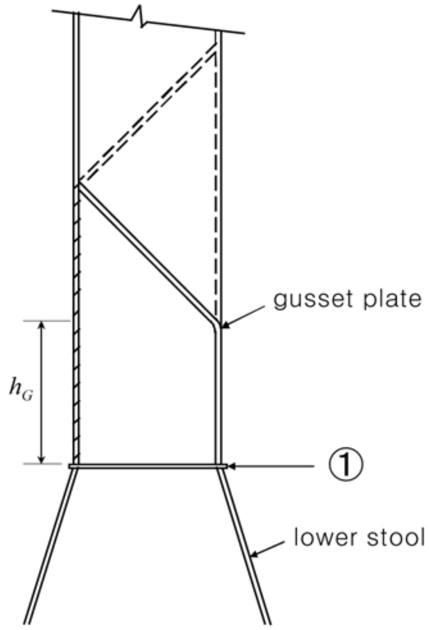


Fig 14: Asymmetrical gusset/shedder plates

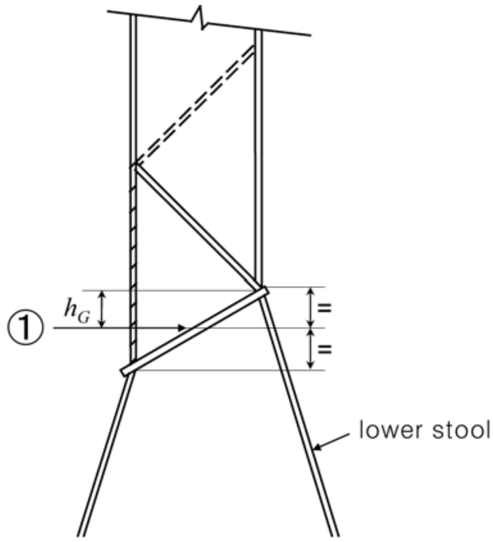


Fig 15: Asymmetrical gusset/shedder plates

3.6.3 Stiffeners in lower stool and upper stool

The net section modulus of stiffeners in lower stool and upper stool is to be greater of the values obtained from the following formula or required by [3.2.5].

$$w = \frac{psl^2}{16\alpha\lambda_s R_Y}10^3$$

Where,

p : Pressure, in kN/m^2, as defined in **Ch 4, Sec 6, [3.3.7]**

α and λ_s : defined in **[3.2.5]**

4. Web stiffeners of primary supporting members

4.1 Net scantlings

4.1.1

Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, their net sectional area at the web stiffener mid-height is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 0.1 k_1 p s \ell$$

where:

k_1 : Coefficient depending on the web connection with the ordinary stiffener, to be taken as:

k_1 = 0.30 for connections without collar plate (see **Ch 3, Sec 6, Fig 8**)

k_1 = 0.225 for connections with a collar plate (see **Ch 3, Sec 6, Fig 9**)

k_1 = 0.20 for connections with one or two large collar plates (see **Ch 3, Sec 6, Fig 10** and **11**)

p : Pressure, in kN/m^2, acting on the ordinary stiffener.

4.1.2

The net section modulus of web stiffeners of non-watertight primary supporting members is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 2.5 s^2 t S_S^2$$

where:

s : Length, in m, of web stiffeners

t : Web net thickness, in mm, of the primary supporting member

S_S : Spacing, in m, of web stiffeners.

4.1.3 Connection ends of web stiffeners

Where the web stiffeners of primary supporting members are welded to ordinary stiffener face plates, the stress at ends of web stiffeners of primary supporting members in water ballast tanks, in N/mm^2, is to comply with the following formula when no bracket is fitted

$$\sigma \le 175$$

where:

$$\sigma = 1.1 K_{con} K_{longi} K_{stiff} \frac{\Delta\sigma}{\cos\theta}$$

K_{con} : Coefficient considering stress concentration, taken equal to:

K_{con} = 3.5 for stiffeners in the double bottom or double side space (see **Fig 8**)

K_{con} = 4.0 for other cases (e.g. hopper tank, top side tank, etc.) (see **Fig 8**)

K_{longi} : Coefficient considering shape of cross section of the longitudinal, taken equal to:

K_{longi} = 1.0 for symmetrical profile of stiffener (e.g. T-section, flat bar)

K_{longi} = 1.3 for asymmetrical profile of stiffener (e.g. angle section, bulb profile)

K_{stiff} : Coefficient considering the shape of the end of the stiffener, taken equal to:

K_{stiff} = 1.0 for standard shape of the end of the stiffener (see **Fig 9**)

K_{stiff} = 0.8 for the improved shape of the end of the stiffener (see **Fig 9**)

θ : As given in Fig 10

$\Delta\sigma$: Stress range, in $\mathrm{N/mm^2}$, transferred from longitudinals into the end of web stiffener, as obtained from the following formula:

$$\Delta\sigma = \frac{2W}{0.322h'[(A_{w1}/\ell_1)+(A_{w2}/\ell_2)]+A_{s0}}$$

W : Dynamic load, in N, as obtained from the following formula:

$$W = 1{,}000(\ell - 0.5s)sp$$

p : Maximum inertial pressure due to liquid in the considered compartment where the web stiffener is located according to **Ch 4, Sec 6, [2.2.1]**, in $\mathrm{kN/m^2}$, of the probability level of 10^{-4}, calculated at mid-span of the ordinary stiffener

ℓ : Span of the longitudinal, in m

s : Spacing of the longitudinal, in m

A_{s0}, A_{w1}, A_{w2} : Geometric parameters as given in **Fig 10**, in $\mathrm{mm^2}$

ℓ_1, ℓ_2 : Geometric parameters as given in **Fig 10**, in mm

h' : As obtained from following formula, in mm:

$$h' = h_s + h_0'$$

h_s : As given in **Fig 10**, in mm

h_0' : As obtained from the following formula, in mm

$h_0' = 0.636b'$ for $b' \le 150$

$h_0' = 0.216b' + 63$ for $150 < b'$

b' : Smallest breadth at the end of the web stiffener, in mm, as shown in **Fig 9**

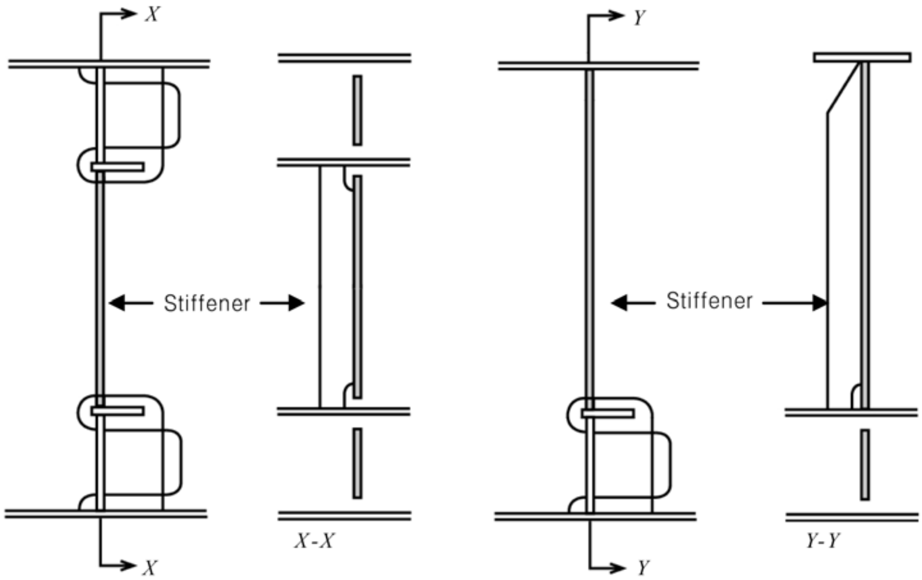


Fig 8: Web stiffeners fitted on primary supporting members

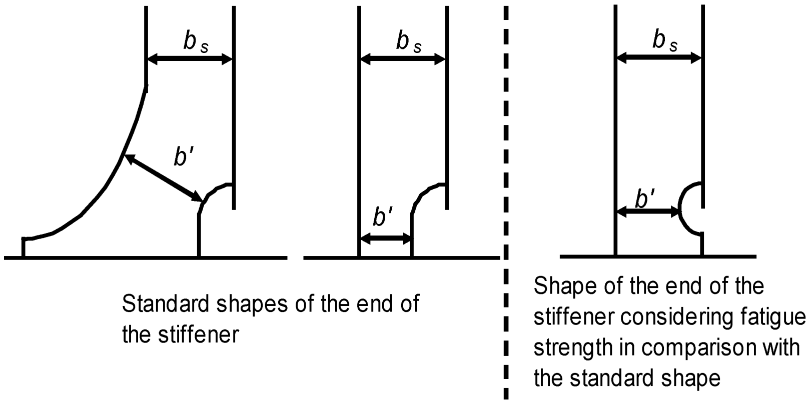
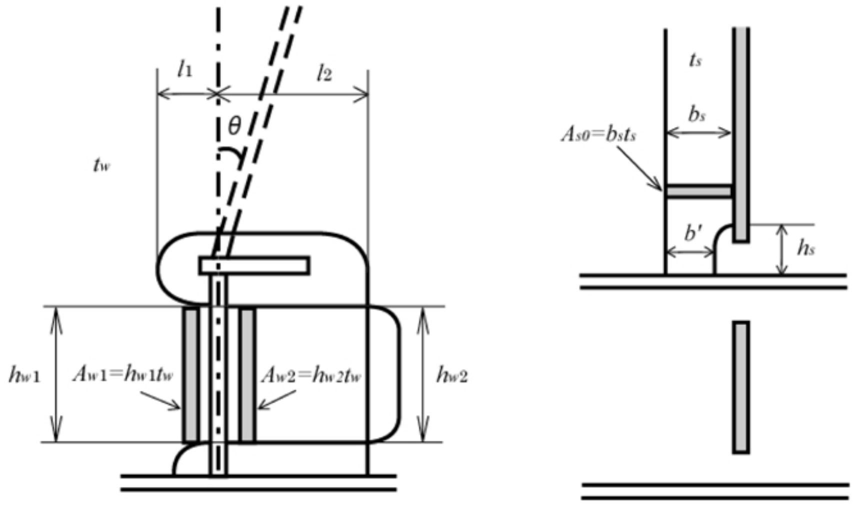


Fig 9: Shape of the end of the web stiffener



Note:

t_s : net thickness of the web stiffener, in mm.

t_w : net thickness of the collar plate, in mm.

Fig 10: Definitions of geometric parameters

Section 3 – BUCKLING & ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

In this section, compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.

a : Length in mm of the longer side of the partial plate field in general or length in mm of the side of the partial plate field according **Table 2**, BLC 3 - 10

b : Length in mm of the shorter side of the partial plate field in general or length in mm of the side of the partial plate field according **Table 2**, BLC 3 - 10

α : Aspect ratio of elementary plate panel, taken equal to:

$\alpha = a/b$

n : Number of elementary plate panel breadths within the partial or total plate panel

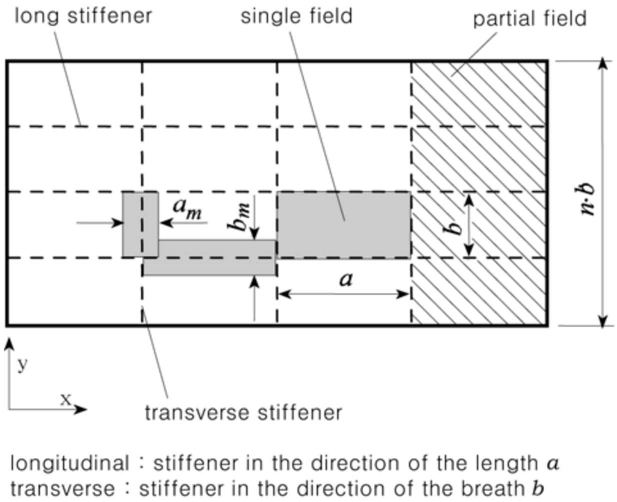


Fig 1: General arrangement of panel

t : Net plate thickness, in mm

σ_n : Normal stress resulting from hull girder bending, in N/mm^2

τ_{SF} : Shear stress induced by the shear forces as defined in **[2.1.3]**, in N/mm^2

σ_x : Membrane stress in x-direction, in N/mm^2

σ_y : Membrane stress in y-direction, in N/mm^2

τ : Shear stress in the x-y plane, in N/mm^2

λ : Reference degree of slenderness, taken equal to:

$$\lambda = \sqrt{\frac{R_{eH}}{K\sigma_e}}$$

K : Buckling factor according to **Table 2** and **Table 3**

Reference stress, to be the following for LC 1 and 2:

σ_e : Reference stress, taken equal to:

$$\sigma_e = 0.9E\left(\frac{t}{b'}\right)^2$$

b' : shorter side of elementary plate panel

Reference stress, to be the following for LC 3 through 10:

σ_e : Reference stress, taken equal to:

$$\sigma_e = 0.9E\left(\frac{t}{b}\right)^2$$

ψ : Edge stress ratio taken equal to:

$\psi = \sigma_2 / \sigma_1$

where:

σ_1 : maximum compressive stress

σ_2 : minimum compressive stress or tensile stress

S : Safety factor, taken equal to:

S = 1.0 except for the case mentioned below

S = 1.1 for structures which are exclusively exposed to local loads (e.g. hatch covers, foundations)

S = 1.15 for the ultimate strength in lateral buckling mode of longitudinal and transverse ordinary stiffeners of the hatchway coamings, sloping plating of the topside tanks and hopper tanks, inner bottom, inner side if any, side shell of single side skin construction and top and bottom stools of transverse bulkheads, assessed according to **[4.2]**.

For constructions of aluminium alloys the safety factors are to be increased in each case by 0.1

F_1 : Correction factor for boundary condition of stiffeners on the longer side of elementary plate panels according to **Table 1**. If the clamping is unequal on the longitudinal sides of the panel, the minimum value of the appropriate F_1-parameter has to be used.

Table 1: Correction factor F_1

	F_1 (2)	Edge stiffener
Stiffeners sniped at both ends	1.00	
Guidance values where both ends are effectively connected to adjacent structures (1)	1.05	Flat bar
	1.10	Bulb section
	1.20	Angle and tee-sections
	1.30	Girders of high rigidity (e.g. bottom transverses)
(1) Exact values may be determined by direct calculations. (2) An average value of F_1 is to be used for plate panels having different edge stiffeners.		

1. General

1.1

1.1.1

The requirements of this Section apply for the buckling check of structural members subjected to compressive stresses, shear stresses and lateral pressure.

1.1.2

The buckling checks have to be performed for the following elements:

a) according to requirements of **[2], [3]** and **[4]** and for all load cases as defined in **Ch 4, Sec 4** in intact condition:
   - elementary plate panels and ordinary stiffeners in a hull transverse section analysis,
   - elementary plate panels modeled in FEM as requested in **Ch 7.**

b) according to requirements of **[6]** and only in flooded condition:
   - transverse vertically corrugated watertight bulkheads.

1.1.3

The boundary condition for elementary plate panels are to be considered as simply supported. If the boundary condition differs significantly from simple support, more appropriate boundary condition can be applied according to cases 3, 4 and 7 to 10 of **Table 2.**

2. Application

2.1 Load model for hull transverse section analysis

2.1.1 General

The structural members at a considered hull transverse section are to be checked for buckling criteria under the combination of:

- the normal stress σ_n resulting from hull girder bending, as defined in **[2.1.2]**
- the shear stress τ_{SF} as defined in **[2.1.3]**
- the lateral pressure in intact condition applied on the members as the case may be.

The lateral pressures and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in **Ch 4, Sec 4.**

2.1.2 Normal stress σ_n

The normal stress σ_n to be considered for each of the mutually exclusive load cases as referred in **[2.1.1]** is the maximum compressive stress on the considered structural member according to the formulas given in **Ch 6, Sec 1, [3.1.5]** and **Ch 6, Sec 2, [3.1.5]**, respectively for elementary plate panels and ordinary stiffeners.
For transverse ordinary stiffeners, the normal stress σ_n for each of the mutually exclusive load cases is the maximum compressive stress calculated at each end.

2.1.3 Shear stress τ_{SF}

The shear stress τ_{SF} to be considered for each of the mutually exclusive load cases as referred in **[2.1.1]** is the shear stress induced by the shear forces, in kN, equal to:

$$Q = Q_{SW} + C_{QW}\, Q_{WV}$$

where:

Q_{SW} : Design still water shear force in intact condition, in kN, at the hull transverse section considered, defined in **Ch 4, Sec 3, [2.3]**

Q_{WV} : Vertical wave shear force in intact condition, in kN, at the hull transverse section considered, defined in **Ch 4, Sec 3, [3.2]**

C_{QW} : Load combination factor as defined in **Ch 4, Sec 4, Table 3**

If the design still water shear force is not available at preliminary design stage, the following default value, in kN, may be used:

$$Q_{SW0} = 30CLB(C_B + 0.7)10^{-2}$$

2.1.4 Lateral pressure

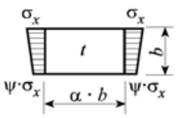
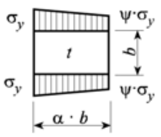
The lateral pressure to be considered for the buckling check is defined in **Ch 6, Sec 1, [3.1]** for curved plate panel and in **Ch 6, Sec 2, [3.1]** for ordinary stiffeners.
The load calculation point for the curved plate panel is located at mid distance of the curved plate panel extremities along the curve.
The load calculation point of ordinary stiffeners is defined in **Ch 6, Sec 2, [1.4]**

2.2 Application

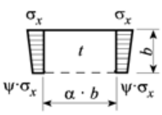
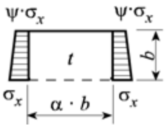
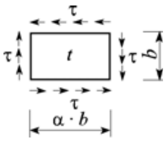
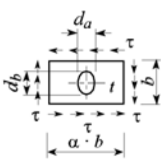
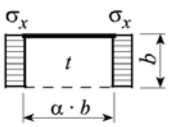
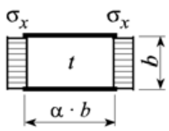
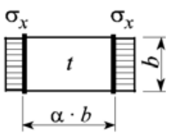
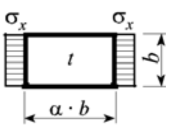
2.2.1

Application of the buckling and ultimate strength criterion is described in **App 1.**

Table 2: Buckling and reduction factors for plane elementary plate panels

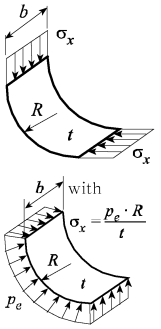
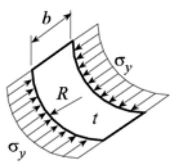
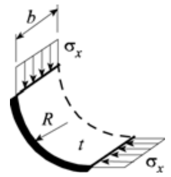
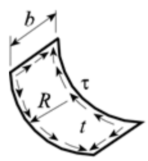
Buckling Load Case	Edge stress ratio ψ	Asp. ratio $\alpha = a/b$	Buckling factor K	Reduction factor k
1 	$1 \ge \psi \ge 0$	$\alpha \ge 1$	$K = \dfrac{8.4}{\psi + 1.1}$	$\kappa_x = 1$ for $\lambda \le \lambda_c$ $\kappa_x = c\left(\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ $c = (1.25 - 0.12\psi) \le 1.25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$
	$0 > \psi > -1$		$K = 7.63 - \psi(6.26 - 10\psi)$	
	$\psi \le -1$		$K = (1-\psi)^2 \cdot 5.975$	
2 	$1 \ge \psi \ge 0$	$\alpha \ge 1$	$K = F_1\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1}{(\psi + 1.1)}$	$\kappa_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2(H - R)}{\lambda^2}\right)$ $c = (1.25 - 0.12\psi) \le 1.25$ $R = \lambda\left(1 - \dfrac{\lambda}{c}\right)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \ge \lambda_c$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0.88}{c}}\right)$ $F = \left(1 - \dfrac{\dfrac{K}{0.91} - 1}{\lambda_p^{\ 2}}\right) \cdot c_1 \ge 0$ $\lambda_p^{\ 2} = \lambda^2 - 0.5$ for $1 \le \lambda_p^{\ 2} \le 3$ $c_1 = 1$, for σ_y due to direct loads $c_1 = \left(1 - \dfrac{F_1}{\alpha}\right) \ge 0$, for σ_y due to bending (in general) $c_1 = 0$, for σ_y due to bending in extreme load cases (e.g. wt. bulkheads) $H = \lambda - \dfrac{2\lambda}{c\left(T + \sqrt{T^2 - 4}\right)} \ge R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1 \le \alpha \le 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1(1+\psi)}{1.1} - \dfrac{\psi}{\alpha^2}(13.9 - 10\psi)\right]$	
		$\alpha > 1.5$	$K = F_1\left[\left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2.1(1+\psi)}{1.1} - \dfrac{\psi}{\alpha^2}(5.87 + 1.87\alpha^2 + \dfrac{8.6}{\alpha^2} - 10\psi)\right]$	
	$\psi \le -1$	$1 \le \alpha \le \dfrac{3(1-\psi)}{4}$	$K = F_1\left(\dfrac{1-\psi}{\alpha}\right)^2 \cdot 5.975$	
		$\alpha > \dfrac{3(1-\psi)}{4}$	$K = F_1\left[\left(\dfrac{1-\psi}{\alpha}\right)^2 \cdot 3.9675 + 0.5375\left(\dfrac{1-\psi}{\alpha}\right)^4 + 1.87\right]$	
Explanations for boundary conditions	--------- plate edge free ——— plate edge simply supported ▬▬▬ plate edge clamped			

Note : The load cases as listed in **Table 2** are general cases. Each stress component (σ_x, σ_y) is to be understood in a local coordinates.

3 	$1 \ge \psi \ge 0$	$\alpha > 0$	$K = \dfrac{4\left(0.425 + \dfrac{1}{\alpha^2}\right)}{3\psi + 1}$	
	$0 > \psi \ge -1$		$K = 4\left(0.425 + \dfrac{1}{\alpha^2}\right)(1+\psi) - 5\psi(1 - 3.42\psi)$	$\kappa_x = 1$ for $\lambda \le 0.7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
4 	$1 \ge \psi \ge -1$	$\alpha > 0$	$K = \left(0.425 + \dfrac{1}{\alpha^2}\right)\dfrac{3-\psi}{2}$	
5 	===		$K = K_\tau \sqrt{3}$	
		$\alpha \ge 1$	$K_\tau = \left[5.34 + \dfrac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \dfrac{5.34}{\alpha^2}\right]$	$\kappa_\tau = 1$ for $\lambda \le 0.84$ $\kappa_\tau = \dfrac{0.84}{\lambda}$ for $\lambda > 0.84$
6 	===		$K = K' r$ $K' = K$ according to load case 5 r = Reductions factor r = $\left(1 - \dfrac{d_a}{a}\right)\left(1 - \dfrac{d_b}{b}\right)$ with $\dfrac{d_a}{a} \le 0.7$ and $\dfrac{d_b}{b} \le 0.7$	
7 	===	$\alpha \ge 1.64$	$K = 1.28$	$\kappa_x = 1$ for $\lambda \le 0.7$ $\kappa_x = \dfrac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
		$\alpha < 1.64$	$K = \dfrac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
8 	===	$\alpha \ge \dfrac{2}{3}$	$K = 6.97$	
		$\alpha < \dfrac{2}{3}$	$K = \dfrac{1}{\alpha^2} + 2.5 + 5\alpha^2$	
9 	===	$\alpha \ge 4$	$K = 4$	
		$4 > \alpha > 1$	$K = 4 + \left[\dfrac{4-\alpha}{3}\right]^4 \cdot 2.74$	$\kappa_x = 1$ for $\lambda \le 0.83$ $\kappa_x = 1.13\left[\dfrac{1}{\lambda} - \dfrac{0.22}{\lambda^2}\right]$ for $\lambda > 0.83$
		$\alpha \le 1$	$K = \dfrac{4}{\alpha^2} + 2.07 + 0.67\alpha^2$	
10 	===	$\alpha \ge 4$	$K = 6.97$	
		$4 > \alpha > 1$	$K = 6.97 + \left[\dfrac{4-\alpha}{3}\right]^4 \cdot 3.1$	
		$\alpha \le 1$	$K = \dfrac{4}{\alpha^2} + 2.07 + 4\alpha^2$	
Explanations for boundary conditions	---------	plate edge free		
	——— (thin line)	plate edge simply supported		
	━━━ (thick line)	plate edge clamped		

Note : The load cases as listed in **Table 2** are general cases. Each stress component (σ_x, σ_y) is to be understood in a local coordinates.

Table 3: Buckling and reduction factor for curved plate panel with R/t ≤ 2500[1]

Buckling Load Case	Aspect ratio b/R	Buckling factor K	Reduction factor k
1 	$\frac{b}{R} \le 1.63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{Rt}} + 3\frac{(Rt)^{0.175}}{b^{0.35}}$	$\kappa_x = 1$ for $\lambda \le 0.4$ [2] $\kappa_x = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_x = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
p_e = external pressure in (N/mm^2)	$\frac{b}{R} > 1.63\sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 2.25\left(\frac{R^2}{bt}\right)^2$	
2 	$\frac{b}{R} \le 0.5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\frac{b^2}{Rt}$	$\kappa_y = 1$ for $\lambda \le 0.25$ [2] $\kappa_y = 1.233 - 0.933 \cdot \lambda$ for $0.25 < \lambda \le 1$ $\kappa_y = 0.3/\lambda^3$ for $1 < \lambda \le 1.5$ $\kappa_y = 0.2/\lambda^2$ for $\lambda > 1.5$
	$\frac{b}{R} > 0.5\sqrt{\frac{R}{t}}$	$K = 0.267\frac{b^2}{Rt}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right]$ $\ge 0.4\frac{b^2}{Rt}$	
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t}}$	$K = \frac{0.6 \cdot b}{\sqrt{Rt}} + \frac{\sqrt{Rt}}{b} - 0.3\frac{Rt}{b^2}$	as in load case 1a
	$\frac{b}{R} > \sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 0.291\left(\frac{R^2}{bt}\right)^2$	
4 	$\frac{b}{R} \le 8.7\sqrt{\frac{R}{t}}$	$K = K_\tau\sqrt{3}$ $K_\tau = \left[28.3 + \frac{0.67 b^3}{R^{1.5} t^{1.5}}\right]^{0.5}$	$\kappa_\tau = 1$ for $\lambda \le 0.4$ $\kappa_\tau = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{b}{R} > 8.7\sqrt{\frac{R}{t}}$	$K_\tau = 0.28\frac{b^2}{R\sqrt{Rt}}$	

Explanations for boundary conditions
- - - - - - - - - plate edge free
——— plate edge simply supported
━━━ plate edge clamped

1. For curved plate fields with a very large radius the κ-value need not to be taken less than for the expanded plane field
2. For curved single fields, e.g. bilge stake, which are located within plane partial or total fields, the reduction factor κ may taken as follow:

Load case 1b : $\kappa_x = \frac{0.8}{\lambda^2} \le 1.0$ Load case 2 : $\kappa_y = \frac{0.65}{\lambda^2} \le 1.0$

3. Buckling criteria of elementary plate panels

3.1 Plates

3.1.1 General

The net thickness of the elementary plate panel is to comply with the following:

$t \geq b/100$

The verification of an elementary plate panel in a transverse section analysis is to be carried out according to **[3.1.2]**. It is to be performed for the two different following combinations of stresses:

- stress combination 1: 100 % of the normal stress as defined in **[2.1.2]** and 70 % of the shear stress as defined in **[2.1.3]**
- stress combination 2: 70 % of the normal stress as defined in **[2.1.2]** and 100 % of the shear stress as defined in **[2.1.3].**

The verification of elementary plate panel in a FEM analysis is to be carried out according to **[3.2].**

3.1.2 Verification of elementary plate panel in a transverse section analysis

Each elementary plate panel is to comply with the following criteria, taking into account the loads defined in **[2.1]**:

- longitudinally framed plating

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$

for stress combination 1 with $\sigma_x = \sigma_n$ and $\tau = 0.7\tau_{SF}$

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$

for stress combination 2 with $\sigma_x = 0.7\sigma_n$ and $\tau = \tau_{SF}$

- transversely framed plating

$$\left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2} + \left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$

for stress combination 1 with $\sigma_y = \sigma_n$ and $\tau = 0.7\tau_{SF}$

$$\left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2} + \left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \leq 1.0$$

for stress combination 2 with $\sigma_y = 0.7\sigma_n$ and $\tau = \tau_{SF}$

Each term of the above conditions must be less than 1.0.
The reduction factors k_x and k_y are given in **Table 2** and/or **Table 3.**
The coefficients $e1$, $e2$ and $e3$ are defined in **Table 4.**
For the determination of $e3$, k_y is to be taken equal to 1 in case of longitudinally framed plating and k_x is to be taken equal to 1 in case of transversely framed plating.

3.2 Verification of elementary plate panel within FEM analysis

3.2.1 General

The buckling check of the elementary plate panel is to be performed under the loads defined in **[3.2.2]**, according to the requirements of **[3].**
The determination of the buckling and reduction factors is made for each relevant case of **Table 2** according to the stresses calculated in **[3.2.2]** loading the considered elementary plate panel.

3.2.2 Stresses

For the buckling check, the buckling stresses are to be determined according to **Table 2** and **Table 3** including their stress ratio ψ for the loading conditions required in **Ch 4, Sec 7** and according to the requirements of **Ch 7.**

3.2.3 Poisson effect

Stresses derived with superimposed or direct method have to be reduced for buckling assessment because of the Poisson effect, which is taken into consideration in both analysis methods. The correction has to be carried out after summation of stresses due to local and global loads.
Both stresses σ_x^* and σ_y^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$$\sigma_x = (\sigma_x^* - 0.3\sigma_y^*)/0.91$$

$$\sigma_y = (\sigma_y^* - 0.3\sigma_x^*)/0.91$$

where:

σ_x^*, σ_y^* : Stresses containing the Poisson effect

Where compressive stress fulfils the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$

Where compressive stress fulfils the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

3.2.4 Checking Criteria

Each elementary plate panel is to comply with the following criteria, taking into account the loads defined in **[2.1]**

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1} + \left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2} - B\left(\frac{\sigma_x \sigma_y S^2}{R_{eH}^2}\right) + \left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \le 1.0$$

In addition, each compressive stress σ_x and σ_y, and the shear stress τ are to comply with the following formulae:

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1} \le 1.0$$

$$\left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2} \le 1.0$$

$$\left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3} \le 1.0$$

The reduction factors k_x, k_y and k_τ are given in **Table 2** and/or **Table 3**.

- where $\sigma_x \le 0$ (tensile stress), k_x = 1.0.
- where $\sigma_y \le 0$ (tensile stress), k_y = 1.0.

The coefficients $e1$, $e2$ and $e3$ as well as the factor B are defined in **Table 4.**

Table 4: Coefficients *e*1, *e*2, *e*3 and factor *B*

Exponents $e1-e3$ and factor B	Plate panel	
	plane	curved
$e1$	$1+k_x^4$	1.25
$e2$	$1+k_y^4$	1.25
$e3$	$1+k_x\,k_y\,k_\tau^2$	2.0
B σ_x and σ_y positive (compressive stress)	$(k_x k_y)^5$	0
B σ_x or σ_y negative (tensile stress)	1	-

3.3 Webs and flanges

3.3.1

For non-stiffened webs and flanges of sections and girders proof of sufficient buckling strength as for elementary plate panels is to be provided according to **[3.1].**

4. Buckling criteria of partial and total panels

4.1 Longitudinal and transverse stiffeners

4.1.1

In a hull transverse section analysis, the longitudinal and transverse ordinary stiffeners of partial and total plate panels are to comply with the requirements of **[4.2]** and **[4.3].**

4.2 Ultimate strength in lateral buckling mode

4.2.1 Checking criteria

The longitudinal and transverse ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_a+\sigma_b}{R_{eH}}S \le 1$$

where:

σ_a : Uniformly distributed compressive stress, in N/mm^2 in the direction of the stiffener axis.

$\sigma_a = \sigma_n$ for longitudinal stiffeners

$\sigma_a = 0$ for transverse stiffeners

σ_b : Bending stress, in N/mm^2, in the stiffener.

σ_b calculated as in **[4.2.2]** with $\sigma_x = \sigma_n$ and $\tau = \tau_{SF}$

4.2.2 Evaluation of the bending stress σ_b

The bending stress σ_b, in N/mm^2, in the stiffeners is equal to:

$$\sigma_b = \frac{M_0 + M_1}{W_{st} 10^3}$$

where:

M_0 : Bending moment, in N.mm, due to the deformation w of stiffener, taken equal to:

$$M_0 = F_{Ki} \frac{p_z w}{c_f - p_z}$$

with $(c_f - p_z) > 0$

M_1 : Bending moment, in N.mm, due to the lateral load p, taken equal to:

$$M_1 = \frac{pba^2}{24 \cdot 10^3}$$ for longitudinal stiffeners

$$M_1 = \frac{pa(n \cdot b)^2}{8c_S 10^3}$$ for transverse stiffeners, with n equal to 1 for ordinary transverse stiffeners.

W_{st} : Net section modulus of stiffener (longitudinal or transverse), in cm^3, including effective width of plating according to **[5]**, taken equal to:

- if a lateral pressure is applied on the stiffener:
  W_{st} is the net section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener.
  W_{st} is the net section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener.
- if no lateral pressure is applied on the stiffener:
  W_{st} is the minimum net section modulus among those calculated at flange and attached plate

c_s : Factor accounting for the boundary conditions of the transverse stiffener

c_s = 1.0 simply supported stiffeners

c_s = 2.0 for partially constraint stiffeners

p : Lateral load in kN/m^2, as defined in **Ch 4, Sec 5** and **Ch 4, Sec 6** calculated at the load point as defined in **Ch 6, Sec 2, [1.4]**

F_{Ki} : Ideal buckling force, in N, of the stiffener, taken equal to:

$$F_{Kix} = \frac{\pi^2}{a^2} EI_x 10^4$$ for longitudinal stiffeners

$$F_{Kiy} = \frac{\pi^2}{(nb)^2} EI_y 10^4$$ for transverse stiffeners

I_x, I_y : Net moments of inertia, in cm^4, of the longitudinal or transverse stiffener including effective width of attached plating according to **[5]**. I_x and I_y are to comply with the following criteria:

$$I_x \geq \frac{bt^3}{12 \cdot 10^4}$$

$$I_y \geq \frac{at^3}{12 \cdot 10^4}$$

p_z : Nominal lateral load, in N/mm^2, of the stiffener due to σ_x, σ_y and τ

$$p_{zx} = \frac{t_a}{b}\left(\sigma_{xl}\left(\frac{\pi b}{a}\right)^2 + 2c_y\sigma_y + \tau_1\sqrt{2}\right)$$ for longitudinal stiffeners

$$p_{zy} = \frac{t_a}{a}\left(2c_x\sigma_{xl} + \sigma_y\left(\frac{\pi a}{nb}\right)^2\left(1+\frac{A_y}{at_a}\right) + \tau_1\sqrt{2}\right)$$ for transverse stiffeners

$$\sigma_{xl} = \sigma_x\left(1+\frac{A_x}{b\cdot t_a}\right)$$

t_a : Net thickness offered of attached plate, in mm

c_x, c_y : Factor taking into account the stresses vertical to the stiffener's axis and distributed variable along the stiffener's length taken equal to:

$0.5(1+\psi)$ for $0 \leq \psi \leq 1$

$\frac{0.5}{1-\psi}$ for $\psi < 0$

A_x, A_y : Net sectional area, in mm^2, of the longitudinal or transverse stiffener respectively without attached plating

$$\tau_1 = \left[\tau - t\sqrt{R_{eH}E\left(\frac{m_1}{a^2}+\frac{m_2}{b^2}\right)}\right] \geq 0$$

m_1, m_2 : Coefficients taken equal to:

for longitudinal stiffeners:

$\frac{a}{b} \geq 2.0$: $m_1 = 1.47$, $m_2 = 0.49$

$\frac{a}{b} < 2.0$: $m_1 = 1.96$, $m_2 = 0.37$

for transverse stiffeners:

$\frac{a}{n\cdot b} \geq 0.5$: $m_1 = 0.37$, $m_2 = \frac{1.96}{n^2}$

$\frac{a}{n\cdot b} < 0.5$: $m_1 = 0.49$, $m_2 = \frac{1.47}{n^2}$

$w = w_0 + w_1$

w_0 : Assumed imperfection, in mm, taken equal to:

$w_0 = \min(\frac{a}{250}, \frac{b}{250}, 10)$ for longitudinal stiffeners

$w_0 = \min(\frac{a}{250}, \frac{n\cdot b}{250}, 10)$ for transverse stiffeners

For stiffeners sniped at both ends w_0 must not be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of its attached plating.

w_1 : Deformation of stiffener, in mm, at midpoint of stiffener span due to lateral load p. In case of uniformly distributed load the following values for w_1 may be used:

$$w_1 = \frac{pba^4}{384\cdot 10^7 EI_x}$$ for longitudinal stiffeners

$$w_1 = \frac{5ap(nb)^4}{384\cdot 10^7 EI_y c_S^2}$$ for transverse stiffeners

c_f : Elastic support provided by the stiffener, in N/mm^2, taken equal to:

- for longitudinal stiffeners

$$c_f = F_{Kix}\frac{\pi^2}{a^2}(1+c_{px})$$

$$c_{px} = \frac{1}{1+\frac{0.91\left(\frac{12\cdot 10^4 I_x}{t^3 b}-1\right)}{c_{xa}}}$$

c_{xa} : Coefficient taken equal to

$$c_{xa} = \left[\frac{a}{2b}+\frac{2b}{a}\right]^2 \quad \text{for} \quad a \geq 2b$$

$$c_{xa} = \left[1+\left(\frac{a}{2b}\right)^2\right]^2 \quad \text{for} \quad a < 2b$$

- for transverse stiffeners

$$c_f = c_S F_{Kiy} \frac{\pi^2}{(n\cdot b)^2}(1+c_{py})$$

$$c_{py} = \frac{1}{1+\frac{0.91\left(\frac{12\cdot 10^4 I_y}{t^3 a}-1\right)}{c_{ya}}}$$

c_{ya} : Coefficient taken equal to

$$c_{ya} = \left[\frac{nb}{2a}+\frac{2a}{nb}\right]^2 \quad \text{for} \quad nb \geq 2a$$

$$c_{ya} = \left[1+\left(\frac{nb}{2a}\right)^2\right]^2 \quad \text{for} \quad nb < 2a$$

4.2.3 Equivalent criteria for longitudinal and transverse ordinary stiffeners not subjected to lateral pressure

Longitudinal and transverse ordinary stiffeners not subjected to lateral pressure are considered as complying with the requirement of **[4.2.1]** if their net moments of inertia I_x and I_y, in cm^4, are not less than the value obtained by the following formula:

- For longitudinal stiffener : $$I_x = \frac{p_{zx} a^2}{\pi^2 10^4}\left(\frac{w_0 h_w}{\frac{R_{eH}}{S}-\sigma_x}+\frac{a^2}{\pi^2 E}\right)$$
- For transverse stiffener : $$I_y = \frac{p_{zy}(nb)^2}{\pi^2 10^4}\left(\frac{w_0 h_w}{\frac{R_{eH}}{S}-\sigma_y}+\frac{(nb)^2}{\pi^2 E}\right)$$

4.3 Torsional buckling

4.3.1 Longitudinal stiffeners

The longitudinal ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_x S}{\kappa_T R_{eH}} \leq 1.0$$

k_T : Coefficient taken equal to:

$k_T = 1.0$ for $\lambda_T \le 0.2$

$k_T = \dfrac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}}$ for $\lambda_T > 0.2$

$\Phi = 0.5\left(1 + 0.21(\lambda_T - 0.2) + \lambda_T^2\right)$

λ_T : Reference degree of slenderness taken equal to:

$\lambda_T = \sqrt{\dfrac{R_{eH}}{\sigma_{KiT}}}$

$\sigma_{KiT} = \dfrac{E}{I_P}\left(\dfrac{\pi^2 I_\omega 10^2}{a^2}\varepsilon + 0.385 I_T\right)$, in $\mathrm{N/mm^2}$

I_p : Net polar moment of inertia of the stiffener, in cm^4, defined in **Table 5**, and related to the point C as shown in **Fig 2**

I_T : Net St. Venant's moment of inertia of the stiffener, in cm^4, defined in **Table 5**,

I_w : Net sectorial moment of inertia of the stiffener, in cm^6, defined in **Table 5**, related to the point C as shown in **Fig 2**

ε : Degree of fixation taken equal to:

$\varepsilon = 1 + 10^{-3}\sqrt{\dfrac{a^4}{\dfrac{4}{3}\pi^4 I_\omega \left(\dfrac{b}{t^3} + \dfrac{4h_w}{3t_w^3}\right)}}$

A_w : Net web area equal to: $A_w = h_w t_w$

A_f : Net flange area equal to: $A_f = b_f t_f$

$e_f = h_w + \dfrac{t_f}{2}$, in mm

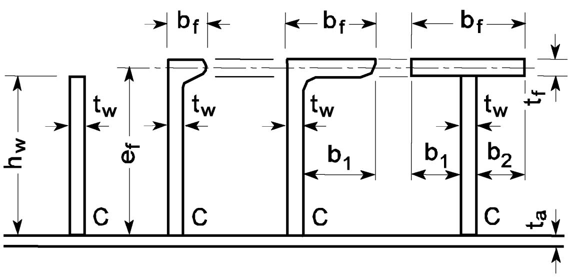


Fig 2: Dimensions of stiffeners

Table 5: Moments of inertia

Profile	I_P	I_T	I_w
Flat bar	$\frac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$	$\frac{h_w^3 \cdot t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left(\frac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right)10^{-4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4}\left(1 - 0.63\frac{t_w}{h_w}\right)$ + $\frac{b_f \cdot t_f^3}{3 \cdot 10^4}\left(1 - 0.63\frac{t_f}{b_f}\right)$	for bulb and angle sections: $\frac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6}\left(\frac{A_f + 2.6A_W}{A_f + A_W}\right)$ for tee-sections: $\frac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

4.3.2 Transverse stiffeners

Transverse stiffeners loaded by axial compressive stresses and which are not supported by longitudinal stiffeners are to comply with the requirements of **[4.3.1]** analogously.

5. Effective width of attached plating

5.1 Ordinary stiffeners

5.1.1

The effective width of attached plating of ordinary stiffeners is determined by the following formulae (see also **Fig 1**):

- for longitudinal stiffeners: $b_m = \min(\kappa_x b; \kappa_s s)$
- for transverse stiffeners: $a_m = \min(\kappa_y a; \kappa_s s)$

where:

$$\kappa_s = 0.0035\left(\frac{\ell_{eff}}{s}\right)^3 - 0.0673\left(\frac{\ell_{eff}}{s}\right)^2 + 0.4422\left(\frac{\ell_{eff}}{s}\right) - 0.0056$$, to be taken notgreater than 1,0

s : Spacing of the stiffener, in mm

ℓ_{eff} : Value taken as follows:

- for longitudinal stiffeners:
  - $\ell_{eff} = a$ if simply supported at both ends
  - $\ell_{eff} = 0.6\,a$ if fixed at both ends
- for transverse stiffeners:
  - $\ell_{eff} = b$ if simply supported at both ends
  - $\ell_{eff} = 0.6\,b$ if fixed at both ends

5.2 Primary supporting members

5.2.1

The effective width e'_m of stiffened flange plates of primary supporting members may be determined as described in a) and b), with the notations:

e : Width of plating supported, in mm, measured from centre to centre of the adjacent unsupported fields

e_m : Effective width, in mm, of attached plating of primary supporting member according to **Table 6** considering the type of loading (special calculations may be required for determining the effective width of one-sided or non-symmetrical flanges).

e_{m1} is to be applied where primary supporting members are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

e_{m2} is to be applied where primary supporting members are loaded by 3 or less single loads.

a) Stiffening parallel to web of the primary supporting member (see **Fig 3**)

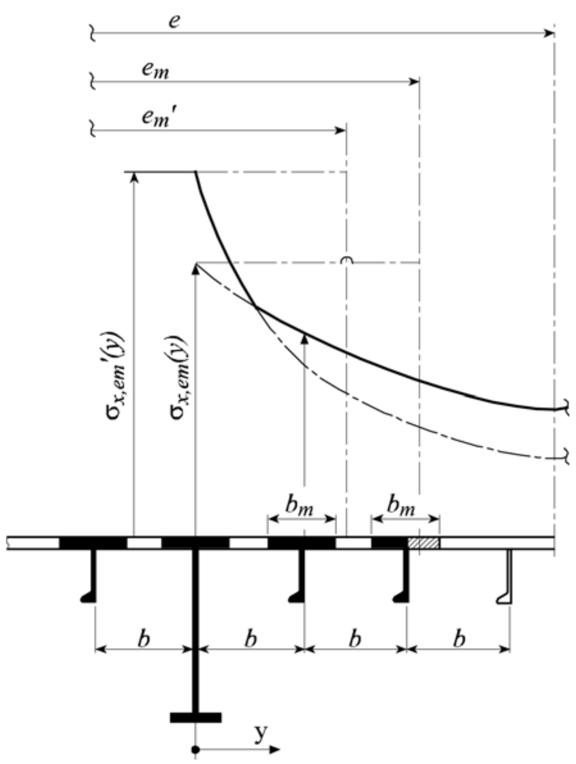


Fig 3: Stiffening parallel to web

$b < e_m$

$e'_m = n \cdot b_m$

n : Integral number of the stiffener spacing b inside the effective width e_m, taken equal to:

$$n = \mathrm{int}\left(\frac{e_m}{b}\right)$$

b) Stiffening perpendicular to web of the primary supporting member (see **Fig 4**)

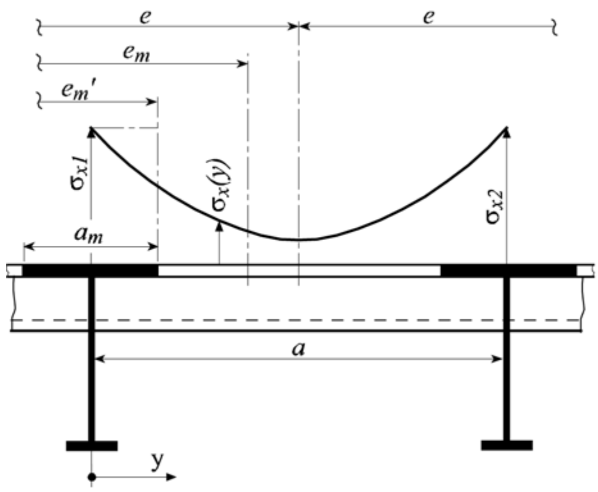


Fig 4: Stiffening perpendicular to web

$a \ge e_m$

$e_m' = n \cdot a_m < e_m$

$n = 2.7\frac{e_m}{a}$, to be taken not greater than 1.0

For $b \ge e_m$ or $a < e_m$ respectively, b and a must be exchanged.

Table 6: Effective Width of attached plating

ℓ/e	0	1	2	3	4	5	6	7	≥ 8
e_{m1}/e	0	0.36	0.64	0.82	0.91	0.96	0.98	1.00	1.00
e_{m2}/e	0	0.20	0.37	0.52	0.65	0.75	0.84	0.89	0.90
Intermediate values may be obtained by direct interpolation. ℓ : Length between zero-points of bending moment curve, i.e. unsupported span in case of simply supported girders and 0.6 times the unsupported span in case of constraint of both ends of girder									

6. Transverse vertically corrugated watertight bulkhead in flooded conditions

6.1 General

6.1.1 Shear buckling check of the bulkhead corrugation webs

The shear stress τ, calculated according to **Ch 6, Sec 2, [3.6.1]**, is to comply with the following formula:

$$\tau < \tau_C$$

where:

τ_C : Critical shear buckling stress to be obtained, in $\mathrm{N/mm^2}$, from the following formulae:

$$\tau_C = \tau_E \qquad \text{for} \quad \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E : Euler shear buckling stress to be obtained, in N/mm^2, from the following formula:

$$\tau_E = 0.9 k_t E \left(\frac{t_w}{10^3 c}\right)^2$$

k_t : Coefficient, to be taken equal to 6.34

t_W : Net thickness, in mm, of the corrugation webs

c : Width, in m of the corrugation webs (see **Ch 3, Sec 6, Fig 28**).

Section 4 – PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

L_2 : Rule length L, but to be taken not greater than 300 m

I_Y : Net moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5]**, on gross of fered thickness reduced by 0.5 t_C for all structural members

I_Z : Net moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to **Ch 5, Sec 1, [1.5]**, on gross offered thickness reduced by 0.5 t_C for all structural members

N : Z co-ordinate with respect to the reference co-ordinate system defined in **Ch 1, Sec 4, [4]**, in m, of the centre of gravity of the hull net transverse section defined in **Ch 5, Sec 1, [1.2]**, considering gross offered thickness reduced by 0.5 t_C for all structural members

p_S , p_W : Still water and wave pressure, in kN/m^2, in intact conditions, defined in **[2.1.2]**

σ_X : Normal stress, in N/mm^2, defined in **[2.1.5]**

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting members, see **Ch 3, Sec 6, [5.3]**

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the member, for the yielding check, defined in **Ch 3, Sec 6, [4.3]**

w : Net section modulus, in cm^3, of the member, with an attached plating of width b_p, to be calculated as specified in **Ch 3, Sec 6, [4.4]**

A_{sh} : Net shear sectional area, in cm^2, of the member, to be calculated as specified in **Ch 3, Sec 6, [5.5]**

m : Coefficient taken equal to 10

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

$\tau_a = 0.4 R_Y$

k : Material factor, as defined in **Ch 1, Sec 4, [2.2.1]**

x, y, z : X, Y and Z co-ordinates, in m, of the evaluation point with respect to the reference co-ordinate system defined in **Ch 1, Sec 4**

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the strength check of pillars and primary supporting members, subjected to lateral pressure and/or hull girder normal stresses for such members contributing to the hull girder longitudinal strength.

The yielding check is also to be carried out for such members subjected to specific loads.

1.2 Primary supporting members for ships less than 150 m in length *L*

1.2.1

For primary supporting members for ships having a length L less than 150 m, the strength check of such members is to be carried out according to the provisions specified in **[2]** and **[4].**

1.2.2

Notwithstanding the above, the strength check of such members may be carried out by a direct strength assessment deemed as appropriate by the Society.

1.3 Primary supporting members for ships of 150 m or more in length *L*

1.3.1

For primary supporting members for ships having a length L of 150 m or more, the direct strength analysis is to be carried out according to the provisions specified in **Ch 7**, and the requirements in **[4]** are also to be complied with. In addition, the primary supporting members for BC-A and BC-B ships are to comply with the requirements in **[3].**

1.4 Net scantlings

1.4.1

As specified in **Ch 3, Sec 2**, all scantlings referred to in this Section are net, i.e. they do not include any corrosion addition.
The gross scantlings are obtained as specified in **Ch 3, Sec 2, [3].**

1.5 Minimum net thicknesses of webs of primary supporting members

1.5.1

The net thickness of the web of primary supporting members, in mm, is to be not less than $0.6\sqrt{L_2}$.

2. Scantling of primary supporting members for ships of less than 150 m in length *L*

2.1 Load model

2.1.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting members under consideration and the type of the compartments adjacent to it.
The wave lateral loads and hull girder loads are to be calculated, for the probability level of 10^{-8}, in the mutually exclusive load cases H1, H2, F1, F2, R1, R2, P1 and P2, as defined in **Ch 4, Sec 4.**

2.1.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.
Still water pressure (p_S) includes:

a) the hydrostatic pressure, defined in **Ch 4, Sec 5, [1]**
b) the still water internal pressure, defined in **Ch 4, Sec 6** for the various types of cargoes and for ballast.

Wave pressure (p_W) includes for each load case H1, H2, F1, F2, R1, R2, P1 and P2:
c) the hydrodynamic pressure, defined in **Ch 4, Sec 5, [1]**
d) the inertial pressure, defined in **Ch 4, Sec 6** for the various types of cargoes and for ballast.

2.1.3 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.1.4 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

2.1.5 Normal stresses

The normal stress to be considered for the strength check of primary supporting members contributing to the hull girder longitudinal strength is the maximum value of σ_X between sagging and hogging conditions, when applicable, obtained, in N/mm^2, from the following formula:

$$\sigma_X = \left[C_{SW} \left| \frac{M_{SW}}{I_Y} \right| (z - N) + C_{WV} \left| \frac{M_{WV}}{I_Y} \right| (z - N) - C_{WH} \left| \frac{M_{WH}}{I_Z} \right| y \right] 10^{-3}$$

where:

M_{SW} : Permissible still water bending moments, in kN.m, in hogging or sagging as the case may be

M_{WV} : Vertical wave bending moment, in kN.m, in hogging or sagging as the case may be, as defined in **Ch 4, Sec 3**

M_{WH} : Horizontal wave bending moment, in kN.m, as defined in **Ch 4, Sec 3**

C_{SW} : Combination factor for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and defined in the **Table 1**

C_{WV}, C_{WH} : Combination factors defined in **Ch 4, Sec 4, [2.2]** for each load case H1, H2, F1, F2, R1, R2, P1 and P2 and given in the **Table 1**

Table 1: Combination factors C_{SW}, C_{WV} and C_{WH}

LC	Hogging			Sagging		
	C_{SW}	C_{WV}	C_{WH}	C_{SW}	C_{WV}	C_{WH}
H1	Not Applicable			-1	-1	0
H2	1	1	0	Not Applicable		
F1	Not Applicable			-1	-1	0
F2	1	1	0	Not Applicable		
R1	1	0	$1.2-\frac{T_{LC}}{T_S}$	-1	0	$1.2-\frac{T_{LC}}{T_S}$
R2	1	0	$\frac{T_{LC}}{T_S}-1.2$	-1	0	$\frac{T_{LC}}{T_S}-1.2$
P1	1	$0.4-\frac{T_{LC}}{T_S}$	0	-1	$0.4-\frac{T_{LC}}{T_S}$	0
P2	1	$\frac{T_{LC}}{T_S}-0.4$	0	-1	$\frac{T_{LC}}{T_S}-0.4$	0

2.2 Center Girders and Side Girders

2.2.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_1 \frac{pS|x-x_c|}{(d_0-d_1)\tau_a}\left\{1-4\left(\frac{y}{B_{DB}}\right)^2\right\}$$ where $|x-x_c|$ is less than 0.25 ℓ_{DB}, $|x-x_c|$ is to be taken as 0.25 ℓ_{DB}

$$t_2 = 1.75\cdot\sqrt[3]{\frac{H^2a^2\tau_a}{C_1'}t_1}$$

$$t_3 = \frac{C_1''a}{\sqrt{k}}$$

where:

P : Differential pressure given by the following formula in $\mathrm{kN/m^2}$:

$$p = \left|\left(p_{S,IB}+p_{W,IB}\right)-\left(p_{S,BM}+p_{W,BM}\right)\right|$$

$P_{S,IB}$: Cargo or ballast pressure of inner bottom plating in still water, in $\mathrm{kN/m^2}$, as calculated at the center of the double bottom structure under consideration, according to **Ch 4, Sec 6**

$P_{W,IB}$: Cargo or ballast pressure of inner bottom plating due to inertia, in $\mathrm{kN/m^2}$, as calculated at the center of the double bottom structure under consideration, according to **Ch 4, Sec 6**

$P_{S,BM}$: External sea and ballast pressure of bottom plating in still water, in $\mathrm{kN/m^2}$, as calculated at the center of the double bottom structure under consideration, according to **Ch 4, Sec 5** and **Ch 4, Sec 6**

$P_{W,BM}$: External sea and ballast pressure of bottom plating due to inertia, in $\mathrm{kN/m^2}$, as calculated at the center of the double bottom structure under consideration, according to **Ch 4, Sec 5** and **Ch 4, Sec 6**

S : Distance between the centers of the two spaces adjacent to the center or side girder under consideration, in m

d_0 : Depth of the center or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

ℓ_{DB} : Length of the double bottom, in m. Where stools are provided at transverse bulkheads, ℓ_{DB} may be taken as the distance between the toes.

x_c : X co-ordinate, in m, of the center of double bottom structure under consideration with respect to ther eference co-ordinate system defined in **Ch 1, Sec 4**

B_{DB} : Distance between the toes of hopper tanks at the midship part, in m, see **Fig 3**

C_1 : Coefficient obtained from **Table 2** depending on B_{DB} / ℓ_{DB}. For intermediate values of B_{DB} / ℓ_{DB}, C_1 is to be obtained by linear interpolation

a : Depth of girders at the point under consideration, in m. However, where horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or floors

C_1' : Coefficient obtained from **Table 3** depending on S_1 / a. For intermediate values of S_1 / a, C_1' is to be determined by linear interpolation

H : Value obtained from the following formulae:

- where the girder is provided with an unreinforced opening : $H = 1 + 0.5\dfrac{\phi}{\alpha}$
- In other cases : $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m.

C_1'' : Coefficient obtained from **Table 4** depending on S_1 / a. For intermediate values of S_1 / a, C_1'' is to be obtained by linear interpolation.

Table 2: Coefficient C_1

B_{DB} / ℓ_{DB}	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_1	0.5	0.71	0.83	0.88	0.95	0.98	1.00

Table 3: Coefficient C_1'

$\dfrac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_1'	64	38	25	19	15	12	10	9	8	7

Table 4: Coefficient C_1''

	$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1''	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

2.3 Floors

2.3.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 to t_3 specified in the following according to each location:

$$t_1 = C_2 \frac{pSB_{DB}}{(d_0 - d_1)\tau_a}\left(\frac{2|y|}{B'_{DB}}\right)\left\{1 - 2\left(\frac{x - x_c}{l_{DB}}\right)^2\right\}$$, where $|x - x_c|$ is less than 0.25 ℓ_{DB}, $|x - x_c|$ is to be taken as 0.25 ℓ_{DB}, and where $|y|$ is less than $B'_{DB}/4$, $|y|$ is to be taken as $B'_{DB}/4$

$$t_2 = 1.75 \cdot \sqrt[3]{\frac{H^2 a^2 \tau_a}{C'_2} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

S : Spacing of solid floors, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m

C_2 : Coefficient obtained from **Table 5** depending on B_{DB} / ℓ_{DB}. For intermediate values of B_{DB} / ℓ_{DB}, C_2 is to be obtained by linear interpolation

p, B_{DB}, x_c, ℓ_{DB} : As defined in **[2.2.1]**

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or girders

C'_2 : Coefficient given in **Table 6** depending on S_1 / d_0. For intermediate values of S_1 / d_0, C'_2 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

a) where openings with reinforcement or no opening are provided on solid floors:

1) where slots without reinforcement are provided:

$$H = \sqrt{4.0 \frac{d_2}{S_1} - 1.0}$$, without being taken less than 1.0

2) where slots with reinforcement are provided: H = 1.0

b) where openings without reinforcement are provided on solid floors:

1) where slots without reinforcement are provided:

$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}$, without being taken less than $1 + 0.5\frac{\phi}{d_0}$

2) where slots with reinforcement are provided: $H = 1 + 0.5\frac{\phi}{d_0}$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater

ϕ : Major diameter of the openings, in m

S_2 : The smaller of S_1 or a, in m.

Table 5: Coefficient C_2

$\frac{B_{DB}}{\ell_{DB}}$	0.4 and under	0.6	0.8	1.0	1.2	1.4	1.6 and over
C_2	0.48	0.47	0.45	0.43	0.40	0.37	0.34

Table 6: Coefficient C_2'

S_1 / d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

2.4 Stringer of double side structure

2.4.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$t_1 = C_3 \frac{pS|x - x_c|}{(d_0 - d_1)\tau_a}$, where $|x - x_c|$ is under 0.25 ℓ_{DS}, $|x - x_c|$ is to be taken as 0.25 ℓ_{DS}

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_3'} t_1}$$

$$t_3 = \frac{8.5S_2}{\sqrt{k}}$$

where :

P : Differential pressure given by the following formula in kN/m^2:

$$p = \left|\left(p_{S,SS} + p_{W,SS}\right) - \left(p_{S,LB} + p_{W,LB}\right)\right|$$

$P_{S,SS}$: External sea and ballast pressure of side shell plating in still water, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to **Ch 4, Sec 5** and **Ch 4, Sec 6**

$P_{W,SS}$: External sea and ballast pressure of side shell plating due to inertia, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to **Ch 4, Sec 5** and **Ch 4, Sec 6**

$P_{S,LB}$: Ballast pressure of longitudinal bulkhead in still water, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to **Ch 4, Sec 6**

$P_{W,LB}$: Ballast pressure of longitudinal bulkhead due to inertia, in kN/m^2, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}, according to **Ch 4, Sec 6**

S : Breadth of part supported by stringer, in m

d_0 : Depth of stringers, in m

d_1 : Depth of opening, if any, at the point under consideration, in m.

x_c : X co-ordinate, in m, of the center of double side structure under consideration with respect to the reference co-ordinate system defined in **Ch 1, Sec 4**

ℓ_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m

h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank, in m

C_3 : Coefficient obtained from **Table 7** depending on h_{DS}/ℓ_{DS}. For intermediate values of h_{DS}/ℓ_{DS}, C_3 is to be obtained by linear interpolation.

a : Depth of stringers at the point under consideration, in m. However, where horizontal stiffeners are fitted on the stringer, a is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of transverse ordinary stiffeners or web frames

C_3' : Coefficient obtained from **Table 8** depending on S_1/a. For intermediate values of S_1/a, C_3' is to be obtained by linear interpolation.

H : Value obtained from the following formulae:

- where the stringer is provided with an unreinforced opening: $H = 1 + 0.5\dfrac{\phi}{\alpha}$
- in other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m

S_2 : The smaller of a or S_1, in m

Table 7: Coefficient C_3

$\dfrac{h_{DS}}{\ell_{DS}}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_3	0.16	0.23	0.30	0.36	0.41	0.44	0.47	0.50	0.54

Table 8 Coefficient C_3'

$\dfrac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_3'	64	38	25	19	15	12	10	9	8	7

2.5 Transverse web in double side structure

2.5.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_4 \frac{pSh_{DS}}{(d_0 - d_1)\tau_a}\left(1 - 1.75\frac{z - z_{BH}}{h_{DS}}\right)$$, where $z - z_{BH}$ is greater than 0.4 h_{DS}, $z - z_{BH}$ is to be taken as 0.4 h_{DS}

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2 \tau_a}{C_4'} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

S : Breadth of part supported by transverses, in m

d_0 : Depth of transverses, in m

d_1 : Depth of opening at the point under consideration, in m

C_4 : Coefficient obtained from **Table 9** depending on h_{DS} / ℓ_{DS}. For intermediate values of h_{DS} / ℓ_{DS}, C_4 is to be obtained by linear interpolation

z_{BH} : Z co-ordinates, in m, of the upper end of hopper tank with respect to the reference co-ordinate system defined in **Ch 1, Sec 4**

p, h_{DS} and ℓ_{DS} : as defined in the requirements of **[2.4.1]**

a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

S_1 : Spacing, in m, of horizontal ordinary stiffeners or stringers

C_4' : Coefficient obtained from **Table 10** depending on S_1 / a. For intermediate values of S_1 / a, C_4' is to be obtained by linear interpolation.

H : Value obtained from the following formulae :

- where the transverse is provided with an unreinforced opening: $H = 1 + 0.5\frac{\phi}{\alpha}$
- in other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1. in m

S_2 : The smaller of a or S_1, in m

Table 9: Coefficient C_4

$\frac{h_{DS}}{\ell_{DS}}$	0.5 and under	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3 and over
C_4	0.62	0.61	0.59	0.55	0.52	0.49	0.46	0.43	0.41

Table 10: Coefficient C_4'

$\frac{S_1}{a}$	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_4'	64	38	25	19	15	12	10	9	8	7

2.6 Primary supporting member in bilge hopper tanks and topside tanks and other structures

2.6.1 Load calculation point

For horizontal members, the lateral pressure and hull girder stress, if any, are to be calculated at mid-span of the primary supporting members considered, unless otherwise specified.
For vertical members, the lateral pressure p is to be calculated as the maximum between the values obtained at mid-span and the pressure obtained from the following formula:

- $p = \frac{p_U + p_L}{2}$, when the upper end of the vertical member is below the lowest zero pressure level
- $p = \frac{\ell_1}{\ell}\frac{p_L}{2}$, when the upper end of the vertical member is at or above the lowest zero pressure level (see **Fig 1**)

where:

ℓ_1 : Distance, in m, between the lower end of vertical member and the lowest zero pressure level

P_U, P_L : Lateral pressures at the upper and lower end of the vertical member span ℓ, respectively

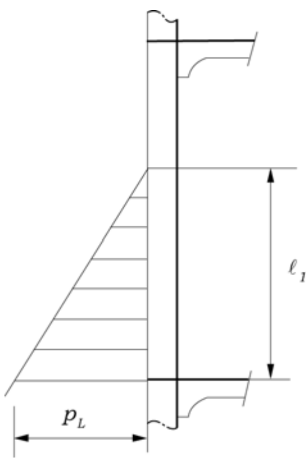


Fig 1: Definition of pressure for vertical members

2.6.2 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case by case basis.

2.6.3 Net section modulus, net shear sectional area and web thickness under intact conditions

The net section modulus w, in cm^3, the net shear sectional area A_{sh}, in cm^2, and the net web thickness t_w, in mm, subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{m\lambda_S R_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

$$t_w = 1.75 \cdot \sqrt[3]{\frac{h_w \tau_a}{10^4 C_5} A_{sh}}$$

where:

λ_S : Coefficient defined in **Table 11**

ϕ : Angle, in deg, between the primary supporting member web and the shell plate, measured at the middle of the member span; the correction is to be applied when f is less than 75 deg.

C_5 : Coefficient defined in **Table 12** according to s_1 and d_0. For intermediate values of s_1 / d_0, coefficient C_5 is to be obtained by linear interpolation.

s_1 : Spacing of stiffeners or tripping brackets on web plate, in m

d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m

Table 11: Coefficient λ_S

Primary supporting members	Coefficient λ_S
Longitudinal members contributing to the hull girder longitudinal strength	$1.1\left(1.0 - 0.85\left\|\frac{\sigma_X}{R_Y}\right\|\right)$, without being taken greater than 0.8
Other members	0.8

Table 12: Coefficient C_5

s_1 / d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0 and over
C_5	60.0	40.0	26.8	20.0	16.4	14.4	13.0	12.3	11.1	10.2

3. Additional requirements for primary supporting members of BC-A and BC-B ships

3.1 Evaluation of double bottom capacity and allowable hold loading in flooded conditions

3.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- all floors adjacent to both hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see **Fig 2**); the floor shear strength is to be calculated according to **[3.1.2]**
- all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted; the girder shear strength is to be calculated according to **[3.1.3].**

Where in the end holds, girders or floors run out and are not directly attached to the boundary stool or hopper tank girder, their strength is to be evaluated for the one end only.
The floors and girders to be considered in calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools (or transverse bulkheads if no stool is fitted). The hopper tank side girders and the floors directly below the connection of the stools (or transverse bulkheads if no stool is fitted) to the inner bottom may not be included.
When the geometry and/or the structural arrangement of the double bottom is/are such as to make the above assumptions inadequate, the shear capacity of the double bottom is to be calculated by means of direct calculations to be carried out according to the requirements specified in **Ch 7**, as far as applicable.

3.1.2 Floor shear strength

The floor shear strength, in kN, is to be obtained from the following formulae:

- in way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the openings in the outermost bay (i.e. that bay which is closer to the hopper tank):

$$S_{f2} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_f : Net sectional area, in mm^2, of the floor panel adjacent to the hopper tank

$A_{f,h}$: Net sectional area, in mm^2, of the floor panels in way of the openings in the outermost bay (i.e. that bay which is closer to the hopper tank)

τ_A : Allowable shear stress, in N/mm^2, equal to the lesser of:

$$\tau_A = 0.645 \frac{R_{eH}^{0.6}}{(s/t_N)^{0.8}} \quad \text{and} \quad \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

t_N : Floor web net thickness, in mm

s : Spacing, in m, of stiffening members of the panel considered

η_1 : Coefficient to be taken equal to 1.1

η_2 : Coefficient to be taken equal to 1.2. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

3.1.3 Girder shear strength

The girder shear strength, in kN, is to be obtained from the following formulae:

- in way of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted):

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool, or transverse bulk-head, if no stool is fitted):

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

A_g : Net sectional area, in mm^2, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted)

$A_{g,h}$: Net sectional area, in mm^2, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool, or transverse bulkhead, if no stool is fitted)

τ_A : Allowable shear stress, in N/mm^2, defined in **[3.1.2]**, where t_N is the girder web net thickness

η_1 : Coefficient to be taken equal to 1.1

η_2 : Coefficient to be taken equal to 1.15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

3.1.4 Allowable hold loading

The allowable hold loading is to be obtained, in t, from the following formula:

$$W = \rho_C V \frac{1}{F}$$

where:

F : Coefficient to be taken equal to:
F = 1.1 in general
F = 1.05 for steel mill products

V : Volume, in m^3, occupied by cargo at a level h_B

h_B : Level of cargo, in m^2, to be obtained from the following formula:

$$h_B = \frac{X}{\rho_C g}$$

X : Pressure, in kN/m^2, to be obtained from the following formulae:

- for dry bulk cargoes, the lesser of:

$$X = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 + \frac{\rho}{\rho_C}(perm - 1)}$$

$$X = Z + \rho g(z_F - 0.1D_1 - h_F\,perm)$$

- for steel mill products:

$$X = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 - \frac{\rho}{\rho_C}}$$

D_1 : Distance, in m, from the base line to the freeboard deck at side amidships

h_F : Inner bottom flooding head is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance z_F, in m, from the baseline.

z_F : Flooding level, in m, defined in **Ch 4, Sec 6, [3.4.3]**

$perm$: Permeability of cargo, which need not be taken greater than 0.3

Z : Pressure, in kN/m^2, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

C_H : Shear capacity of the double bottom, in kN, to be calculated according to **[3.1.1]**, considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} (see **[3.1.2]**) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see **[3.1.3]**)

C_E : Shear capacity of the double bottom, in kN, to be calculated according to **[3.1.1]**, considering, for each floor, the shear strength S_{f1} (see **[3.1.2]**) and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} (see **[3.1.3]**)

- $A_{DB,H} = \sum_{i=1}^{n} S_i B_{DB,i}$
- $A_{DB,E} = \sum_{i=1}^{n} S_i (B_{DB} - s)$

n : Number of floors between stools (or transverse bulkheads, if no stool is fitted)

S_i : Space of i-th floor, in m

$B_{DB,i}$: Length, in m, to be taken equal to :

$B_{DB,i} = B_{DB} - s$ for floors for which $S_{f1} < S_{f2}$ (see **[3.1.2]**)

$B_{DB,i} = B_{DB,h}$ for floors for which $S_{f1} \geq S_{f2}$ (see **[3.1.2]**)

B_{DB} : Breadth, in m, of double bottom between the hopper tanks (see **Fig 3**)

$B_{DB,h}$: Distance, in m, between the two openings considered (see **Fig 3**)

s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

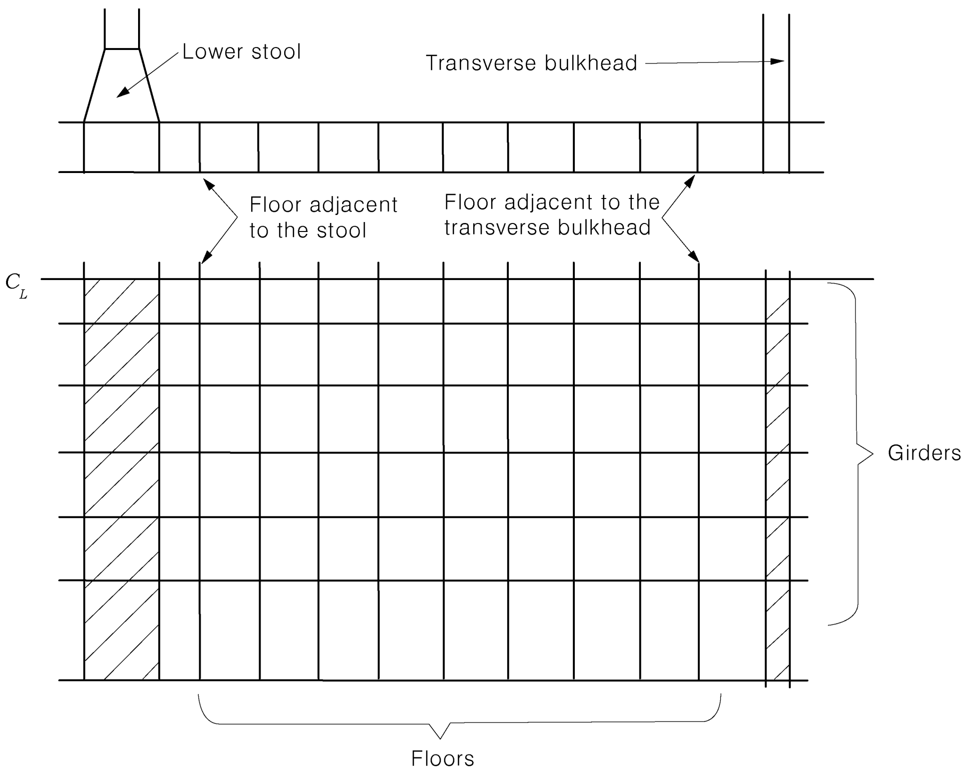


Fig 2: Double bottom structure

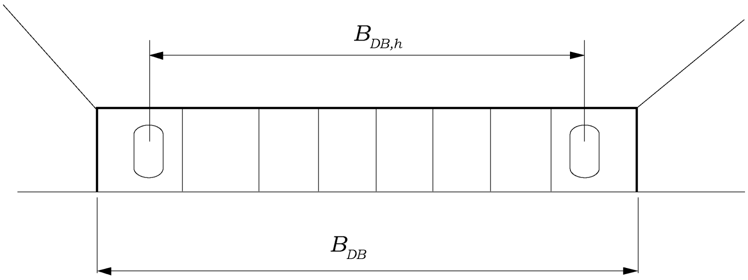


Fig 3: Dimensions B_{DB} and $B_{DB,h}$

4. Pillars

4.1 Buckling of pillars subjected to compressive axial load

4.1.1 General

It is to be checked that the compressive stress of pillars does not exceed the critical column buckling stress calculated according to **[4.1.2].**

4.1.2 Critical column buckling stress of pillars

The critical column buckling stress of pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm^2, from the following formula:

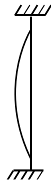
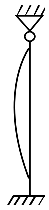
$$\sigma_{E1} = \pi^2 E \frac{I}{A(fl)^2} 10^{-4}$$

I : Minimum net moment of inertia, in cm^4, of the pillar

A : Net cross-sectional area, in cm^2, of the pillar

f : Coefficient to be obtained from **Table 13.**

Table 13: Coefficient *f*

Boundary conditions of the pillar	f
Both ends fixed 	0.5
One end fixed, one end pinned 	$\frac{\sqrt{2}}{2}$
Both ends pinned 	1.0

Appendix 1 - BUCKLING & ULTIMATE STRENGTH

1. Application of Ch 6, Sec 3

1.1 General application

1.1.1 Mutable shear stress

If shear stresses are not uniform on the width b of the elementary plate panel, the greater of the two following values is to be used:

- mean value of τ
- $0.5\,\tau_{max}$

1.1.2 Change of thickness within an elementary plate panel

If the plate thickness of an elementary plate panel varies over the width b, the buckling check may be performed for an equivalent elementary plate panel $a \times b'$ having a thickness equal to the smaller plate thickness t_1.
The width of this equivalent elementary plate panel is defined by the following formula:

$$b' = b_1 + b_2 \left(\frac{t_1}{t_2} \right)^{1.5}$$

where:

b_1 : Width of the part of the elementary plate panel with the smaller plate thickness t_1

b_2 : Width of the part of the elementary plate panel with the greater plate thickness t_2

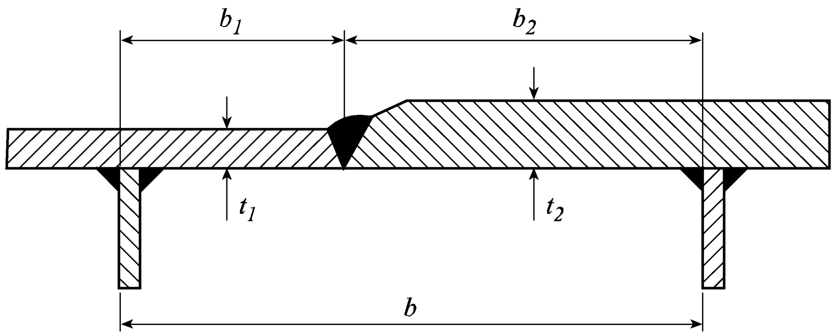


Fig 1: Plate thickness change within the field breath

1.1.3 Evaluation of floors or other high girders with holes

The following procedure may be used to assess high girders with holes:

a) Divide the plate field in sub elementary plate panels according the **Fig 2**

b) Assess the elementary plate panel and all sub elementary plate panels separately with the following boundary conditions:

- for sub panels 1 to 4: all edges are simply supported (load cases 1 and 2 in **Ch 6, Sec 3, Table 2**)
- for sub panels 5 and 6: simply supported, one side free (load case 3 in **Ch 6, Sec 3, Table 2**).

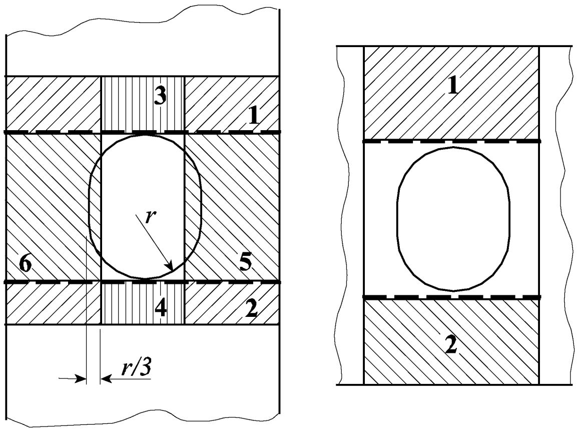


Fig 2: Elementary plate panels of high girder with hole

1.2 Application to hull transverse section analysis

1.2.1 Idealization of elementary plate panels

The buckling check of the elementary plate panel is to be performed under the loads defined in **Ch 6, Sec 3, [2.1]**, according to the requirements of **Ch 6, Sec 3, [3].**
The determination of the buckling and reduction factors is made according to the **Ch 6, Sec 3, Table 2** for the plane plate panel and **Ch 6, Sec 3, Table 3** for the curved plate panel.
For the determination of the buckling and reduction factors in **Ch 6, Sec 3, Table 2**, the following cases are to be used according to the type of stresses and framing system of the plating:

- For the normal compressive stress:
  - Buckling load case 1 for longitudinally framed plating, the membrane stress in x-direction σ_x being the normal stress σ_n defined in **Ch 6, Sec 3, [2.1.2]**
  - Buckling load case 2 for transversely framed plating, the membrane stress in y-direction σ_y being the normal stress σ_n defined in **Ch 6, Sec3, [2.1.2]**, and the values a and b being exchanged to obtain α value greater than 1 as it is considered in load case 2.
- For the shear stress: Buckling case 5, τ being the shear stress τ_{SF} defined in **Ch 6, Sec 3, [2.1.3].**

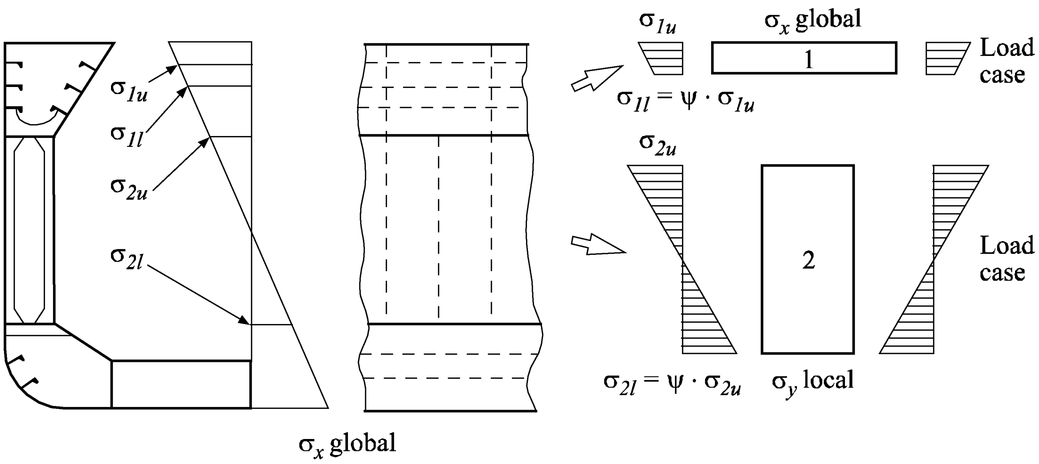


Fig 3: Idealization of elementary plate panels

1.2.2 Ordinary stiffeners

The buckling check of the longitudinal and transverse ordinary stiffeners of partial and total plate panels is to be performed under the loads defined in **Ch 6, Sec 3, [2.1]**, according to **Ch 6, Sec 3, [4]** with:

- σ_x = normal stress σ_n defined in **Ch 6, Sec 3, [2.1.2]**
- σ_y = 0

The effective width of the attached plating of the stiffeners is to be determined in accordance with **Ch 6, Sec 3, [5]**. A constant stress is to be assumed corresponding to the greater of the following values:

- stress at half length of the stiffener
- 0.5 of the maximum compressive stress of adjacent elementary plate panels

1.2.3 Primary supporting members with stiffeners in parallel

The effective width of the attached plating of the primary supporting members is to be determined in accordance with **Ch 6, Sec 3, [5.2].**
In addition, when ordinary stiffeners are fitted on the attached plate and parallel to a primary supporting member, the buckling check is to consider a moment of inertia I_x taking account the moments of inertia of the parallel ordinary stiffeners connected to its attached plate (see **Ch 6, Sec 3, Fig 3**).

1.2.4 Primary supporting members with stiffener perpendicular to girder

The effective width of the attached plating of the primary supporting members is to be determined in accordance with **Ch 6, Sec 3, [5.2].**
In addition, when ordinary stiffeners are fitted on the attached plate and perpendicular to a primary supporting member, the buckling check is to consider a moment of inertia I_x taking account the effective width according to (see **Ch 6, Sec 3, Fig 4**).

1.3 Additional application to FEM analysis

1.3.1 Non uniform compressive stresses along the length of the buckling panel

If compressive stresses are not uniform over the length of the unloaded plate edge (e.g. in case of girders subjected to bending), the compressive stress value is to be taken at a distance of $b/2$ from the transverse plate edge having the largest compressive stress (see **Fig 4**). This value is not to be less than the average value of the compressive stress along the longitudinal edge.

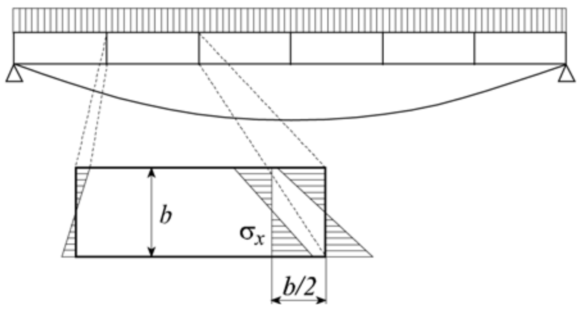
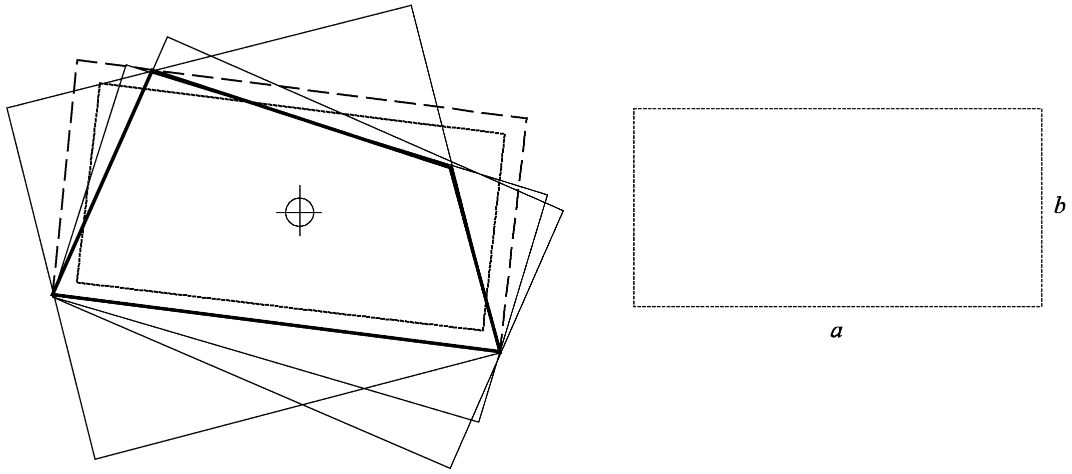


Fig 4: Non uniform compressive stress along longitudinal edge *a*

1.3.2 Buckling stress calculation of non rectangular elementary plate panels

a) Quadrilateral panels

According to **Fig 5**, rectangles that completely surround the irregular buckling panel are searched. Among several possibilities the rectangle with the smallest area is taken. This rectangle is shrunk to the area of the original panel, where the aspect ratio and the centre are maintained. This leads to the final rectangular panel with the dimensions a, b.



Original irregular panel (———)
Intermediate rectangles (———)
Rectangle with smallest area (— — — -)
Final rectangle (----------)

Fig 5: Approximation of non rectangular elementary plate panels

b) Trapezoidal elementary plate panel
A rectangle is derived with a being the mean value of the bases and b being the height of the original panel.

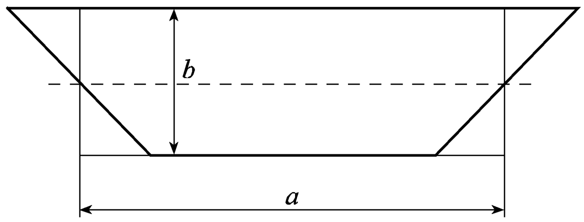


Fig 6: Approximation of trapezoidal elementary plate panel

c) Right triangle
The legs of the right triangle are reduced by $\sqrt{0.5}$ to obtain a rectangle of same area and aspect ratio.

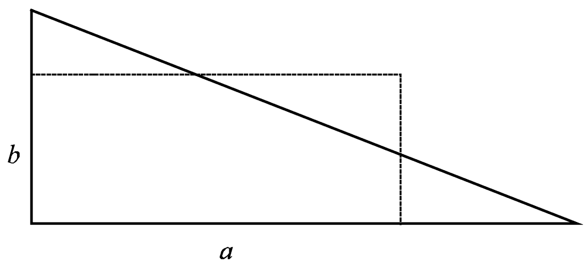


Fig 7: Approximation of right triangle

d) General triangle
General triangle is treated according to a) above.

1.3.3 Buckling assessment of side shell plates

In order to assess the buckling criteria for vertically stiffened side shell plating, the following cases have to be considered:
In case vertical and shear stresses are approximately constant over the height of the elementary plate panel:

- Buckling load cases 1, 2 and 5, according to **Ch 6, Sec 3, Table 2** are to be considered
- $\psi = f(\sigma_1, \sigma_2)$ for horizontal stresses
- $\psi = 1.0$ for vertical stresses
- $t = t_{min}$ (Elementary plate panel)

In case of distributed horizontal, vertical and shear stresses over the height of the elementary plate panel, the following stress situations are to be considered separately:

a) Pure vertical stress
   - The size of buckling field to be considered is b times b ($\alpha = 1$)
   - $\psi = 1.0$
   - The maximum vertical stress in the elementary plate panel is to be considered in applying the criteria

b) Shear stress associated to vertical stress
   - The size of buckling field to be considered is $2b$ times b ($\alpha = 2$)
   - $\psi = 1.0$
   - The following two stress combinations are to be considered:
     - The maximum vertical stress in the elementary plate panel plus the shear stress and longitudinal stress at the location where maximum vertical stress occurs
     - The maximum shear stress in the elementary plate panel plus the vertical stress and longitudinal stress at the location where maximum shear stress occurs
   - The plate thickness t to be considered is the one at the location where the maximum vertical/shear stress occurs

c) Distributed longitudinal stress associated with vertical and shear stress
   - The actual size of the elementary plate panel is to be used ($\alpha = f(a, b)$).
   - The actual edge factor ψ for longitudinal stress is to be used
   - The average values for vertical stress and shear stress are to be used.
   - $t = t_{min}$ (Elementary plate panel)

1.3.4 Buckling assessment of corrugated bulkheads

The transverse elementary plate panel (face plate) is to be assesed using the normal stress parallel to the corrugation. The slanted elementary plate panel (web plate) is to be assessed using the combination of normal and shear stresses.
The plate panel breadth b is to be measured according to **Fig 8.**

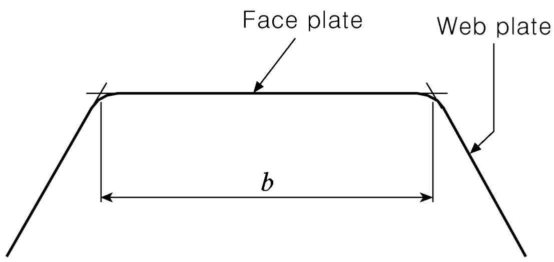


Fig 8: Measuring *b* of corrugated bulkheads

a) Face plate assessment

- The buckling load case 1, according to **Ch 6, Sec 3, Table 2**, is to be used
- The size of the buckling field to be considered is b times b ($\alpha = 1$)
- $\psi = 1.0$
- The maximum vertical stress in the elementary plate panel is to be considered in applying the criteria
- The plate thickness t to be considered is the one at the location where the maximum vertical stress occurs

b) Web plate assessment

- The buckling load cases 1 and 5, according to **Ch 6, Sec 3, Table 2**, are to be used.
- The size of the buckling field to be considered is $2b$ times b ($\alpha = 2$)
- $\psi = 1.0$
- The following two stress combinations are to be considered:
  - The maximum vertical stress in the elementary plate panel plus the shear stress and longitudinal stress at the location where maximum vertical stress occurs
  - The maximum shear stress in the elementary plate panel plus the vertical stress and longitudinal stress at the location where maximum shear stress occurs
- The plate thickness t to be considered is the one at the location where the maximum vertical/shear stress occurs. ⚓

Chapter 7

Direct Strength Analysis

Section 1 – DIRECT STRENGTH ASSESSMENT OF THE PRIMARY SUPPORTING MEMBERS

1. General

1.1 Application

1.1.1

Direct strength assessment of primary supporting members based on a three-dimensional (3D) finite element (FE) analysis is to be applied to ships having length L of 150 m or above.

1.1.2

Three kinds of FE analysis procedures are specified in this Chapter:

a) global strength FE analysis (first FE analysis step) to assess global strength of primary supporting members of the cargo hold structure, according to **Sec 2.**

b) detailed stress assessment (second FE analysis step) to assess highly stressed areas with refined meshes, according to **Sec 3**

c) hot spot stress analysis (third FE analysis step) to calculate hot spot stresses at stress concentration points with very fine meshes for fatigue strength assessment, according to **Sec 4.**

A flowchart of FE analysis procedure for direct strength assessment is shown in **Fig 1.**

1.2 Computer program

1.2.1

Computer programs for FE analysis are to be suitable for the intended analysis. Reliability of unrecognized programs is to be demonstrated to the satisfaction of the Society prior to the commencement of the analysis.

1.3 Submission of analysis report

1.3.1

A detailed report of direct strength FE analysis is to be submitted, including background information of the analysis. This report is to include the following items:

a) list of drawings/plans used in the analysis, including their versions and dates

b) detailed description of structural modeling principles and any deviations in the model from the actual structures

c) plots of structural model

d) material properties, plate thickness and beam properties used in the model

e) details of boundary conditions

f) all loading conditions analyzed

g) data for loads application

h) summaries and plots of calculated deflections

i) summaries and plots of calculated stresses

j) details of buckling strength assessment

k) tabulated results showing compliance with the design criteria

l) reference of the finite element computer program, including its version and date.

1.4 Net scantling

1.4.1

Direct strength analysis is to be based on the net scantling approach according to **Ch 3, Sec 2.**

1.5 Applied loads

1.5.1 Design loads

Direct strength analysis is to be carried out by applying design loads given in **Ch 4** at a probability level of 10^{-8}, except for fatigue strength assessment where probability level is 10^{-4}. Combination of static and dynamic loads which are likely to impose the most severe load regime are to be applied to the 3D FE model.

1.5.2 Structural weight

Effect of the hull structure weight is to be included in static loads, but is not to be included in dynamic loads. Standard density of steel is to be taken as 7.85 t/m^3.

1.5.3 Loading conditions

The loading conditions specified in **Ch 4, Sec 7** are to be considered in 3D FE analysis.

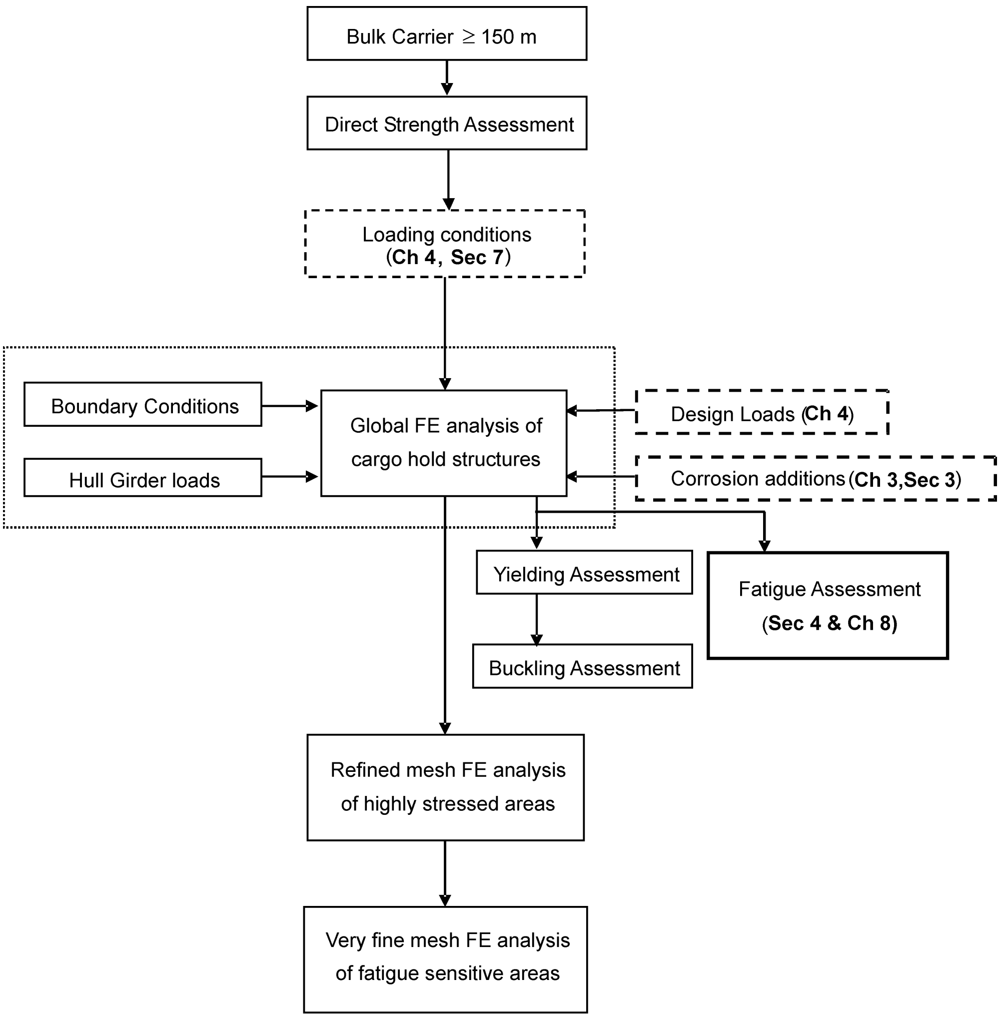


Fig 1: Flowchart of FE analysis procedure

Section 2 – GLOBAL STRENGTH FE ANALYSIS OF CARGO HOLD STRUCTURES

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

M_{SW} : Design vertical bending moment as defined in **Ch 4, Sec 7, Table 2.**

M_{WV} : Vertical wave bending moment, in hogging or sagging condition, as defined in **Ch 4, Sec 3, [3.1.1]**

M_{WH} : Horizontal wave bending moment, as defined in **Ch 4, Sec 3, [3.3.1]**

Q_{SW} : Allowable still water shear force at the considered bulkhead position as provided in **Ch 4, Sec 7, Table 3**

Q_{WV} : Vertical wave shear force as defined in **Ch 4, Sec 3, [3.2.1]**

C_{WV}, C_{WH} : Load combination factors, as defined in **Ch 4, Sec 4, Table 3.**

1. General

1.1 Application

1.1.1

The procedure given in this Section focuses on direct strength analysis of cargo hold structures in mid-ship area.

1.1.2

The global strength FE analysis of cargo hold structures is intended to verify that the following are within the acceptance criteria under the applied static and dynamic loads:

a) stress level in the hull girder and primary supporting members

b) buckling capability of primary supporting members

c) deflection of primary supporting members.

2. Analysis model

2.1 Extent of model

2.1.1

The longitudinal extent of FE model is to cover three cargo holds and four transverse bulkheads. The transverse bulkheads at the ends of the model extent are to be included, together with their associated stools. Both ends of the model are to form vertical planes and to include any transverse web frames on the planes if any. The details of the extent of the model are given in **App 1.**

2.1.2

FE model is to include both sides of ship structures considering unsymmetrical wave-induced loads in the transverse direction.

2.1.3

All main structural members are to be represented in FE model. These include inner and outer shell, floor and girder system in double bottom, transverse and vertical web frames, stringers, transverse and longitudinal bulkhead structures. All plates and stiffeners on these structural members are to be modelled.

2.2 Finite element modeling

2.2.1

All main structural members (plates and stiffeners) detailed in **[2.1.3]** are to be represented in FE model.

2.2.2

Mesh boundaries of finite elements are to simulate the stiffening systems on the actual structures as far as practical and are to represent the correct geometry of the panels between stiffeners.

2.2.3

Stiffness of each structural member is to be represented correctly by using proper element type for the structural member. The principle for selection of element type is given below.

(1) Stiffeners are to be modeled by beam or bar element having axial, torsional, bi-directional shear and bending stiffness. However, web stiffeners and face plates of primary supporting members may be modeled by rod element having only axial stiffness and a constant cross-sectional area along its length.

(2) Plates are to be modeled by shell element having out-of-plane bending stiffness in addition to bi-axial and in-plane stiffness. However, membrane element having only bi-axial and in-plane stiffness can be used for plates that are not subject to lateral pressures.

For membrane and shell elements, only linear quad or triangle elements, as shown in Fig 1, are to be adopted.

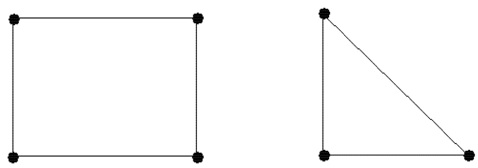


Fig 1: Linear membrane and shell quad and triangle elements

Triangle elements are to be avoided as far as possible, especially in highly stressed areas and in such areas around openings, at bracket connections and at hopper connections where significant stress gradient should be predicted.

(3) Stiffened panels may be modeled by two-dimensional (2D) orthotropic elements that can represent the stiffness of the panels properly.

2.2.4

When orthotropic elements are not used in FE model:

- mesh size is to be equal to or less than the representative spacing of longitudinal stiffeners or transverse side frames
- stiffeners are to be modeled by using rod and/or beam/bar elements
- webs of primary supporting members are to be divided by at least three elements height-wise. However, for transverse primary supporting members inside hopper tank and top side tank, which are less in height than the space between ordinary longitudinal stiffeners, two elements on the height of supporting primary members are accepted.
- side shell frames and their end brackets are to be modeled by using shell elements for web and shell/beam/rod elements for face plate. Webs of side shell frames need not be divided along the direction of depth
- aspect ratio of elements is not to exceed 1:4.

An example of typical mesh is given in **App 1.**

2.2.5

When orthotropic elements are used in FE model for stiffened panels:

- for the members such as the double bottom girder or floor, the element height is to be the double bottom height.
- where a stiffener is located along the edge between two orthotropic elements, either it is to be modelled by using beam/rod element, or it is virtually modelled by reporting the stiffness of the stiffener onto the two orthotropic elements
- where a stiffener is located along the edge between an orthotropic element and a membrane/shell element, it is to be modelled by using beam/rod element
- where a stiffener is located along the edge between two membrane/shell elements, it is to be modelled by using beam/rod element
- where a double hull is fitted, the web of the primary supporting members is to be modelled with one element on its height
- where no double hull construction is fitted, at least one over three frame and its associated end brackets are to be modelled by using shell elements for the webs and shell/beam elements for the flanges
- the aspect ratio of the elements is not to exceed 1:2.

2.3 Boundary conditions

2.3.1

Both ends of the model are to be simply supported according to **Table 1** and **Table 2**. The nodes on the longitudinal members at both end sections are to be rigidly linked to independent points at the neutral axis on the centreline as shown in **Table 1**. The independent points of both ends are to be fixed as shown in **Table 2**.

Table 1: Rigid-link of both ends

Nodes on longitudinal members at both ends of the model	Translational			Rotational		
	Dx	Dy	Dz	Rx	Ry	Rz
All longitudinal members	RL	RL	RL	-	-	-
RL means rigidly linked to the relevant degrees of freedom of the independent point						

Table 2: Support condition of the independent point

Location of the independent point	Translational			Rotational		
	Dx	Dy	Dz	Rx	Ry	Rz
Independent point on aft end of model	-	Fix	Fix	Fix	-	-
Independent point on fore end of model	Fix	Fix	Fix	Fix	-	-

2.4 Loading conditions

2.4.1 General

The loading conditions, combined with loading patterns and load cases, as illustrated in **Ch 4, App 2**, are to be considered as mandatory conditions for the conventional designs.

2.5 Consideration of hull girder loads

2.5.1 General

Each loading condition is to be associated with its corresponding hull girder loads. The load combination is to be considered using Load Combination Factors (LCFs) of the wave-induced vertical and horizontal bending moments and of the wave-induced vertical shear forces specified in **Ch 4, Sec 4** for each Load Case.

2.5.2 Vertical bending moment analysis

Vertical bending moment analysis is to be performed for cases listed in **Ch 4, Sec 7, Table 2**, the minimum required cases being listed in **Ch 4, App 2.**

In vertical bending moment analysis the target hull girder loads are the maximum vertical bending moments which may occur at the centre of the mid-hold in the FE model. The target values of hull girder loads are to be obtained in accordance with **Table 3** with considering still water vertical bending moments specified in **Ch 4, Sec 7, Table 2**, and in **Ch 4, App 2.**

Table 3: Target loads for vertical bending moment analysis

Hull girder effect	Still water	Wave	Considered Location
Vertical bending moment	M_{SW}	$C_{WV}M_{WV}$	Centre of mid-hold
Vertical shear force	0	0	Centre of mid-hold
Horizontal bending moment	---	$C_{WH}M_{WH}$	Centre of mid-hold
Horizontal shear force	---	0	Centre of mid-hold

2.5.3 Vertical shear force analysis

Vertical shear force analysis is to be performed for cases listed in **Ch 4, Sec 7, Table 3**, the minimum required cases being listed in **Ch 4, App 2**.

In vertical shear force analysis the target hull girder loads are the maximum vertical shear force which may occur at one of the transverse bulkheads of the mid-hold in the FE model. Reduced vertical bending moments are considered simultaneously. The target values of hull girder loads are to be obtained in accordance with Table 4 with considering still water vertical bending moments and shear forces specified in **Ch 4, Sec 7, Table 2** and **Ch 4, Sec 7, Table 3**, and in **Ch 4, App 2.**

Table 4: Target loads for vertical shear force analysis

Hull girder effect	Still water	Wave	Location
Vertical bending moment	0.8 M_{SW}	0.65 $C_{WV}M_{WV}$	Transverse bulkhead
Vertical shear force	Q_{SW}	Q_{WV}	Transverse bulkhead
Horizontal bending moment	---	0	Transverse bulkhead
Horizontal shear force	---	0	Transverse bulkhead

2.5.4 Influence of local loads

The distribution of hull girder shear force and bending moment induced by local loads applied on the model are calculated using a simple beam theory for the hull girder.

Reaction forces at both ends of the model and distributions of shearing forces and bending moments induced by local loads can be determined by following formulae:

$$R_{V\_fore} = -\frac{\sum_i (x_i - x_{aft})\vec{f}_i \cdot \vec{z}}{x_{fore} - x_{aft}} \qquad R_{V\_aft} = \sum_i \vec{f}_i \cdot \vec{z} + R_{V\_fore}$$

$$R_{H\_fore} = \frac{\sum_i (x_i - x_{aft})\vec{f}_i \cdot \vec{y}}{x_{fore} - x_{aft}} \qquad R_{H\_aft} = -\sum_i \vec{f}_i \cdot \vec{y} + R_{H\_fore}$$

$$Q_{V\_FEM}(x) = R_{V\_aft} - \sum_i \vec{f}_i \cdot \vec{z} \qquad \text{when } x_i < x$$

$$Q_{H\_FEM}(x) = R_{H\_aft} + \sum_i \vec{f}_i \cdot \vec{y} \qquad \text{when } x_i < x$$

$$M_{V\_FEM}(x) = (x - x_{aft})R_{V\_aft} - \sum_i (x - x_i)\vec{f}_i \cdot \vec{z} \qquad \text{when } x_i < x$$

$$M_{H\_FEM}(x) = (x - x_{aft})R_{H\_aft} + \sum_i (x - x_i)\vec{f}_i \cdot \vec{y} \qquad \text{when } x_i < x$$

where:

x_{aft} : Location of the aft end support,

x_{fore} : Location of the fore end support,

x : Considered location,

R_{V_aft}, R_{V_fore}, R_{H_aft} and R_{H_fore} : Vertical and horizontal reaction forces at the fore and aft ends

Q_{V_FEM}, Q_{H_FEM}, M_{V_FEM} and M_{H_FEM} : Vertical and horizontal shear forces and bending moments created by the local loads applied on the FE model. Sign of Q_{V_FEM}, M_{V_FEM} and M_{H_FEM} is in accordance with the sign convention defined in **Ch 4, Sec 3**. The sign convention for reaction forces is that a positive creates a positive shear force.

$\vec{f}_i$: Applied force on node i due to all local loads,

x_i : Longitudinal coordinate of node i.

2.5.5 Methods to account for hull girder loads

For bending moment analysis, two alternative methods can be used to consider the hull girder loads/stresses in the assessment of the primary supporting members:

a) to add the hull girder loads directly to FE model (direct method), or

b) to superimpose the hull girder stresses separately onto the stresses obtained from the structural analysis using the lateral loads (superimposition method).

For shear force analysis, the “direct method” is to be used.

2.5.6 Direct method

In direct method the effect of hull girder loads are directly considered in 3D FE model. The equilibrium loads are to be applied at both model ends in order to consider the hull girder loads as specified in **[2.5.2]** and **[2.5.3]** and influence of local loads as specified in **[2.5.4].**

In order to control the shear force at the target locations, two sets of enforced moments are applied at both ends of the model. These moments are calculated by following formulae:

$$M_{Y\_aft\_SF} = M_{Y\_fore\_SF} = \frac{(x_{fore} - x_{aft})}{2}\left[Q_{V\_T}(x_{eq}) - Q_{V\_FEM}(x_{eq})\right]$$

$$M_{Z\_aft\_SF} = M_{Z\_fore\_SF} = \frac{(x_{fore} - x_{aft})}{2}\left[Q_{H\_T}(x_{eq}) - Q_{H\_FEM}(x_{eq})\right]$$

In order to control the bending moments at the target locations, another two sets of enforced moments are applied at both ends of the model. These moments are calculated by following formulae:

$$M_{Y\_aft\_BM} = -M_{Y\_fore\_BM} = -\left[M_{V\_T}(x_{eq}) - M_{V\_FEM}(x_{eq}) - M_{Y\_aft\_SF}\left(2\frac{x_{eq} - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right]$$

$$M_{Z\_aft\_BM} = -M_{Z\_fore\_BM} = -\left[M_{H\_T}(x_{eq}) - M_{H\_FEM}(x_{eq}) - M_{Z\_aft\_SF}\left(2\frac{x_{eq} - x_{aft}}{x_{fore} - x_{aft}} - 1\right)\right]$$

where:

x_{eq} : Considered location for the hull girder loads evaluation,

$Q_{V\_FEM}, Q_{H\_FEM}, M_{V\_FEM}, M_{H\_FEM}$: As defined in **[2.5.4]**

$Q_{V\_T}, Q_{H\_T}, M_{V\_T}, M_{H\_T}$: Target vertical and horizontal shear forces and bending moments, defined in **Table 3** or **Table 4**, at the location x_{eq}. Sign of Q_{V_T}, M_{V_T} and M_{H_T} is in accordance with sign convention defined in **Ch 4, Sec 3.**

$M_{Y\_aft\_SF}, M_{Y\_fore\_SF}, M_{Y\_aft\_BM}, M_{Y\_fore\_BM}$: Enforced moments to apply at the aft and fore ends for vertical shear force and bending moment control, positive for clockwise around y-axis. The sign convention for $M_{Y\_aft\_SF}$, $M_{Y\_fore\_SF}$, $M_{Y\_aft\_BM}$ and $M_{Y\_fore\_BM}$ is that of the FE model axis. The sign convention for other bending moment, shear forces and reaction forces is in accordance with the sign convention defined in **Ch 4, Sec 3.**

$M_{Z\_aft\_SF}, M_{Z\_fore\_SF}, M_{Z\_aft\_BM}, M_{Z\_fore\_BM}$: Enforced moments to apply at the aft and fore ends for horizontal shear force and bending moment control, positive for clockwise around z-axis. The sign convention for $M_{Z\_aft\_SF}$, $M_{Z\_fore\_SF}$, $M_{Z\_aft\_BM}$ and $M_{Z\_fore\_BM}$ is that of the FE model axis. The sign convention for other bending moment, shear forces and reaction forces is in accordance with the sign convention defined in **Ch 4, Sec 3.**

The enforced moments at the model ends can be generated by one of the following methods:

- to apply distributed forces at the end section of the model, with a resulting force equal to zero and a resulting moment equal to the enforced moment. The distributed forces are applied to the nodes on the longitudinal members where boundary conditions are given according to **Table 1**. The distributed forces are to be determined by using the thin wall beam theory
- to apply concentrated moments at the independent points defined in **[2.3.1].**

2.5.7 Superimposition method

For vertical bending moment analysis in the superimposition method, the stress obtained from the following formula is to be superimposed to the longitudinal stress of each element in longitudinal members obtained from 3D FE analysis. Vertical shear force analyses are to be in accordance with **[2.5.6].**

$$\sigma_{SIM} = \frac{M_{V\_T}}{I_Y/(z-N)} - \frac{M_{H\_T}}{I_Z/y}$$

where

M_{V_T}, M_{H_T} : Target vertical and horizontal bending moments at considering section, respectively, with corrections due to local loads, taken equal to:

$$M_{V\_T} = M_{SW} + C_{WV} \cdot M_{WV} - M_{V\_FEM}$$
$$M_{H\_T} = C_{WH} \cdot M_{WH} - M_{H\_FEM}$$

I_Y : Vertical inertia of the section around horizontal neutral axis, calculated according to **Ch 3, Sec 2, [3.2.1]**

I_Z : Horizontal inertia of the section, calculated according to **Ch 3, Sec 2, [3.2.1]**

N : Z co-ordinate of the centre of gravity of the hull transverse section, as defined in **Ch 5, Sec 1**

y : Y co-ordinate of the element

z : Z co-ordinate of the element.

3. Analysis criteria

3.1 General

3.1.1 Assessment holds

All the primary supporting members in the mid-hold of the three-hold (1+1+1) FE model, including bulkheads, are to be evaluated in 3D FE analysis.

3.1.2

The results of the structural analysis are to satisfy the criteria for yielding strength, buckling strength and deflection of primary members.

3.2 Yielding strength assessment

3.2.1 Reference stresses

Reference stress is Von Mises equivalent stress at the centre of a plane element (shell or membrane) or axial stress of a line element (bar, beam or rod) obtained by FE analysis through considering hull girder loads according to **[2.5.4]** or **[2.5.5].**
Where the effects of openings are not considered in the FE model, the reference stresses in way of the openings are to be properly modified with adjusting shear stresses in proportion to the ratio of web height and opening height.
Where elements under assessment are smaller than the standard mesh size specified in **[2.2.4]** or **[2.2.5]**, the reference stress may be obtained from the averaged stress over the elements within the standard mesh size.

3.2.2 Equivalent stress

Von Mises equivalent stress is given by the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

σ_x, σ_y : Element normal stresses, in N/mm^2

τ_{xy} : Element shear stress, in N/mm^2

In superimposition method, the stress σ_{SIM}, defined in **[2.5.7]**, is to be superimposed onto to longitudinal stress component.

3.2.3 Allowable stress

The reference stresses in FE model that does not include orthotropic elements, as specified in **[2.2.4]**, are not to exceed $235/k$ N/mm^2, where k is the material factor defined in **Ch3, Sec1.**
The reference stresses in FE model that includes orthotropic elements, as specified in **[2.2.5]**, are not to exceed $205/k$ N/mm^2,where k is the material factor defined in **Ch3, Sec1.**

3.3 Buckling and ultimate strength assessment

3.3.1 General

Buckling and ultimate strength assessment is to be performed for the panels on primary supporting members according to **Ch 6, Sec 3.**

3.3.2 Stresses of panel

The stresses in each panel are to be obtained according to the following procedures:

1) when the mesh model differs from the elementary plate panel geometry, the stresses σ_x, σ_y and τ acting on an elementary plate panel are to be evaluated by extrapolation and/or interpolation of surrounding meshes using the elements stresses or using the displacement based method described in App 2.
2) stresses obtained from with superimposed or direct method have to be reduced for buckling assessment because of the Poisson effect, which is taken into consideration in both analysis methods. The correction has to be carried out after summation of stresses due to local and global loads.

   When the stresses σ_x^* and σ_y^* are both compressive stresses, a stress reduction is to be made according to the following formulae:

   $\sigma_x = (\sigma_x^* - 0.3\sigma_y^*)/0.91$

   $\sigma_y = (\sigma_y^* - 0.3\sigma_x^*)/0.91$

   Where compressive stress fulfils the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$

   Where compressive stress fulfils the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

   σ_x^*, σ_y^* : Stresses containing the Poisson effect

3) determine stress distributions along edges of the considered buckling panel by introducing proper linear approximation as shown in **Fig 2.**
4) calculate edge factor Ψ according to **Ch 6, Sec 3.**

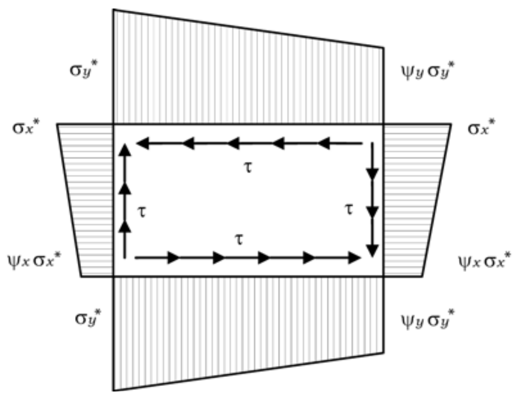


Fig 2: Stresses of panel for buckling assessment

3.3.3 Boundary conditions

Buckling load cases 1, 2, 5 or 6 of **Ch 6, Sec 3, Table 2** are to be applied to the buckling panel under evaluation, depending on the stress distribution and geometry of openings.
If the actual boundary conditions are significantly different from simple support condition, another case in **Ch 6, Sec 3, Table 2** can be applied.

3.3.4 Safety factor

The safety factor for the buckling and ultimate strength assessment of the plate is to be taken equal to 1.0.

3.4 Deflection of primary supporting members

The relative deflection, δ_{max}, in mm, in the outer bottom plate obtained by FEA is not to exceed the following criteria:

$$\delta_{max} \le \frac{\ell_i}{150}$$

where:

δ_{max} : Maximum relative deflection, in mm, obtained by the following formula, and not including secondary deflection

$$\delta_{max} = \max(|\delta_{B1}|, |\delta_{B2}|)$$

where, δ_{B1} and δ_{B2} are shown in **Fig 3.**

ℓ_i : Length or breadth of the flat part of the double bottom, in mm, whichever is the shorter.

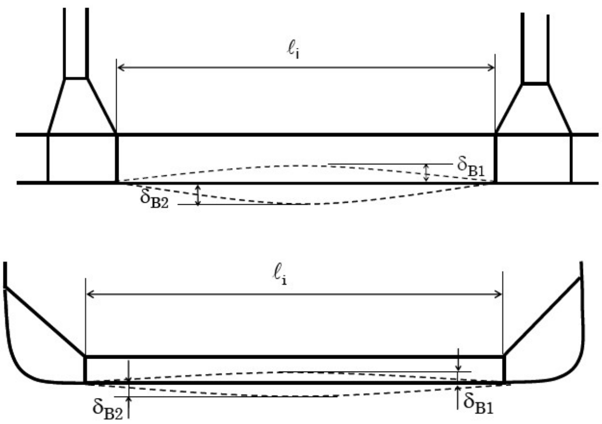


Fig 3: Definition of relative deflection

Section 3 – DETAILED STRESS ASSESSMENT

1. General

1.1 Application

1.1.1

This Section describes the procedure for the detailed stress assessment with refined meshes to evaluate highly stressed areas of primary supporting members.
Where the global cargo hold analysis of **Sec 2** is carried out using a model complying with the modeling criteria of **Sec 2, [2.2.4]**, the areas listed in Table 1 are to be refined at the locations whose calculated stresses exceed 95 % for non-orthotropic elements or 85 % for orthotropic element but do not exceed 100 % of the allowable stress as specified in **Sec 2, [3.2.3].**

2. Analysis model

2.1 Areas to be refined

2.1.1

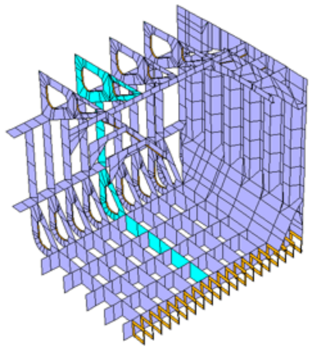
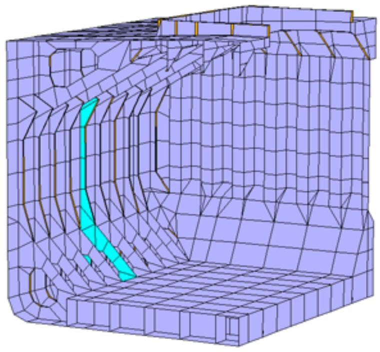
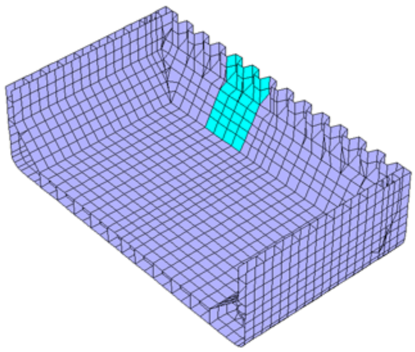
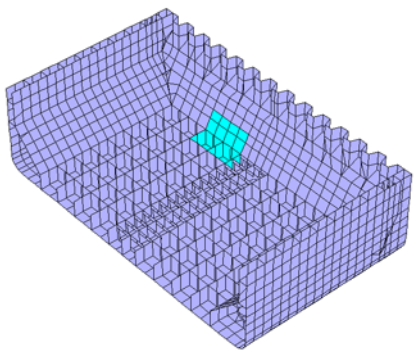
Where the global cargo hold analysis of **Sec 2** is carried out using a model complying with the modeling criteria of **Sec 2, [2.2.4]**, the areas listed in **Table 1** are to be refined at the locations whose calculated stresses exceed 95 % of the allowable stress as specified in **Sec 2, [3.2.3].**

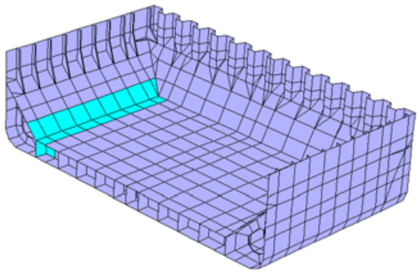
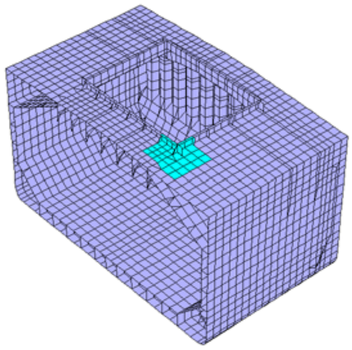
2.1.2

Where the global cargo hold analysis of **Sec 2** is carried out using a model complying with the modeling criteria of **Sec 2, [2.2.5]**, all the high stressed areas listed below are to be refined:

- areas whose calculated stresses exceed 85 % of the allowable stress as specified in **Sec 2, [3.2.3].**
- typical details of the primary supporting members as shown in **Table 1.**
- typical details of the transverse bulkheads of the considered hold as shown in **Table 1.**

Table 1: Typical details to be refined

Structural member	Area of interest	Additional specifications	Description
Primary supporting member	Most stressed transverse primary supporting member for double skin side bulk carriers	Refining of the most stressed transverse primary supporting members located in: • double bottom • hopper tank • double skin side • topside tank	
	Most stressed transverse primary supporting member for single skin side bulk carriers	Refining of the most stressed transverse primary supporting members located in: • double bottom • hopper tank • topside tank side shell frame with end brackets and connections to hopper tank and topside tank	
Transverse bulkhead and its associated lower stool	Most stressed connection of the corrugations with the lower stool	High stressed elements, including the diaphragm(s) of the lower stool, are to be modeled	
	Most stressed connection of the lower stool with the inner bottom	High stressed elements are to be modeled	

Structural member	Area of interest	Additional specifications	Description
Inner bottom and hopper sloping plates with their associated supporting members	Most stressed connection of the inner bottom with the hopper sloping plate	Refining of the most stressed following members: • inner bottom • hopper sloping plate • floor • girder	
Deck plating	Deck plating in way of the most stressed hatch corners	High stressed elements are to be modeled	

2.2 Refining method

2.2.1

Two methods can be used for refining the high stressed areas:

- refined areas can be directly included in FE model used for the global cargo hold analysis of **Ch 7, Sec 2** (See **Fig 1**).
- detailed stresses in refined areas can be analysed by separate sub-models.

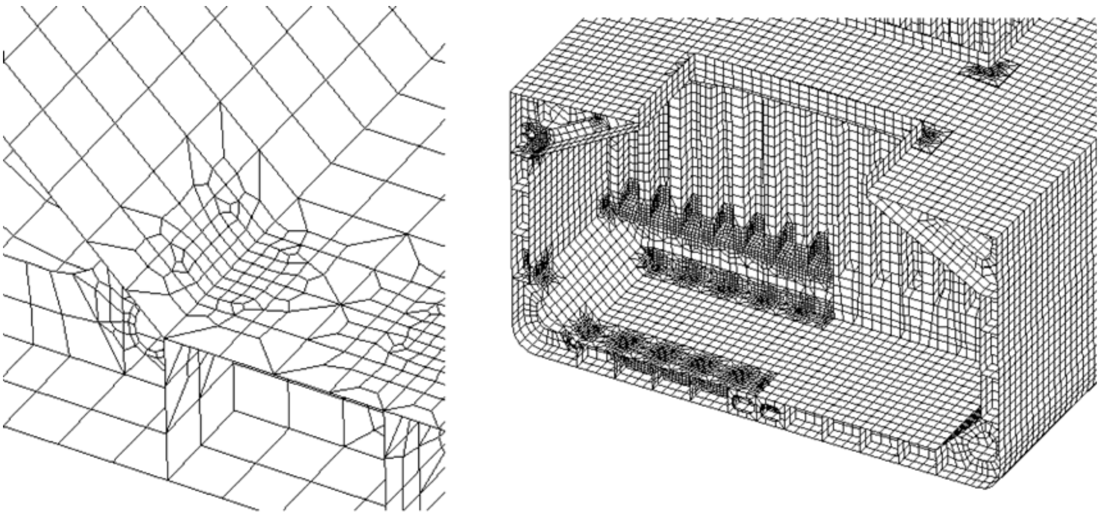


Fig 1: "Direct" modelling with refined meshes

2.3 Modeling

2.3.1 Element type

Each structural members is to be modeled by using proper element type for the structure in accordance with the principle in **Sec 2, [2.2.3]**. Orthotropic elements are not to be used in refined areas.

2.3.2 Mesh

The element size in refined areas is to be approximately one fourth of the representative spacing of ordinary stiffeners in the corresponding area, i.e. 200 × 200 mm mesh size for structures whose ordinary stiffener spacing is 800 mm.
In addition, the web height of primary supporting members and web frames of single side bulk carriers is to be divided at least into 3 elements.
The aspect ratio of element is not to exceed 3. Quad elements are to have 90° angles as much as practicable, or to have angles between 45° and 135°.

2.3.3 Extent of sub-model

The minimum extent of sub-model is to be such that the boundaries of the sub-model correspond to the locations of adjacent supporting members (see **Fig 2**).

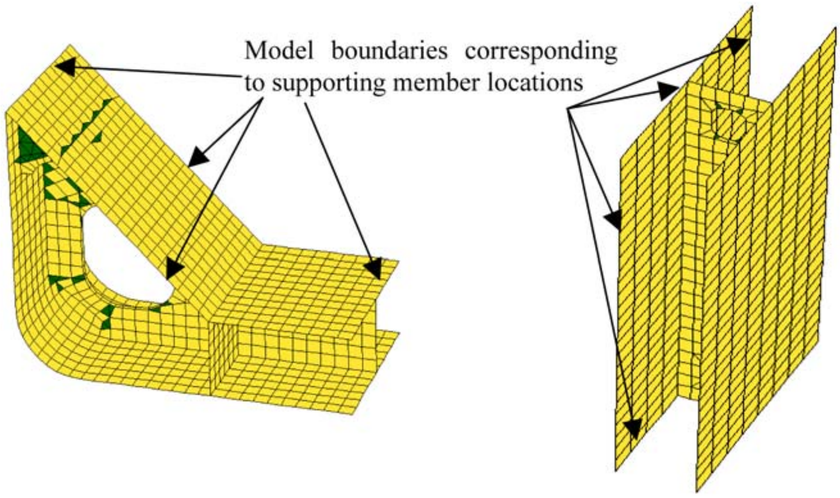


Fig 2: Boundaries of sub-models

2.4 Loading conditions

2.4.1

Loading conditions, which are applied to 3D FE model for the global cargo hold analysis according to **Sec 2** and which induce stresses at considered locations exceeding the criteria specified in **[2.1]**, are to be considered in the detailed stress assessment.

2.5 Boundary conditions

2.5.1

Boundary conditions as specified in **Sec 2, [2.3.1]** are to be applied to the global cargo hold FE model with refined meshes.

2.5.2

Nodal forces or nodal displacements obtained from the global cargo hold analysis of **Sec 2** are to be applied to the sub-models. Where nodal forces are given, the supporting members located at the boundaries of a sub-model are to be included in the sub-model. Where nodal displacements are given and additional nodes are provided in sub-models, nodal displacements at the additional nodes are to be determined by proper interpolations.

3. Analysis criteria

3.1 Allowable stress

3.1.1

Von Mises equivalent stresses in plate elements and axial stresses in line elements within refined areas are not to exceed $280/k\ N/mm^2$, where k is the material factor defined in **Ch 3, Sec 1.**
In case elements significantly smaller than the size defined in **[2.3.2]** are used, this criteria applies to the average stress of all elements included in an area corresponding to a single element having the size specified in **[2.3.2].**

Section 4 – HOT SPOT STRESS ANALYSIS FOR FATIGUE STRENGTH ASSESSMENT

1. General

1.1 Application

1.1.1

This Section describes the procedure to compute hot spot stresses for fatigue strength assessment of each location specified in **Ch 8, Sec 1, Table 1** by using finite element method.

1.1.2

The loading conditions and the load cases specified in **[2.2]** are to be considered for hot spot stress analysis.

2. Analysis model

2.1 Modeling

2.1.1

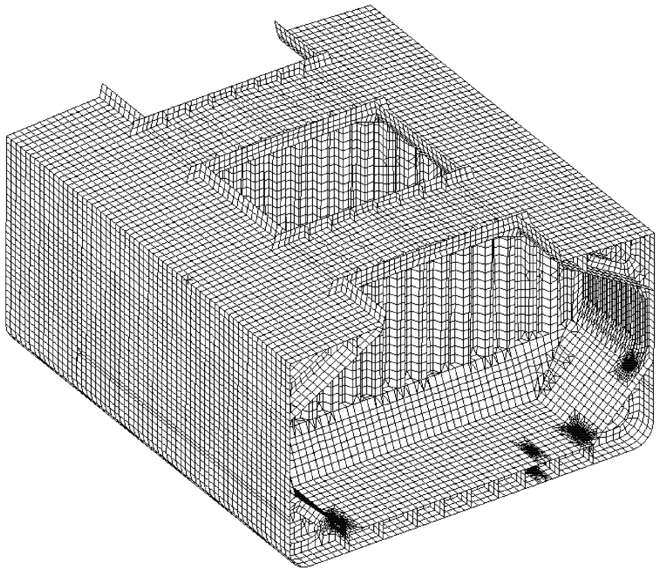
Hot spot stresses for fatigue assessment are to be obtained by the global cargo hold models where the areas for fatigue assessment are modeled by very fine meshes, as shown in **Fig 1.**
Alternatively, hot spot stresses can be obtained from sub-models, by using the similar procedures specified in **Sec 3, [2].**

2.1.2

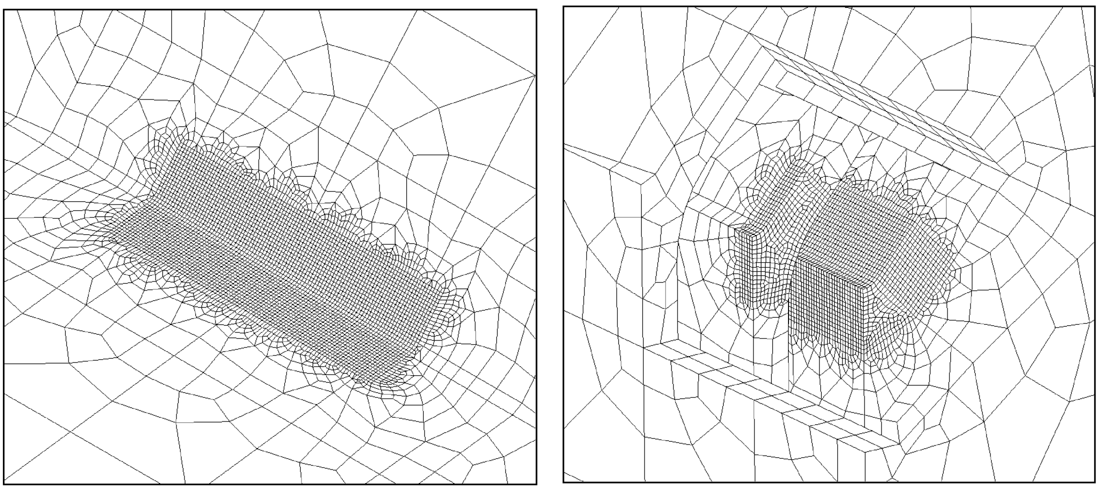
Areas within at least a quarter of frame spacing in all directions from the hot spot position are to be modeled by very fine meshes. The element size in very fine mesh areas is to be approximately equal to the representative net thickness in the assessed areas, and the aspect ratio of elements is to be close to 1.

2.1.3

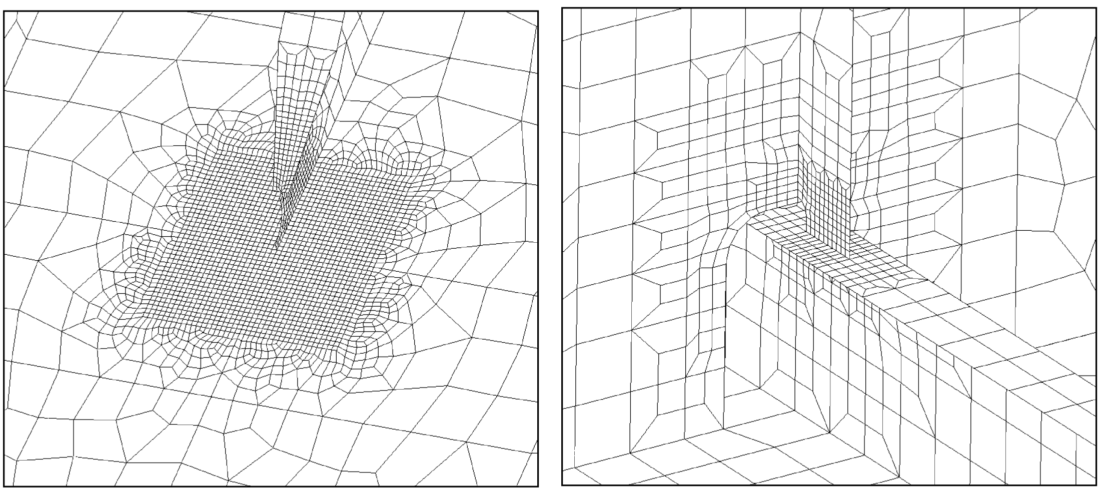
The mesh size is to be gradually changed from very fine mesh to fine mesh through the transition areas as shown in **Fig 2**. All structural members, including brackets, stiffeners, longitudinals and faces of transverse rings, etc., within transition areas are to be modeled by shell elements with bending and membrane properties. Geometries of welds are not to be modeled.



(a) Part of global cargo hold model with very fine mesh



(b) Bilge hopper knuckle part



(c) End of hold frame (d) Longitudinal

Fig 1: Example of very fine mesh model

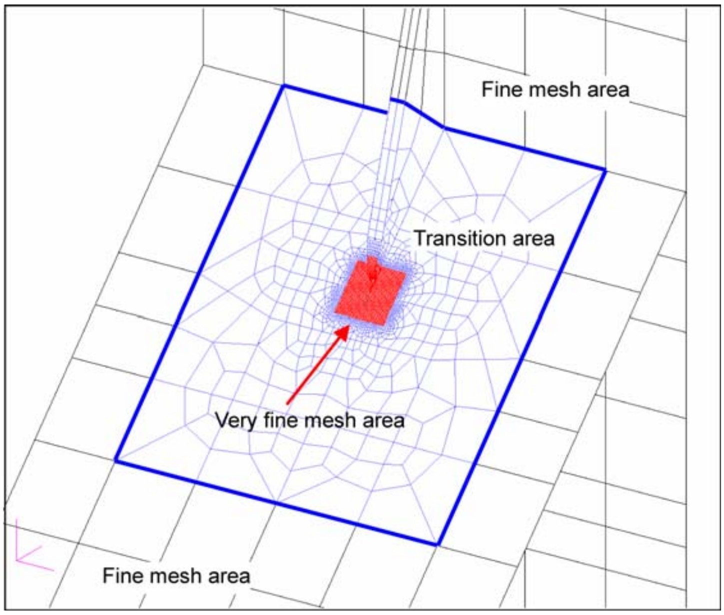


Fig 2: Very fine mesh area, transition area and fine mesh area

2.2 Loading conditions

2.2.1

The loading conditions, specified in **Ch 8, Sec 1, Table 2** and illustrated in **Ch 4, App 3**, are to be considered.

2.2.2

Probability level of 10^{-4} is to be used for calculation of design loads.

2.3 Boundary conditions

2.3.1

The boundary conditions specified in **Sec 2, [2.3.1]** are to be applied to the cargo hold model with localized very fine meshes or the mother model for sub-models. When using sub-models, nodal displacements or forces obtained from the mother model are to be applied to sub-models.

3. Hot spot stress

3.1 Definition

3.1.1

The hot spot stress is defined as the structural geometric stress on the surface at a hot spot.

3.1.2

The hot spot stresses obtained by using superimposition method are to be modified according to **Ch 8, Sec 3, [2.2]** and **[3.2].**

3.2 Evaluation of hot spot stress

3.2.1

The hot spot stress in a very fine mesh is to be obtained using a linear extrapolation. The surface stresses located at 0.5 times and 1.5 times the net plate thickness are to be linearly extrapolated at the hot spot location, as described in **Fig 3** and **Fig 4.**
The principal stress at the hot spot location having an angle with the assumed fatigue crack greater than 45° is to be considered as the hot spot stress.

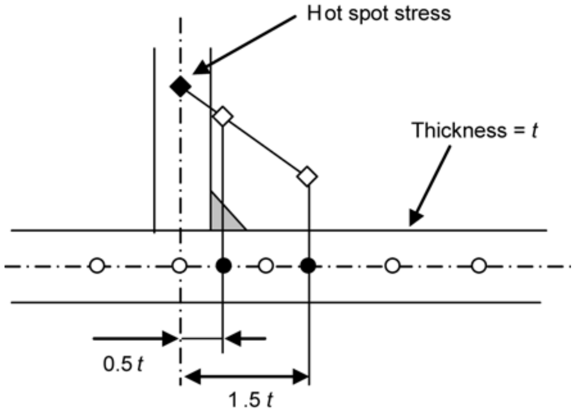


Fig 3: Definition of hot spot stress at an intersection of two plates

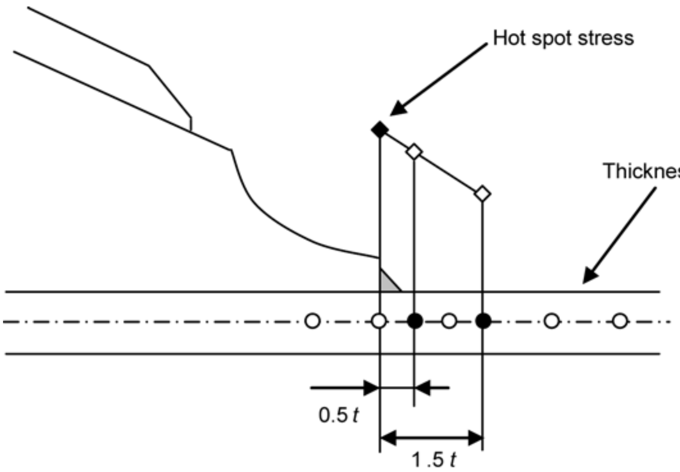


Fig 4: Definition of hot spot stress at an intersection of plating and bracket

3.2.2

The hot spot stress at the intersection of two plates, as obtained from **[3.2.1]**, is to be multiplied by the correction factor λ defined below, considering the difference between the actual hot spot location and assumed location and the difference of stress gradient depending on the angle θ, in deg, between the two plates, to be measured between 0° and 90°.

- welded intersection between plane plates:

$$\lambda = \begin{cases} 0.8 & : \ \theta \le 75 \\ 0.8 - \dfrac{0.2}{15}(\theta - 75) & : \ 75 < \theta \end{cases}$$

- welded intersection between bent plate and plane plate: $\lambda = 0.7$ (i.e. bend type bilge knuckle part)

3.2.3

The hot spot stress in a non-welded area or along free edge is to be determined by extrapolating the principal stresses of the two adjacent elements, as shown in **Fig 5.**

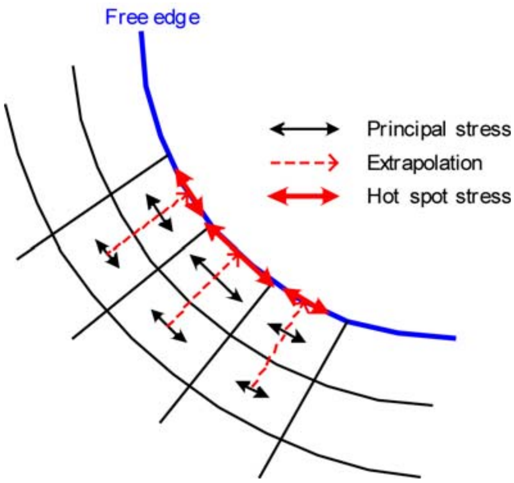


Fig 5: Definition of the hot spot stress along free edge

3.3 Simplified method for the bilge hopper knuckle part

3.3.1

At the bilge knuckle part, the hot spot stress $\sigma_{hotspot}$ may be computed by multiplying the nominal stress $\sigma_{nominal}$ with the stress concentration factor K_{gl} defined in **[3.3.3].**

$$\sigma_{hotspot} = K_{gl}\, \sigma_{nominal}$$

3.3.2

The nominal stress at the hot spot location is to be determined by extrapolating the membrane stresses located at 1.5 times and 2.5 times the frame spacing from the hot spot location, as shown in **Fig 6.**

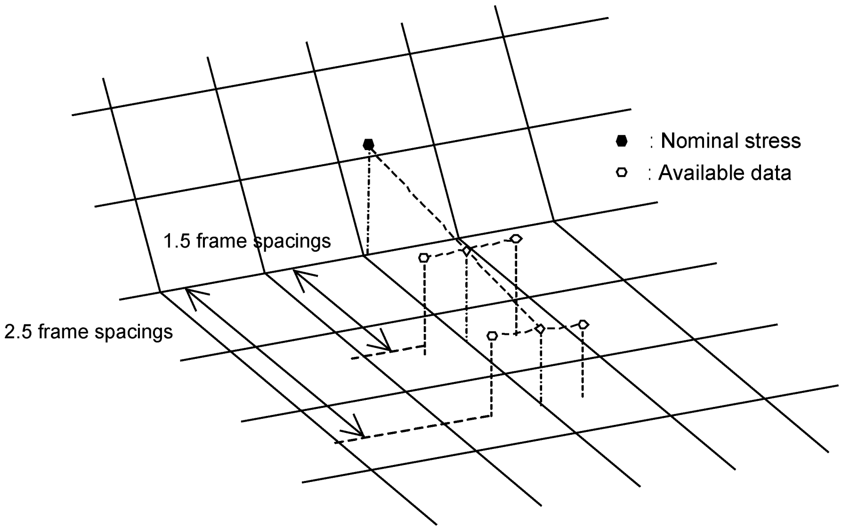


Fig 6: Definition of nominal stress at the bilge hopper knuckle part

3.3.3

The geometrical stress concentration factor K_{gl} for the bilge hopper knuckle part is given by the following equation:

$$K_{gl} = K_0 K_1 K_2 K_3 K_4$$

where:

K_0 : Stress concentration factor depending on the dimensions of the considered structure, defined in **Table 1**

K_1 : Correction coefficient depending on the type of knuckle connection, defined in **Table 2**

K_2 : Correction coefficient depending on the thickness increment of the transverse web, defined in **Table 2** or taken equal to 1.0 if there is no thickness increment

K_3 : Correction coefficient depending on the insertion of horizontal gusset or longitudinal rib (see **Fig 7**), defined in **Table 2** or taken equal to 1.0 if there is no horizontal gusset or longitudinal rib

K_4 : Correction coefficient depending on the insertion of transverse rib, defined in **Table 2** (see **Fig 8**) or taken equal to 1.0 if there is no transverse rib

Table 1: Stress concentration factor K_0

Plate net thickness in FE model t (mm)	Angle of hopper slope plate to the horizontal θ(deg.)			
	40	45	50	90
16	3.0	3.2	3.4	4.2
18	2.9	3.1	3.3	4.0
20	2.8	3.0	3.2	3.8
22	2.7	2.9	3.1	3.6
24	2.6	2.8	3.0	3.5
26	2.6	2.7	2.9	3.4
28	2.5	2.7	2.8	3.3
30	2.4	2.6	2.7	3.2

Note: Alternatively, K_0 can be determined by the following formula.

$$K_0 = \frac{0.14\theta \cdot (1.15 - 0.0033\theta)}{(0.5t)^{(0.2+0.0028\theta)}}$$

Table 2: Correction coefficients

Type of knuckle	K_1	K_2	K_3	K_4
Weld Type	1.7	0.9	0.9	0.9
Bend Type	1.75 ; $R/t < 4$ 2.80 ; $R/t > 8$		0.85 ; $R/t < 4$ 0.55 ; $R/t > 8$	

Notes :
(1) The linear interpolation is applied between $4 \le R/t \le 8$
"R" denotes the radius of bend part and "t" denotes the plate thickness
(2) In using the correction coefficient K_2, the members should be arranged such that the bending deformation of the radius part is effectively suppressed.
(3) The increase in web thickness is taken based on the plate thickness of the inner bottom plating.

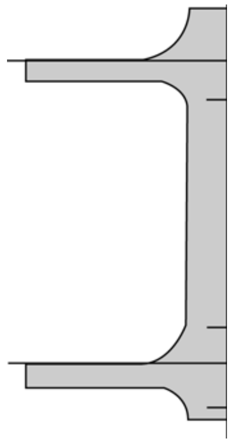


Fig 7: Example of insertion of horizontal gusset or longitudinal rib

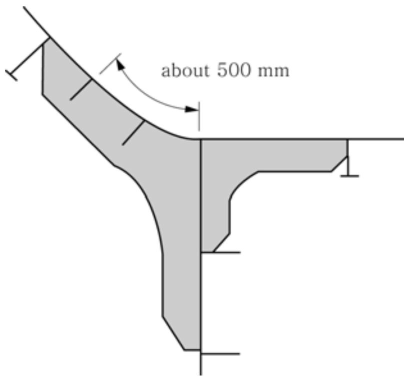


Fig 8: Example of insertion of transverse rib

Appendix 1 - Longitudinal extent of the finite element models

1. Longitudinal extent

A three-hold length finite element model is recommended for the analysis, with the mid-hold as the target of assessment.
The three-hold length finite element model reduces the adverse effects of the boundary conditions to a minimum in the assessed mid-hold.

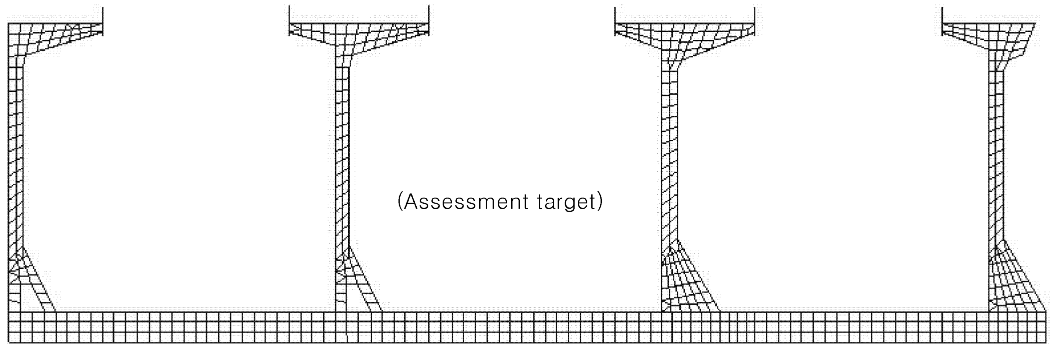


Fig 1: Longitudinal extent of the finite element model

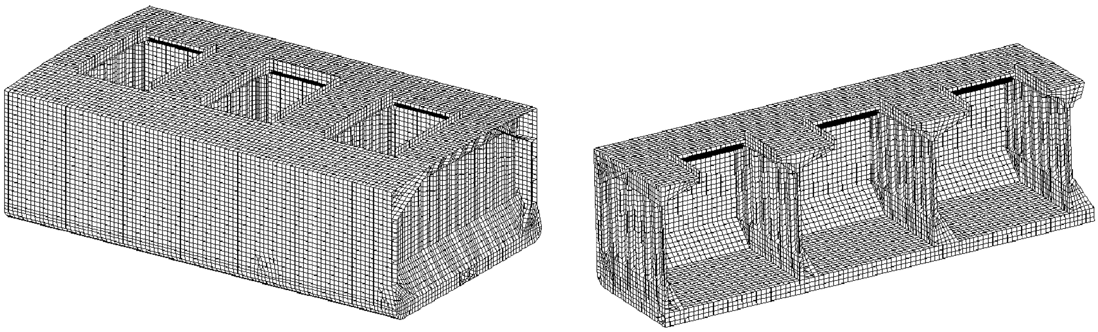


Fig 2: Example of a finite element model

2. Typical Mesh

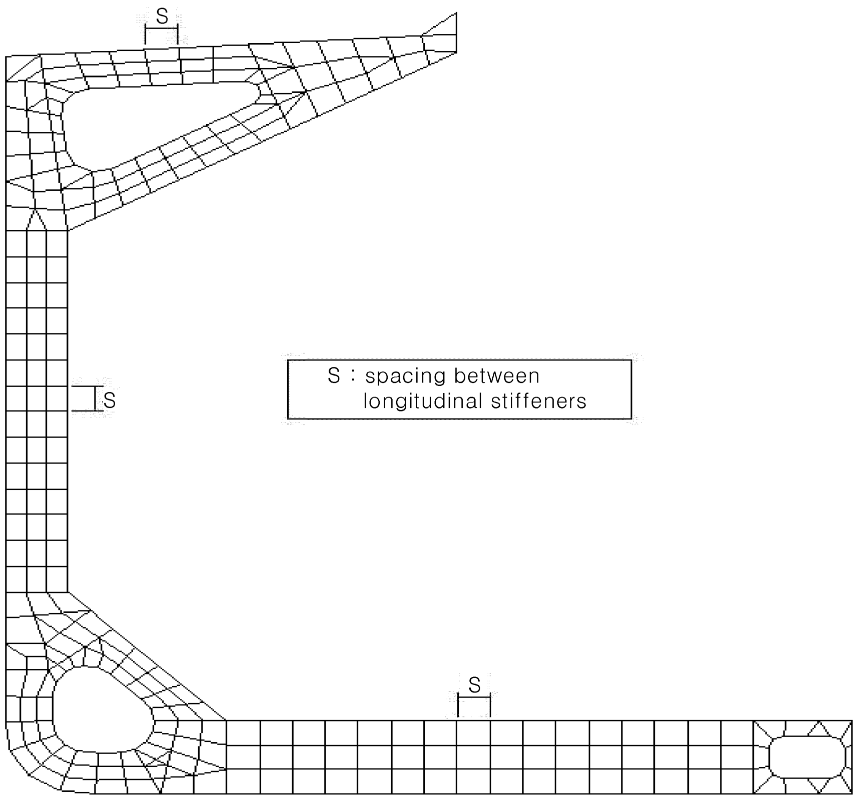


Fig 3: Typical mesh of a web frame

Appendix 2 – DISPLACEMENT BASED BUCKLING ASSESSMENT IN FINITE ELEMENT ANALYSIS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

a : Length of the longer plate panel side

b : Length of the shorter plate panel side

x : Direction parallel to a, taken as the longitudinal direction

y : Direction parallel to b, taken as the transverse direction

C : Coefficient taken equal to:

for 4-node buckling panel: $C = \frac{E}{2(1-\nu^2)}$

for 8-node buckling panel: $C = \frac{E}{4(1-\nu^2)}$

ν : Poisson ratio

m : Coefficient taken equal to:

$m = 1 - \nu$

1. Introduction

1.1

1.1.1

This Appendix provides a method to obtain the buckling stresses and edge stress ratios for elementary plate panels (EPP) from a finite element calculation. This method is called "Displacement Method".

2. Displacement method

2.1 General

2.1.1

As the mesh of the finite elements does not correspond, in general, to the buckling panels the nodal points of the EPP can be mapped onto the FE-mesh and the displacements of these nodes can be derived from the FE-calculation.
Whenever operations on displacements are performed, full numerical accuracy of the displacements should be used.

2.1.2 4-node and 8-node panels

When the aspect ratio of the EPP is less than 3 and the variation of the longitudinal stresses in longitudinal direction of the EPP is small, a 4-node panel may be used. Otherwise an 8-node panel is to be taken.

2.1.3 Calculation of nodal displacements

Three different node locations are possible:

- If a node of the buckling panel is located at an FE-node, then the displacements can be transferred directly.
- If a node of the buckling panel is located on the edge of a plane stress element, then the displace-

ments can be linearly interpolated between the FE-nodes at the edge.

- If a node of the buckling panel is located inside of an element, then the displacements can be obtained using bi-linear interpolation of all nodes of the element.

2.1.4 Transformation in local system

The transformation of the nodal displacements from the global FE-system into the local system of the buckling panel is performed by

$$(u) = [\lambda] \cdot (u_g)$$

where:

(u) : Local displacement vector

(u_g) : Global displacement vector

$[\lambda]$: Transformation matrix (2×3), of direction cosines of angles formed between the two sets of axes.

2.2 Calculation of buckling stresses and edge stress ratios

2.2.1

The displacements, derived at the corners of the elementary plate panel, are to be considered as input from which the stresses at certain stress-points are derived. In the 4-node buckling panel these points are identical but in the 8-node buckling panel they differ. The locations and the numbering convention may be taken from **Fig 1** and **Fig 2.**
The derived stresses at EPP corner nodes can be directly used as input for the buckling assessment according **Ch 6, Sec 3.** The buckling load cases, which have to be considered in the FEM buckling assessment and defined in **Ch 7** are buckling load cases 1, 2 and 5 of **Ch 6, Sec 3, Table 2** and 1a, 1b, 2 and 4 of **Ch 6, Sec 3, Table 3.** In special cases, other buckling load cases may be used for the buckling assessment by a hand calculation.

2.2.2 4-node buckling panel

Stress displacement relationship for a 4-node buckling panel (compressive Stresses are positive)

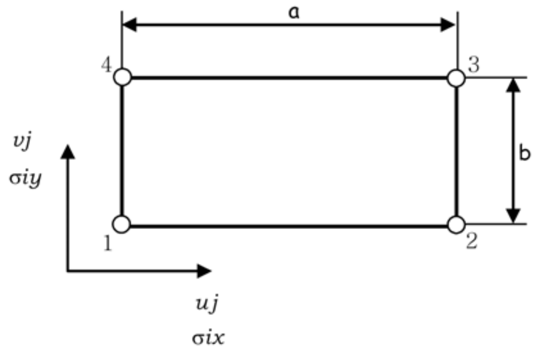


Fig 1: 4-node buckling panel

From the displacements of the EPP corner nodes the stresses of these nodes can be obtained using

$$\begin{pmatrix} \sigma_{1x}^{*} \\ \sigma_{1y}^{*} \\ \tau_1 \\ \sigma_{2x}^{*} \\ \sigma_{2x}^{*} \\ \tau_2 \\ \sigma_{3x}^{*} \\ \sigma_{3y}^{*} \\ \tau_3^{*} \\ \sigma_{4x}^{*} \\ \sigma_{4y}^{*} \\ \tau_4 \end{pmatrix} = -C \cdot \begin{pmatrix} -2/a & -2\nu/b & 2/a & 0 & 0 & 0 & 0 & 2\nu/b \\ -2\nu/a & -2/b & 2\nu/a & 0 & 0 & 0 & 0 & 2/b \\ -m/b & -m/a & 0 & m/a & 0 & 0 & m/b & 0 \\ -2/a & 0 & 2/a & -2\nu/b & 0 & 2\nu/b & 0 & 0 \\ -2\nu/a & 0 & 2\nu/a & -2/b & 0 & 2/b & 0 & 0 \\ 0 & -m/a & -m/b & m/a & m/b & 0 & 0 & 0 \\ 0 & 0 & 0 & -2\nu/b & 2/a & 2\nu/b & -2/a & 0 \\ 0 & 0 & 0 & -2/b & 2\nu/a & 2/b & -2\nu/a & 0 \\ 0 & 0 & -m/b & 0 & m/b & m/a & 0 & -m/a \\ 0 & -2\nu/b & 0 & 0 & 2/a & 0 & -2/a & 2\nu/b \\ 0 & -2/b & 0 & 0 & 2\nu/a & 0 & -2\nu/a & 2/b \\ -m/b & 0 & 0 & 0 & 0 & m/a & m/b & -m/a \end{pmatrix} \cdot \begin{pmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \end{pmatrix}$$

where:

$(\sigma_{1x}^{*}, \sigma_{1y}^{*}, \tau_1, \cdots, \sigma_{4x}^{*}, \sigma_{4y}^{*}, \tau_4)^T = (\sigma^{*})$: Element stress vector

$(u_1, v_1, \cdots, u_4, v_4)^T = (u)$: Local node displacement vector

If both σ_x^{*} and σ_y^{*} are compressive stresses then the stresses sx and sy must be obtained as follows:

$$\sigma_x = (\sigma_x^{*} - 0.3\sigma_y^{*}) / 0.91$$

$$\sigma_y = (\sigma_y^{*} - 0.3\sigma_x^{*}) / 0.91$$

Where compressive stress fulfils the condition $\sigma_y^{*} < 0.3\sigma_x^{*}$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^{*}$

Where compressive stress fulfils the condition $\sigma_x^{*} < 0.3\sigma_y^{*}$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^{*}$

This leads to the following stress vector:

$$(\sigma) = (\sigma_{1x}, \sigma_{1y}, \tau_1, \cdots, \sigma_{4x}, \sigma_{4y}, \tau_4)^T$$

Finally the relevant buckling stresses and edge stress ratios are obtained by:

- LC 1: longitudinal compression

$$\sigma_l = \max\left(\frac{\sigma_{1x} + \sigma_{4x}}{2}, \frac{\sigma_{2x} + \sigma_{3x}}{2}\right)$$

$$\Delta\sigma_l = \frac{1}{2}\left(-\sigma_{1x} + \sigma_{4x} - \sigma_{2x} + \sigma_{3x}\right)$$

$$\sigma_x = \sigma_l + 0.5\left|\Delta\sigma_l\right|$$

$$\psi_x = 1 - \left|\Delta\sigma_l\right| / \sigma_x$$

- LC 2: transverse compression

$$\sigma_t = 0.25\sum_{i=1}^{4}\sigma_{iy}$$

$$\Delta\sigma_t = \frac{1}{2}\left(-\sigma_{1y} - \sigma_{4y} + \sigma_{2y} + \sigma_{3y}\right)$$

$$\sigma_y = \sigma_t + 0.5\left|\Delta\sigma_t\right|$$

$$\psi_y = 1 - \left|\Delta\sigma_t\right| / \sigma_y$$

- LC 5: shear

$$\tau = \left|\frac{\tau_1 + \tau_2 + \tau_3 + \tau_4}{4}\right|$$

2.2.3 8-node buckling panel

Stress displacement relationship for a 8-node buckling panel (compressive stresses are positive)

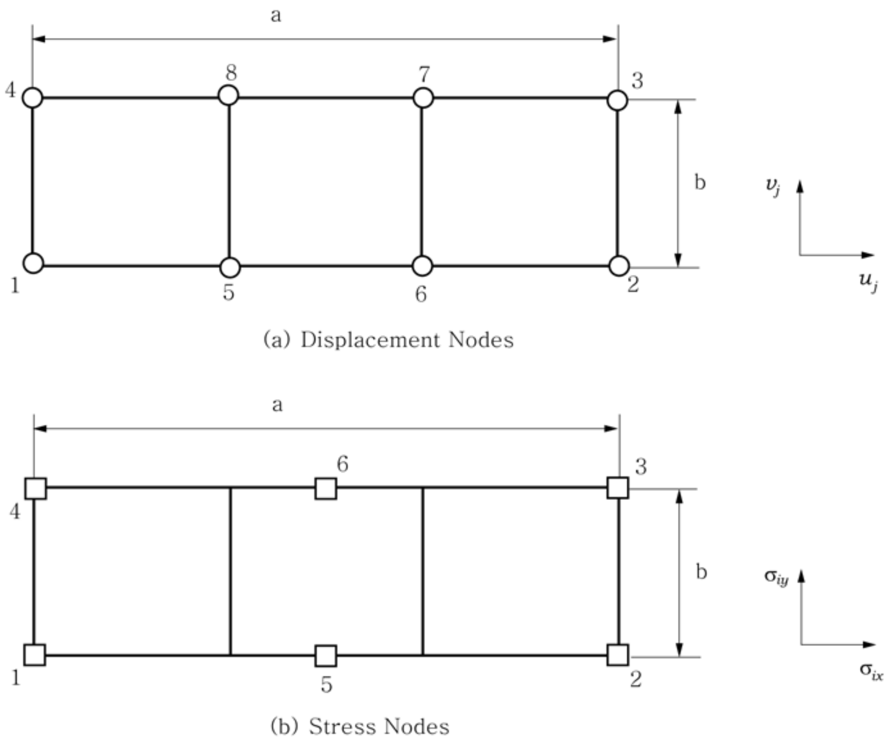


Fig 2: 8-node buckling panel

From the displacements of the EPP corner nodes the stresses of these nodes and on mid positions can be obtained using:

$$\begin{pmatrix} \sigma^*_{1x} \\ \sigma^*_{1y} \\ \tau_1 \\ \sigma^*_{2x} \\ \sigma^*_{2y} \\ \tau_2 \\ \sigma^*_{3x} \\ \sigma^*_{3y} \\ \tau_3 \\ \sigma^*_{4x} \\ \sigma^*_{4y} \\ \tau_4 \\ \sigma^*_{5x} \\ \sigma^*_{5y} \\ \tau_5 \\ \sigma^*_{6x} \\ \sigma^*_{6y} \\ \tau_6 \end{pmatrix} = -C \cdot \begin{pmatrix}
-12/a & -4\nu/b & 0 & 0 & 0 & 0 & 0 & 4\nu/b & 12/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-12\nu/a & -4/b & 0 & 0 & 0 & 0 & 0 & 4/b & 12\nu/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-2m/b & -6m/a & 0 & 0 & 0 & 0 & 2m/b & 0 & 0 & 6m/a & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 12/a & -4\nu/b & 0 & 4\nu/b & 0 & 0 & 0 & 0 & -12/a & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 12\nu/a & -4/b & 0 & 4/b & 0 & 0 & 0 & 0 & -12\nu/a & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & -2m/b & 6m/a & 2m/b & 0 & 0 & 0 & 0 & 0 & 0 & -6m/a & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -4\nu/b & 12/a & 4\nu/b & 0 & 0 & 0 & 0 & 0 & 0 & -12/a & 0 & 0 & 0 \\
0 & 0 & 0 & -4/b & 12\nu/a & 4/b & 0 & 0 & 0 & 0 & 0 & 0 & -12\nu/a & 0 & 0 & 0 \\
0 & 0 & -2m/b & 0 & 2m/b & 6m/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -6m/a & 0 & 0 \\
0 & -4\nu/b & 0 & 0 & 0 & 0 & -12/a & 4\nu/b & 0 & 0 & 0 & 0 & 0 & 0 & 12/a & 0 \\
0 & -4/b & 0 & 0 & 0 & 0 & -12\nu/a & 4/b & 0 & 0 & 0 & 0 & 0 & 0 & 12\nu/a & 0 \\
-2m/b & 0 & 0 & 0 & 0 & 0 & 2m/b & -6m/a & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 6m/a \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -12/a & -2\nu/b & 12/a & -2\nu/b & 0 & 2\nu/b & 0 & 2\nu/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -12\nu/a & -2/b & 12\nu/a & -2/b & 0 & 2/b & 0 & 2/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -m/b & -6m/a & -m/b & 6m/a & m/b & 0 & m/b & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2\nu/b & 0 & -2\nu/b & 12/a & 2\nu/b & -12/a & 2\nu/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2/b & 0 & -2/b & 12\nu/a & 2/b & -12\nu/a & 2/b \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -m/b & 0 & -m/b & 0 & m/b & 6m/a & m/b & -6m/a
\end{pmatrix} \cdot \begin{pmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \\ u_4 \\ v_4 \\ u_5 \\ v_5 \\ u_6 \\ v_6 \\ u_7 \\ v_7 \\ u_8 \\ v_8 \end{pmatrix}$$

where:

$$(\sigma^*) = (\sigma^*_{1x}, \sigma^*_{1y}, \tau_1, \cdots, \sigma^*_{6x}, \sigma^*_{6y}, \tau_6)^T$$

$$(u) = (u_{1x}, v_{1y}, \cdots, u_{8x}, v_{8y})^T$$

If both σ^*_x and σ^*_y are compressive stresses then the stresses sx and sy must be obtained as follows:

$\sigma_x = (\sigma_x^* - 0.3 \cdot \sigma_y^*) / 0.91$

$\sigma_y = (\sigma_y^* - 0.3 \cdot \sigma_x^*) / 0.91$

Where compressive stress fulfils the condition $\sigma_y^* < 0.3\sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$

Where compressive stress fulfils the condition $\sigma_x^* < 0.3\sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$

This leads to the following stress vector:

$(\sigma) = (\sigma_{1x}, \sigma_{1y}, \tau_1, \cdots, \sigma_{6x}, \sigma_{6y}, \tau_6)^T$

The relevant buckling stresses can be obtained by:

- LC 1: longitudinal compression

$$\sigma_l = \max\left(\frac{\sigma_{1x} + \sigma_{4x}}{2}, \frac{\sigma_{6x} + \sigma_{5x}}{2}, \frac{\sigma_{2x} + \sigma_{3x}}{2}\right)$$

$$\Delta\sigma_l = \frac{1}{3}\left(\sigma_{4x} - \sigma_{1x} - \sigma_{5x} + \sigma_{6x} + \sigma_{3x} - \sigma_{2x}\right)$$

$$\sigma_x = \sigma_l + 0.5|\Delta\sigma_l|$$

$$\psi_x = 1 - |\Delta\sigma_l| / \sigma_x$$

- LC 2: transverse compression

$$\sigma_t = \frac{1}{6}\sum_{i=1}^{6}\sigma_{iy}$$

$$\Delta\sigma_t = \frac{1}{2}\left(-\sigma_{1y} - \sigma_{4y} + \sigma_{2y} + \sigma_{3y}\right)$$

$$\sigma_y = \sigma_t + 0.5|\Delta\sigma_t|$$

$$\psi_y = 1 - |\Delta\sigma_t| / \sigma_y$$

- LC 5: shear

$$\tau = Max\left\{\left|\frac{\tau_1 + \tau_4 + \tau_5 + \tau_6}{4}\right|, \left|\frac{\tau_2 + \tau_3 + \tau_5 + \tau_6}{4}\right|\right\}$$

Chapter 8

Fatigue Check of Structural Details

Section 1 – GENERAL CONSIDERATION

1. General

1.1 Application

1.1.1

The requirements of this Chapter are to be applied to ships having length L of 150 m or above, with respect to 25 years operation life in North Atlantic.

1.1.2

The requirements of this Chapter apply to fatigue cycles induced by wave loads. Fatigue induced by vibrations, low cycle loads or impact loads such as slamming, is out of the scope of this Chapter.

1.1.3

The requirements of this Chapter are applicable where steel materials have a minimum yield stress less than 400 N/mm^2.

1.2 Net scantlings

1.2.1

All scantlings and stresses referred to in this Chapter are net scantlings obtained in accordance with **Ch 3, Sec 2.**

1.3 Subject members

1.3.1

Fatigue strength is to be assessed, in cargo hold area, for members described in **Table 1**, at the considered locations.

Table 1: Members and locations subjected to fatigue strength assessment

Members	Details
Inner bottom plating	Connection with sloping and /or vertical plate of lower stool
	Connection with sloping plate of hopper tank
Inner side plating	Connection with sloping plate of hopper tank
Transverse bulkhead	Connection with sloping plate of lower stool
	Connection with sloping plate of upper stool
Hold frames of single side bulk carriers	Connection to the upper and lower wing tank
Ordinary stiffeners in double side space	Connection of longitudinal stiffeners with web frames and transverse bulkhead
	Connection of transverse stiffeners with stringer or similar
Ordinary stiffeners in upper and lower wing tank	Connection of longitudinal stiffeners with web frames and transverse bulkhead
Ordinary stiffeners in double bottom	Connection of longitudinal stiffeners with floors and floors in way of lower stool or transverse bulkhead
Hatch corners	Free edges of hatch corners

2. Definitions

2.1 Hot spot

2.1.1

Hot spot is the location where fatigue crack may initiate.

2.2 Nominal stress

2.2.1

Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds.
Nominal stresses are to be obtained either with the coarse mesh FE analysis specified in **Ch 7, Sec 4**, or with the simplified procedure specified in **Sec 4.**

2.3 Hot spot stress

2.3.1

Hot spot stress is defined as the local stress at the hot spot. The hot spot stress takes into account the influence of structural discontinuities due to the geometry of the connection but excludes the effects of welds.
Hot spot stresses are to be obtained either by fine mesh FE analysis specified in **Ch 7, Sec 4**, or by multiplying nominal stresses by stress concentration factors defined in **Sec 4.**

2.4 Notch stress

2.4.1

Notch stress is defined as the peak stress at the weld toe taking into account stress concentrations due to the effects of structural geometry as well as the presence of welds.
Notch stress is to be obtained by multiplying hot spot stress by fatigue notch factor defined in **Sec 2, [2.3.1], Table 1.**

3. Loading

3.1 Loading condition

3.1.1

The loading conditions to be considered are defined in **Table 2** depending on the ship type. The standard loading conditions illustrated in **Ch 4, App 3** are to be considered.

Table 2: Loading conditions

Ship type	Full load condition		Ballast condition	
	Homogeneous	Alternate	Normal ballast	Heavy ballast
BC-A	√	√	√	√
BC-B	√	---	√	√
BC-C	√	---	√	√

3.2 Load case

3.2.1 Load cases

For each loading condition, the load cases to be considered, defined in **Ch 4, Sec 4, [2]**, are:

(a) “H1” and “H2” corresponding to the EDW “H” (head sea)

(b) “F1” and “F2” corresponding to the EDW “F” (following sea)

(c) “R1” and “R2” corresponding to the EDW “R” (beam sea)

(d) “P1” and “P2” corresponding to the EDW “P” (beam sea)

3.2.2

In the case of fatigue assessment of hatch corners, only oblique sea is to be considered, taking into account the wave torsional moments defined in **Ch 4, Sec 3, [3.4].**

3.2.3 Predominant load case

From the above mentioned load cases and for each loading condition, the load case where the combined stress range is maximum, corresponds to the predominant load case.

Section 2 – FATIGUE STRENGTH ASSESSMENT

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

i : Suffix which denotes load case “H”, “F”, “R” or “P” specified in **Ch 4, Sec 4**
“i1” denotes load case “H1”, “F1”, “R1” or “P1” and “i2” denotes load case “H2”, “F2”, “R2” or “P2”

(k) : Suffix which denotes loading condition “homogeneous condition”, “alternate condition”, “normal ballast condition” or “heavy ballast condition” as defined in **Sec 1, Table 2**

$\Delta\sigma_{W,i(k)}$: Hot spot stress range, in N/mm^2, in load case “i” of loading condition “(k)”

$\sigma_{mean,i(k)}$: Structural hot spot mean stress, in N/mm^2, in load case “i” of loading condition “(k)”

1. General

1.1 Application

1.1.1

This Section gives the linear cumulative damage procedure for the fatigue strength assessment of this Chapter.

1.1.2

Fatigue strength is assessed based on an equivalent notch stress range obtained by multiplying an equivalent hot spot stress range by a fatigue notch factor.

1.1.3

Hot spot stress ranges and hot spot mean stresses of primary members, longitudinal stiffeners connections and hatch corners are to be assessed respectively by **Sec 3, Sec 4** and **Sec 5.**

1.1.4 Primary members and longitudinal stiffeners connections

Predominant load cases and ‘condition 1’ are to be obtained respectively in **[2.1]** and **[2.2]**. The hot spot stress ranges calculated in **Sec 3** or **Sec 4**, corresponding to the predominant load case for each loading condition, are to be used in **[2.3.2]** to calculate the equivalent hot spot stress range.

1.1.5 Hatch corners

The hot spot stress range calculated in **Sec 5** is to be used in **[2.3.2]** to calculate the equivalent hot spot stress range.

2. Equivalent notch stress range

2.1 Predominant load case

2.1.1

The predominant load case “I” in fatigue assessment for each loading condition is the load case for which the combined stress range for the considered member is the maximum among the load cases “H”, “F”, “R” and “P” specified in **Sec 1, [3.2.1].**

$$\Delta\sigma_{W,I(k)} = \max_i\left(\Delta\sigma_{W,i(k)}\right)$$

where:

$\Delta\sigma_{W,i(k)}$: Combined hot spot stress range, in N/mm^2, defined either in **Sec 3, [2.1.1], [2.2.1]** or **Sec 4, [2.3.1].**

I : Suffix which denotes the selected predominant load case of loading condition "(k)".

2.2 Loading 'condition 1'

2.2.1

The 'condition 1' is the condition in which the maximum stress calculated by the equation below for the considered member is the largest on the tension side among the loading conditions "homogeneous", "alternate", "normal ballast" and "heavy ballast" specified in **Sec 1, Table 2.**

$$\sigma_{\max,1} = \max_k \left(\sigma_{mean,\,I(k)} + \frac{\Delta\sigma_{W,\,I(k)}}{2} \right)$$

where:

$\sigma_{mean,I(k)}$: Structural hot spot mean stress, in N/mm^2, in predominant load case of loading condition "(k)" defined in **[2.1.1]**

$\Delta\sigma_{W,I(k)}$: Hot spot stress range, in N/mm^2, in predominant load case of loading condition "(k)" defined in [2.1.1]

2.2.2

Further to the determination of 'condition 1' according to **[2.2.1]**, the corresponding loading condition is to be indexed with the suffix "j" equal1.

2.3 Equivalent notch stress range

2.3.1 Equivalent notch stress range

The equivalent notch stress range, in N/mm^2, for each loading condition is to be calculated with the following formula:

$$\Delta\sigma_{eq,\,j} = K_f \Delta\sigma_{equiv,\,j}$$

where:

$\Delta\sigma_{equiv,j}$: Equivalent hot spot stress range, in N/mm^2, in loading condition "j" obtained by **[2.3.2].**

K_f : Fatigue notch factor defined in **Table 1.**

Table 1: Fatigue notch factors K_f

Subject	Without weld grinding	With weld grinding (not applicable for ordinary stiffeners and boxing fillet welding[*1])
Butt welded joint	1.25	1.10
Fillet welded joint	1.30	1.152
Non welded part	1.00	-

Note:

*1 Boxing fillet welding is defined as a fillet weld around a corner of a member as an extension of the principal weld.

*2 This is applicable for deep penetration welding, or full penetration welding only
In case where grinding is performed, full details regarding grinding standards including the extent, smoothness particulars, final welding profiles and grinding workmanship as well as quality acceptance criteria are to be submitted to the Society for approval.
It is preferred that any grinding is carried out by rotary burrs, is to extend below plate surfaces in order to remove any toe defects and ground areas are to have sufficient corrosion protection. Such treatments are to procedure smooth concave profiles at weld toes with the depth of these depressions penetrating into plate surfaces to at least 0.5 mm below the bottom of any visible undercuts.
The depth of any grooves produced is to be kept to a minimum and, in general, kept to a maximum of 1 mm.
Under no circumstances is grinding depth to exceed 2 mm or 7 % of plate growth thickness, whichever is smaller.
Grinding has to extend to 0.5 longitudinal spacing or 0.5 frame spacing at the each side of hot spot locations.

2.3.2 Equivalent hot spot stress range

The equivalent hot spot stress range, in N/mm², is to be calculated for each loading condition with the following formula:

$$\Delta\sigma_{equiv,j} = f_{mean,j}\,\Delta\sigma_{W,j}$$

where:

$f_{mean,j}$: Correction factor for mean stress:

- for hatch corners $f_{mean,j} = 0.77$
- for primary members and longitudinal stiffeners connections, $f_{mean,j}$ corresponding to the condition "j" taken equal to:

$$f_{mean,j} = \max\left\{0.4,\left[\max\left(0,\frac{1}{2}+\frac{-\ln\left(10^{-4}\right)}{4}\frac{\sigma_{m,j}}{\Delta\sigma_{W,j}}\right)\right]^{0.25}\right\}$$

$\sigma_{m,1}$: Local hot spot mean stress, in N/mm², in the condition "1", obtained from the following formulae:

- if $0.6\Delta\sigma_{W,1} \geq 2.5R_{eH}$:

$$\sigma_{m,1} = -0.18\Delta\sigma_{W,1}$$

- if $0.6\Delta\sigma_{W,1} < 2.5R_{eH}$:

$$\sigma_{m,1} = R_{eH} - 0.6\Delta\sigma_{W,1} \quad \text{for} \quad 0.6\Delta\sigma_{W,1} > R_{eH} - \sigma_{res} - \sigma_{mean,1}$$

$$\sigma_{m,1} = \sigma_{mean,1} + \sigma_{res} \quad \text{for} \quad 0.6\Delta\sigma_{W,1} \leq R_{eH} - \sigma_{res} - \sigma_{mean,1}$$

$\sigma_{m,j}$: Local hot spot mean stress, in N/mm², in the condition "j", obtained from the following formulae:

- if $0.24\Delta\sigma_{W,j} \geq R_{eH}$:

$$\sigma_{m,j(j\neq 1)} = -0.18\Delta\sigma_{W,j}$$

- if $0.24\Delta\sigma_{W,j} < R_{eH}$:

$$\sigma_{m,j(j\neq 1)} = -R_{eH} + 0.24\Delta\sigma_{W,j} \quad \text{for} \quad 0.24\Delta\sigma_{W,j} > R_{eH} + \sigma_{m,1} - \sigma_{mean,1} + \sigma_{mean,j}$$

$$\sigma_{m,j(j\neq 1)} = \sigma_{m,1} - \sigma_{mean,1} + \sigma_{mean,j} \quad \text{for} \quad 0.24\Delta\sigma_{W,j} \leq R_{eH} + \sigma_{m,1} - \sigma_{mean,1} + \sigma_{mean,j}$$

$\sigma_{mean,j}$: Structural hot spot mean stress, in N/mm^2, corresponding to the condition "*j*"

σ_{res} : Residual stress, in N/mm^2, taken equal to:

$\sigma_{res} = 0.25R_{eH}$ for stiffener end connection

$s_{res} = 0$ for non welded part and primary members (cruciform joint or butt weld)

3. Calculation of fatigue damage

3.1 Correction of the equivalent notch stress range

3.1.1

The equivalent notch stress range is to be corrected with the following formula:

$$\Delta\sigma_{E,j} = f_{coat}\, f_{material}\, f_{thick}\, \Delta\sigma_{eq,j}$$

where:

f_{coat} : Correction factor for corrosive environment, taken equal to:

f_{coat} = 1.05 for water ballast tanks and fuel oil tank

f_{coat} = 1.03 for dry bulk cargo holds and void space

$f_{material}$: Correction factor for material, taken equal to:

$$f_{material} = \frac{1200}{965 + R_{eH}}$$

f_{thick} : Correction factor for plate thickness, taken equal to 1.0 for hatch corners, flat bar or bulb stiffeners, otherwise to be taken equal to:

$$f_{thick} = \left(\frac{t}{22}\right)^{0.25} \quad \text{for} \quad t \geq 22 \text{ mm}$$

$$f_{thick} = 1.0 \quad \text{for} \quad t < 22 \text{ mm}$$

t : Net thickness, in mm, of the considered member, taken as the flange in case of stiffeners

$\Delta\sigma_{eq,j}$: Equivalent notch stress range, in N/mm^2, defined in **[2.3.1]**.

3.2 Long-term distribution of stress range

3.2.1

The cumulative probability density function of the long-term distribution of combined notch stress ranges is to be taken as a two-parameter Weibull distribution:

$$F(x) = 1 - \exp\left[-\left(\frac{x}{\Delta\sigma_{E,j}}\right)^{\xi}(\ln N_R)\right]$$

where:

ξ : Weibull shape parameter, taken equal to 1.0

N_R : Number of cycles, taken equal to 10^4.

3.3 Elementary fatigue damage

3.3.1

The elementary fatigue damage for each loading condition is to be calculated with the following formula:

$$D_j = \frac{\alpha_j N_L}{K} \frac{\Delta\sigma_{E,j}{}^4}{(\ln N_R)^{4/\xi}} \left[\Gamma\left(\frac{4}{\xi}+1, \nu\right) + \nu^{-3/\xi} \gamma\left(\frac{7}{\xi}+1, \nu\right) \right]$$

where:

K : S-N curve parameter, taken equal to 1.014×10^{15}

α_j : Coefficient taken equal to 1.0 for the assessment of hatch corners and depending on the loading condition specified in Table 2 for primary members and longitudinal stiffeners connections.

N_L : Total number of cycles for the design ship's life, taken equal to:

$$N_L = \frac{0.85 T_L}{4 \log L}$$

T_L : Design life, in seconds, corresponding to 25 years of ship's life, taken equal to 7.884×10^8

$$\nu = \left(\frac{100.3}{\Delta\sigma_{E,j}}\right)^{\xi} \ln N_R$$

Γ : Type 2 incomplete gamma function

γ : Type 1 incomplete gamma function

Table 2: Coefficient α_j depending on the loading condition

	Loading Conditions	BC-A	BC-B, BC-C
L < 200 m	Homogeneous	0.6	0.7
	Alternate	0.1	---
	Normal ballast	0.15	0.15
	Heavy ballast	0.15	0.15
$L \geq$ 200 m	Homogeneous	0.25	0.5
	Alternate	0.25	---
	Normal ballast	0.2	0.2
	Heavy ballast	0.3	0.3

4. Fatigue strength criteria

4.1 Cumulative fatigue damage

4.1.1

The cumulative fatigue damage D calculated for the combined equivalent stress is to comply with the following criteria:

$$D = \sum_j D_j \leq 1.0$$

where

D_j : Elementary fatigue damage for each loading condition "j".

Section 3 – STRESS ASSESSMENT OF PRIMARY MEMBERS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

i : Suffix which denotes load case "H", "F", "R" or "P" specified in **Ch 4, Sec 4**
"$i1$" denotes load case "H1", "F1", "R1" or "P1" and "$i2$" denotes load case "H2", "F2", "R2" or "P2"

(k) : Suffix which denotes loading condition, "homogeneous condition", "alternate condition", "normal ballast condition" or "heavy ballast condition" as defined in **Sec 1, Table 2**

$\Delta\sigma_{W,i(k)}$: Hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)"

$\sigma_{mean,i(k)}$: Structural hot spot mean stress, in N/mm^2, in load case "i" of loading condition "(k)".

1. General

1.1 Application

1.1.1

Hot spot stress ranges and structural hot spot mean stresses of primary members are to be assessed according to the requirements of this Section, with the requirements given in **Ch 7, Sec 4.**

2. Hot spot stress range

2.1 Stress range according to the direct method

2.1.1

The hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\sigma_{W,i1(k)} - \sigma_{W,i2(k)}\right|$$

where:

$\sigma_{W,i1(k)}$, $\sigma_{W,i2(k)}$: Hot spot stress, in N/mm^2, in load case "$i1$" and "$i2$" of loading condition "(k)", obtained by direct FEM analysis using fine mesh model specified in **Ch 7, Sec 4.**

2.2 Stress range according to the superimposition method

2.2.1 Hot spot stress range

The hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\left(\sigma_{GW,i1(k)} + \sigma_{LW,i1(k)}\right) - \left(\sigma_{GW,i2(k)} + \sigma_{LW,i2(k)}\right)\right|$$

where:

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$: Hot spot stress, in N/mm^2, due to local loads in load cases "$i1$" and "$i2$" for loading condition "(k)" obtained by the direct analysis using fine mesh FE model specified in **Ch 7,**

Sec 4

$\sigma_{GW,i1(k)}$, $\sigma_{GW,i2(k)}$: Hot spot stress, in N/mm², due to hull girder moments in load cases "*i*1" and "*i*2" for loading condition "(*k*)" obtained according to **[2.2.2].**

2.2.2 Stress due to hull girder moments

The hull girder hot spot stress, in N/mm², in load cases "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{GW,ij(k)} = C_{WV,ij}\,\sigma_{WV,ij} - C_{WH,ij}\,\sigma_{WH,(k)} \qquad (j = 1, 2)$$

where:

$C_{WV,i1}$, $C_{WV,i2}$, $C_{WH,i1}$, $C_{WH,i2}$: Load combination factors for each load case defined in **Ch 4, Sec 4, [2.2]**

$\sigma_{WV,i1}$: Nominal hull girder stress, in N/mm², in sagging condition induced by vertical wave bending moment

$$\sigma_{WV,i1} = \frac{M_{WV,S}\,(z-N)}{I_Y}\,10^{-3}$$

$\sigma_{WV,i2}$: Nominal hull girder stress, in N/mm², in hogging condition induced by vertical wave bending moment

$$\sigma_{WV,i2} = \frac{M_{WV,H}\,(z-N)}{I_Y}\,10^{-3}$$

$M_{WV,H}$, $M_{WV,S}$: Vertical wave bending moments, in kN.m, in hogging and sagging conditions defined in **Ch 4, Sec 3, [3.1.1]**, with $f_p = 0.5$

N : Z co-ordinate, in m, of the neutral axis , as defined in **Ch 5, Sec 1**

z : Z co-ordinate, in m, of the point considered

$\sigma_{WH,(k)}$: Nominal hull girder stress, in N/mm², induced by horizontal wave bending moment

$$\sigma_{WH,(k)} = \frac{M_{WH,(k)}\,y}{I_Z}\,10^{-3}$$

$M_{WH,(k)}$: Horizontal wave bending moment, in kN.m, in loading condition "(*k*)" defined in **Ch 4, Sec 3, [3.3.1]**, with $f_p = 0.5$

y : Y co-ordinate, in m, of the point considered, to be taken positive at port side and negative at starboard side

I_Y, I_Z : Net moments of inertia of hull cross-section, in m⁴, about transverse and vertical axis respectively, as defined in **Ch 5, Sec 1.**

3. Hot spot mean stress

3.1 Mean stress according to the direct method

3.1.1

The structural hot spot mean stress, in N/mm², in load case "*i*" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{mean,i(k)} = \frac{\sigma_{W,i1(k)} + \sigma_{W,i2(k)}}{2}$$

3.2 Mean stress according to the superimposition method

3.2.1 Hot spot mean stresses

The structural hot spot mean stress, in N/mm^2, in load case "i" for loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{mean,\,i(k)} = \sigma_{GS,\,(k)} + \frac{\sigma_{LW,\,i1(k)} + \sigma_{LW,\,i2(k)}}{2}$$

where:

$\sigma_{GS,(k)}$: Hot spot mean stress, in N/mm^2, due to still water hull girder moment in loading condition "(k)" obtained according to **[3.2.2].**

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$: As defined in **2.2.1**

3.2.2 Stress due to still water hull girder moment

The hot spot stress, in N/mm^2, due to still water bending moment in loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{GS,\,(k)} = \frac{M_{S,\,(k)}\,(z-N)}{I_Y}\,10^{-3}$$

where:

$M_{S,(k)}$: Still water vertical bending moment, in kN.m, depending on the loading condition defined in **Ch 4, Sec 3, [2.2]**. If the design still water bending moments are not defined at a preliminary design stage, still water bending moment in each loading condition may be obtained from the following formulae:

homogeneous condition ; $M_{S,(1)} = -0.5F_{MS}M_{SW,S}$

alternate condition ; $M_{S,(2)} = F_{MS}M_{SW,H}$

normal ballast condition ; $M_{S,(3)} = F_{MS}M_{SW,H}$

heavy ballast condition ;

$$M_{S,(4)} = \begin{cases} 2.66\dfrac{x}{L}M_{SW,H} & ; \quad 0 < x \le 0.15L \\ 2.66\left(0.3-\dfrac{x}{L}\right)M_{SW,H} & ; \quad 0.15L < x \le 0.3L \\ -3.5\left(\dfrac{x}{L}-0.3\right)M_{SW,S} & ; \quad 0.3L < x \le 0.5L \\ -3.5\left(0.7-\dfrac{x}{L}\right)M_{SW,S} & ; \quad 0.5L < x \le 0.7L \\ 2.66\left(\dfrac{x}{L}-0.7\right)M_{SW,H} & ; \quad 0.7L < x \le 0.85L \\ 2.66\left(1-\dfrac{x}{L}\right)M_{SW,H} & ; \quad 0.85L < x \le L \end{cases}$$

$M_{SW,H}$, $M_{SW,S}$: Permissible still water bending moment, in kN.m, in hogging and sagging conditions

F_{MS} : Distribution factor defined in **Ch 4, Sec 3, Fig 2**

Section 4 – STRESS ASSESSMENT OF STIFFENERS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

i : Suffix which denotes load case "H", "F", "R" or "P" specified in **Ch 4, Sec 4**
"i1" denotes load case "H1", "F1", "R1" or "P1" and "i2" denotes load case "H2", "F2", "R2" or "P2"

(k) : Suffix which denotes loading condition, "homogeneous condition", "alternate condition", "normal ballast condition" or "heavy ballast condition" as defined in **Sec 1, Table 2**

$\Delta\sigma_{W,i(k)}$: Hot spot stress range, in N/mm^2, in load case "i" of loading condition "(k)"

$\sigma_{mean,i(k)}$: Structural hot spot mean stress, in N/mm^2, in load case "i" of loading condition "(k)"

1. General

1.1 Application

1.1.1

Hot spot stress ranges and structural hot spot mean stresses of longitudinal stiffeners are to be assessed in line with the requirements of this Section.

1.1.2

The hot spot stress ranges and structural hot spot mean stresses of longitudinal stiffeners are to be evaluated at the face plate of the longitudinal considering the type of longitudinal end connection and the following locations.

(1) Transverse webs or floors other than those at transverse bulkhead of cargo hold or in way of stools, such that additional hot spot stress due to the relative displacement may not be considered. These longitudinal end connections are defined in **Table 1.** When transverse webs or floors are watertight, the coefficients K_{gl} and K_{gh} as defined in **Table 2** are to be considered instead of those defined in **Table 1.**

(2) Transverse webs or floors at transverse bulkhead of cargo hold in way of stools, such that additional hot spot stress due to the relative displacement should be considered. These longitudinal end connections are defined in **Table 2.** When transverse webs or floors at transverse bulkhead of cargo hold or in way of stools are not watertight, the coefficients K_{gl} and K_{gh} as defined in **Table 1** are to be considered instead of those defined in **Table 2.**

2. Hot spot stress range

2.1 Stress range obtained by the direct method

2.1.1

Hot spot stress ranges, in N/mm^2, calculated with direct calculation for each load case "H", "F", "R" and "P" of each loading condition, are to be obtained according to **Sec 3, [2.1].**

2.2 Stress range according to the superimposition method

2.2.1

The hot spot stress ranges, in N/mm^2, for each load case "H", "F", "R" and "P" of each loading condition according to the superimposition method are to be obtained according to **Sec 3, [2.2].**

2.3 Stress range according to the simplified procedure

2.3.1 Hot spot stress ranges

The hot spot stress range, in N/mm^2, due to dynamic loads in load case "*i*" of loading condition "(*k*)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\left(\sigma_{GW,i1(k)} + \sigma_{W1,i1(k)} - \sigma_{W2,i1(k)} + \sigma_{d,i1(k)}\right) - \left(\sigma_{GW,i2(k)} + \sigma_{W1,i2(k)} - \sigma_{W2,i2(k)} + \sigma_{d,i2(k)}\right)\right|$$

where

$\sigma_{GW,i1(k)}$, $\sigma_{GW,i2(k)}$: Stress due to hull girder moment, defined in **[2.3.2]**

$\sigma_{W1,i1(k)}$, $\sigma_{W1,i2(k)}$: Stress $\sigma_{LW,ij(k)}$, $\sigma_{CW,ij(k)}$ and $\sigma_{LCW,ij(k)}$ due to hydrodynamic or inertial pressure when the pressure is applied on the same side as the ordinary stiffener depending on the considered case

$\sigma_{W2,i1(k)}$, $\sigma_{W2,i2(k)}$: Stress $\sigma_{LW,ij(k)}$, $\sigma_{CW,ij(k)}$ and $\sigma_{LCW,ij(k)}$ due to hydrodynamic or inertial pressure when the pressure is applied on the side opposite to the stiffener depending on the considered case

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$: Stresses due to wave pressure, defined in **[2.3.3]**

$\sigma_{CW,i1(k)}$, $\sigma_{CW,i2(k)}$: Stresses due to liquid pressure, defined in **[2.3.4]**

$\sigma_{LCW,i1(k)}$, $\sigma_{LCW,i2(k)}$: Stresses due to dry bulk cargo pressure, defined in **[2.3.5]**

$\sigma_{d,i1(k)}$, $\sigma_{d,i2(k)}$: Stress due to relative displacement of transverse bulkhead, or floor in way of stools, defined in **[2.3.6].**

2.3.2 Stress due to hull girder moments

The hull girder hot spot stress, in N/mm^2, in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{GW,ij(k)} = K_{gh} \cdot \left(C_{WV,ij}\,\sigma_{WV,ij} - C_{WH,ij}\,\sigma_{WH,(k)}\right) \qquad (j = 1, 2)$$

where:

K_{gh} : Geometrical stress concentration factor for nominal hull girder stress. K_{gh} is given in **Table 1** and **Table 2** for the longitudinal end connection specified in **[1.1.2]**(1) and **[1.1.2]**(2), respectively.
The stress concentration factor can be evaluated directly by the FE analysis.

$C_{WV,i1}$, $C_{WV,i2}$, $C_{WH,i1}$, $C_{WH,i2}$: Load combination factors for each load case defined in **Ch 4, Sec 4, [2.2]**

$\sigma_{WV,i1}$, $\sigma_{WV,i2}$, $\sigma_{WH,(k)}$: Nominal hull girder stresses, in N/mm^2, defined in **Sec 3, [2.2.2]**

2.3.3 Stress due to wave pressure

The hot spot stress, in N/mm^2, due to the wave pressure in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{LW,ij(k)} = \frac{K_{gl} K_s p_{CW,ij(k)}\, s\ell^2 \left(1 - \dfrac{6x_f}{\ell} + \dfrac{6x_f^{\,2}}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1, 2)$$

$$p_{CW,i1(k)} = \begin{cases} 2C_{NE,i1(k)}\, p_{W,i1(k)} & ; C_{NE,i1(k)} < 0.5 \\ p_{w,i1(k)} & ; C_{NE,i1(k)} \geq 0.5 \end{cases}$$

$$p_{CW,i2(k)} = \begin{cases} 0 & ; C_{NE,i2(k)} < 0.5 \\ (2C_{NE,i2(k)} - 1)\, p_{W,i2(k)} & ; C_{NE,i2(k)} \geq 0.5 \end{cases}$$

where:

$p_{W,ij(k)}$: Hydrodynamic pressure, in kN/m^2, specified in **Ch 4, Sec 5, [1.3], [1.4]** and **[1.5]**, with f_p = 0.5, in load case "i1" and "i2" for loading condition "(k)". When the location of the considered member is above the waterline, the hydrodynamic pressure is to be taken as the pressure at waterline.

K_{gl} : Geometrical stress concentration factor for stress due to lateral pressure. K_{gl} is given in **Table 1** and **Table 2** for the longitudinal end connection specified in **[1.1.2]**(1) and **[1.1.2]**(2), respectively. The stress concentration factor can be evaluated directly by the FE analysis.

K_s : Geometrical stress concentration factor due to stiffener geometry

$$K_s = 1 + \left[\frac{t_f(a^2 - b^2)}{2w_b}\right]\left[1 - \frac{b}{b_f}\left(1 + \frac{w_b}{w_a}\right)\right]10^{-3}$$

a, b : Eccentricity, in mm, of the face plate as defined in **Fig 1**. For angle profile, "b" is to be taken as half the net actual thickness of the web.

t_f, b_f : Thickness and breadth of face plate, in mm, respectively, as defined in **Fig 1**

w_a, w_b : Net section modulus in A and B respectively (see **Fig 1**), in cm^3, of the stiffener about the neutral axis parallel to Z axis without attached plating.

$C_{NE,ij(k)}$: Correction factor for the non linearity of the wave pressure range in load case "i1" and "i2" of loading condition "(k)"

$$C_{NE,ij(k)} = \begin{cases} \exp\left[-\left(\dfrac{z - T_{LC(k)} + \dfrac{|p_{W,ij(k),WL}|}{\rho g}}{\dfrac{|p_{W,ij(k),WL}|}{\rho g}(-\ln 0.5)^{-1/2.5}}\right)^{2.5}\right] & \text{for} \quad z > T_{LC(k)} - \dfrac{|p_{W,ij(k),WL}|}{\rho g} \\ 1.0 & \text{for} \quad z \le T_{LC(k)} - \dfrac{|p_{W,ij(k),WL}|}{\rho g} \end{cases}$$

$T_{LC(k)}$: Draught, in m, of the considered loading condition "(k)"

$p_{W,ij(k),WL}$: Hydrodynamic pressure, in kN/m^2, at water line in load case "i1" and "i2" of loading condition "(k)"

z : Z co-ordinate, in m, of the point considered

s : Stiffener spacing, in m

ℓ : Span, in m, to be measured as shown in **Fig 2**. The ends of the span are to be taken at points where the depth of the end bracket, measured from the face plate of the stiffener is equal to half the depth of the stiffener

x_f : Distance, in m, to the hot spot from the closest end of the span ℓ (see **Fig 2**)

w : Net section modulus, in cm^3, of the considered stiffener. The section modulus w is to be calculated considering an effective breadth s_e, in m, of attached plating obtained from the following formulae:

$$s_e = \begin{cases} 0.67s \cdot \sin\left[\dfrac{\pi}{6}\left(\dfrac{\ell(1 - 1/\sqrt{3})}{2s}\right)\right] & \text{for} \quad \dfrac{\ell}{s} \le \dfrac{6}{1 - 1/\sqrt{3}} \\ 0.67s & \text{for} \quad \dfrac{\ell}{s} > \dfrac{6}{1 - 1/\sqrt{3}} \end{cases}$$

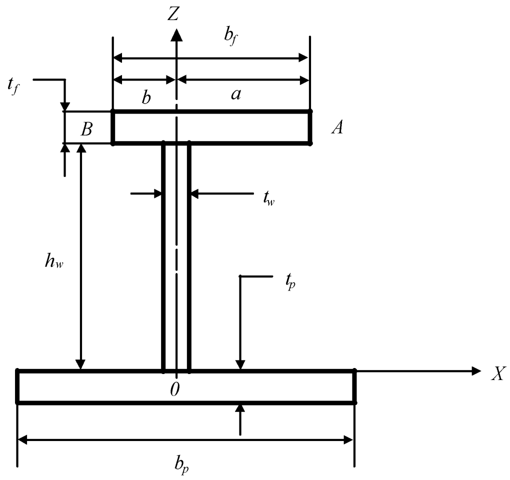


Fig 1: Sectional parameters of a stiffener

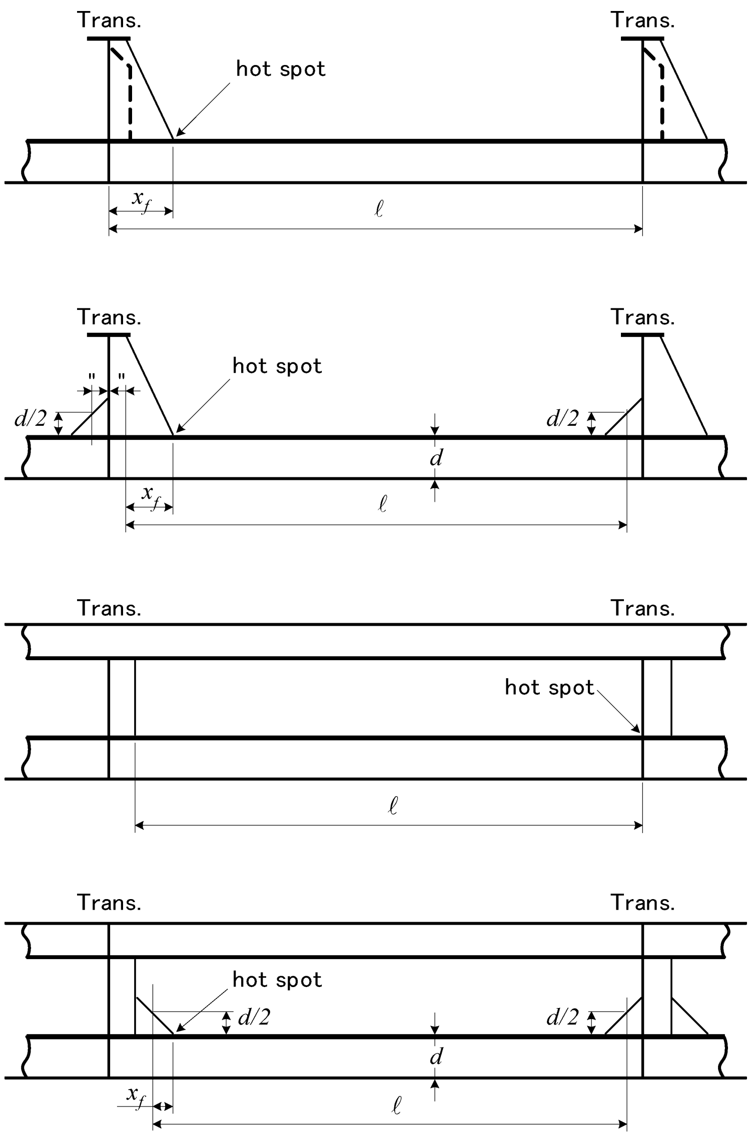


Fig 2: Span and hot spot of longitudinal stiffeners

2.3.4 Stress due to liquid pressure

The hot spot stress, in N/mm², due to the liquid pressure in load case "i1" and "i2" for loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{CW,ij(k)} = \frac{K_{gl} K_s C_{NI,ij(k)} p_{BW,ij(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} \cdot 10^3 \qquad (j = 1, 2)$$

where:

$p_{BW,ij(k)}$: Inertial pressure, in kN/m², due to liquid specified in **Ch 4, Sec 6, [2.2]**, with $f_p = 0.5$, in load case "i1" and "i2" for loading condition "(k)". Where the considered location is located in fuel oil, other oil or fresh water tanks, no inertial pressure is considered for the tank top longitudinals and when the location of the considered member is above the liquid surface in static and upright condition, the inertial pressure is to be taken at the liquid surface line.

$C_{NI,ij(k)}$: Correction factor for the non linearity of the inertial pressure range due to liquid in load case "i1" and "i2" for loading condition "(k)"

$$C_{NI,ij(k)} = \begin{cases} \exp\left[-\left(\dfrac{z - z_{SF} + \dfrac{|p_{BW,ij(k),SF}|}{\rho g}}{\dfrac{|p_{BW,ij(k),SF}|}{\rho g}(-\ln 0.5)^{-1/2.5}}\right)^{2.5}\right] & \text{for } z > z_{SF} - \dfrac{|p_{BW,ij(k),SF}|}{\rho g} \\ 1.0 & \text{for } z \le z_{SF} - \dfrac{|p_{BW,ij(k),SF}|}{\rho g} \end{cases}$$

z_{SF} : Z co-ordinate, in m, of the liquid surface. In general, it is taken equal to "z_{TOP}" defined in **Ch 4, Sec 6.** If the considered location is located in fuel oil, other oil or fresh water tanks, it may be taken as the distance to the half height of the tank.

z : Z co-ordinate, in m, of the point considered

$p_{BW,ij(k),SF}$: Inertial pressure due to liquid, in kN/m², taken at the liquid surface in load case "i1" and "i2" for loading condition "(k)". In calculating the inertial pressure according to **Ch 4, Sec 6, [2.2.1]**, x and y coordinates of the reference point are to be taken as liquid surface instead of tank top.

$K_{gh}K_s$: The stress concentration factor defined in **[2.3.3]**

2.3.5 Stress due to dry bulk cargo pressure

The hot spot stress, in N/mm², due to the dry bulk cargo pressure in load case "i1" and "i2" for loading condition "(k)" is to be obtained from the following formula:

$$\sigma_{LCW,ij(k)} = \frac{K_{gl} K_s p_{CW,ij(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1, 2)$$

where:

$p_{CW,ij(k)}$: Inertial pressure, in kN/m², due to dry bulk cargo specified in **Ch 4, Sec 6 [1.3]**, with f_p = 0.5, in load case "i1" and "i2" for loading condition "(k)"

2.3.6 Stress due to relative displacement of transverse bulkhead or floor in way of transverse bulkhead or stool

For longitudinal end connection specified in **[1.1.2]**(2), the additional hot spot stress, in N/mm^2, due to the relative displacement in the direction perpendicular to the attached plate between the transverse bulkhead or floor in way of stools and the adjacent transverse web or floor in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{d,ij(k)} = \begin{cases} K_{dF-a}\sigma_{dF-a,ij(k)} + K_{dA-a}\sigma_{dA-a,ij(k)} & \text{for point "}a\text{"} \\ K_{dF-f}\sigma_{dF-f,ij(k)} + K_{dA-f}\sigma_{dA-f,ij(k)} & \text{for point "}f\text{"} \end{cases} \qquad (j=1,2)$$

where:

a, *f* : Suffix which denotes the location considered as indicated in **Table 2.**

A, *F* : Suffix which denotes the direction, forward (*F*) and after ward (*A*), of the transverse web or floor where the relative displacement is occurred as indicated in **Table 2**. (see **Fig 3**)

$\sigma_{dF-a,ij(k)}$, $\sigma_{dA-a,ij(k)}$, $\sigma_{dF-f,ij(k)}$, $\sigma_{dA-f,ij(k)}$: Additional stress at point "*a*" and "*f*", in N/mm^2, due to the relative displacement between the transverse bulkhead or floors in way of stools and the forward (*F*) and after ward (*A*) transverse web or floor respectively in load case "*i*1" and "*i*2" for loading condition "(*k*)"

$$\sigma_{dF-a,ij(k)} = \frac{3.9\delta_{F,ij(k)} E I_A I_F}{w_A \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) 10^{-5}$$

$$\sigma_{dA-a,ij(k)} = \left[\frac{3.9\delta_{A,ij(k)} E I_A I_F}{w_A \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) - \frac{0.9\delta_{A,ij(k)} E I_A |x_{fA}|}{w_A \ell_A^{\,3}}\right] 10^{-5}$$

$$\sigma_{dF-f,ij(k)} = \left[\frac{3.9\delta_{F,ij(k)} E I_A I_F}{w_F \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) - \frac{0.9\delta_{F,ij(k)} E I_F |x_{fF}|}{w_F \ell_F^{\,3}}\right] 10^{-5}$$

$$\sigma_{dA-f,ij(k)} = \frac{3.9\delta_{A,ij(k)} E I_A I_F}{w_F \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) 10^{-5}$$

$\delta_{F,ij(k)}$, $\delta_{A,ij(k)}$: Relative displacement, in mm, in the direction perpendicular to the attached plate between the transverse bulkhead or floor in way of stools and the forward (*F*) and afterward (*A*) transverse web or floor in load case "*i*1" and "*i*2" for loading condition "(*k*)" (see **Fig 3**)

(a) For longitudinals penetrating floors in way of stools

Relative displacement is defined as the displacement of the longitudinal in relation to the line passing through the stiffener end connection at the base of the stool measured at the first floor forward (*F*) or afterward (*A*) of the stool.

(b) For longitudinals other than (a)

Relative displacement is defined as the displacement of the longitudinal in relation to its original position measured at the first forward (*F*) or afterward (*A*) of the transverse bulkhead.

Where the stress of the face of longitudinal at the assessment point due to relative displacement is tension, the sign of the relative displacement is positive.

I_F, I_A : Net moment of inertia, in cm4, of forward (*F*) and afterward (*A*) longitudinal

K_{dF-a}, K_{dA-a}, K_{dF-f}, K_{dA-f} : Stress concentration factor for stiffener end connection at point "*a*" and "*f*" subject to relative displacement between the transverse bulkhead and the forward (*F*) and afterward (A) transverse web or floors in way of stool respectively as defined in **Table 2**. The stress concentration can be evaluated directly by the FE analysis when the detail of end connection is not defined in **Table 2.**

ℓ_F, ℓ_A : Span, in m, of forward (F) and afterward (A) longitudinal to be measured as shown in **Fig 2**

x_{fF}, x_{fA} : Distance, in m, to the hot spot from the closest end of ℓ_F and ℓ_A respectively (see **Fig 2**).

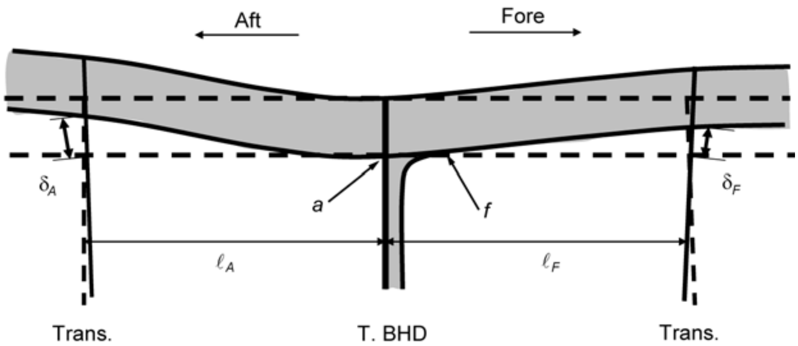


Fig 3: Definition of the relative displacement (Example of the side longitudinal)

3. Hot spot mean stress

3.1 Mean stress according to the direct method

3.1.1

The structural hot spot mean stress, in N/mm^2, in each loading condition calculated with the direct method is to be obtained according to **Sec 3, [3.1].**

3.2 Mean stress according to the superimposition method

3.2.1

The structural hot spot mean stress, in N/mm^2, in each loading condition calculated with the superimposition method is to be obtained according to **Sec 3, [3.2].**

3.3 Mean stress according to the simplified procedure

3.3.1 Hot spot mean stresses

The structural hot spot mean stress, in N/mm^2, in loading condition "(k)" regardless of load case "i" is to be obtained from the following formula:

$$\sigma_{mean,(k)} = \sigma_{GS,(k)} + \sigma_{S1,(k)} - \sigma_{S2,(k)} + \sigma_{dS,(k)}$$

where

$\sigma_{GS,(k)}$: Stress due to still water hull girder moment, defined in **[3.3.2]**

$\sigma_{S1,(k)}$: Stress due to static pressure when the pressure is applied on the same side as the ordinary stiffener depending on the considered case, with consideration of the stresses defined in **[3.3.3]** to **[3.3.5]**

$\sigma_{S2,(k)}$: Stress due to static pressure when the pressure is applied on the side opposite to the stiffener depending on the considered case

$\sigma_{dS,(k)}$: Stress due to relative displacement of transverse bulkhead in still water, defined in **[3.3.6]**.

3.3.2 Stress due to still water hull girder moment

The hot spot stress due to still water bending moment, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{GS,(k)} = K_{gh} \frac{M_{S,(k)}(z-N)}{I_Y} 10^{-3}$$

where:

$M_{S,(k)}$: Still water vertical bending moment, in kN.m, defined in **Sec 3, [3.2.2].**

3.3.3 Stress due to hydrostatic and hydrodynamic pressure

The hot spot stress due to hydrostatic and hydrodynamic pressure, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{LS,(k)} = \frac{K_{gl}K_s\left\{p_{s,(k)} + \frac{p_{CW,i1(k)}+p_{CW,i2(k)}}{2}\right\}s\ell^2\left(1-\frac{6x_f}{\ell}+\frac{6x_f^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{S,(k)}$: Hydrostatic pressure, in kN/m^2, in loading condition "(k)" specified in **Ch 4, Sec 5, [1.2].**

$p_{CW,ij(k)}$: Corrected hydrodynamic pressure, in kN/m^2, according to **[2.3.3]**, with $f_p = 0.5$, in load case "i1" and "i2" for loading condition "(k)"

i : Suffix which denotes the load case specified in **Sec 2 [2.1.1]**, when calculating the mean stress, "I" is to be used.

3.3.4 Stress due to liquid pressure in still water

The structural hot spot mean stress due to liquid pressure in still water, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{CS,(k)} = \frac{K_{gl}K_s p_{CS,(k)} s\ell^2\left(1-\frac{6x_f}{\ell}+\frac{6x_f^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{CS,(k)}$: Liquid pressure in still water, in kN/m^2, in loading condition "(k)" specified in **Ch 4, Sec 6 [2.1].** Where the considered location is located in fuel oil, other oil or fresh water tanks, d_{AP} and P_{PV} defined in **Ch 4, Sec 6** are to be taken equal to 0 and z_{TOP} specified in **Ch 4, Sec 6, [2.1]** is to be takene qual to z_{SF} specified in **[2.3.4]**

3.3.5 Stress due to dry bulk cargo pressure in still water

The structural hot spot mean stress due to dry bulk cargo pressure in still water, in N/mm^2, in loading condition "(k)" is to be obtained with the following formula:

$$\sigma_{LCS,(k)} = \frac{K_{gl} K_s p_{CS,(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6{x_f}^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{CS,(k)}$: Dry bulk cargo pressure in still water, in kN/m², in loading condition "(k)" specified in **Ch 4, Sec 6, [1.2]**

3.3.6 Stress due to relative displacement of transverse bulkhead in still water

The additional hot spot mean stress, in N/mm², due to the relative displacement in the transverse direction between the transverse bulkhead and the adjacent transverse web or floor in loading condition "(k)", is to be obtained with the following formula:

$$\sigma_{dS,(k)} = \begin{cases} K_{dF-a}\sigma_{dSF-a,(k)} + K_{dA-a}\sigma_{dSA-a,(k)} & \text{for point "}a\text{"} \\ K_{dF-f}\sigma_{dSF-f,(k)} + K_{dA-f}\sigma_{dSA-f,(k)} & \text{for point "}f\text{"} \end{cases}$$

where:

$\sigma_{dSF-a,(k)}$, $\sigma_{dSA-a,(k)}$, $\sigma_{dSF-f,(k)}$, $\sigma_{dSA-f,(k)}$: Additional stress at point "a" and "f", in N/mm², due to the relative displacement between the transverse bulkhead and the forward (F) and afterward (A) transverse web or floor respectively in loading condition (k)

$$\sigma_{dSF-a,(k)} = \frac{3.9\delta_{SF,(k)} E I_A I_F}{w_A \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) 10^{-5}$$

$$\sigma_{dSA-a,(k)} = \left[\frac{3.9\delta_{SA,(k)} E I_A I_F}{w_A \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) - \frac{0.9\delta_{SA,(k)} E I_A |x_{fA}|}{w_A {\ell_A}^3}\right] 10^{-5}$$

$$\sigma_{dSF-f,(k)} = \left[\frac{3.9\delta_{SF,(k)} E I_A I_F}{w_F \ell_F (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) - \frac{0.9\delta_{SF,(k)} E I_F |x_{fF}|}{w_F {\ell_F}^3}\right] 10^{-5}$$

$$\sigma_{dSA-f,(k)} = \frac{3.9\delta_{SA,(k)} E I_A I_F}{w_F \ell_A (\ell_A I_F + \ell_F I_A)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) 10^{-5}$$

$\delta_{SF,(k)}$, $\delta_{SA,(k)}$: Relative displacement, in mm, in still water in the transverse direction between the transverse bulkhead and the forward (F) and afterward (A) transverse web or floor respectively in loading condition (k)

Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools

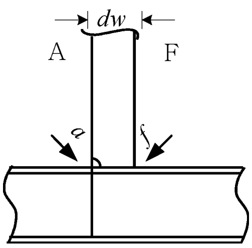
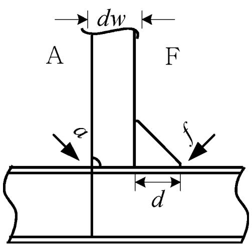
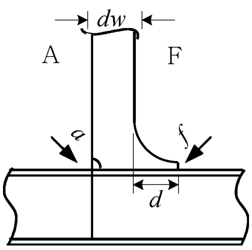
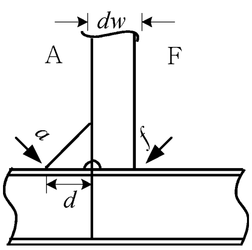
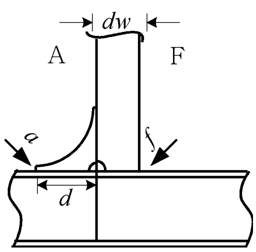
Bracket type	Assessed point	Bracket size	Stress concentration factors K_{gl}	Stress concentration factors K_{gh}
1 	a	-----	1.65	1.1
2 	a	$dw \le d < 1.5\,dw$	1.55	1.1
		$1.5\,dw \le d$	1.5	1.05
3 	a	$dw \le d < 1.5\,dw$	1.5	1.1
		$1.5\,dw \le d$	1.45	1.05
4 	f	$dw \le d < 1.5\,dw$	1.4	1.1
		$1.5\,dw \le d$	1.4	1.05
5 	f	$dw \le d < 1.5\,dw$	1.35	1.1
		$1.5\,dw \le d$	1.35	1.05

Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools (continued)

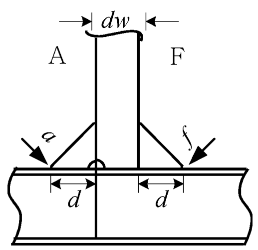
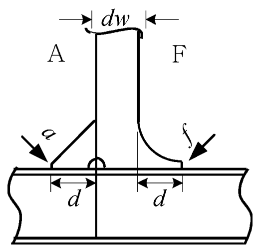
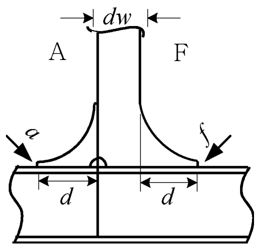
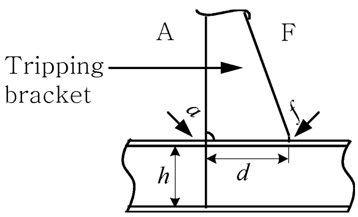
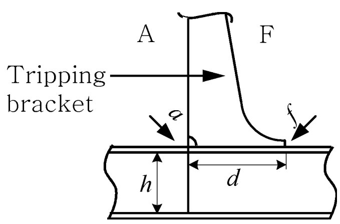
Bracket type	Assessed point	Bracket size	Stress concentration factors	
			K_{gl}	K_{gh}
6 	a	$dw \le d < 1.5\,dw$	1.15	1.05
		$1.5\,dw \le d$	1.1	1.05
7 	a	$dw \le d < 1.5\,dw$	1.15	1.05
		$1.5\,dw \le d$	1.1	1.05
8 	a	$dw \le d < 1.5\,dw$	1.1	1.1
		$1.5\,dw \le d$	1.05	1.05
9 	a	$d \le 2h$	1.45	1.1
10 	a	$d \le 2.5h$	1.35	1.1

Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools (continued)

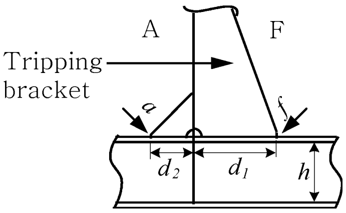
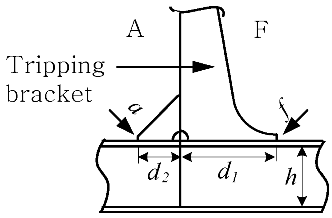
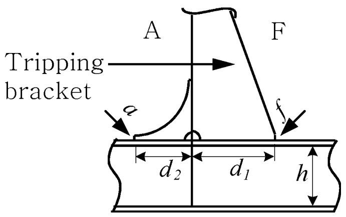
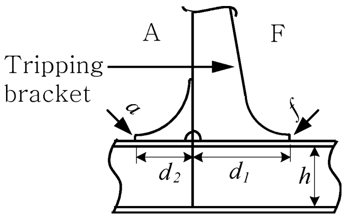
Bracket type	Assessed point	Bracket size	Stress concentration factors	
			K_{gl}	K_{gh}
11 	a	$d_1 \le 2h$ and $h \le d_2$	1.15	1.1
	f		1.85	1.1
12 	a	$d_1 \le 2.5h$ and $h \le d_2$	1.15	1.1
	f		1.35	1.1
13 	a	$d_1 \le 2h$ and $h \le d_2$	1.1	1.1
	f		2.05	1.1
14 	a	$d_1 \le 2.5h$ and $h \le d_2$	1.1	1.1
	f		1.8	1.1

Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools

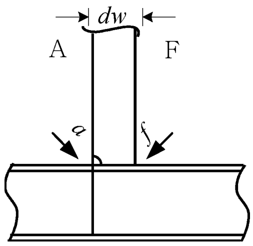
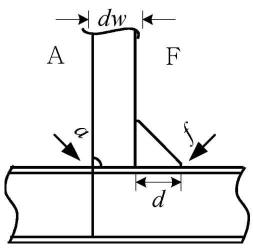
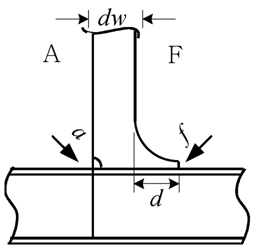
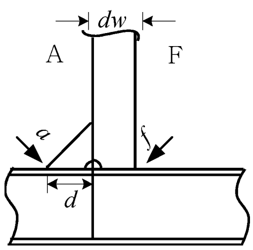
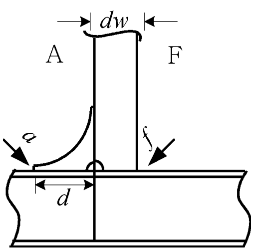
Bracket type	Assessed point	Bracket size	Stress concentration factors			
			K_{gl}	K_{gh}	K_{dF}	K_{dA}
1 	a	-----	1.5	1.1	1.15	1.5
	f	-----	1.1	1.05	1.55	1.05
2 	a	$dw \leq d < 1.5dw$	1.45	1.1	1.15	1.4
		$1.5dw \leq d$	1.4	1.05	1.15	1.35
	f	$dw \leq d < 1.5dw$	1.1	1.05	1.15	1.1
		$1.5dw \leq d$	1.05	1.05	1.1	1.05
3 	a	$dw \leq d < 1.5dw$	1.4	1.1	1.1	1.35
		$1.5dw \leq d$	1.35	1.05	1.05	1.3
	f	$dw \leq d < 1.5dw$	1.05	1.05	1.1	1.05
		$1.5dw \leq d$	1.05	1.05	1.05	1.05
4 	a	$dw \leq d < 1.5dw$	1.1	1.05	1.05	1.25
		$1.5dw \leq d$	1.05	1.05	1.05	1.2
	f	$dw \leq d < 1.5dw$	1.3	1.1	1.35	1.05
		$1.5dw \leq d$	1.3	1.05	1.3	1.05
5 	a	$dw \leq d < 1.5dw$	1.1	1.05	1.05	1.2
		$1.5dw \leq d$	1.05	1.05	1.05	1.15
	f	$dw \leq d < 1.5dw$	1.3	1.1	1.55	1.1
		$1.5dw \leq d$	1.3	1.05	1.5	1.05

Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools (continued)

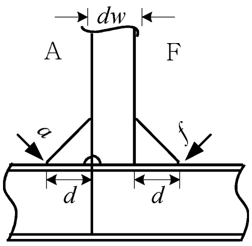
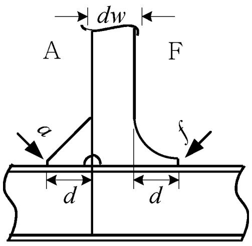
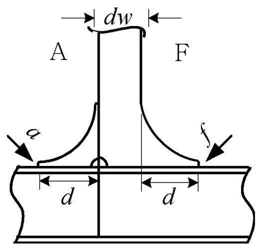
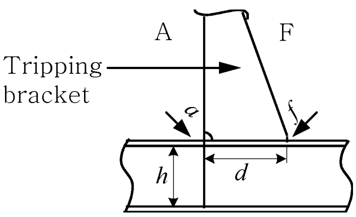
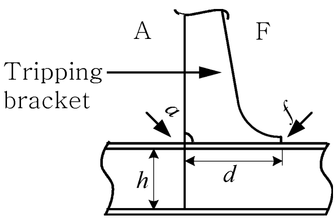
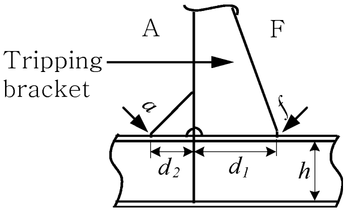
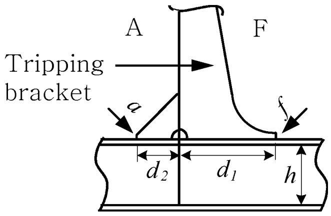
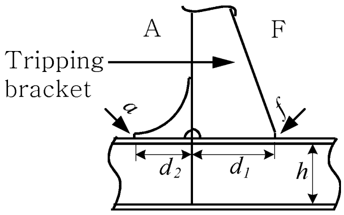
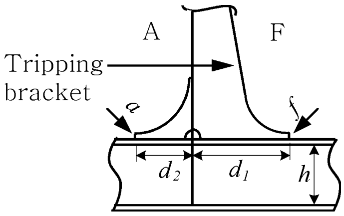
Bracket type	Assessed point	Bracket size	Stress concentration factors			
			K_{gl}	K_{gh}	K_{dF}	K_{dA}
6 	a	$dw \le d < 1.5dw$	1.1	1.05	1.05	1.1
		$1.5dw \le d$	1.05	1.05	1.05	1.05
	f	$dw \le d < 1.5dw$	1.05	1.05	1.1	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05
7 	a	$dw \le d < 1.5dw$	1.1	1.05	1.05	1.2
		$1.5dw \le d$	1.05	1.05	1.05	1.15
	f	$dw \le d < 1.5dw$	1.05	1.05	1.05	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05
8 	a	$dw \le d < 1.5dw$	1.1	1.1	1.05	1.15
		$1.5dw \le d$	1.05	1.05	1.05	1.1
	f	$dw \le d < 1.5dw$	1.05	1.05	1.1	1.05
		$1.5dw \le d$	1.05	1.05	1.05	1.05
9 	a	$d \le 2h$	1.4	1.05	1.05	1.75
	f		1.6	1.05	1.7	1.05
10 	a	$d \le 2.5h$	1.3	1.05	1.05	1.75
	f		1.55	1.05	1.3	1.05

Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools (continued)

Bracket type	Assessed point	Bracket size	Stress concentration factors			
			K_{gl}	K_{gh}	K_{dF}	K_{dA}
11 	a	$d_1 \le 2h$ and $h \le d_2$	1.1	1.05	1.05	1.2
	f		1.75	1.05	1.4	1.05
12 	a	$d_1 \le 2.5h$ and $h \le d_2$	1.1	1.05	1.05	1.2
	f		1.3	1.05	1.05	1.05
13 	a	$d_1 \le 2h$ and $h \le d_2$	1.05	1.05	1.05	1.15
	f		1.95	1.05	1.55	1.05
14 	a	$d_1 \le 2.5h$ and $h \le d_2$	1.05	1.05	1.05	1.15
	f		1.7	1.05	1.15	1.05

Section 5 – STRESS ASSESSMENT OF HATCH CORNERS

1. General

1.1 Application

1.1.1

Hot spot stress ranges and structural hot spot mean stresses of hatch corners based on the simplified procedure are to be assessed according to the requirements of this Section.

2. Nominal stress range

2.1 Nominal stress range due to wave torsional moment

2.1.1

The nominal stress range, in N/mm^2, due to cross deck bending induced by wave torsion moments is to be obtained from the following formula:

$$\Delta\sigma_{WT} = \frac{2}{1000} F_S F_L \frac{Q \cdot B_H}{W_Q}$$

where:

$$Q = 1000u \Big/ \left(\frac{(B_H + b_s)}{12EI_Q} + \frac{2.6B_H}{EA_Q} \right)$$

u : Displacement of hatch corner in longitudinal direction, in m, taken equal to:

$$u = \frac{31.2}{1000} \frac{M_{WT}\,\omega}{I_T E\ DOC}$$

DOC : Deck opening coefficient, taken equal to:

$$DOC = \frac{L_C B}{\sum_{i=1}^{n} L_{H,i} B_{H,i}}$$

M_{WT} : Maximum wave torsional moment, in kN.m, defined in **Ch 4, Sec 3, [3.4.1]**, with $f_p = 0.5$

F_S : Stress correction factor, taken equal to:

$F_s = 5$

F_L : Correction factor for longitudinal position of hatch corner, taken equal to:

$F_L = 1.75\frac{x}{L}$ for $0.57 \le x/L \le 0.85$

$F_L = 1.0$ for $x/L < 0.57$ and $x/L > 0.85$

B_H : Breadth of hatch opening, in m

W_Q : Section modulus of the cross deck about z-axis, in m^3, including upper stool, near hatch corner (see **Fig 2**)

I_Q : Moment of inertia of the cross deck about z-axis, in m^4, including upper stool, near the hatch corner (see **Fig 2**)

A_Q : Effective shear area of the whole section of the cross deck, in m^2, including upper stool, near the hatch corner (see **Fig 2**). For the determination of the effective shear area the consideration of only the plate elements is sufficient, and the stiffeners can be neglected.

b_S : Breadth of remaining deck strip on one side, in m, beside the hatch opening

I_T : Torsion moment of inertia of ships cross section, in m^4, calculated within cross deck area by neglecting upper and lower stool of the bulkhead (see **Fig 1**). It may be calculated according to **App 1**

ω : Sector coordinate, in m^2, calculated at the same cross section as I_T and at the Y and Z location of the hatch corner (see **Fig 1**) It may be calculated according to **App 1**

L_C : Length of cargo area, in m, being the distance between engine room bulkhead and collision bulkhead

$B_{H,i}$: Breadth of hatch opening of hatch i, in m

$L_{H,i}$: Length of hatch opening of hatch i, in m

n : Number of hatches.

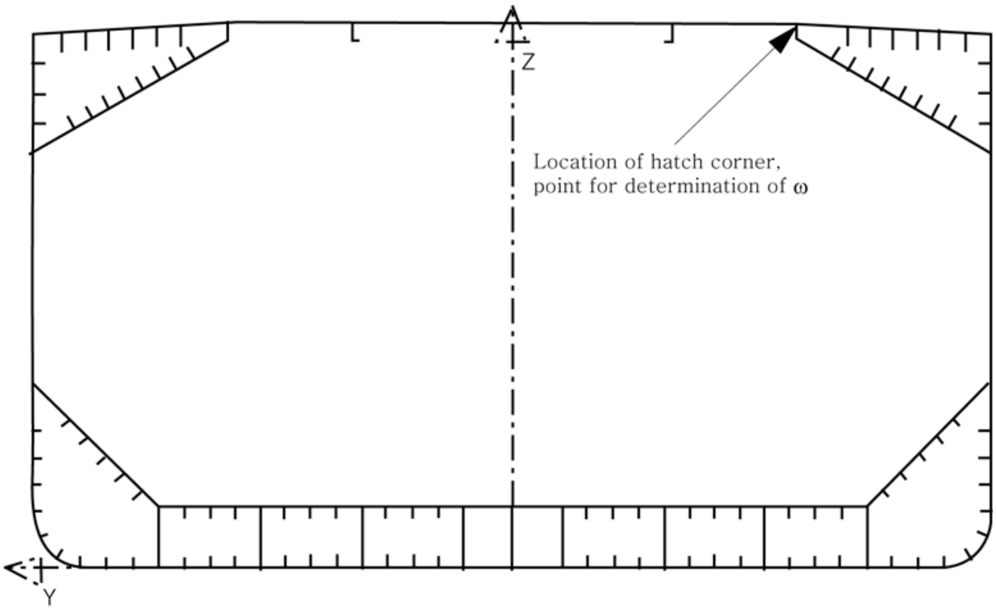


Fig 1: Cross section for determination of I_T and ω

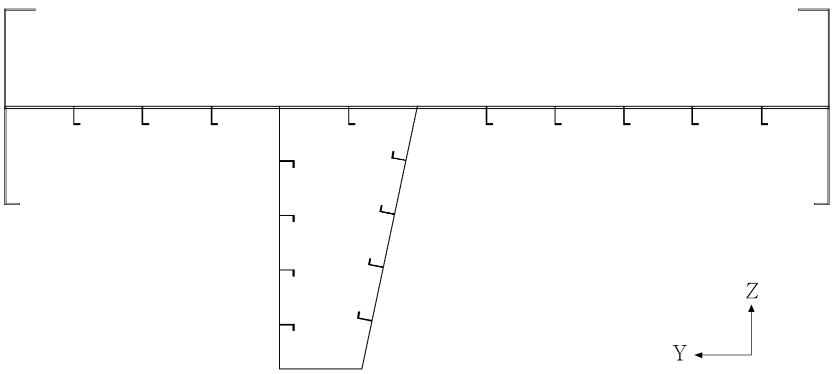


Fig 2: Elements to be considered for the determination of A_Q, W_Q and I_Q

2.2 Nominal mean stress

2.2.1

The mean stress due to still water bending moment within the cross deck is set to 0.

3. Hot spot stress

3.1 Hot spot stress range

3.1.1

The hot spot stress range, in N/mm^2, is to be obtained from the following formula:

$$\Delta\sigma_W = K_{gh} \cdot \Delta\sigma_{WT}$$

where:

K_{gh} : Stress concentration factor for the hatch corner, taken equal to:

$$K_{gh} = \frac{r_a + 2r_b}{3r_a}\left\{1 + \left(\frac{2b}{1.23\ell_{CD} + 1.6b}\frac{0.22\ell_{CD}}{r_a}\right)^{0.65}\right\}$$, to be taken not less than 1.0

r_a : Radius, in m, in major axis

r_b : Radius, in m, in minor axis (if the shape of corner is a circular arc, r_b is to be equal to r_a)

ℓ_{CD} : Length of cross deck, in m, in longitudinal direction

b : Distance, in m, from the edge of hatch opening to the ship's side.

Appendix 1 – CROSS SECTIONAL PROPERTIES FOR TORSION

1. Calculation Formulae

1.1 Torsion Function Φ

1.1.1

For any partial area of closed cells the following geometric figures and ratios have to be computed:

$$A_y = \frac{1}{2}(z_i + z_k)(y_k - y_i)$$

$$l = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$\frac{s}{t} = \frac{\ell}{t}$$

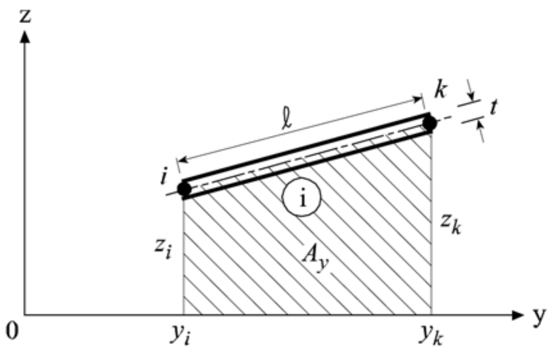


Fig 1:

The following three versions of algorithms may be applied depending on the type of cross section:

Version A: Asymmetric open cross sections as shown in **Fig 2**

Version B: Symmetric cross sections with particular closed cells (closed cells without shared walls) as shown in **Fig 3**. In this case the torsion function can be calculated for each cell separately.

$$\Phi_0 = \frac{2\sum_{Cell\,0} A_y}{\sum_{Cell\,0} \frac{s}{t}} \quad ; \quad \Phi_2 = \frac{2\sum_{Cell\,2} A_y}{\sum_{Cell\,2} \frac{s}{t}}$$

Version C: Symmetric cross sections with multiple closed cells (closed cells with shared walls) as shown in **Fig 4**. In this case the torsion function for each cell i can be calculated by solving a linear system of equations considering the shared walls.

$$\Phi_0 \sum_{Cell\,0} \frac{s}{t} + \Phi_1 \left(\frac{s}{t}\right)_{Common\,Wall} = 2A_{Cell0}$$

$$\Phi_1 \sum_{Cell\,1} \frac{s}{t} + \Phi_0 \left(\frac{s}{t}\right)_{Common\,Wall} = 2A_{Cell1}$$

From this system of equations the torsion functions Φ_0 and Φ_1 can be derived.

1.2 Co-ordinate system, running coordinate s

1.2.1

A 2-D cartesian co-ordinate system is to be used. The choice of the reference point O (origin of co-ordinate system) is free, but for symmetric cross sections it is advantageous to define the origin at the line of symmetry of the cross section. The running co-ordinate s starts within symmetric cross sections at the intersection of the line of symmetry with the cross section geometry, e.g. in hull cross sections at the intersection of centreline and bottom shell or double-bottom as indicated by '0' in **Fig 2** to **Fig 4.** The orientation of s as well as the direction of integration within closed cells is to be considered with respect to the algebraic signs and the assembly of the system of equations for the torsion function.

1.3 Computation of several properties for each part of the cross section

1.3.1

ω_i = ω_k of the preceding partial area or of the preceding point of bifurcation. (to be set equal to zero at the beginning of the computation)

ω_k = $\omega_i + y_i z_k - y_k z_i - \Phi \dfrac{\ell_i}{t_i}$, with $\Phi \dfrac{\ell_i}{t_i}$ within closed cells

l = $\sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$

			Summation
A	=	ℓt	$\sum A$
S_y	=	$A/2 (z_i + z_k)$	$\sum S_y$
S_z	=	$A/2 (y_i + y_k)$	$\sum S_z$
S_ω	=	$A/2 (\omega_i + \omega_k)$	$\sum S_\omega$
I_y	=	$A/3 \left(z_i^2 + z_i z_k + z_k^2\right)$	$\sum I_y$
I_z	=	$A/3 \left(y_i^2 + y_i y_k + y_k^2\right)$	$\sum I_y$
I_{yz}	=	$A/6 [(2y_k + y_i)z_k + (2y_i + y_k)z_i]$	$\sum I_{yz}$
I_ω	=	$A/3 \left(\omega_i^2 + \omega_i \omega_k + \omega_k^2\right)$	$\sum I_\omega$
$I_{\omega y}$	=	$A/6 [(2y_k + y_i)\omega_k + (2y_i + y_k)\omega_i]$	$\sum I_{\omega y}$
$I_{\omega z}$	=	$A/6 [(2z_k + z_i)\omega_k + (2z_i + z_k)\omega_i]$	$\sum I_{\omega z}$
$s t^3$	=	ℓt^3	$\sum s \cdot t^3$

1.4 Computation of cross sectional properties for the entire cross section

Asymmetric cross section:			Symmetric cross section (only half of the section is modeled)		
A	=	$\sum A$	A	=	$2\sum A$
y_s	=	$\frac{\sum S_z}{\sum A}$	y_s	=	$\frac{\sum S_z}{\sum A}$
z_s	=	$\frac{\sum S_y}{\sum A}$	z_s	=	$\frac{\sum S_y}{\sum A}$
I_y	=	$\sum I_y - \sum A z_s^2$	I_y	=	$2\left(\sum I_y - \sum A z_s^2\right)$
I_z	=	$\sum I_z - \sum A y_s^2$	I_z	=	$2\left(\sum I_z - \sum A y_s^2\right)$
I_{yz}	=	$\sum I_{yz} - \sum A y_s z_s$			
I_T	=	$\sum \frac{s t^3}{3} + \sum_{Cell\ i}\left(2 A_{yi} \Phi_i\right)$	I_T	=	$2\left[\sum \frac{s t^3}{3} + \sum_{Cell\ i}\left(2 A_{yi} \Phi_i\right)\right]$
ω_0	=	$\frac{\sum S_\omega}{\sum A}$			
$I_{\omega y}$	=	$\sum I_{\omega y} - \sum A y_s \omega_0$	$I_{\omega y}$	=	$2\sum I_{\omega y}$
$I_{\omega z}$	=	$\sum I_{\omega z} - \sum A z_s \omega_0$			
y_M	=	$\frac{I_{\omega z} I_z - I_{\omega y} I_{yz}}{I_y I_z - I_{yz}^2}$			
z_M	=	$\frac{I_{\omega z} I_{yz} - I_{\omega y} I_y}{I_y I_z - I_{yz}^2}$	z_M	=	$-\frac{I_{\omega y}}{I_z}$
I_ω	=	$\sum I_\omega - \sum A \omega_0^2 + z_M I_{\omega y} - y_M I_{\omega z}$	I_ω	=	$2\sum I_\omega + z_M I_{\omega y}$

I_y, I_z, I_{yz} are to be computed with relation to the centre of gravity.

S_x, S_y, S_ω, I_ω, $I_{\omega y}$ and $I_{\omega z}$ are to be computed with relation to shear centre M

The sector-coordinate ω has to be transformed with respect to the location of the shear centre M. For cross sections of type A, ω_0 is to be added to each ω_i and ω_k as defined in **[1.3]**
For cross sections of type B and C, $\Delta\omega$ can be calculated as follows:

$$\Delta\omega_i = z_M y_i$$

where:

ω_0 : Calculated sector co-ordinate with respect to the centre of the coordinate system (O) selected for the calculation according to the formulae for ω_k given in **[1.3]**

ω : Transformed sector co-ordinate with respect to shear centre M

y_M, z_M : Distance between shear centre M and centre of the coordinate system B.

The transformed values of ω can be obtained by adding $\Delta\omega$ to the values of ω_0 obtained according to the formulae in **[1.3].**

The transformed value for ω is to be equal to zero at intersections of the cross section with the line of symmetry (centreline for ship-sections).

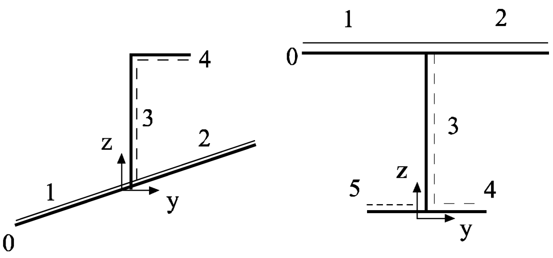


Fig 2: Cross sections of type A

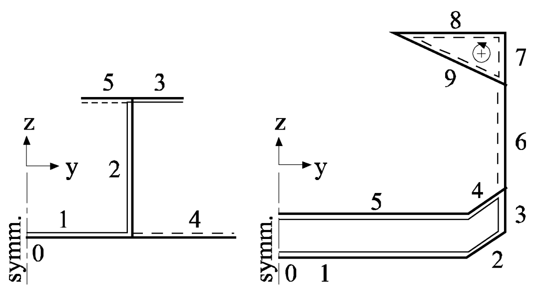


Fig 3: Cross sections of type B

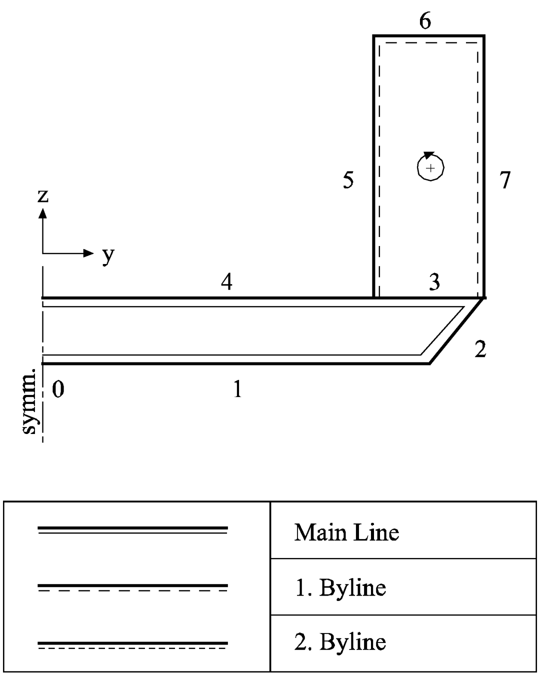


Fig 4: Cross section of type C

Designation of line types (numbers at particular parts of cross sections) gives the order of the particular parts for the calculation and therefore the direction of the running coordinate s.

2. Example calculation for a single side hull cross section

2.1 Cross section data

2.1.1

The cross section is shown in **Fig 5.** The co-ordinates of the node-points marked by filled black circles in **Fig 5** are given in the **Table 1**, where the plate thicknesses and the line segments (marked by circles in **Fig 5**) of the cross section are given in **Table 2.**

Table 1: Node-coordinates of cross-section

Node number	Y Coordinate	Z Coordinate
0	0.00	0.00
1	14.42	0.00
2	16.13	1.72
3	16.13	6.11
4	11.70	1.68
5	0.00	1.68
6	16.13	14.15
7	16.13	19.6
8	7.50	20.25
9	7.50	19.63
10	0.00	20.25

2.2 Determination of the torsion function Φ

2.2.1

The first step is to build a linear system of equation for the determination of the torsion function Φ of each closed cell. The cross section and the cells are shown in **Fig 5.**

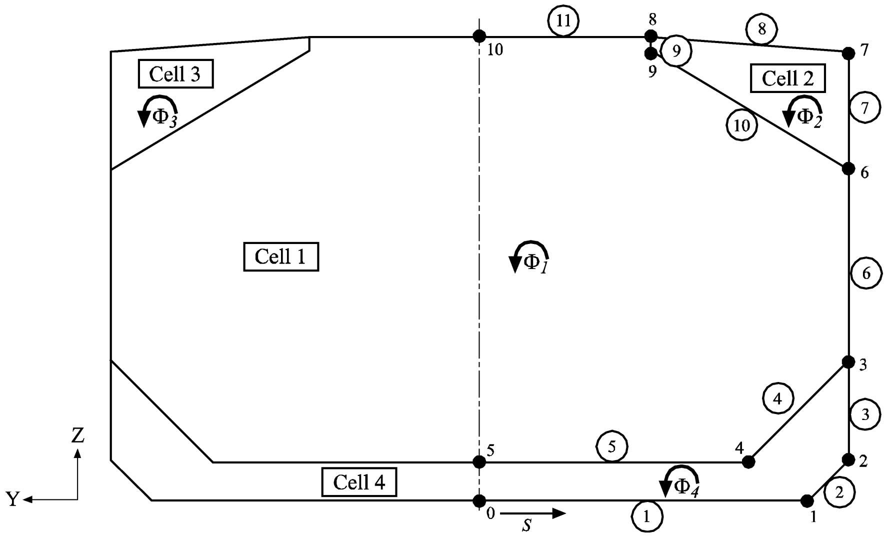


Fig 5: Single side hull cross section

Table 2: Dimensions and nodes of line segments of the cross section

Line-No.	Node i	Node k	y_i	z_i	y_k	z_k	Length	Thickness
1	0	1	0.00	0.00	14.42	0.00	14.42	0.017
2	1	2	14.42	0.00	16.13	1.72	2.43	0.017
3	2	3	16.13	1.72	16.13	6.11	4.39	0.018
4	3	4	16.13	6.11	11.70	1.68	6.26	0.019
5	4	5	11.70	1.68	0.00	1.68	11.70	0.021
6	3	6	16.13	6.11	16.13	14.15	8.04	0.018
7	6	7	16.13	14.15	16.13	19.6	5.45	0.021
8	7	8	16.13	19.60	7.50	20.25	8.65	0.024
9	8	9	7.50	20.25	7.50	19.63	0.62	0.024
10	9	6	7.50	19.63	16.13	14.15	10.22	0.015
11	8	10	7.50	20.25	0.00	20.25	7.50	0.012

Under consideration of the 4 cells (marked by rectangles in **Fig 5**) of the cross section, the following system of equation for the determination of the torsion function Φ can be developed. It should be noted that the direction of the rotation is to be considered (the rotation directions for the torsion functions Φ_i should point in the same direction for all Φ_i to build up the system of equations).

$$\begin{array}{lllll}
\sum_{1}\frac{s}{t}\Phi_1 & -\sum_{1-2}\frac{s}{t}\Phi_2 & -\sum_{1-3}\frac{s}{t}\Phi_3 & -\sum_{1-4}\frac{s}{t}\Phi_4 & = 2\sum_{1}A \\
-\sum_{1-2}\frac{s}{t}\Phi_1 & +\sum_{2}\frac{s}{t}\Phi_2 & & & = 2\sum_{2}A \\
-\sum_{1-3}\frac{s}{t}\Phi_1 & & +\sum_{3}\frac{s}{t}\Phi_3 & & = 2\sum_{3}A \\
-\sum_{1-4}\frac{s}{t}\Phi_1 & & & +\sum_{4}\frac{s}{t}\Phi_4 & = 2\sum_{4}A
\end{array}$$

The coefficients of the matrix can be calculated as follows:

$$\sum_{1}\frac{s}{t} = \frac{2\cdot 11700}{21} + \frac{2\cdot 6265}{19} + \frac{2\cdot 8040}{18} + \frac{2\cdot 10223}{15} + \frac{2\cdot 620}{24} + \frac{2\cdot 7500}{12} = 5331.81$$

$$\sum_{2}\frac{s}{t} = \frac{10223}{15} + \frac{5450}{21} + \frac{620}{24} + \frac{8654}{24} = 1327.48$$

$$\sum_{3}\frac{s}{t} = 1327.48$$

$$\sum_{4}\frac{s}{t} = \frac{2\cdot 14420}{17} + \frac{2\cdot 11700}{21} + \frac{2\cdot 6265}{19} + \frac{2\cdot 2425}{17} + \frac{2\cdot 4390}{18} = 4243.34$$

$$\sum_{1-2}\frac{s}{t} = \frac{10223}{15} + \frac{620}{24} = 707.36$$

$$\sum_{1-3}\frac{s}{t} = 707.36$$

$$\sum_{1-4}\frac{s}{t} = \frac{2\cdot 11700}{21} + \frac{2\cdot 6265}{19} = 1773.76$$

The areas of the cells can be calculated as follows:

$$2\sum_1 A = 2\cdot 2\cdot 260.72 = 1042.90 \quad m^2$$
$$2\sum_2 A = 2\cdot 26.19 = 52.38 \quad m^2$$
$$2\sum_3 A = 52.38 \quad m^2$$
$$2\sum_4 A = 2\cdot 2\cdot 35.44 = 141.76 \quad m^2$$

With these results the coefficient matrix will become:

$$\begin{array}{lllllll}
5331.81\Phi_1 & -707.360\Phi_2 & -707.36\Phi_3 & -1773.76\Phi_4 & = & 1042.90 \\
-707.36\Phi_1 & +1327.48\Phi_2 & & & = & 52.38 \\
-707.36\Phi_1 & & +1327.48\Phi_3 & & = & 52.38 \\
-1773.76\Phi_1 & & & +4243.34\Phi_4 & = & 141.76
\end{array}$$

The solution of this system gives:

$$\Phi_1 = 0.3018$$
$$\Phi_2 = 0.2003$$
$$\Phi_3 = 0.2003$$
$$\Phi_4 = 0.1596$$

2.3 Determination of the line-segment properties

2.3.1

The next step is the determination of ω_k according to the formulae given in **[1.3].** '*s*' starts at point 0 (**Fig 5**) with $\omega_i = 0$ and follows the path from point 0 to point 1, 2, 3, 4 up to point 5. It is to be noted, that the term $\Phi(\ell_i/t_i)$ is for the line segments 1 to 3 (between points 0 and 3) calculated as $\Phi_4(\ell_{1...3}/t_{1...3})$ where for the line segments 4 and 5 this term becomes $(\Phi_4 - \Phi_1)(\ell_{4...5}/t_{4...5})$ because line segments 4 and 5 are shared walls of cell 4 and cell 1. The rotation direction for the torsion functions together with the direction of integration (direction of path, which one follows for the calculation) determines the algebraic sign within this term.
For the line segment 6 ω_i has to be set to the value at point 3 and $\Phi(\ell_i/t_i) = \Phi_1(\ell_6/t_6)$. '*s*' follows now the path from point 6 to point 7, 8, 9 back to point 6. The shared wall between cell 2 and cell 1 has to be considered for the terms which include the torsion function Φ. For the line segment 11 between point 8 and 10, ω_i has to be set to the value at point 8.
The other properties of the line segments can be calculated by the formulas given in **[1.3].**

2.4 Determination of cross-section properties

2.4.1

After the summation of the line-segment properties, the cross section properties can be calculated as described in **[1.4].**
The sector coordinate has to be transformed with respect to the shear centre as described in **[1.4]**
The result of the calculations gives the sector co-ordinates, as indicated in **Table 3.**

Table 3: Sector co-ordinates for the cross section of Fig 5

Point i	$\omega_{O,i}$	$\Delta\omega_i$	ω_i
0	0.00	0.00	0.00
1	-135.97	84.99	-50.98
2	-134.04	95.07	-38.97
3	-102.32	95.07	-7.25
4	-99.49	68.96	-30.53
5	-0.06	0.00	-0.06
6	-108.20	95.07	-13.13
7	-72.30	95.07	22.77
8	35.07	44.21	79.27
9	33.08	44.21	77.28
10	-2.75	0.00	-2.75

2.5 Notes

2.5.1

For single side bulk carrier, the hull cross section normally can be simplified in a section with four boxes (cell 1 cargo hold, cell 2 and 3 wing tanks and cell 4 hopper tanks and double bottom as shown in the calculation example) whereas the cross section of a double side bulk carrier can be simplified to a cross section with two closed cells only (cell 1 cargo hold, cell 2 double hull). For the plate thickness of the line elements with variable thicknesses an equivalent plate thickness can be used calculated by the following formulae:

$$t_{eq} = \frac{t_1\ell_1 + t_2\ell_2 + \ldots + t_i\ell_i + \ldots + t_k\ell_k}{\sum_{i=1}^{k}\ell_i}$$

Due to the simplifications, the value of the sector co-ordinate ω can differ from 0 at the intersections between the cross section and centreline. The difference between the value of the sector co-ordinate ω and the value of the torsional moment of inertia I_T for the simplified cross section is in normal cases less than 3 % compared to the values of the original cross section. ⚓

Chapter 9

Other Structures

Section 1 – FORE PART

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

L_2 : Rule length L, but to be taken not greater than 300 m

T_B : Minimum ballast draught, in m, for normal ballast conditions

k : Material factor, defined in **Ch 3, Sec 1, [2.2]**

m : Coefficient taken equal to:

m = 10 for vertical stiffeners

m = 12 for other stiffeners

τ_a : Allowable shear stress, in N/mm², takene qual to:

$$\tau_a = \frac{R_Y}{\sqrt{3}}$$

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners, measured along the chord between the supporting members, see **Ch 3, Sec 6, [4.2]**

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1.21\sqrt{1 + 0.33\left(\frac{s}{\ell}\right)^2} - 0.69\frac{s}{\ell}$$, to be taken not greater than 1.0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0.5\frac{s}{r}$$, to be taken not less than 0.4

r : Radius of curvature, in m.

1.1 Application

1.1.1

The requirement of this Section apply to:

- the structures located forward of the collision bulkhead, i.e.:
  - the fore peak structures
  - the stem
- the reinforcements of the bow flare area, according to **[4.1]**
- the reinforcements of the flat bottom forward area, according to **[5.1].**

1.2 Net thicknesses

1.2.1

As specified in **Ch 3, Sec 2**, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition. The gross thicknesses are to be obtained as specified in **Ch 3, Sec 2, [3].**

2. Arrangement

2.1 Structural arrangement principles

2.1.1 General

Scantlings of the shell envelope, upper deck and inner bottom, if any, are to be tapered towards the forward end. Special consideration is to be paid to the structural continuity of major longitudinal members in order to avoid abrupt changes in section.
Structures within the fore peak, such as platforms, decks, horizontal ring frames or side stringers are to be scarphed into the structure aft into the cargo hold.
Where inner hull structures terminate at the collision bulkhead, the structural continuity is to be ensured forward of the collision bulkhead by adequate structure with tapering brackets.
Longitudinal stiffeners of deck, bottom and side shell are to be extended as far forward as practicable.
All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed tat their ends. Where the brackets are provided to ensure the structural continuity from the forward end to $0.15\,L$ behind fore perpendicular, flanged brackets have to be used.

2.1.2 Structures in tanks

Where peaks are used as tanks, stringer plates are to be flanged or face bars are to be fitted at their inner edges. Stringers are to be effectively fitted to the collision bulkhead so that the forces can be properly transmitted.

2.2 Tripping brackets

2.2.1

For peaks or other tanks forward of the collision bulkhead transversely framed, tripping brackets vertically spaced not more than 2.6 m are to be fitted, according to **Fig 1**, between primary supporting members, decks and/or platforms

The as-built thickness of the tripping brackets is to be not less than the as-built thickness of the side frame webs to which they are connected.

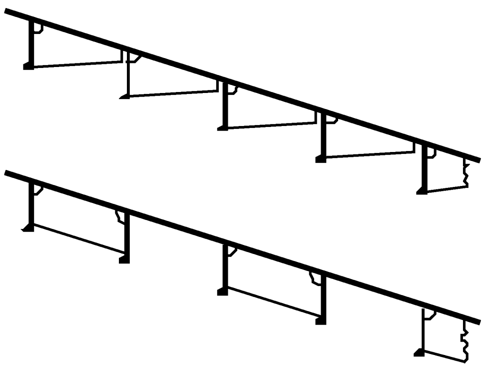


Fig 1: Tripping brackets

2.3 Floors and bottom girders

2.3.1

Where no centreline bulkhead is provided, a centre bottom girder is to be fitted.
In general, the minimum depth of the floor at the centerline and center girders is to be not less than the required depth of the double bottom of the foremost cargo hold.

2.3.2

In case of transverse framing, solid floors are to be fitted at every frame.
In case of the longitudinal framing, the spacing of solid floors is not to be greater than 3.5 m or four transverse frame spaces, whichever is the smaller.

2.3.3

In case of transverse framing, the spacing of bottom girders is not to exceed 2.5 m
In case of longitudinal framing, the spacing of bottom girders is not to exceed 3.5 m.

3. Load model

3.1 Load point

3.1.1

Unless otherwise specified, lateral pressure is to be calculated at load points according to:

- **Ch 6, Sec 1, [1.5]**, for plating
- **Ch 6, Sec 2, [1.4]**, for stiffeners.

3.2 Pressure in bow area

3.2.1 Lateral pressure in intact conditions

The pressure in bow area, in $\mathrm{kN/m^2}$, is to be taken equal to $(p_S + p_W)$.

where:

p_S, p_W : Hydrostatic and hydrodynamic pressures according to **Ch 4, Sec 5** or internal still water and inertial pressures according to **Ch 4, Sec 6, [2]** to be considered among load cases H, F, R and P.

3.2.2 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise

where:

p_{ST} : Testing pressure defined in **Ch 4, Sec 6, [4]**

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in **Ch 4, Sec 5, [1]** for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat
- if the testing is not carried out afloat: $p_S = 0$

3.2.3 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

3.2.4 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3.3 Bow flare area pressure

3.3.1

The bow pressure p_{FB}, in kN/m^2, is to be obtained according to **Ch 4, Sec 5, [4.1].**

3.4 Bottom slamming pressure

3.4.1

The bottom slamming pressure p_{SL}, in kN/m^2, in the flat bottom forward is to be obtained according to **Ch 4, Sec 5, [4.2].**

4. Scantlings

4.1 Bow flare reinforcement

4.1.1

The bow flare area to be reinforced is that extending forward of $0.9\,L$ from the aft end and above the normal ballast waterline according to the applicable requirements in **[4.2]** to **[4.4].**

4.2 Plating

4.2.1

The net thickness of plating are to be not less than those obtained from the formulae in **Table 1** and **Table 2.**

Table 1: Net minimum thickness of plating

Minimum net thickness, in mm	
Bottom,	$5.5 + 0.03\,L$
Side	$0.85\,L^{1/2}$
Inner bottom	$5.5 + 0.03\,L$
Strength deck	$4.5 + 0.02\,L$
Platform and wash bulkhead	6.5

Table 2: Net thickness of plating

Net thickness, in mm	
Intact conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_S + p_W}{0.9 R_Y}}$
Bow flare area	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_{FB}}{0.9 R_Y}}$
Testing conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_T}{1.05 R_Y}}$

4.3 Ordinary stiffeners

4.3.1 General

The requirements of this sub-article apply to ordinary stiffeners considered as clamped at both ends. For other boundary conditions, the yielding check is to be considered on a case by case basis.

4.3.2

The net dimensions of ordinary stiffeners are to comply with the requirements in **Ch 6, Sec 2, [2.3]**

4.3.3

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015 L_2$
- 40 % of the net required thickness of the attached plating, to be determined according to **[4.2]** and **[5.2].**

The net dimensions of ordinary stiffeners are to comply with the requirement in **Ch 6 Sec 2, [2.2.2]** and **[2.3].**

4.3.4

The net scantlings of single-span ordinary stiffeners are to be not less than those obtained from the formulae in **Table 3.**

Table 3: Net scantlings of single span ordinary stiffeners

Stiffener type	Net section modulus w, in cm^3	Net sectional shear area A_{sh}, in cm^2
Single span ordinary stiffeners subjected to lateral pressure	$w = \frac{(p_S + p_W) s \ell^2}{0.9 m R_Y} 10^3$	$A_{sh} = \frac{5 (p_S + p_W) s \ell}{\tau_a \sin \phi}$
Single span ordinary stiffeners located in bow flare area	$w = \frac{p_{FB} s \ell^2}{0.9 m R_Y} 10^3$	$A_{sh} = \frac{5 p_{FB} s \ell}{\tau_a \sin \phi}$
Single span ordinary stiffeners subjected to testing pressure	$w = \frac{p_T s \ell^2}{1.05 m R_Y} 10^3$	$A_{sh} = \frac{5 p_T s \ell}{1.05 \tau_a \sin \phi}$
where: ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75.		

4.3.5

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to comply with the formulae in **Table 4.**

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

Table 4: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Testing
Normal stress	$\sigma \le 0.9R_Y$	$\sigma \le 1.05R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le 1.05\tau_a$

4.4 Primary supporting members

4.4.1 Minimum thickness

The net thickness of the web of primary supporting members, in mm, is to be not less than that obtained from the following formula:

$$t = 0.7\sqrt{L_2}$$

4.4.2 Side transverses

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side transverses are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

In addition, the net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side transverses located within the bow flare area are to be not less than the values obtained from the following formulae:

$$w = \frac{p_{FB}s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5p_{FB}s\ell}{\tau_a \sin\phi}$$

4.4.3 Side girders

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side girders are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

In addition, the net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side girders located within the bow flare area are to be not less than the values obtained from the following formulae:

$$w = \frac{p_{FB} s \ell^2}{0.9 m R_Y} 10^3$$

$$A_{sh} = \frac{5 p_{FB} s \ell}{\tau_a \sin\phi}$$

4.4.4 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with **Ch 6, Sec 4**, considering the loads in **[3.2]** and **[3.3].**

5. Strengthening of flat bottom forward area

5.1 Application

5.1.1

The flat bottom forward area to be reinforced is the flat part of the ship's bottom extending forward of $0.2V\sqrt{L}$ from the fore perpendicular end, up to a height of $0.05T_B$ or 0.3 m above base line, whichever is the smaller.

5.2 Bottom plating

5.2.1

The net thickness, in mm, of the flat bottom forward area, is not to be less than:

$$t = 15.8 C_a C_r s \sqrt{\frac{C_s p_{SL}}{R_{eH}}}$$

where:

C_s : Coefficient relating to load patch of impact pressure, taken equal to:

$C_s = 1.0$ where no intermediate longitudinals is provided between or dinary stiffeners

$C_s = 1.3$ where intermediate longitudinals are provided between ordinary stiffeners.

5.2.2

For ships with a rise of floor the strengthened plating must at least extend to the bilge curvature.

5.3 Ordinary stiffeners

5.3.1

The net section modulus, in cm^3, of transverse or longitudinal ordinary stiffeners of the flat bottom forward area is not to be less than:

$$w = \frac{C_s p_{SL} s \ell^2}{16 R_{eH}} 10^3$$

where:

C_s : Coefficient defined in **[5.2.1].**

5.3.2

The net shear area, in cm^2, of transverse or longitudinal ordinary stiffeners of the flat bottom forward area is not to be less than:

$$A = \frac{5\sqrt{3} p_{SL} s(\ell - 0.5s)}{R_{eH} \sin\phi}$$

The area of the welded connection has to be at least twice this value.

5.4 Primary supporting members

5.4.1

The net thickness of girders in double bottom forward area, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = \frac{c_A p_{SL} S\ell}{2(d_0 - d_1)\tau_a}$$

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_1'} t_1}$$

$$t_3 = \frac{C_1'' a}{\sqrt{k}}$$

where:

c_A : Coefficient taken equal to:
$c_A = 3/A$, with $0.3 \le c_A \le 1.0$

A : Loaded area, in m^2, between the supports of the structure considered, obtained from the following formula:
$A = S\ell$

p_{SL} : As defined in **[3.4]**

S : Spacing of centre or side girders under consideration, in m

ℓ : Span of centre or side girders between floors under consideration, in m

d_0 : Depth of the centre or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

H : Value obtained from the following formulae:

(a) Where the girder is provided with an unreinforced opening : $H = 1 + 0.5\dfrac{\phi}{\alpha}$

(b) In other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m.

a : Depth of girders at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the girder, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or floors

C_1' : Coefficient obtained from **Table 5** depending on S_1/a. For intermediate values of S_1/a, C_1' is to be determined by linear interpolation.

C_1'' : Coefficient obtained from **Table 6** depending on S_1/a. For intermediate values of S_1/a, C_1'' is to be obtained by linear interpolation.

Table 5: Coefficient C_1'

S_1/a	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_1'	64	38	25	19	15	12	10	9	8	7

Table 6: Coefficient C_1''

S_1/a		0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6 and over
C_1''	Centre girder	4.4	5.4	6.3	7.1	7.7	8.2	8.6	8.9	9.3	9.6	9.7
	Side girder	3.6	4.4	5.1	5.8	6.3	6.7	7.0	7.3	7.6	7.9	8.0

5.4.2 Floors

The net thickness of floors in double bottom forward area, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = \frac{c_A p_{SL} S\ell}{2(d_0 - d_1)\tau_a}$$

$$t_2 = 1.75 \cdot \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_2'} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

c_A : Coefficient taken equal to:

$c_A = 3/A$, with $0.3 \le c_A \le 1.0$

A : Loaded area, in m^2, between the supports of the structure considered, obtained from the following formula:

$A = S\ell$

p_{SL} : As defined in **[3.4]**

S : Spacing of floors under consideration, in m

ℓ : Span of floors between centre girder and side girder or side girders under consideration, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

H : Value obtained from the following formulae:

a) Where openings with reinforcement or no opening are provided on solid floors:

1) Where slots without reinforcement are provided:

$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$, without being taken less than 1.0

2) Where slots with reinforcement are provided: $H = 1.0$

b) Where openings without reinforcement are provided on solid floors:

1) Where slots without reinforcement are provided:

$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}$, without being taken less than $1 + 0.5\frac{\phi}{d_0}$

2) Where slots with reinforcement are provided:

$H = 1 + 0.5\frac{\phi}{d_0}$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater

S_1 : Spacing, in m, of vertical ordinary stiffeners or girders

ϕ : Major diameter of the openings, in m.

a : Depth of the solid floor at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

S_2 : The smaller of S_1 or a, in m

C_2' : Coefficient given in **Table 7** depending on S_1/d_0. For intermediate values of S_1/d_0, C_2' is to be determined by linear interpolation.

Table 7: Coefficient C_2'

S_1/d_0	0.3 and under	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4 and over
C_2'	64	38	25	19	15	12	10	9	8	7

6. Stem

6.1 Bar stem

6.1.1

The gross cross sectional area, in cm^2, of a bar stem below the load waterline is not to be less than:

$A_b = 1.25L$

6.1.2

Starting from the load waterline, the cross sectional area of the bar stem may be reduced towards the upper end to $0.75 A_b$.

6.2 Plate stem and bulbous bows

6.2.1

The gross thickness, in mm, is not to be less than the values obtained from the following formula:

$t = (0.6 + 0.4 s_B)(0.08L + 6)\sqrt{k}$, without being taken greater than $22\sqrt{k}$

where:

s_B : Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members.

The gross plate thickness is to be not less than the net thickness, obtained according to **[4.2]**, plus the corrosion addition t_C as defined in **Ch 3, Sec 3.**
Scantlings of the ordinary stiffeners are to be determined according to **[4.3].**

6.2.2

Starting from 0.6 m above the load waterline up to $T+C$, the gross thickness may gradually be reduced to 0.8 t, where t is the gross thickness defined in **[6.2.1].**

6.2.3

Plate stems and bulbous bows must be stiffened by breasthooks and/or frames.

7. Forecastle

7.1 General

7.1.1

An enclosed forecastle is to be fitted on the freeboard deck.
The aft bulkhead of the enclosed forecastle is to be fitted in way or aft of the forward bulkhead of the foremost hold, as shown in **Fig 2.**
However, if this requirement hinders hatch cover operation, the aft bulkhead of forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7 % of ship length for freeboard as specified in **Ch 1, Sec 4, [3.2]** abaft the fore side of stem.

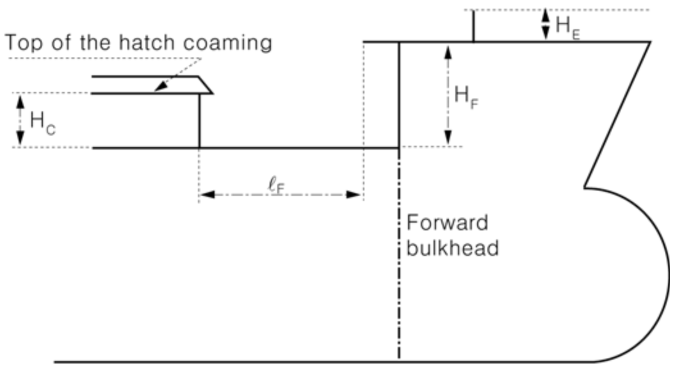


Figure 2: Forecastle

7.1.2

The forecastle height H_F above the main deck is to be not less than the greater of the following values:

- the standard height of a superstructure as specified in **Ch 1, Sec 4, [3.18]**
- $H_C + 0.5$ m, where H_C is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No.1.

7.1.3

All points of the aft edge of the forecastle deck are to be located at a distance less than or equal to ℓ_F:

$$\ell_F = 5\sqrt{H_F - H_C}$$

from the hatch coaming plate in order to apply the reduced loading to the No.1 forward transverse hatch coaming and No.1 hatch cover in applying **Ch 9, Sec 5, [6.2.2]** and **Ch 9, Sec 5, [7.3.8].**

7.1.4

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than H_B /tan20° forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see **Fig 2**).

Section 2 – AFT PART

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

L_1 : Rule length L, but to be taken not greater than 200 m

L_2 : Rule length L, but to be taken not greater than 300 m

k : Material factor, defined in **Ch 3, Sec 1, [2.2]**

z_{TOP} : Z co-ordinate, in m, of the top of the tank

m : Coefficient taken equal to:

m = 10 for vertical stiffeners

m = 12 for other stiffeners

τ_a : Allowable shear stress, in N/mm^2, taken equal to:

$$\tau_a = \frac{R_Y}{\sqrt{3}}$$

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners, measured along the chord between the supporting members, see **Ch 3, Sec 6, [4.2]**

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1.21\sqrt{1+0.33\left(\frac{s}{\ell}\right)^2} - 0.69\frac{s}{\ell}$$, to be taken not greater than 1.0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0.5\frac{s}{r}$$, to be taken not less than 0.4

r : Radius of curvature, in m.

1. General

1.1 Introduction

1.1.1

The requirements of this Section apply for the scantlings of structures located aft of the aft peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2

Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Ch 6.

1.2 Connections of the aft part with structures located fore of the aft peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the aft peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1

As specified in **Ch 3, Sec 2**, all thicknesses referred to in this Section are net, i.e. they do not include any corrosion addition. The gross thicknesses are to be obtained as specified in **Ch 3, Sec 2, [3].**

2. Load model

2.1 Load point

2.1.1

Unless otherwise specified, lateral pressure is to be calculated at load points according to:

- **Ch 6, Sec 1, [1.5]**, for plating
- **Ch 6, Sec 2, [1.4]**, for stiffeners.

2.2 Lateral pressures

2.2.1 Lateral pressure in intact conditions

The aft part lateral pressure in intact conditions, in kN/m^2, is to be taken equal to $(p_S + p_W)$.

where:

p_S, p_W : Hydrostatic and hydrodynamic pressures according to **Ch 4, Sec 5**, or internal still water and inertial pressures according to **Ch 4, Sec 6, [2]**, to be considered among load cases H, F, R and P.

2.2.2 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise

where:

p_{ST} : Testing pressure defined in **Ch 4, Sec 6, [4]**

p_S : Pressure taken equal to:

- if the testing is carried out afloat: hydrostatic pressure defined in **Ch 4, Sec 5, [1]** for the draught T_1, defined by the Designer, at which the testing is carried out. If T_1 is not defined, the testing is considered as being not carried out afloat.
- if the testing is not carried out afloat: $p_S = 0$

2.2.3 Elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure considering the compartment adjacent to the outer shell as being loaded. If the compartment adjacent to the outer shell is intended to carry liquids, this still water and wave internal pressures are to be reduced from the corresponding still water and wave external sea pressures.

2.2.4 Elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3. Aft peak

3.1 Arrangement

3.1.1 General

The aft peak is, in general, to be transversely framed.

3.1.2 Floors

Solid floors are to be fitted at every frame spacing.
The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.
In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case by case basis, depending on the arrangement proposed.
Floors are to be provided with stiffeners located at intervals not exceeding 800 mm.

3.1.3 Side frames

Side frames are to be extended up to a deck located above the full load waterline.
Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10 % of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses.

3.1.4 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.
Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.
Where the aft peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the aft peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.
Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

4. Scantlings

4.1 Plating

4.1.1

The net thickness of plating are to be not less than those obtained from the formulae in **Table 1** and **Table 2.**

Table 1: Net minimum thickness of plating

Minimum net thickness, in mm	
Bottom	$5.5 + 0.03L$
Side and transom	$0.85L^{1/2}$
Inner bottom	$5.5 + 0.03L$
Strength deck	$4.5 + 0.02L$
Platform and wash bulkhead	6.5

Table 2: Net thickness of plating

Net thickness, in mm	
Intact conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_S + p_W}{0.9R_Y}}$
Testing conditions	$t = 15.8 c_a c_r s \sqrt{\dfrac{p_T}{1.05R_Y}}$

4.2 Ordinary stiffeners

4.2.1 General

The requirements of this sub-articleapply to ordinary stiffeners considered as clamped at both ends. For other boundary conditions, the yielding check is to be considered on a case by case basis.

4.2.2

The net dimensions of ordinary stiffeners are to comply with the requirements in **Ch 6, Sec 2, [2.3].**

4.2.3

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40 % of the net required thickness of the attached plating, to be determined according to **[4.1].**

The net dimensions of ordinary stiffeners are to comply with the requirement in **Ch 6, Sec 2, [2.2.2]** and **[2.3].**

4.2.4

The net scantlings of single-span ordinary stiffeners are to be not less than those obtained from the formulae in **Table 3.**

Table 3: Net scantlings of single span ordinary stiffeners

Stiffener type	Net section modulus w, in cm^3	Net sectional shear area A_{sh}, in cm^2
Single span ordinary stiffeners subjected to lateral pressure	$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$	$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$
Single span ordinary stiffeners subjected to testing pressure	$w = \frac{p_T s\ell^2}{1.05mR_Y}10^3$	$A_{sh} = \frac{5 p_T s\ell}{1.05\tau_a \sin\phi}$
where: ϕ : Angle, in deg, between the stiffener web and the shell plate, measured at the middle of the stiffener span; the correction is to be applied when ϕ is less than 75.		

4.2.5

The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to comply with the formulae in **Table 4.**
The maximum normal stress σ and shear stress τ in a multi-span ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

Table 4: Checking criteria for multi-span ordinary stiffeners

Condition	Intact	Testing
Normal stress	$\sigma \le 0.9R_Y$	$\sigma \le 1.05R_Y$
Shear stress	$\tau \le \tau_a$	$\tau \le 1.05\tau_a$

4.3 Primary supporting members

4.3.1 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$$t = 0.7\sqrt{L_2}$$

4.3.2 Side transverses

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side transverses are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

4.3.3 Side girders

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of side girders are to be not less than the values obtained from the following formulae:

$$w = \frac{(p_S + p_W)s\ell^2}{0.9mR_Y}10^3$$

$$A_{sh} = \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}$$

4.3.4 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with **Ch 6, Sec 4**, considering the loads in **[2.2].**

5. Connection of hull structures with the rudder horn

5.1 Connection of aft peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the stern-frame is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.
The scantlings of the rudder horn, which are to comply with **Ch 10, Sec 1, [9.2]**, may be gradually tapered inside the hull.
Connections by slot welds are not acceptable.

5.1.3 Hull structures

The vertical extension of hull structure to support the rudder horn between the horn intersection with the shell and the peak tank top is in accordance with the requirements of **Ch 10, Sec 1, [9.2.6]** and **[9.2.7].**
The thickness ofthe structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

5.2 Structural arrangement above the aft peak

5.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.
The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the aft peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased with respect to those obtained from the formulae in **[4.3.2].**

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2.6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6. Sternframes

6.1 General

6.1.1

Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2

Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.
Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than $1500 + 6L$ mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the aft peak bulkhead.
The net thickness of shell plating connected with the sternframe is to be not less than that obtained, in mm, from the following formula:

$$t = 8.5 + 0.045L$$

6.2.2 Connection with the keel

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.
Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$$t = 9 + 0.023L_1$$

6.2.4 Connection with centre keelson

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

With reference to **Ch 3, Sec 2**, all scantlings and dimensions referred to in **[6.3.2]** to **[6.3.4]** are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in **Table 5** for single screw ships and **Table 6** for twin screw ships.
Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in **Table 5** or **Table 6** as applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85 % of the value calculated with the scantlings in **Table 5** or **Table 6** as applicable.
In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

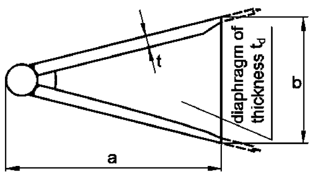
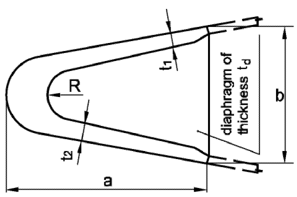
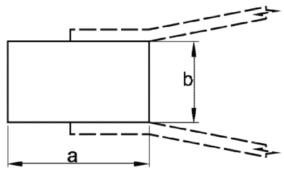
Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with **Ch 11, Sec 2.**

6.4 Propeller shaft bossing

6.4.1

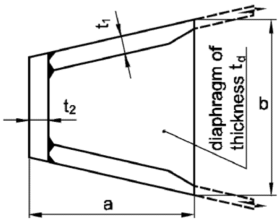
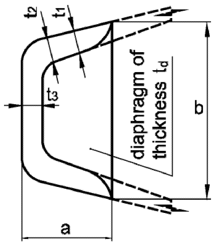
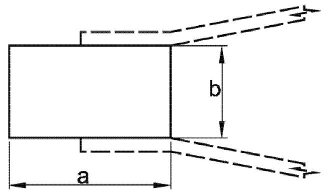
In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60 % of the dimension b required in **[6.3.2]** for bar propeller posts with a rectangular section.

Table 5: Single screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having rectangular section
			
a	$50\,L^{1/2}$	$33\,L^{1/2}$	$10\sqrt{7.2L-256}$
b	$35\,L^{1/2}$	$23\,L^{1/2}$	$10\sqrt{4.6L-164}$
t_1 (1)	$2.5\,L^{1/2}$	$3.2\,L^{1/2}$ to be taken not less than 19 mm	-
t_2 (1)	-	$4.4\,L^{1/2}$ to be taken not less than 19 mm	-
t_D	$1.3\,L^{1/2}$	$2.0\,L^{1/2}$	-
R	-	$50\,L^{1/2}$	-

(1) Propeller post thicknesses t_1, and t_2 are, in any case, to be not less than $(0.05\,L + 9.5)$ mm.

Table 6: Twin screw ships – Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post 	Cast propeller post 	Bar propeller post, cast or forged, having rectangular section 
a	$25\,L^{1/2}$	$12.5\,L^{1/2}$	$2.4L+6$
b	$25\,L^{1/2}$	$25\,L^{1/2}$	$0.8L+2$
t_1 (1)	$2.5\,L^{1/2}$	$2.5\,L^{1/2}$	-
t_2 (1)	$3.2\,L^{1/2}$	$3.2\,L^{1/2}$	-
t_3	-	$4.4\,L^{1/2}$	-
t_D	$1.3\,L^{1/2}$	$2.0\,L^{1/2}$	-

(1) Propeller post thicknesses t_1, t_2 and t_3 are, in any case, to be not less than $(0.05\,L + 9.5)$ mm.

6.5 Sterntubes

6.5.1 Sterntubes

The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the stern-frame.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

Section 3 - MACHINERY SPACE

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

k : Material factor, defined in **Ch 3, Sec 1, [2.2]**

P : Maximum continuous rating, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1. General

1.1 Application

1.1.1

The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements that have to be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in **Ch 3, Sec 2** all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.
The gross scantlings are obtained as specified in **Ch 3, Sec 2, [3.1].**

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in **Ch 6.** In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case by case basis.
The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Transition zone between engine room and cargo area

In the transition zone between the engine room and the aftermost cargo hold due consideration is to be given to the proper tapering of major longitudinal members within the engine room such as flats, decks, horizontal rings or side stringers into the cargo hold, and for longitudinal bulkheads (inner skin, upper and lower wing tank) into the engine room.

Where such structure is in line with longitudinal members aft or forward of the cargo hold bulkhead, adequate tapering is to be achieved by fitting large tapering brackets inside the wing tanks or engine room.

1.3.3 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2. Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in **Ch 3, Sec 6, [6.1].** This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.
The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.
Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure. The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.
Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.
Bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and are to be supported by floors and side primary supporting members at the ends.
Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame.
Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in **Ch 3, Sec 6**, floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.
The section modulus of web stiffeners is to be not less than 1.2 times that required in **Ch 6, Sec 2, [4.1.2].**

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.
The depth of manholes is generally to be not greater than 40 % of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.
In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.
Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.
Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1

The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in **Table 1.**

Table 1: Double bottom – Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm
Inner bottom	$6.6 + 0.024 L$ The Society may require the thickness of the inner bottom in way of the machinery seatings and on the main thrust blocks to be increased, on a case by case basis.
Margin plate	$0.9 L^{1/2} + 1$
Centre girder	$1.55 L^{1/2} + 3.5$
Floors and side girders	$1.7 L^{1/2} + 1$
Girder bounding a duct keel	$0.8 L^{1/2} + 2.5$, to be taken not less than that required for the centre girder.

3. Side

3.1 Arrangement

3.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

3.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.
In any event, the longitudinal structure is to be maintained for at least 0.3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided.

3.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.
For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.
For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.
Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society’s requirements to be defined on a case by case basis.

4. Platforms

4.1 Arrangement

4.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

4.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.
For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

4.2 Minimum thicknesses

4.2.1

The net thickness of platforms is to be not less than 6.5 mm.

5. Pillaring

5.1 Arrangement

5.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines.

5.1.2 Pillars

Pillars are to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

5.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted in 'tween decks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.
Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.
Pillar bulkhead scantlings are to be not less than those required in **[6.3]** for machinery casing bulkheads.

6. Machinery casing

6.1 Arrangement

6.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings that are particularly exposed to wave action is considered by the Society on a case by case basis.

6.2 Openings

6.2.1 General

All machinery space openings, which are to comply with the requirements in **Sec 6, [6]**, are to be enclosed in a steel casing leading to the highest open deck. Casings are to be reinforced at the ends by deck beams and girders associated to pillars.
In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.
Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

6.2.2 Access doors

Access doors to casings are to comply with **Sec 6, [6.2].**

6.3 Scantlings

6.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in **Ch 9, Sec 4.**

6.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5.5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

7. Main machinery seating

7.1 Arrangement

7.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

7.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.
They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

7.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.
The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

7.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.
The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

7.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

7.1.6 Number of girders in way of machinery seatings

At least two girders are to be fitted in way of main machinery seatings.
One girder may be fitted only where the following three formulae are complied with:
$L < 150$ m
$P < 7100$ kW
$P < 2.3\, n_r L_E$

7.2 Minimum scantlings

7.2.1

The net scantlings of the structural elements in way of the internal combustion engine seatings are to be obtained from the formulae in **Table 2**. However, the net cross-sectional area of each bedplate of the seatings may be determined by the engine manufacturers, provided the information regarding permissible foundation stiffness considering the engine characteristics and engine room arrangement, etc.

Table 2: Minimum scantlings of the structural elements in way of machinery seatings

Scantling minimum value	Scantling minimum value
Net cross-sectional area, in cm^2, of each bedplate of the seatings	$40+70\frac{P}{n_r L_E}$
Bedplate net thickness, in mm	Bedplates supported by two or more girders: $\sqrt{240+175\frac{P}{n_r L_E}}$ Bedplates supported by one girder: $5+\sqrt{240+175\frac{P}{n_r L_E}}$
Total web net thickness, in mm, of girders fitted in way of machinery seatings	Bedplates supported by two or more girders: $\sqrt{320+215\frac{P}{n_r L_E}}$ Bedplates supported by one girder: $\sqrt{95+65\frac{P}{n_r L_E}}$
Web net thickness, in mm, of floors fitted in way of machinery seatings	$\sqrt{55+40\frac{P}{n_r L_E}}$

Section 4 - SUPERSTRUCTURES AND DECKHOUSES

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

L_2 : Rule length L, but to be taken not greater than 300 m

p_D : Lateral pressure for decks, in kN/m^2, as defined in **[3.2.1]**

p_{SI} : Lateral pressure for sides of superstructures, in kN/m^2, as defined in **[3.2.3]**

k : Material factor, defined in **Ch 3, Sec 1, [2.2]**

s : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see **Ch 3, Sec 6, [4.2]**

c : Coefficient taken equal to:

$c = 0.75$ for beams, girders and transverses which are simply supported on one or both ends

$c = 0.55$ in othe rcases

m_a : Coefficient taken equal to:

$$m_a = 0.204\frac{s}{\ell}\left[4-\left(\frac{s}{\ell}\right)^2\right], \text{ with } \frac{s}{\ell}\le 1$$

1. General

1.1 Definitions

1.1.1 Superstructure

See **Ch 1, Sec 4, [3.12.1]**

1.1.2 Deckhouse

See **Ch 1, Sec 4, [3.15.1]**

1.1.3 Long deckhouse

A long deckhouse is a deckhouse the length of which within $0.4L$ amidships exceeds $0.2L$. The strength of along deckhouse is to be specially considered.

1.1.4 Short deckhouse

A short deckhouse is a deckhouse not covered by the definition given in **[1.1.3].**

1.1.5 Non-effective superstructure

For the purpose of this section, all superstructures being located beyond $0.4L$ amidships or having a length of less than $0.15L$ are considered as non-effective superstructures.

1.1.6 Insulated funnel

Scantlings of insulated funnels are to be determined as for deckhouses.

1.1.7 Effective superstructure

Effective superstructure is a superstructure not covered by the definition given in **[1.1.5]**

1.2 Gross scantlings

1.2.1

With reference to **Ch 3, Sec 2**, all scantlings and dimensions referred to in **[4]** and **[5]** are gross, i.e. they include the margins for corrosion.

2. Arrangement

2.1 Strengthening at the ends of superstructures

2.1.1

In way of end bulkheads of superstructures located within $0.4\,L$ amidships, the thickness of the strength deck in a breadth of $0.1\,B$ from the shell, the thickness of the sheerstrake, and the thickness of the superstructure side plating are to be increased by the percentage of strengthening specified in **Table 1.** The strengthening is to be extended over a region from 4 frame spacings abaft the end bulkhead to 4 frame spacings forward of the end bulkhead.

Table 1: Percentage of strengthening

Type of superstructure	Strength deck and sheerstrake	Side plating of superstructure
Effective	30 %	20 %
Non-effective	20 %	10 %

2.1.2

Under strength decks in way of $0.6\,L$ amidships, girders are to be fitted in alignment with longitudinal walls, which are to extend at least over three frame spacings beyond the end points of the longitudinal walls. The girders are to overlap with the longitudinal walls by at least two frame spacings.

2.2 Attachment of stiffening members

2.2.1 Attachment of deck beams

Transverse deck beams are to be connected to the frames by brackets according to **Ch 3, Sec 6.**
Deck beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

2.2.2 Attachment of deck girders and transverses

End attachments of girders at bulkheads are to be so dimensioned that the bending moments and shear forces can be transferred. Bulkhead stiffeners under girders are to be sufficiently dimensioned to support the girders.
Face plates are to be stiffened by tripping brackets according to **Ch 3, Sec 6.** At girders of symmetrical section, they are to be arranged alternately on both sides of the web.

2.2.3 End attachment of superstructure frames

Superstructure frames are to be connected to the main frames below, or to the deck. The end attachment may be carried out in accordance with **Fig 1.**

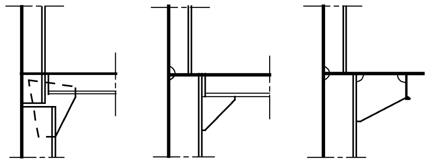


Fig 1: End attachment of superstructure frames

2.3 Transverse structure of superstructures and deckhouses

2.3.1

The transverse structure of superstructures and deckhouses is to be sufficiently dimensioned by a suitable arrangement of end bulkheads, web frames, steel walls of cabins and casings, or by other measures.

2.4 Openings in enclosed superstructures

2.4.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 12(1))
All access openings in bulkheads at ends of enclosed superstructures are to be fitted with weathertight doors permanently attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the un-pierced bulkhead. The doors are to be so arranged that they can be operated from both sides of the bulkhead.

2.4.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 12(3))
The height of the sills of access openings in bulkheads at ends of enclosed superstructures shall be at least 380 mm above the deck.

2.4.3

Any opening in a superstructure deck or in a deckhouse deck directly above the freeboard deck (deckhouse surrounding companionways), is to be protected by efficient weathertight closures.

3. Load model

3.1 Load calculation point

3.1.1

Unless otherwise specified, lateral pressure is to be calculated at load calculation points defined in:
- **Ch 6, Sec 1, [1.5]**, for plating
- **Ch 6, Sec2, [1.4]** for ordinary stiffeners and primary supporting members.

3.2 Loads

3.2.1 Lateral pressure for decks

The lateral pressure for decks of superstructures and deckhouses, in kN/m^2, is to be taken equal to:
- the external pressure p_D defined in **Ch 4, Sec 5, [2.1]** for exposed decks,
- 5 kN/m^2 for unexposed decks.

3.2.2 Lateral pressure for exposed wheel house top

The lateral pressure p for exposed wheel house tops, in kN/m^2, is to be obtained according to **Ch 4, Sec 5, [3.2].**

3.2.3 Lateral pressure for sides of superstructures

The lateral pressure p_{SI} for sides of superstructures, in kN/m^2, is to be obtained according to **Ch 4, Sec 5, [3.3].**

4. Scantlings

4.1 Side plating of non-effective superstructures

4.1.1

The gross thickness, in mm, of the side plating of non-effective superstructures is not to be less than the greater of the following values:

$$t = 1.21 s\sqrt{k p_{SI}} + 1.5$$

$$t = 0.8\sqrt{kL}$$

4.2 Deck plating of non-effective superstructures

4.2.1

The gross thickness, in mm, of deck plating of non-effective superstructures is not to be less than the greater of the following values:

$$t = 1.21 s\sqrt{k p_D} + 1.5$$

$$t = (5.5 + 0.02L)\sqrt{k}$$

where L is not to be taken greater than 200 m.

4.2.2

Where additional superstructures are arranged on non-effective superstructures located on the freeboard deck, the gross thickness required by **[4.2.1]** may be reduced by 10 %.

4.2.3

Where plated decks are protected by sheathing, the gross thickness of the deck plating according to **[4.2.1]** and **[4.2.2]** may be reduced by 1.5 mm. However, such deck plating is not to be less than 5 mm. Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

4.3 Deck beams and supporting deck structure

4.3.1 Transverse deck beams and deck longitudinal ordinary stiffeners

The section modulus w, in cm^3, and the shear area A_{sh}, in cm^2, of transverse deck beams and of deck longitudinal ordinary stiffeners are not to be less than the values obtained from the following formulae:

$$w = c k p_D s \ell^2$$

$$A_{sh} = 0.05(1 - 0.817 m_a) k p_D s \ell$$

4.3.2 Deck girders and transverses

The section modulus w, in cm^3, and the shear area A_{sh}, in cm^2, of deck girders and transverses are not to be less than the values obtained from the following formulae:

$$w = ckp_D e\ell^2$$

$$A_{sh} = 0.05kp_D e\ell$$

where:

e : Width of loaded area, in m, of the unsupported adjacent plate fields, measured from each mid of plate field to mid of opposite plate filed.

The girder depth is not to be less than $\ell/25$. The web depth of girders scalloped for continuous deck beams is to be at least 1.5 times the depth of the deck beams.
Where a girder does not have the same section modulus throughout all girder fields, the greater scantlings are to be maintained above the supports and are to be reduced gradually to the smaller scantlings.

4.4 Superstructure frames

4.4.1 Section modulus and shear area

The section modulus w, in cm^3, and the shear area A_{sh}, in cm^2, of the superstructure frames are not to be less than the values obtained from the following formulae:

$$w = 0.55kp_{SI}s\ell^2$$

$$A_{sh} = 0.05(1 - 0.817m_a)kp_{SI}s\ell$$

4.4.2

Where frames are supported by a longitudinally framed deck, the frames fitted between web frames are to be connected to the adjacent longitudinal ordinary stiffeners by brackets. The scantlings of the brackets are to be determined in accordance with **Ch 3, Sec 6** on the basis of the section modulus of the frames.

4.4.3

Where further superstructures or deckhouses are arranged on the superstructures, strengthening of the frames of the space below may be required.

4.5 Decks of short deckhouses

4.5.1 Plating

The thickness, in mm, of weather deck of short deckhouses and is not to be less than:

$$t = 8s\sqrt{k} + 1.5$$

For weather decks of short deckhouses protected by sheathing and for decks within deckhouses, the gross thickness may be reduced by 1.5mm. However, such deck plating is not to be less than 5 mm.

4.5.2 Deck beams

The scantlings of deck beams and supporting deck structure are to be determined according to **[4.3].**

5. End bulkheads of superstructure and deckhouse

5.1 Application

5.1.1

The requirements in **[5.2]** and **[5.3]** apply to end bulkhead of superstructure and deckhouse forming the only protection for openings, as required by ILLC as amended, and for accommodations.

5.2 Loads

5.2.1

The design load p_A, in kN/m^2, for determining the scantlings is to be obtained according to **Ch 4, Sec 5, [3.4].**

5.3 Scantlings

5.3.1 Stiffeners

The section modulus w, in cm^3, of the stiffeners is not to be less than the value obtained from the following formula:

$$w = 0.35 k p_A s \ell^2$$

This requirement assume the webs of lowest tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections may be specially considered.
The section modulus of deckhouse side stiffeners needs not to be greater than that of side frames on the deck situated directly below; taking account of spacing s and span ℓ.

5.3.2 Plate thickness

The gross thickness of the plating, in mm, is not to be less than the greater of the values obtained from the following formulae:

$$t = 0.9 s \sqrt{k p_A} + 1.5$$

$$t_{min} = \left(5.0 + \frac{L_2}{100}\right)\sqrt{k}$$, for the lowest tier

$$t_{min} = \left(4.0 + \frac{L_2}{100}\right)\sqrt{k}$$, for the upper tiers, without being less than 5.0 mm.

Section 5 - HATCH COVERS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

p_S : Still water pressure, in kN/m^2, defined in **[4.1]**

p_W : Wave pressure, in kN/m^2, defined in **[4.1]**

p_C : Pressure acting on the hatch coaming, in kN/m^2, defined in **[6.2]**

F_S, F_W : Coefficients taken equal to:

F_S = 0 and F_W = 0.9 for ballast water loads on hatch covers of the ballast hold

F_S = 1.0 and F_W = 1.0 in other cases

s : Length, in m, of the shorter side of the elementary plate panel

ℓ : Length, in m, of the longer side of the elementary plate panel

b_p : Effective width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in **[3]**

w : Net section modulus, in cm^3, of the ordinary stiffener or primary supporting member, with an attached plating of width b_p

A_{sh} : Net shear sectional area, in cm^2, of the ordinary stiffener or primary supporting member

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

m = 8, in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end

m = 12, in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Total corrosion addition, in mm, defined in **[1.4]**

σ_a , τ_a : Allowable stresses, in N/mm^2, defined in **[1.5]**

1. General

1.1 Application

1.1.1

The requirements in **[1]** to **[8]** apply to steel hatch covers in positions 1 and 2 on weather decks, defined in **Ch 1, Sec 4, [3.20].**
The requirements in **[9]** apply to steel hatch covers of small hatches fitted on the exposed fore deck over the forward 0.25 L.

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in **[5]** are applicable to steel hatch covers.
Materials used for the construction of steel hatch covers are to comply with the applicable requirements of the Society.

1.2.2 Other materials

The use of materials other than steel is considered by the Society on a case by case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.3 Net scantlings

1.3.1

All scantlings referred to in this Section, except otherwise specified, are net, i.e. they do not include any margin for corrosion.
When calculating the stresses σ and τ in **[5.3]** and **[5.4]**, the net scantlings are to be used.
The gross scantlings are obtained as specified in **Ch 3, Sec 2.**
The corrosion additions are given in **[1.4].**

1.4 Corrosion additions

1.4.1

The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in **Table 1.**
The corrosion addition for hatch coamings and coaming stays is defined according to **Ch 3, Sec 3.**

Table 1: Corrosion addition t_C for hatch covers

Corrosion addition t_C, in mm, for both sides	
Plating and stiffeners of single skin hatch cover	2.0
Top and bottom plating of double skin hatch cover	2.0
Internal structures of double skin hatch cover	1.5

1.5.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15(6) and 16(5))
The allowable stresses σ_a and τ_a, in N/mm^2, are to be obtained from **Table 2.**

Table 2: Allowable stresses, in N/mm^2

Members of	Subjected to	σ_a, in N/mm^2	τ_a, in N/mm^2
Weathertight hatch cover	External pressure, as defined in Ch 4, Sec 5, [5.2.1]	0.80 R_{eH}	0.46 R_{eH}
Pontoon hatch cover		0.68 R_{eH}	0.39 R_{eH}
Weathertight hatch cover and pontoon hatch cover	Other loads, as defined in Ch 4, Sec 5, [5.1.1] and Ch 4, Sec 6, [2]	0.90 R_{eH}	0.51 R_{eH}

2. Arrangements

2.1 Height of hatch coamings

2.1.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 14 (1, 1))
The height above the deck of hatch coamings is to be not less than:

- *600 mm in position 1*
- *450 mm in position 2.*

2.1.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 14 (1, 2))
The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and se-

curing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.
In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case by case basis.

2.1.3

Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures.

2.2 Hatch covers

2.2.1

Hatch covers on exposed decks are to be weathertight.
Hatch covers in closed superstructures need not be weathertight.
However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2

The ordinary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.3

The spacing of primary supporting members parallel to the direction of ordinary stiffeners is to be not greater than 1/3 of the span of primary supporting members.

2.2.4

The breadth of the primary supporting member face plate is to be not less than 40 % of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.
The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.2.5

Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.2.6

The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1

Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2

Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3

Longitudinal coamings are to be extended at least to the lower edge of deck beams.

- where they are not part of continuous deck girders, the lower edge of longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.
- where longitudinal coamings are part of deck girders, their scantlings are to be as required in **Ch 6, Sec 4.**

2.3.4

A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

2.4 Small hatchways

2.4.1

The height of small hatchway coamings is to be not less than 600 mm if located in position 1 and 450 mm if located in position 2.
Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.4.2

Small hatch covers are to have strength equivalent to that required for main hatchways and are to be of steel, weathertight and generally hinged.
Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.
At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.4.3

Hold accesses located on the weather deck are to be provided with weathertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.4.4

Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced.

2.4.5

Hatchways of special design are considered by the Society on a case by case basis.

3. Width of attached plating

3.1 Ordinary stiffeners

3.1.1

The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:

$$b_p = s$$

- where the attached plating extends on one side of the stiffener:

$$b_p = 0.5s$$

3.2 Primary supporting members

3.2.1

The effective width of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through isolated beam or grillage model is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

$$b_p = b_{p,1} + b_{p,2}$$

- where the plating extends on one side of the primary supporting member:

$$b_p = b_{p,1}$$

where:

$$b_{p,1} = \min(0.165\ell_p \, , \, S_{p,1})$$

$$b_{p,2} = \min(0.165\ell_p \, , \, S_{p,2})$$

ℓ_p : Span, in m, of the considered primary supporting member

$S_{p,1}$, $S_{p,2}$: Half distance, in m, between the considered primary supporting member and the adjacent ones, $S_{p,1}$ for one side, $S_{p,2}$ for the other side.

When a isolated beam or a grillage analysis is used, the areas of ordinary stiffeners are not to be included in the attached plating of the primary members.

4. Load model

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are indicated in **[4.1.2]** to **[4.1.6]**. When two or more panels are connected by hinges, each individual panel is to be considered separately.
In any case, the sea pressures defined in **[4.1.2]** are to be considered for hatch covers located on exposed decks.
Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in **[4.1.3]** to **[4.1.6]** are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- still water pressure: $p_s = 0$
- wave pressure p_W, as defined in **Ch 4, Sec 5 [5.2].**

4.1.3 Internal pressures due ballast water

If applicable, the static and dynamic lateral pressures are to be considered and are defined in **Ch 4, Sec 6, [2].**

4.1.4 Pressures due to uniform cargoes

If applicable, the static and dynamic pressures are to be considered and are defined in **Ch 4, Sec 5, [2.4.1]**

4.1.5 Pressures or forces due to special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case by case basis.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- longitudinally, at the hatch cover mid-length
- transversely, on the longitudinal plane of symmetry of the ship
- vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated:

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

5. Strength check

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to a uniform pressure, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.
In the latter case, the stresses in the primary supporting members are to be determined by a grillage or a finite element analysis.
It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in **[5.4.4].**

5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting containers are to comply with the applicable provisions of the Society.

5.1.3 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in **[5.4.4].**

5.1.4 Covers of small hatchways

The gross thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 0.6 m.

5.2 Plating

5.2.1 Net thickness

The net thickness of steel hatch cover top plating, in mm, is to be not less than the value obtained from the following formula:

$$t = 15.8 F_p s \sqrt{\frac{F_S p_S + F_W p_W}{0.95 R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

$F_p = 1.5$ in general

$F_p = 1.9\sigma/\sigma_a$, for $\sigma \geq 0.8\sigma_a$ for the attached plating of primary supporting members

σ : Normal stress, in N/mm^2, in the attached plating of primary supporting members, calculated according to **[5.4.3]** or determined through a grillage analysis or a finite element analysis, as the case may be.

5.2.2 Minimum net thickness

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 16 (5, c))
In addition to **[5.2.1]**, the net thickness, in mm, of the plating forming the top of the hatch cover is to be not less than the greater of the following values:

$$t = 10s$$

$$t = 6$$

5.2.3 Critical buckling stress check

The compressive stress σ in the hatch cover plating, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \leq \frac{0.88}{S}\sigma_{C1}$$

where:

S : Safety factor defined in **Ch 6, Sec 3**

σ_{C1} : Critical buckling stress, in N/mm^2, taken equal to:

$$\sigma_{C1} = \sigma_{E1} \quad \text{for} \quad \sigma_{E1} \leq \frac{R_{eH}}{2}$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

$$\sigma_{E1} = 3.6\, E\left(\frac{t}{1000s}\right)^2$$

t : Net thickness, in mm, of plate panel

The compressive stress σ in the hatch cover plating, induced by the bending of primary supporting members, perpendicular to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \le \frac{0.88}{S}\sigma_{C2}$$

where:

S : Safety factor defined in **Ch 6, Sec 3**

σ_{C2} : Critical buckling stress, in N/mm^2, taken equal to:

$$\sigma_{C2} = \sigma_{E2} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

$$\sigma_{E2} = 0.9\, m\, E\left(\frac{t}{1000 s_s}\right)^2$$

m : Coefficient taken equal to:

$$m = c\left[1 + \left(\frac{s_s}{\ell_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$$

t : Net thickness, in mm, of plate panel

s_s : Length, in m, of the shorter side of the plate panel

ℓ_s : Length, in m, of the longer side of the plate panel

Ψ : Ratio between smallest and largest compressive stress

c : Coefficient taken equal to:

c = 1.3 when plating is stiffened by primary supporting members

c = 1.21 when plating is stiffened by ordinary stiffeners of angle or Ttype

c = 1.1 when plating is stiffened by ordinary stiffeners of bulb type

c = 1.05 when plating is stiffened by flat bar.

c = 1.30 when plating is stiffened by ordinary stiffeners of U type. The higher c value but not greater than 2.0 may be taken if it is verified by buckling strength check of panel using non-linear FEA and deemed appropriate by the Society.

An averaged value of c is to be used for plate panels having different edge stiffeners.

The bi-axial compression stress in the hatch cover plating, when calculated by means of finite element analysis, is to comply with the requirements in **Ch 6, Sec 3.**

5.3 Ordinary stiffeners

5.3.1

For flat bar ordinary stiffeners, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.3.2 Minimum net thickness of web

The web net thickness of the ordinary stiffener, in mm, is to be not less than 4 mm.

5.3.3 Net section modulus and net shear sectional area

The net section modulus w, in cm^3, and the net shear sectional area A_{sh}, in cm^2, of an ordinary stiffener subject to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{(F_S p_S + F_W p_W) s \ell_s^2}{m \sigma_a} 10^3$$

$$A_{sh} = \frac{5(F_S p_S + F_W p_W) s \ell_s}{\tau_a}$$

where:

ℓ_s : Ordinary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all ordinary stiffener spans, the ordinary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10 % of the gross span, for each bracket.

5.3.4 Critical buckling stress check

The compressive stress s in the face plate of ordinary stiffeners, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \le \frac{0.88 \sigma_{CS}}{S}$$

where:

S : Safety factor defined in **Ch 6, Sec 3**

σ_{CS} : Critical buckling stress, in N/mm^2, taken equal to:

$$\sigma_{CS} = \sigma_{ES} \quad \text{for} \quad \sigma_{ES} \le \frac{R_{eH}}{2}$$

$$\sigma_{CS} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{ES}}\right) \quad \text{for} \quad \sigma_{ES} > \frac{R_{eH}}{2}$$

$$\sigma_{ES} = \min(\sigma_{E3}, \sigma_{E4})$$

$$\sigma_{E3} = 0.001 \frac{E I_a}{A \ell^2}$$

I_a : Moment of inertia, in cm^4, of the ordinary stiffener, including a face plate equal to spacing of ordinary stiffeners

A : Cross-sectional area, in cm^2, of the ordinary stiffener, including a face plate equal to spacing of ordinary stiffeners

ℓ : Span, in m, of the ordinary stiffener

$$\sigma_{E4} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385 E \frac{I_t}{I_p}$$

$$K = \frac{C \ell^4}{\pi^4 E I_w} 10^6$$

m : Number of half waves, given in **Table 3.**

Table 3: Number of half waves

	$0 < K < 4$	$4 < K < 36$	$36 < K < 144$	$(m-1)^2m^2 < K \le m^2(m+1)^2$
m	1	2	3	m

I_w : Sectorial moment of inertia, in cm^6, of the ordinary stiffener about its connection with the plating, taken equal to:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$ for flat bar ordinary stiffeners

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$ for "Tee" ordinary stiffeners

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}\left[t_f\left(b_f^2 + 2 b_f h_w + 4 h_w^2\right) + 3 t_w b_f h_w\right]10^{-6}$$ for angles and bulb ordinary stiffeners

I_p : Polar moment of inertia, in cm^4, of the ordinary stiffener about its connection with the plating, taken equal to:

$$I_t = \frac{h_w^3 t_w}{3} 10^{-4}$$ for flat bar ordinary stiffeners

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$$ for flanged ordinary stiffeners

I_t : St Venant's moment of inertia, in cm^4, of the ordinary stiffener without face plate, taken equal to:

$$I_t = \frac{h_w t_w^3}{3} 10^{-4}$$ for flat bar ordinary stiffeners

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3 \left(1 - 0.63\frac{t_f}{b_f}\right)\right] 10^{-4}$$ for flanged ordinary stiffeners

C : Spring stiffness exerted by the hatch cover top plating, taken equal to:

$$C = \frac{k_p E t_p^3}{3s\left(1 + \dfrac{1.33 k_p h_w t_p^3}{1000 s t_w^3}\right)} 10^{-3}$$

$k_p = 1 - \eta_p$, to be taken not less than zero; for flanged ordinary stiffeners, k_p need not be taken less than 0.1

$$\eta_p = \frac{\sigma}{\sigma_{E1}}$$

σ_{E1} : As defined in **[5.2.3]**

t_p : Net thickness, in mm, of the hatch cover plate panel.

5.4 Primary supporting members

5.4.1 Application

The requirements in **[5.4.3]** to **[5.4.5]** apply to primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in **[5.4.4]**.

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is to be not less than 6 mm.

5.4.3 Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in **[5.1.1]**, the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \frac{s(F_S p_S + F_W p_W)\ell_m^2}{mW} 10^3$$

$$\tau = \frac{5s(F_S p_S + F_W p_W)\ell_m}{A_{sh}}$$

where:

ℓ_m : Span of the primary supporting member.

5.4.4 Checking criteria

The normal stress s and the shear stress τ, calculated according to **[5.4.3]** or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae:

$$\sigma \le \sigma_a$$

$$\tau \le \tau_a$$

5.4.5 Deflection limit

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15 (6) and 16 (5, b))

The net moment of inertia of a primary supporting member, when loaded by sea pressure, is to be such that the deflection does not exceed $\mu\ell_{max}$, where:

μ : Coefficient taken equal to:

μ = 0.0056 for weathertight hatch covers

μ = 0.0044 for pontoon hatch covers

ℓ_{max} : Greatest span, in m, of primary supporting members.

5.4.6 Critical buckling stress check of the web panels of the primary supporting members.

The shear stress τ in the web panels of the primary supporting members, calculated according to **[5.4.3]** or determined through a grillage analysis or a finite element analysis, as the case may be, is to comply with the following formula:

$$\tau \le \frac{0.88\tau_C}{S}$$

where:

S : Safety factor defined in **Ch 6, Sec 3**

τ_C : Critical shear buckling stress, in N/mm^2, taken equal to:

$$\tau_C = \tau_E \quad \text{for} \quad \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for} \quad \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_E = 0.9 k_t E \left(\frac{t_{pr,n}}{1000d}\right)^2$$

$$k_t = 5.35 + 4.0\left(\frac{a}{d}\right)^2$$

$t_{pr,n}$: Net thickness, in mm, of web of primary supporting member

a : Greater dimension, in m, of web panel of primary supporting member

d : Smaller dimension, in m, of web panel of primary supporting member.

For primary supporting members parallel to the direction of ordinary stiffeners, τ_C is to be calculated by considering the actual dimensions of the panels.
For primary supporting members perpendicular to the direction of ordinary stiffeners or for hatch covers built without ordinary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C, where d is the smaller dimension, in m, of web panel of the primary supporting member. the In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

5.4.7

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

5.5 Ordinary stiffeners and primary supporting members of variable cross-section

5.5.1

The net section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the value obtained, in cm^3, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) w_{CS}$$

where:

w_{CS} : Net section modulus, in cm^3, for a constant cross-section, complying with the checking criteria in **[5.4.4]**

α : Coefficient taken equal to:

$$\alpha = \frac{\ell_1}{\ell_0}$$

Ψ : Coefficient taken equal to:

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m (see **Fig 1**)

ℓ_0 : Span measured, in m, between end supports (see **Fig 1**)

w_1 : Net section modulus at end, in cm^3 (see **Fig 1**)

w_0 : Net section modulus at mid-span, in cm^3 (see **Fig 1**).

Moreover, the net moment of inertia of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^4, from the following formulae:

$$I = I_{CS}$$

$$I = \left[1 + 8\alpha^3\left(\frac{1-\varphi}{0.2 + 3\sqrt{\varphi}}\right)\right] I_{CS}$$

where:

I_{CS} : Net moment of inertia with a constant cross-section, in cm^4, complying with **[5.4.5]**

φ : Coefficient taken equal to:

$$\varphi = \frac{I_1}{I_0}$$

I_1 : Net moment of inertia at end, in cm^4 (see **Fig 1**)

I_0 : Net moment of inertia at mid-span, in cm^4 (see **Fig 1**).

The use of these formulae is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

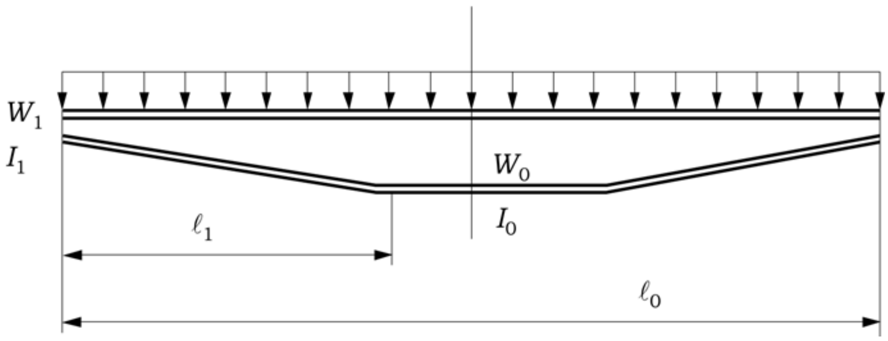


Fig 1: Variable cross-section stiffener

6. Hatch coamings

6.1 Stiffening

6.1.1

The ordinary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

6.1.3

Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.
Where the height of the coaming exceeds 900 mm, additional strengthening may be required.
However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.
Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.
In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

6.2.1

The lateral pressure p_C to be considered as acting on the hatch coamings is defined in **[6.2.2]** and **[6.2.3].**

6.2.2

The wave lateral pressure p_C, in $\mathrm{kN/m^2}$, on the No 1 forward transverse hatch coaming is to be taken equal to:

- p_C = 220, when a forecastle is fitted in accordance with **Sec 1, [7.1]**
- p_C = 290, in the other cases.

6.2.3

The wave lateral pressure p_C, in $\mathrm{kN/m^2}$, on the hatch coamings other than the No 1 forward transverse hatch coaming is to be taken equal to:

- p_C = 220

6.2.4

For cargo holds intended for the carriage of liquid cargoes, the liquid internal pressures applied on hatch coaming is also to be determined according to **Ch 4, Sec 6.**

6.3 Scantlings

6.3.1 Plating

The net thickness of the hatch coaming plate is to be not less than the greater value obtained, in mm, from the following formulae:

$$t = 15.98 s \sqrt{\frac{p_C}{0.95 R_{eH}}}$$

t = 9.5

6.3.2 Ordinary stiffeners

The net section modulus of the longitudinal or transverse ordinary stiffeners of hatch coamings is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 1.21 \frac{p_C s \ell^2 10^3}{m c_p R_{eH}}$$

where:

m : Coefficient taken equal to:

m = 16 in general

m = 12 for the end span of stiffeners sniped at the coaming corners

c_p : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached plate breadth, in mm, equal to $40t$, where t is the plate net thickness.

c_p = 1.16 in the absence of more precise evaluation.

6.3.3 Coaming stays

The net section modulus w, in cm^3, and the net thickness t_w, in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in **Fig 2** and **Fig 3**) are to be not less than the values obtained from the following formulae at the connection with deck:

$$w = \frac{s_C p_C H_C^2 10^3}{1.9 R_{eH}}$$

$$t_w = \frac{s_C p_C H_C 10^3}{0.5 h R_{eH}}$$

where:

H_C : Stay height, in m

s_C : Stay spacing, in m

h : Stay depth, in mm, at the connection with deck.

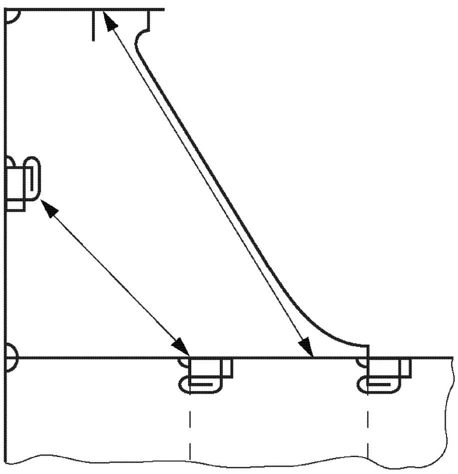


Fig 2: Coaming stay: example1

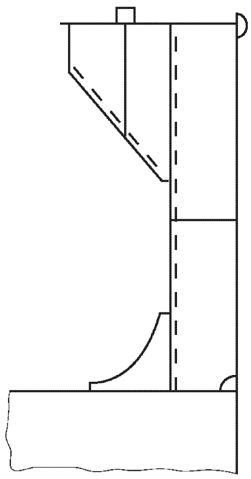


Fig 3: Coaming stay: example 2

For calculating the section modulus of coaming stays, their face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.
For other designs of coaming stays, such as, for example, those shown in **Fig 4** and **Fig 5**, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \le 0.95 R_{eH}$

$\tau \le 0.5 R_{eH}$

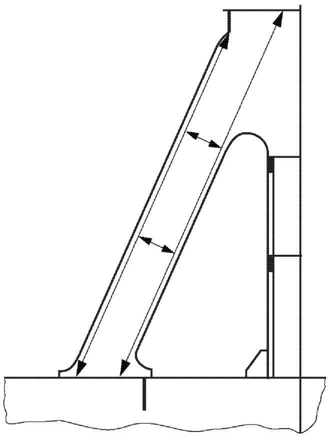


Fig 4: Coaming stay: example 3

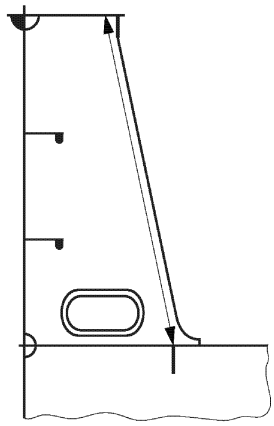


Fig 5: Coaming stay: example 4

6.3.4 Local details

The design of local details is to comply with the requirements in this section for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below.
Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.
The normal stress σ and the shear stress τ, in $\mathrm{N/mm^2}$, induced in the underdeck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \le 0.95 R_{eH}$

$\tau \le 0.5 R_{eH}$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society's requirements.
Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld throat thickness is to be not less than $0.44\,t_w$, where t_w is the gross thickness of the stay web.
Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15 % of the stay width.

6.3.5 Coamings of small hatchways

The gross thickness of coaming plate is to be not less than the lesser of the following values:

- the gross thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0.8 m or their greatest horizontal dimension exceeds 1.2 m, unless their shape ensures an adequate rigidity.

7. Weathertightness, closing arrangement, securing devices and stoppers

7.1 Weathertightness

7.1.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 16 (1))
Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.
Weathertightness may also be ensured means of tarpaulins.

7.1.2

In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure through steel to steel contact.
This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship's structure or by means of defined bearing pads.

7.2.2

The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.
Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3

The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.
If necessary, suitable devices are to be fitted to limit such movements.

7.2.4

The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.
The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.
The gasket is to be effectively secured to the hatch cover.

7.2.5

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6

Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

7.3 Closing arrangement, securing devices and stoppers

7.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.
The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.
In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.
Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to **[7.3.5]** to **[7.3.7].** Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.
Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.
Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see **[2.1]**) are considered by the Society on a case by case basis.
In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.
Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.
At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.
The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.
Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.
Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices

The net cross area of each securing device is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 1.4 S_S \left(\frac{235}{R_{eH}} \right)^{\alpha}$$

where:

S_S : Spacing, in m, of securing devices

α : Coefficient taken equal to:

$\alpha = 0.75$ for $R_{eH} > 235\ N/mm^2$

$\alpha = 1.0$ for $R_{eH} \leq 235\ N/mm^2$

In the above calculations, R_{eH} may not be taken greater than 0.7 R_m.
Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.
In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

7.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.
The moment of inertia of edge elements is to be not less than the value obtained, in cm^4, from the following formula:

$$I = 6 p_L S_S^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5

S_S : Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

7.3.8 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.
With the exclusion of No 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.
No 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2. This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with **Sec 1, [7.1].**
The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0.8 R_{eH}.

7.4 Tarpaulins

7.4.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15 (11))
Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.
Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.
The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0.65 kg/m^2 for waterproofing by tarring
- 0.60 kg/m^2 for waterproofing by chemical dressing
- 0.55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

7.5 Cleats

7.5.1

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

7.5.2

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

7.6 Wedges

7.6.1 Wedges

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15 (10))
Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width. They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

8. Drainage

8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

9. Small hatches fitted on the exposed fore deck

9.1 Application

9.1.1

The requirements of this article apply to steel covers of small hatches fitted on the exposed fore deck over the forward $0.25\,L$, where the height of the exposed deck in way of the hatch is less than $0.1\,L$ or 22 m above the summer load waterline, whichever is the lesser.
Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weather-tight or watertight, as applicable. Their opening is generally equal to or less than $2.5\ \mathrm{m}^2$.

9.1.2

Small hatches designed for use of emergency escape are to comply with the requirements of this article with exception of **[9.4.1]** a) and b), **[9.4.3]** and **[9.5.1].**

9.2 Strength

9.2.1

For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from **Table 4** and **Fig 6.**
Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in **[9.3.1]** (see also **Fig 6**).
Primary stiffeners are to be continuous.
All stiffeners are to be welded to the inner edge stiffener (see **Fig 7**).

Table 4: Gross scantlings for small steel hatch covers on the fore deck

Nominal size (mm × mm)	Cover plate thickness (mm)	Primary stiffeners	Ordinary stiffeners
		Flat bar (mm × mm); number	
630 × 630	8	-	-
630 × 830	8	100 × 8 ; 1	-
830 × 630	8	100 × 8 ; 1	-
830 × 830	8	100 × 10 ; 1	-
1030 × 1030	8	120 × 12 ; 1	80 × 8 ; 2
1330 × 1330	8	150 × 12 ; 2	100 × 10 ; 2

9.2.2

The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, generally not more than 170 to 190 mm from the upper edge of the coamings.

9.2.3

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with **[5.2].**

9.2.4

For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

9.3 Weathertightness

9.3.1

The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with **Fig 6** and a sufficient capacity to withstand the bearing force.

9.4 Primary securing devices

9.4.1

Small hatches located on exposed fore deck are to be fitted with primary securing devices such their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

a) butterfly nuts tightening onto forks (clamps)

b) quick acting cleats

c) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

9.4.2

The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

9.4.3

For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in **Fig 7.**

9.4.4

For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green seas will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

9.4.5

On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

9.5 Secondary securing devices

9.5.1

Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

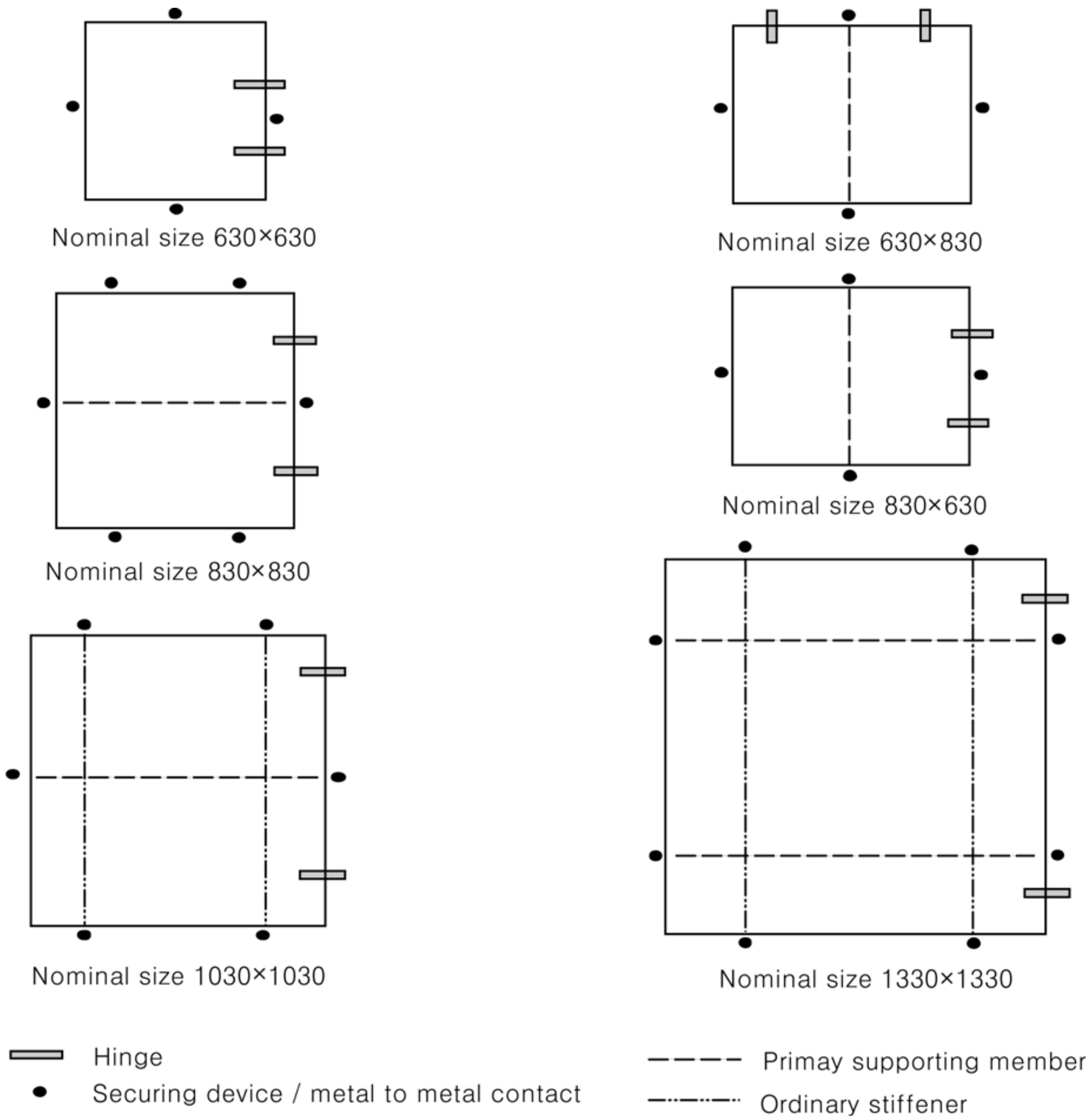
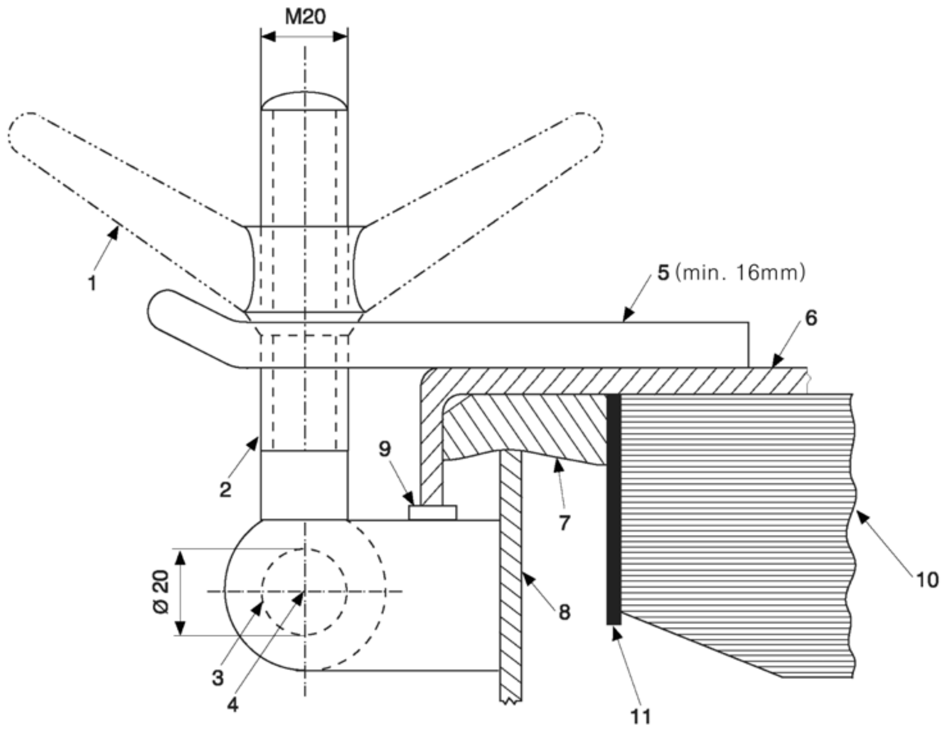


Fig 6: Arrangement of stiffeners



1) Butterfly nut
2) Bolt
3) Pin
4) Centre of pin
5) Fork (clamp) plate
6) Hatch cover
7) Gasket
8) Hatch coaming
9) Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10) Stiffener
11) Inner edge stiffener.

Fig 7: Example of a primary securing method

Section 6 – ARRANGEMENT OF HULL AND SUPERSTRUCTURE OPENINGS

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

p : Lateral pressure for glasses, in kN/m^2, defined in **[3.3.2].**

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in **Ch 9, Sec 5** apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in **Ch 1, Sec 4.**

1.2.2 Standard sheer

The standard sheer is that defined according to the International Load Line Convention, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance equal to or less than 0.04 *B*.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0.04 *B*.

2. External openings

2.1 General

2.1.1

Ref. SOLAS Reg.II-1/25-10 .1
All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2

Ref. SOLAS Reg.II-1/25-10 .2
External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3

No openings, be they permanent openings or temporary openings such as shell doors, windows or ports, are allowed on the side shell between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition. Windows and side scuttles of the non-opening type are allowed if the Society's applicable criteria for fire integrity are complied with.

2.1.4

Ref. SOLAS Reg.II-1/25-10 .5
Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

2.2 Gangway, cargo and coaling ports

2.2.1

Ref. SOLAS Reg.II-1/17-1 & Reg.II-1/17.10.1 & .10.2 and ILLC, as amended (Resolution MSC.143(77) Reg. 21(2))
Gangway, cargo and coaling ports fitted below the freeboard deck are to be of sufficient strength. They are to be effectively closed and secured watertight before the ship leaves port, and to be kept closed during navigation.
Such ports are in no case to be so fitted as to have their lowest point below the deepest subdivision load line.
Unless otherwise permitted by the Society, the lower edge of openings is not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost load line.

3. Side scuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in **[3.1]** to **[3.4]** apply to side scuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Side scuttle definition

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(2))
Side scuttles are round or oval openings with an area not exceeding 0.16 m^2*. Round or oval openings having areas exceeding 0.16* m^2 *are to be treated as windows.*

3.1.3 Window definition

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(3))
Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0.16 m^2.

3.1.4 Number of openings in the shell plating

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .1
The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(1))
Side scuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or

international standards.
Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for side scuttles below the freeboard deck.

3.1.6 Means of closing and opening

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .2
The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of side scuttles

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .3.2
All side scuttles, the sills of which are below the freeboard deck, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

3.2 Opening arrangement

3.2.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(5))
Side scuttles are not be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 0.025 B or 0.5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

3.2.2 Side scuttles below (1.4 + 0.025*B*) m above the water

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .3.3.1 and .3.3.3
Where in 'tween decks the sills of any of the side scuttles are below a line drawn parallel to the freeboard deck at side and having its lowest point 1.4 + 0.025 B m above the water when the ship departs from any port, all the side scuttles in that 'tween decks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.
For any ship that has one or more side scuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these side scuttles are to have their sills above the line drawn parallel to the freeboard deck at side, and having its lowest point 1.4 + 0.025 B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0.3 m.

3.2.3 Cargo spaces

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .6.1 to .6.3
No side scuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo or coal.
Side scuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.
If cargo is carried in such spaces, the side scuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type side scuttles

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(6))
Side scuttles are to be of the non-opening type where they become immersed by any intermediate stage

of flooding or the final equilibrium waterline in any required damage case for ships subject to damage stability regulations.

3.2.5 Manholes and flush scuttles

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18(1))
Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Automatic ventilating scuttles

Ref. SOLAS Reg.II-1/17-1& Reg.II-1/17 .7
Automatic ventilating side scuttles, fitted in the shell plating below the freeboard deck, are considered by the Society on a case by case basis.

3.2.7 Window arrangement

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(7))
Windows are not to be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered buoyant in the stability calculations or protecting openings leading below.

3.2.8 Skylights

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(12))
Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for side scuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards. The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

The design load is to be determined in accordance with the applicable requirements of **Ch 9, Sec 4.**

3.3.3 Materials

Toughened glasses are to be in accordance with ISO 1095 for side scuttles and ISO 3254 for windows.

3.3.4 Thickness of toughened glasses in side scuttles

The thickness of toughened glasses in side scuttles is to be not less than that obtained, in mm, from the following formula:

$$t = \frac{d}{358}\sqrt{p}$$

where:

d : Side scuttle diameter, in mm.

3.3.5 Thickness of toughened glasses in rectangular windows

The thickness of toughened glasses in rectangular windows is to be not less than that obtained, in mm, from the following formula:

$$t = \frac{b}{200}\sqrt{\beta p}$$

where:

β : Coefficient defined in **Table 1**. β is to be obtained by linear interpolation for intermediate values of a/b

a : Length, in mm, of the longer side of the window

b : Length, in mm, of the shorter side of the window.

Table 1: Coefficient β

a/b	β
1.0	0.284
1.5	0.475
2.0	0.608
2.5	0.684
3.0	0.716
3.5	0.734
$\geq$ 4.0	0.750

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.4 Deadlight arrangement

3.4.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(4))
Side scuttles to the following spaces are to be fitted with hinged inside deadlights:

- *spaces below freeboard deck*
- *spaces within the first tier of enclosed superstructures*
- *first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.*

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

3.4.2 Openings at the side shell in the second tier

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(8))
Side scuttles and windows at the side shell in the second tier are to be provided with efficient, hinged inside deadlights capable of being closed and secured weathertight, if the superstructure protects direct access to an opening leading below or is considered buoyant in the stability calculations.

3.4.3 Openings set inboard in the second tier

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(9) and .23(10))

Side scuttles and windows in side bulkheads set inboard from the side shell in the second tier which protect direct access below to spaces listed in [3.4.1], are to be provided with either hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial constructioncapableofbeingclosedandsecuredweathertight.
Cabin bulkheads and doors in the second tier and above separating side scuttles and windows from a direct access leading below or the second tier considered buoyant in the stability calculations may be accepted in place of deadlights or storm covers fitted to the side scuttles and windows.
Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and side scuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.4 Deckhouses on superstructures of less than standard height

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 23(11))
Deckhouses situated on a raised quarter deck or on the deck of a superstructure of less than standard height may be regarded as being in the second tier as far as the requirements for deadlights are concerned, provided the height of the raised quarterdeck or superstructure is equal to or greater than the standard quarter deck height.

3.4.5 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those side scuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4. Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

Ref. SOLAS Reg.II-1/17-1 & Reg.II-1/17 .9.1
All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-shoot, rubbish-shoot, etc.

Ref. SOLAS Reg.II-1/17-1 & Reg.II-1/17 .11.1 and .11.2
The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.
If the inboard opening is situated below the freeboard deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the shoot in an easily accessible position above the deepest subdivision load line. When the shoot is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(1, b))
The inboard end is to be located above the waterline formed by an 8.5° heel, to port or starboard, at a draft corresponding to the assigned summer freeboard, but not less than 1000 mm above the summer load waterline.
Where the inboard end of the garbage chute exceeds 0.01 L above the summer load waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(4))
Where the inboard end of a garbage chute is below the waterline corresponding to the deepest draught after damage in a ship of more than 100 m in length, then:

- *the inboard end hinged cover/valve is to be watertight*
- *the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line*
- *the screw-down non-return valve is to be controlled from a position above the freeboard deck and provided with open/shut indicators. The valve control is to be clearly marked: «Keep closed when not in use».*

4.2.3 Gate valves

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(1, a))
For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the freeboard deck. In addition, the lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.
The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(1, c))
The upper and lower gate valves, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap.
The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 22-1(3))
The controls for the gate valves and/or hinged covers are to be clearly marked: «Keep closed when not in use».

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from **Table 2.**

Table 2: Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7.0
$80 < d < 180$	$7.0 + 0.03(d - 80)$
$180 \leq d \leq 220$	$10.0 + 0.063(d - 180)$
$d > 220$	12.5

5. Freeing ports

5.1 General provisions

5.1.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, a) and Reg.3 (15))
Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.
A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24)
The minimum required freeing port areas in bulwarks on the freeboard deck are specified in Table 3.

Table 3: Freeing port area in bulwark located on freeboard deck

Ship types or ship particulars	Area A of freeing ports, in m^2	Applicable requirement
Type B-100	$0.33\,\ell_B h_B$	[5.5.2]
Type B-60	$0.25\,\ell_B h_B$	[5.5.1]
Ships fitted with a trunk included in freeboard calculation and/ or breadth ≥ 0.6 B	$0.33\,\ell_B h_B$	[5.3.1]
Ships fitted with a trunk not included in freeboard calculation and/or continuous or substantially continuous hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures	[5.4.2]
	A_W for wells	[5.4.3]
Other ships	A_1	[5.2.1]

where:
ℓ_B : Length, in m, of bulwark in a well at one side of the ship
h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.1.3 Freeing port arrangement

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (5))
Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.
One third of the freeing port area required is to be evenly spread along the remaining length of the well. With zero or little sheer on the exposed freeboard deck or an exposed superstructure deck the freeing port area is to be evenly spread along the length of the well.
However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

5.1.4 Freeing port positioning

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (5) and 24 (6))
The lower edge of freeing ports is to be as near the deck as practicable.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

5.1.5 Freeing port closures

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (6))
If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, b and c))
Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m^2*, in Table 4.*
In ships with no sheer, the above area is to be increased by 50 %. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

Table 4: Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m^2	
	$\ell_B \le 20$	$\ell_B > 20$
Freeboard deck and raised quarterdecks	$0.7 + 0.035\,\ell_B + A_C$	$0.07\,\ell_B + A_C$
Superstructure decks	$0.35 + 0.0175\,\ell_B + 0.5A_C$	$0.035\,\ell_B + 0.5A_C$

where:
ℓ_B : Length, in m, of bulwark in the well, but need in no case to be taken as greater than $0.7\,L_{LL}$
A_C : Area, in m^2, to be taken, with its sign, equal to:

$$A_C = \frac{\ell_B}{25}(h_B - 1.2) \quad \text{for} \quad h_B > 1.2$$
$$A_C = 0 \quad \text{for} \quad 0.9 \le h_B \le 1.2$$
$$A_C = \frac{\ell_B}{25}(h_B - 0.9) \quad \text{for} \quad h_B < 0.9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

5.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0.8 *B*

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, d))
Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0.8 B and the width of the passageways along the side of the ship less than 1.5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Table 4, where ℓ_B *is to be taken equal to the actual length of the well considered.*

5.2.3 Minimum freeing port area for screen bulkhead

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (1, e))
Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [5.1.2].

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing area for continuous trunk or continuous hatchway coaming

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (2))
Where the ship is fitted with a continuous trunk not included in the calculation of freeboard or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m^2*, from Table 5.*

Table 5: Freeing port area in a well contiguous to a continuous trunk or hatchway

Breadth B_H, in m, of hatchway or trunk	Area A_2 of freeing ports, in m^2
$B_H \leq 0.4\,B$	$0.2\,\ell_B h_B$
$0.4B < B_H < 0.75\,B$	$\left[0.2 - 0.286\left(\frac{B_H}{B} - 0.4\right)\right]\ell_B h_B$
$B_H \geq 0.75\,B$	$0.1\,\ell_B h_B$
where: ℓ_B : Length, in m, of bulwark in a well at one side of the ship h_B : Mean height, in m, of bulwark in a well of length ℓ_B.	

Where the ship is fitted with a continuous trunk having breadth not less than $0.6\,B$, included in the calculation of freeboard, and where open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33 % of the total area of the bulwarks.

5.3.2 Freeing area for non-continuous trunk or hatchway coaming

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (3))
Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m^2*, from Table 6.*

Table 6: Freeing port area in a well contiguous to a non-continuous trunk or hatchway

Free flow area f_P, in m^2	Freeing port area A_3, in m^2
$f_P \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1
where: f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark A_1 : Area of freeing ports, in m^2, to be obtained from **Table 4** A_2 : Area of freeing ports, in m^2, to be obtained from **Table 5**.	

5.4 Freeing port area in an open space within superstructures

5.4.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (4))
In ships having superstructures on the freeboard or superstructure decks, which are open at either or

both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

5.4.2 Freeing port area for open superstructures

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (4))
The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m^2*, from the following formula:*

$$A_S = A_1 C_{SH}\left[1-\left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_s}{2\ell_T h_W}\right)$$

where:

ℓ_T : *Total well length, in m, to be taken equal to:*
$\ell_T = \ell_W + \ell_S$

ℓ_W : *Length, in m, of the open deck enclosed by bulwarks*

ℓ_S : *Length, in m, of the common space within the open superstructures*

A_1 : *Freeing port area, in* m^2*, required for an open well of length* ℓ_T*, in accordance with Table 4, where* A_C *is to be taken equal to zero*

C_{SH} : *Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:*
C_{SH} = *1.0 in the case of standard sheer or sheer greater than standard sheer*
C_{SH} = *1.5 in the case of no sheer*

b_0 : *Breadth, in m, of the openings in the end bulkhead of enclosed superstructures*

h_S : *Standard superstructure height, in m, defined in [1.2.1]*

h_W : *Distance, in m, of the well deck above the freeboard deck.*

5.4.3 Freeing port area for open well

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 24 (4))
The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m^2*, from the following formula:*

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2h_W}\right)$$

A_1 : *Freeing port area, in* m^2*, required for an open well of length* ℓ_W*, in accordance with* ***Table 4***

c_{SH}, h_S, h_W, ℓ_W : *Defined in* ***[5.4.2].***

The resulting freeing port areas for the open superstructure A_S *and for the open well* A_W *are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.*

5.5 Freeing port area in bulwarks of the freeboard deck for ships of types B-100 and B-60

5.5.1 Freeing arrangement for type B-60

For type B-60 ships, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 25 % of the total area of the bulwarks in the well considered.
The upper edge of the sheer strake is to be kept as low as possible.

5.5.2 Freeing arrangement for type B-100 ships with trunks

For type B-100 ships, open rails are to be fitted on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts.
Alternatively, if a continuous bulwark is fitted, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 33 % of the total area of the bulwarks in the well considered.

6. Machinery space openings

6.1 Engine room skylights

6.1.1

Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

6.2 Closing devices

6.2.1 Machinery casings

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (1)and 12 (1))
Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.
Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2 Height of the sill of the door

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (1 and 2))
The height of the sill of the door is to be not less than:

- *600 mm above the deck if in position 1*
- *380 mm above the deck if in position 2*
- *230 mm in all other cases.*

6.2.3 Double doors

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (1 and 2))
Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required for ships assigned freeboard less than that based on Table B of the International Load Line Convention, as amended. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

6.2.4 Fiddly openings

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (5))
Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (3))
Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the freeboard

deck or superstructure deck are to be as high above the deck as is reasonable and practicable.
In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [8.1.3], but need not be fitted with weathertight closing appliances.

6.3.2

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 17 (4))
Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7. Companionway

7.1 General

7.1.1 Openings in freeboard deck

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (2))
Openings in freeboard deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (2))
Openings in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck which give access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

7.1.3 Openings in superstructures having height less than standard height

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (3))
Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the height of the superstructure. Openings in the top of the deckhouse on a deckhouse of less than a standard superstructure height may be treated in a similar manner.

7.2 Scantlings

7.2.1

Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (2))
Doorways in deckhouses or companionways leading to or giving access to spaces below the freeboard deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.
Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways

fitted with weathertight doors, the external door need not be weathertight.
Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 18 (4 to 6))
The height above the deck of sills to the doorways in companionways is to be not less than:

- *600 mm in position 1*
- *380 mm in position 2.*

Where access is provided from the deck above as an alternative to access from the freeboard deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the freeboard deck.
Where access is not provided from above, the height of the sills to doorways in deckhouses on the freeboard deck is to be 600 mm.

8. Ventilators

8.1 Closing appliances

8.1.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (4))
Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material.

8.1.2 Closing appliance exemption

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (3))
Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- *4.5 m above the deck in position 1*
- *2.3 m above the deck in position 2.*

8.1.3 Closing appliances for ships of not more than 100 m in length

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (4))
In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships of more than 100 m in length

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (4))
Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with **[8.1.2]**, i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4.5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 19 (1 and 2))
Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.
Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from **Table 7.**
In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

Table 7: Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	h = 900 in position 1 h = 760 in position 2
Thickness of the coaming, in mm(1)	$t = 5.5 + 0.01 d_V$ with $7.5 \le t \le 10$
Support	If $h > 900$ mm, the coaming is to be suitably stiffened or supported by stays.

where:
d_V : External diameter of the ventilator, in mm.
(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6.5 mm.

9. Tank cleaning openings

9.1 General

9.1.1

Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces. ⚓

Chapter 10

Hull Outfitting

Section 1 - RUDDER AND MANOEUVRING ARRANGEMENT

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

C_R : Rudder force, in N

Q_R : Rudder torque, in N.m

A : Total movable area of the rudder, in m^2, measured at the mid-plane of the rudder
For nozzle rudders, A is not to be taken less than 1.35 times the projected area of the nozzle.

A_t : Area equal to A + area of a rudder horn, if any, in m^2

A_f : Portion of rudder area located ahead of the rudder stock axis, in m^2

b : Mean height of rudder area, in m

c : Mean breadth of rudder area, in m, see **Fig 1**

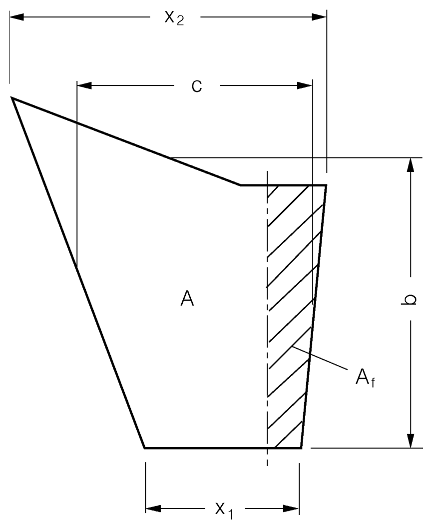
Λ : Aspect ratio of rudder area At, taken equal to:

$$\Lambda = \frac{b^2}{A_t}$$

V_0 : Maximum ahead speed, in knots, as defined in **Ch 1, Sec 4.** If this speed is less than 10, V_0 is to be replaced by:

$$V_{min} = \frac{(V_0 + 20)}{3}$$

V_a : Maximum astern speed, in knots, to be taken not less than 0.5 V_0. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor k_2 is not to be taken less than given in **Table 1** for astern condition.



$$c = \frac{x_1 + x_2}{2} \qquad b = \frac{A}{c}$$

Fig 1: Dimensions of rudder

1. General

1.1 Manoeuvring arrangement

1.1.1

The manoeuvring arrangement includes all parts from the rudder and steering gear to the steering position necessary for steering the ship.

1.1.2

Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section. The steering gear is to comply with the appropriate Rules of the Society.

1.1.3

The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space.

Note: Concerning the use of non-magnetisable material in the wheel house in way of a magnetic compass, the requirements of the national Administration concerned are to be observed.

1.2 Structural details

1.2.1

Effective means are to be provided for supporting the weight of the rudder body without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.2.2

Suitable arrangements are to be provided to prevent the rudder from lifting.

1.2.3

Connections of rudder blade structure with solid parts in forged or cast steel, which are used as rudder stock housing, are to be suitably designed to avoid any excessive stress concentration at these areas.

1.2.4

The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.3 (void)

1.4 Materials

1.4.1

For materials for rudder stock, pintles, coupling bolts etc. refer to the Society’s Rules for Materials.

1.4.2

In general, materials having R_{eH} of less than 200 $\mathrm{N/mm^2}$ and R_m of less than 400 $\mathrm{N/mm^2}$ or more than 900 $\mathrm{N/mm^2}$ are not to be used for rudder stocks, pintles, keys and bolts. The requirements of this

Section are based on a with R_{eH} of 235 N/mm^2. If material is used having a R_{eH} differing from 235 N/mm^2, the material factor k_r is to be determined as follows:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0.75} \quad \text{for} \quad R_{eH} > 235$$

$$k_r = \frac{235}{R_{eH}} \quad \text{for} \quad R_{eH} \le 235$$

where:

R_{eH} : Minimum yield stress of material used, in N/mm^2. R_{eH} is not to betaken greater than 0.7 R_m or 450 N/mm^2, whichever is less.

1.4.3

Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 N/mm^2 are accepted, the Society may require the evaluation of the elastic rudder stock deflections. Large deflections should be avoided in order to avoid excessive edge pressures in way of bearings.

1.4.4

The permissible stresses given in **[5.1]** are applicable for normal strength steel. When higher strength steels are used, higher values may be used for the permissible stresses, on a case by case basis.

2. Rudder force and torque

2.1 Rudder force and torque for normal rudders

2.1.1

The rudder force is to be determined, in N, according to the following formula:

$$C_R = 132\, A V^2 \kappa_1 \kappa_2 \kappa_3 \kappa_t$$

where:

V : V_0 for ahead condition
V_a for astern condition

k_1 : Coefficient, depending on the aspect ratio Λ, taken equal to:
$\kappa_1 = (\Lambda + 2)/3$, where Λ need not be taken greater than 2

k_2 : Coefficient, depending on the type of the rudder and the rudder profile according to **Table 1**

Table 1: Coefficient k_2

Profile / type of rudder	k_2	
	Ahead	Astern
NACA-00 series Göttingen profiles	1.10	0.80
Flat side profiles	1.10	0.90
Mixed profiles (e.g. HSVA)	1.21	0.90
Hollow profiles	1.35	0.90
High lift rudders	1.70	to be specially considered; if not known: 1.30
Fish tail	1.40	0.80
Single plate	1.00	1.00

k_3 : Coefficient, depending on the location of the rudder, taken equal to:

k_3 = 0.80 for rudders outside the propeller jet

k_3 = 1.00 elsewhere, including also rudders within the propeller jet

k_3 = 1.15 for rudders aft of the propeller nozzle

k_t : Coefficient equal to 1.0 for rudders behind propeller. Where a thrust coefficient $C_{Th} > 1.0$, the Society may consider a coefficient k_t different from 1.0, on a case by case basis.

2.1.2

The rudder torque, in Nm, is to be determined by the following formula:

$$Q_R = C_R \cdot r$$

where:

r : Lever of the force C_R, in m, taken equal to:

$r = c(\alpha - k_{bc})$, without being less than 0.1 c for ahead condition

α : Coefficient taken equal to:

α = 0.33 for ahead condition

α = 0.66 for astern condition (general)

α = 0.75 for astern condition (hollow profiles)

For parts of a rudder behind a fixed structure such as a rudder horn:

α = 0.25 for ahead condition

α = 0.55 for astern condition

For high lift rudders is to be specially considered. If not known, $\alpha = 0.40$ may be used for the ahead condition

k_{bc} : Balance factor as follows:

$$k_{bc} = \frac{A_f}{A}$$

$k_{bc} = 0.08$ for unbalanced rudders

2.1.3

Effects of the provided type of rudder/profile on choice and operation of the steering gear are to be observed.

2.2 Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

2.2.1

The total rudder force C_R is to be calculated according to **[2.1.1]**. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength are to be based, is to be obtained as follows:

- the rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, see **Fig 2.**
- the resulting force, in N, of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

2.2.2

The resulting torque, in N.m, of each part is to be taken as:

$$Q_{R1} = C_{R1} \cdot r_1$$

$$Q_{R2} = C_{R2} \cdot r_2$$

where:

$r_1 = c_1(\alpha - k_{b1})$, in m

$r_2 = c_2(\alpha - k_{b2})$, in m

$$k_{b1} = \frac{A_{1f}}{A_1}$$

$$k_{b2} = \frac{A_{2f}}{A_2}$$

A_{1f}, A_{2f} : As defined in **Fig 2**

$$c_1 = \frac{A_1}{b_1}$$

$$c_2 = \frac{A_2}{b_2}$$

b_1, b_2 : Mean heights of the partial rudder areas A_1 and A_2 (see **Fig 2**).

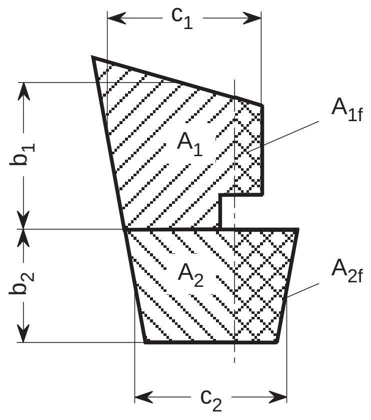


Fig 2: Areas A_1 and A_2

2.2.3

The total rudder torque, in N.m, is to be determined according to the following formulae:

$Q_R = Q_{R1} + Q_{R2}$, without being less than $Q_{R\min} = C_R \cdot r_{1,2\min}$

where:

$r_{1,2\min} = \frac{0.1}{A}(c_1 \cdot A_1 + c_2 \cdot A_2)$, in m.

3. Scantlings of the rudder stock

3.1 Rudder stock diameter

3.1.1

The diameter of the rudder stock, in mm, for transmitting the rudder torque is not to be less than:

$$D_t = 4.2\sqrt[3]{Q_R \cdot k_r}$$

where:

Q_R : As defined in **[2.1.2], [2.2.2]** and **[2.2.3]**

The related torsional stress, in N/mm^2, is:

$$\tau_t = \frac{68}{k_r}$$

where:

k_r : As defined in **[1.4.2]** and **[1.4.3].**

3.1.2

The diameter of the rudder stock determined according to **[3.1.1]** is decisive for the steering gear, the stopper and the locking device.

3.1.3

In case of mechanical steering gear the diameter of the rudder stock in its upper part which is only intended for transmission of the torsional moment from the auxiliary steering gear may be 0.9 D_t. The length of the edge of the quadrangle for the auxiliary tiller must not be less than 0.77 Dt and the height not less than 0.8 Dt.

3.1.4

The rudder stock is to be secured against axial sliding. The degree of the permissible axial clearance depends on the construction of the steering engine and on the bearing.

3.2 Strengthening of rudder stock

3.2.1

If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.
For the increased rudder stock diameter the equivalent stress of bending and torsion, in N/mm^2, is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} \le \frac{118}{k_r}$$

where:

σ_b : Bending stress, in N/mm^2, equal to:

$$\sigma_b = \frac{10.2 M_b}{D_1^3}$$

M_b : Bending moment at the neck bearing, in N.m

τ : Torsional stress, in N/mm^2, equal to:

$$\tau = \frac{5.1 Q_R}{D_1^3}$$

D_1 : Increased rudder stock diameter, in cm, equal to:

$$D_1 = 0.1 D_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_b}{Q_R}\right)^2}$$

Q_R : As defined in **[2.1.2], [2.2.2]** and **[2.2.3]**

D_t : As defined in **[3.1.1].**

Note: Where a double-piston steering gear is fitted, additional bending moments may be transmitted from the steering gear into the rudder stock. These additional bending moments are to be taken into account for determining the rudder stock diameter.

3.3 Analysis

3.3.1 General

The bending moments, shear forces and support forces for the system rudder stock are to be obtained from **[3.3.2]** and **[3.3.3]**, for rudder types as shown in **Fig 3** to **Fig 7.**

3.3.2 Data for the analysis

ℓ_{10} ,.., ℓ_{50} : Lengths, in m, of the individual girders of the system

I_{10} ,.., I_{50} : Moments of inertia of these girders, in cm^4

For rudders supported by a sole piece the length ℓ_{20} is the distance between lower edge of rudder body and centre of sole piece, and I_{20} is the moment of inertia of the pintle in the sole piece.
Load on rudder body, in kN/m, (general):

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3}$$

Load on semi-spade rudders, in kN/m:

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3}$$

C_R, C_{R1}, C_{R2} : As defined in **[2.1]** and **[2.2]**

Z : Spring constant, in kN/m, of support in the sole piece or rudder horn respectively:

for the support in the sole piece (see **Fig 3**):

$$Z = \frac{6.18 \cdot I_{50}}{\ell_{50}^3}$$

for the support in the rudder horn (see **Fig 4**):

$$Z = \frac{1}{f_b + f_t}$$

f_b : Unit displacement of rudder horn, in m/kN, due to a unit force of 1 kN acting in the centre of support

$$f_b = \frac{1.3 d^3 10^8}{3 E I_n}$$

$$f_b = 0.21 \frac{d^3}{I_n} \text{ (guidance value for steel)}$$

I_n : Moment of inertia of rudder horn, in cm^4, around the x-axis at $d/2$ (see **Fig 4**)

f_t : Unit displacement due to a torsional moment of the amount 1, in m/kN

$$f_t = \frac{d e^2}{G J_t}$$

$$f_t = \frac{d e^2 \sum u_i / t_i}{3.14 \cdot 10^8 F_T^2} \text{ for steel}$$

G : Modulus of rigity, $\mathrm{kN/m^2}$:

$G = 7.92 \cdot 10^7$ for steel

J_t : Torsional moment of inertia, in m^4

F_T : Mean sectional area of rudder horn, in m^2

u_i : Breadth, in mm, of the individual plates forming the mean horn sectional area

t_i : Plate thickness of individual plate having breadth u_i, in mm

e, d : Distances, in m, according to **Fig 4**

K_{11}, K_{22}, K_{12} : Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (**Fig 5**). The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

at the lower rudder horn bearing:

$y_1 = - K_{12} B_2 - K_{22} B_1$

at the upper rudder horn bearing:

$y_2 = - K_{11} B_2 - K_{12} B_1$

where

y_1, y_2 : Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively

B_1, B_2 : Horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} : Obtained, in m/kN, from the following formulae:

$$K_{11} = 1.3 \cdot \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \lambda}{GJ_{th}}$$

$$K_{12} = 1.3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d - \lambda)}{2EJ_{1h}} \right] + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{22} = 1.3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d - \lambda)}{EJ_{1h}} + \frac{\lambda \cdot (d - \lambda)^2}{EJ_{1h}} + \frac{(d - \lambda)^3}{3EJ_{2h}} \right] + \frac{e^2 \cdot d}{GJ_{th}}$$

d : Height of the rudder horn, in m, defined in **Fig 5**. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length, in m, as defined in **Fig 5**. This length is measured downwards from the upper rudder hornend, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part

e : Rudder-horn torsion lever, in m, as defined in **Fig 5** (value taken at $z = d/2$)

J_{1h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length (see **Fig 5**)

J_{2h} : Moment of inertia of rudder horn about the x axis, in m4, for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see **Fig 5**)

J_{th} : Torsional stiffness factor of the rudder horn, in m^4
For any thin wall closed section

$$J_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness, in mm, of the individual plates mentioned above.

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

3.3.3 Moments and forces to be evaluated

a) The bending moment M_R and the shear force Q_1 in the rudder body, the bending moment M_b in the neck bearing and the support forces B_1, B_2, B_3 are to be evaluated.
The so evaluated moments and forces are to be used for the stress analyses required by **[3.2]**, **[5]**, **[9.1]** and **[9.2]**

b) For spade rudders (see **Fig 6**) the moments, in N.m, and forces, in N, may be determined by the following formulae:

$$M_b = C_R \left(\ell_{20} + \frac{\ell_{10}(2x_1 + x_2)}{3(x_1 + x_2)} \right)$$

$$B_3 = \frac{M_b}{\ell_{30}}$$

$$B_2 = C_R + B_3$$

c) For spade rudders with rudders trunks (see **Fig 7**) the moments, in N.m, and forces, in N, may be determined by the following formulae:

M_R is the greatest of the following values:

$M_R = C_{R2}(\ell_{10} - CG_{2Z})$

$M_R = C_{R1}(CG_{1Z} - \ell_{10})$

where

C_{R1} : Rudder force over the rudder blade area A_1

C_{R2} : Rudder force over the rudder blade area A_2

CG_{1Z} : Vertical position of the centre of gravity of the rudder blade area A_1

CG_{2Z} : Vertical position of the centre of gravity of the rudder blade area A_2

$M_B = C_{R2}(\ell_{10} - CG_{2Z})$

$B_3 = (M_B + M_{CR1})/(\ell_{20} + \ell_{30})$

$B_2 = C_R + B_3$

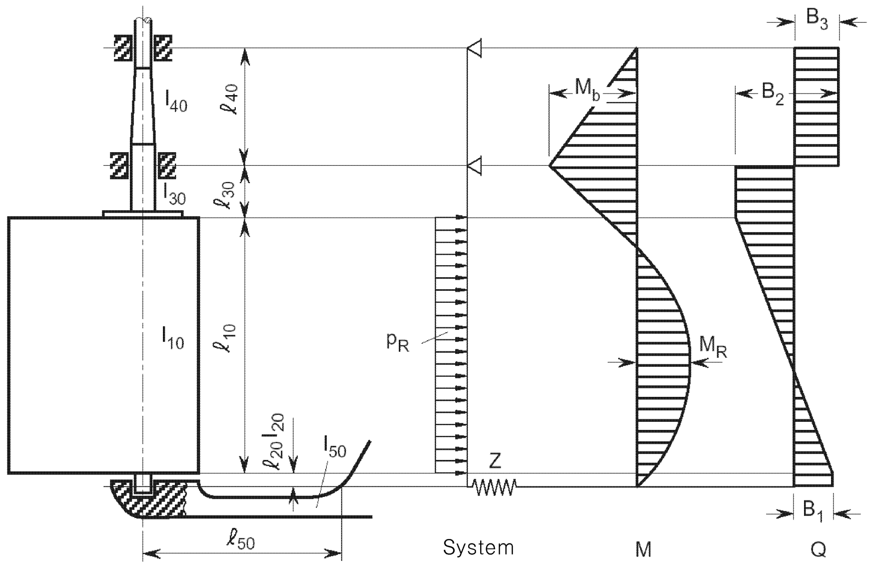


Fig 3: Rudder supported by sole piece

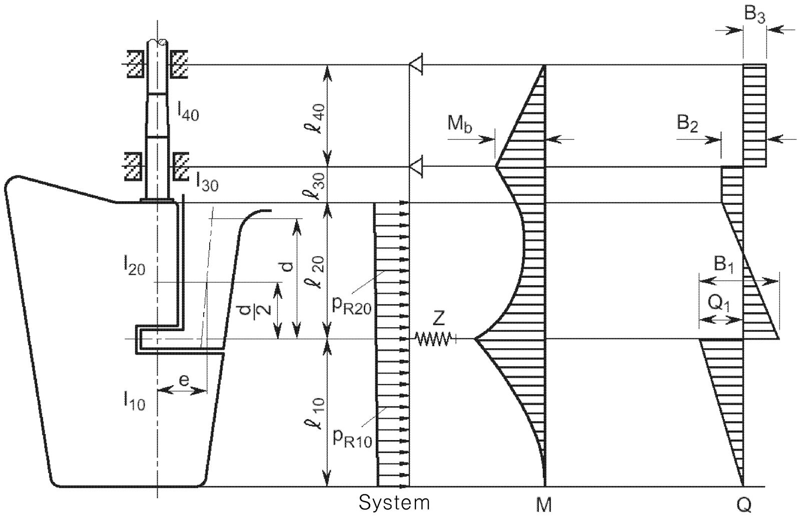


Fig 4: Semi-spade rudder (with 1-elastic support)

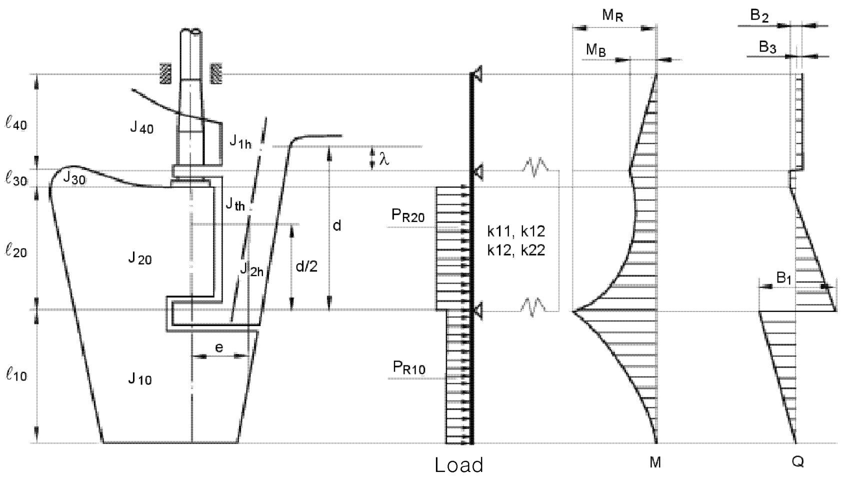


Fig 5: Semi-spade rudder (with 2-conjugate elastic supports)

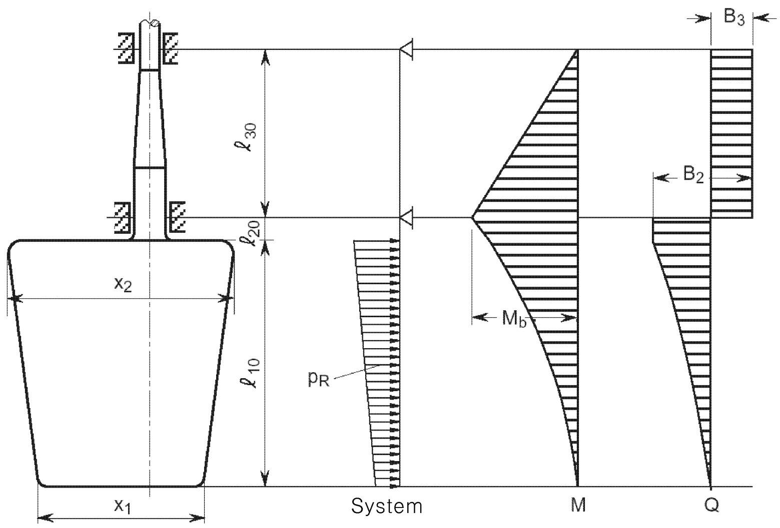


Fig 6: Spade rudder

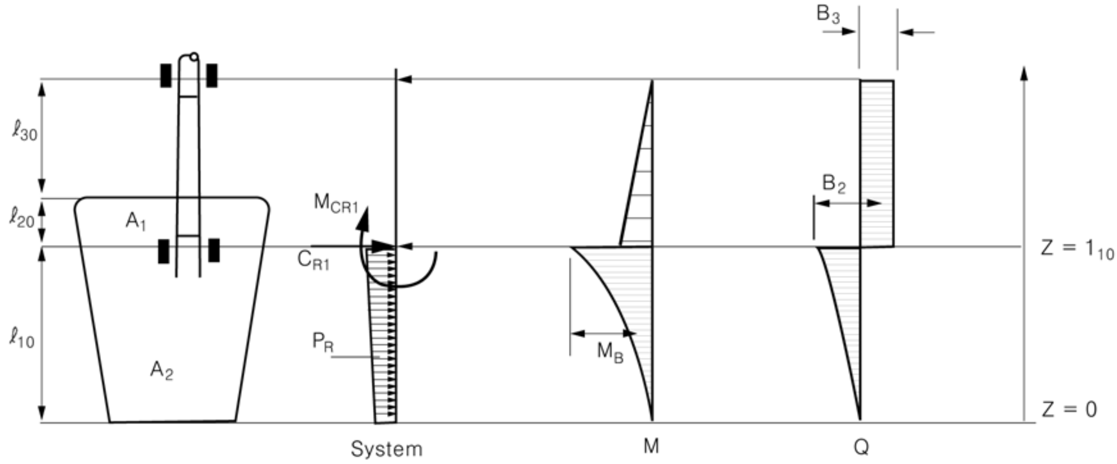


Fig 7: Spade rudders with rudder trunks

3.4 Rudder trunk

3.4.1

Where the rudder stock is arranged in a trunk in such a way that the trunk is stressed by forces due to rudder action, the scantlings of the trunk are to be as such that the equivalent stress due to bending and shear does not exceed $0.35R_{eH}$ of the material used.

3.4.2

In case where the rudder stock is fitted with a rudder trunk welded in such a way the rudder trunk is loaded by the pressure induced on the rudder blade, as given in **[2.1.1]**, the bending stress in the rudder trunk, in $\mathrm{N/mm^2}$, is to be in compliance with the following formula:

$\sigma \leq 80/k$

where the material factor k for the rudder trunk is not to be taken less than 0.7.

For the calculation of the bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

3.4.3

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23 % on ladle analysis and a carbon equivalent CEQ not exceeding 0.41.

3.4.4

The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.
The fillet shoulder radius r, in mm, is to be as large as practicable and to comply with the following formulae:

$r = 60$ when $\sigma \geq 40/k$ $\mathrm{N/mm^2}$

$r = 0.1\,D_l$, without being less than 30, when $\sigma < 40/k$ $\mathrm{N/mm^2}$

where D_l is defined in **[3.2.1]**.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld.
The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

3.4.5

Before welding is started, a detailed welding procedure specification is to be submitted to the Society covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures. This welding procedure is to be supported by approval tests in accordance with the applicable requirements of materials and welding sections of the rules. The manufacturer is to maintain records of welding, subsequent heat treatment and inspections traceable to the welds. These records are to be submitted to the Surveyor.

3.4.6

Non destructive tests are to be conducted at least 24 hours after completion of the welding. The welds are to be 100 % magnetic particle tested and 100 % ultrasonic tested. The welds are to be free from cracks, lack of fusion and incomplete penetration. The non destructive tests reports are to be handed over to the Surveyor.

3.4.7

Rudder trunks in materials other than steel are to be specially considered by the Society.

3.4.8

The thickness of the shell or of the bottom plate is to be compatible with the trunk thickness.

4. Rudder couplings

4.1 General

4.1.1

The couplings are to be designed in such a way as to enable them to transmit the full torque of the rudder stock.

4.1.2

The distance of the bolt axis from the edges of the flange is not to be less than 1.2 times the diameter of the bolt. In horizontal couplings, at least 2 bolts are to be arranged forward of the stock axis.

4.1.3

The coupling bolts are to be fitted bolts. The bolts and nuts are to be effectively secured against loosening.

4.1.4

For spade rudders, horizontal couplings according to **[4.2]** are permitted only where the required thickness of the coupling flanges t_f is less than 50 mm, otherwise cone coupling according to **[4.4]** or **[4.5]**, as applicable, is to be applied. For spade rudders of the high lift type, only cone coupling according to **[4.4]** or **[4.5]**, as applicable, is permitted.

4.2 Horizontal couplings

4.2.1

The diameter of coupling bolts, in mm, is not to be less than:

$$d_b = 0.62\sqrt{\frac{D^3 \cdot k_b}{k_r \cdot n \cdot e}}$$

where:

D : Rudder stock diameter according to **[6]**, in mm

n : Total number of bolts, which is not to be less than 6

e : Mean distance of the bolt axes from the centre of bolt system, in mm

kr : Material factor for the rudder stock as defined in **[1.4.2]**

kb : Material factor for the bolts, obtained according to **[1.4.2].**

4.2.2

The thickness of the coupling flanges, in mm, is not to be less than determined by the following formulae:

$$t_f = 0.62\sqrt{\frac{D^3 \cdot k_f}{k_r \cdot n \cdot e}}$$, without being less than $0.9 d_b$

where:

k_f : Material factor for the coupling flanges, obtained according to **[1.4.2]**

The thickness of the coupling flanges clear of the bolt holes is not to be less than $0.65 t_f$.

The width of material outside the bolt holes is not to be less than $0.67 d_b$.

4.2.3

The coupling flanges are to be equipped with a fitted key according to DIN6885 or equivalent standard for relieving the bolts.
The fitted key may be dispensed with if the diameter of the bolts is increased by 10 %.

4.2.4

Horizontal coupling flanges are to be either forged together with the rudder stock or welded to the rudder stock, according to **[10.1.3].**

4.2.5

For the connection of the coupling flanges with the rudder body, see also **[10].**

4.3 Vertical couplings

4.3.1

The diameter of the coupling bolts, in mm, is not to be less than:

$$d_b = \frac{0.81 \cdot D}{\sqrt{n}}\sqrt{\frac{k_b}{k_r}}$$

where:

D, k_b, k_r, n are defined in **[4.2.1]**, where n is not to be less than 8.

4.3.2

The first moment of area of the bolts, in cm^3, about the centre of the coupling is not to be less than:

$$S = 0.00043 D^3$$

4.3.2

The thickness of the coupling flanges, in mm, is not to be less than $t_f = d_b$
The width of material outside the bolt holes is not to be less than $0.67 d_b$.

4.4 Cone couplings with key

4.4.1

Cone couplings should have a taper c on diameter of 1:8 to 1:12, where $c = (d_0 - d_u)/l$ (see **Fig 8**).
The cone shapes are to fit very exact. The nut is to be carefully secured, e.g. by a securing plate as shown in **Fig 8.**

4.4.2

The coupling length ℓ is to be, in general, not less than $1.5 d_0$.

4.4.3

For couplings between stock and rudder a key is to be provided, the shear area of which, in cm^2, is not to be less than:

$$a_s = \frac{17.55 Q_F}{d_k R_{eH1}}$$

where:

Q_F : Design yield moment of rudder stock, in Nm according to **[6]**

d_k : Diameter of the conical part of the rudder stock, in mm, at the key

R_{eH1} : Minimum yield stress of the key material, in N/mm^2

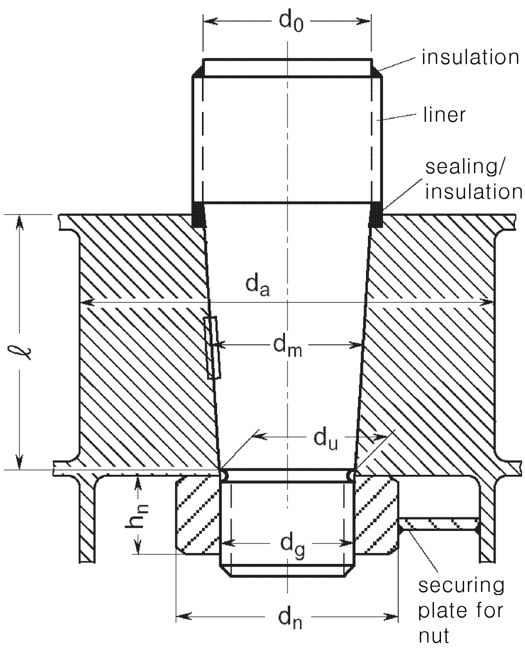


Fig 8: Cone coupling with key

4.4.4

The effective surface area, in cm^2, of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5Q_F}{d_k R_{eH2}}$$

where:

R_{eH2} : Minimum yield stress of the key, stock or coupling material, in N/mm^2, whichever is less.

4.4.5

The dimensions of the slugging nut are to be as follows (see **Fig 8**):

- height: $h_n = 0.6\, d_g$
- outer diameter, the greater value of: $d_n = 1.2\, d_u$ or $d_n = 1.5\, d_g$
- external thread diameter: $d_g = 0.65\, d_0$

4.4.6

It is to be proved that 50 % of the design yield moment will be solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to **[4.5.3]** for a torsional moment $Q'_F = 0.5 \cdot Q_F$.

4.5 Cone couplings with special arrangements for mounting and dismounting the couplings

4.5.1

Where the stock diameter exceeds 200 mm, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, $c \approx 1:12$ to $c \approx 1:20$.

4.5.2

In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. A securing plate for securing the nut against the rudder body is not to be provided (see **Fig 9**).

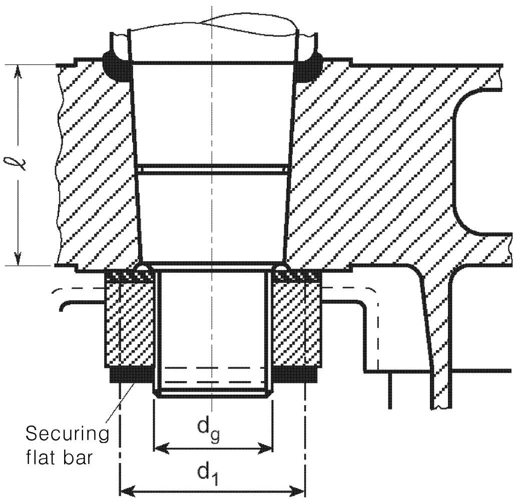


Fig 9: Cone coupling without key

Note: A securing flat bar will be regarded as an effective securing device of the nut, if its shear area, in mm^2, is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}}$$

where:

P_s : Shear force, in N, as follows:

$$p_s = \frac{P_e}{2}\mu_1\left(\frac{d_1}{d_g} - 0.6\right)$$

P_e : Push-up force according to [4.5.3], in N

μ_1 : Frictional coefficient between nut and rudder body, normally $\mu_1 = 0.3$

d_1 : Mean diameter of the frictional area between nut and rudder body

d_g : Thread diameter of the nut

R_{eH} : Minimum yield stress, in N/mm^2, of the securing flat bar material.

4.5.3 Push-up pressure and push-up length

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up length and the push-up pressure are to be determined according to **[4.5.4]** and **[4.5.5].**

4.5.4 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_m^2 \, \ell \, \pi \, \mu_0} 10^3$$

$$p_{req2} = \frac{6 \cdot M_b}{\ell^2 \, d_m} 10^3$$

where:

Q_F : Design yield moment of rudder stock according to **[6]**, in N.m

d_m : Mean cone diameter, in mm

ℓ : Cone length, in mm

μ_0 : Frictional coefficient, equal to about 0.15

M_b : Bending moment in the cone coupling (e.g. in case of spade rudders), in N.m

It has to be proved that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0.8 R_{eH}\left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}}$$

where:

R_{eH} : Minimum yield stress, in N/mm^2, of the material of the gudgeon

$$\alpha = \frac{d_m}{d_a}$$

d_m : Diameter, in mm, as defined in **Fig 8**

d_a : Outer diameter of the gudgeon (see **Fig 8**), in mm, to be not less than 1.5 d_m.

4.5.5 Push-up length

The push-up length, in mm, is not to be less than:

$$\Delta\ell_1 = \frac{p_{req} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c}$$

where:

R_{tm} : Mean roughness, in mm , taken equal to about 0.01

c : Taper on diameter according to **[4.5.1]**

The push-up length, in mm, is, however, not to be taken greater than:

$$\Delta\ell_2 = \frac{1.6\,R_{eH}\,d_m}{E\,c\sqrt{3+\alpha^4}} + \frac{0.8R_{tm}}{c}$$

Note: In case of hydraulic pressure connections the required push-up force P_e for the cone, in N, may be determined by the following formula:

$$P_e = p_{req} \cdot d_m \cdot \pi \cdot \ell\left(\frac{c}{2} + 0.02\right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.
Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by the Society.

4.5.6 Push-up pressure for pintle bearings

The required push-up pressure for pintle bearings, in N/mm^2, is to be determined by the following formula:

$$p_{req} = 0.4\frac{B_1 \cdot d_0}{d_m^2 \cdot \ell}$$

where:

B_1 : Supporting force in the pintle bearing, in N (see **Fig 4**)

d_m, ℓ : As defined in **[4.5.3]**

d_0 : Pintle diameter, in mm, according to **Fig 8.**

5. Rudder body, rudder bearings

5.1 Strength of rudder body

5.1.1

The rudder body is to be stiffened by horizontal and vertical webs in such a manner that the rudder body will be effective as a beam. The rudder should be additionally stiffened at the aft edge.

5.1.2

The strength of the rudder body is to be proved by direct calculation according to **[3.3]**

5.1.3

For rudder bodies without cut-outs the permissible stress are limited to:

- bending stress, in N/mm², due to M_R defined in **[3.3.3]**:
  $\sigma_b = 110$
- shear stress, in N, due to Q_1 defined in **[3.3.3]**:
  $\tau_t = 50$
- equivalent stress due to bending and shear:
  $\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = 120$

In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to **[5.1.4]** apply. Smaller permissible stress values may be required if the corner radii are less than 0.15 h_0, where h_0 is the height of opening.

5.1.4

In rudder bodies with cut-outs (semi-spade rudders) the following stress values are not to be exceeded:

- bending stress, N/mm², due to M_R:
  $\sigma_b = 90$
- shear stress, N/mm², due to Q_1:
  $\tau = 50$
- torsional stress, N/mm²,due to M_t:
  $\tau_t = 50$
- equivalent stress, in N/mm², due to bending and shear and equivalent stress due to bending and torsion:

$$\sigma_{v1} = \sqrt{\sigma_b^2 + 3\tau^2} = 120$$

$$\sigma_{v2} = \sqrt{\sigma_b^2 + 3\tau_t^2} = 100$$

where:

$M_R = C_{R2} \cdot f_1 + B_1 \frac{f_2}{2}$, in N.m

$Q_1 = C_{R2}$, in N

f_1, f_2 : As defined in **Fig 10**

τ_t : Torsional stress, in N/mm², taken equal to:

$$\tau_t = \frac{M_t}{2 \ell h t}$$

$M_t = C_{R2} e$, in N.m

C_{R2} : Partial rudder force, in N, of the partial rudder area A_2 below the cross section under consideration

e : Lever for torsional moment, in m (horizontal distance between the centre of pressure of area A_2 and the centre line a-a of the effective cross sectional area under consideration, see **Fig 10.** The centre of pressure is to be assumed at 0.33 c_2 aft of the forward edge of area A_2, where c_2 is the mean breadth of area A_2).

h, ℓ, t : Dimensions, in cm, as defined in **Fig 10.**

The distance ℓ between the vertical webs should not exceed 1.2 h.
The radii in the rudder plating are not to be less than 4times the plate thickness, but in no case less than 50 mm.

Note: It is recommended to keep the natural frequency of the fully immersed rudder and of local structural components at least 10above the exciting frequency of the propeller (number of revolutions × number of blades) or if relevant above higher order.

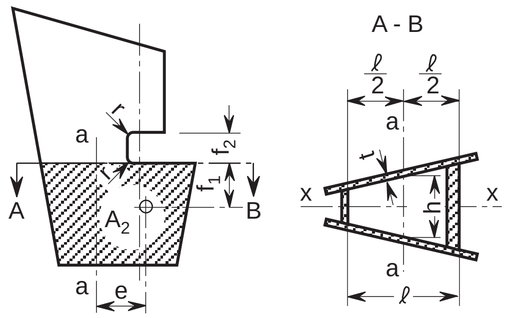


Fig 10: Geometry of rudder

5.2 Rudder plating

5.2.1

The thickness of the rudder plating, in mm, is to be determined according to the following formula:

$$t_P = 1.74 a \beta \sqrt{p_R k} + 2.5$$

where:

$p_R = 10 \cdot T + \dfrac{C_R}{10^3 \cdot A}$, in $\mathrm{kN/m^2}$

a : Smaller unsupported width of a plate panel, in m.

$\beta = \sqrt{1.1 - 0.5\left(\dfrac{a}{b}\right)^2}$ max, 1.00, if $\dfrac{b}{a} \geq 2.5$

b : greatest unsupported width of a plate panel, in m.

However, the thickness is to be not less than the thickness of the shell plating at aft part according to **Ch 9, Sec 2.**
Regarding dimensions and welding, **[10.1.1]** is to be comply with.

5.2.2

For connecting the side plating of the rudder to the webs tenon welding is not to be used. Where application of fillet welding is not practicable, the side plating is to be connected by means of slot welding to flat bars which are welded to the webs.

5.2.3

The thickness of the webs, in mm, is not to be less than 70 % of the thickness of the rudder plating according to **[5.2.1]**, but not less than:

$$t_{\min} = 8\sqrt{k}$$

Webs exposed to seawater are to be dimensioned according to **[5.2.1].**

5.3 Connections of rudder blade structure with solid parts in forged or cast steel

5.3.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

5.3.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm^3, from the following formula:

$$w_S = c_S\, d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:

c_S = 1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate

c_S = 1.5 if there is an opening in the considered cross-section of the rudder

D_1 : Rudder stock diameter, in mm, defined in **[3.2.1]**

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined for the rudder blade plating and the rudder stock, respectively.

5.3.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

s_V : Spacing, in m, between the two vertical webs (see **Fig 11**)

H_X : Distance defined in **[5.3.2]**

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted (see **Fig 11**).

5.3.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t_H = 1.2\, t_P$$

$$t_H = 0.045 \frac{d_S^2}{s_H}$$

where:

t_P : Defined in **[5.2.1]**

d_S : Diameter, in mm, to be taken equal to:

$d_S = D_1$ for the solid part connected to the rudder stock

$d_S = d_a$ for the solid part connected to the pintle

D_1 : Rudder stock diameter, in mm, defined in **[3.2.1]**

d_a : Pintle diameter, in mm, defined in **[5.5.1]**

s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

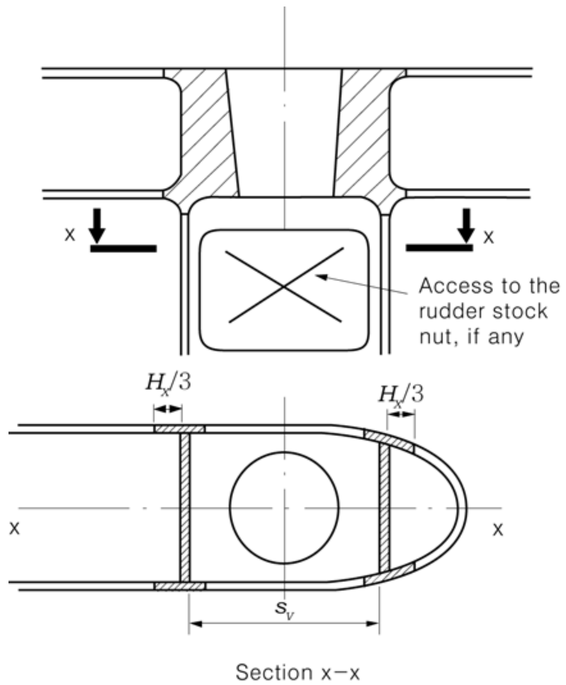


Fig 11: Cross-section of the connection between rudder blade structure and rudder stock housing

5.3.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from **Table 2.**

Table 2: Thickness of side plating and vertical web plates

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Rudder supported by sole piece (**Fig 3**)	1.2 t_P	1.6 t_P	1.2 t_P	1.4 t_P
Semi-spade and spade rudders (**Fig 4** to **Fig 7**)	1.4 t_P	2.0 t_P	1.3 t_P	1.6 t_P
t_P : Defined in [5.2.1]				

5.3.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.
These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

5.3.7

If the torque is transmitted by a prolonged shaft extended into the rudder, the latter must have the diameter D_t or D_l, whichever is greater, at the upper 10% of the intersection length. Downwards it may be tapered to 0.6 D_t, in spade rudders to 0.4 times the strengthened diameter, if sufficient support is provided for.

5.4 Rudder bearings

5.4.1

In way of bearings liners and bushes are to be fitted.
Their minimum thickness is equal to:

- t_{min} = 8 mm for metallic materials and synthetic material
- t_{min} = 22 mm for lignum material

Where in case of small ships bushes are not fitted, the rudder stock is to be suitably increased in diameter in way of bearings enabling the stock to be re-machined later.

5.4.2

An adequate lubrication is to be provided.

5.4.3

The bearing forces result from the direct calculation mentioned in **[3.3]**. As a first approximation the bearing force may be determined without taking account of the elastic supports. This can be done as follows:

- normal rudder with two supports:

  The rudder force C_R is to be distributed to the supports according to their vertical distances from the centre of gravity of the rudder area.
- semi-spade rudders:

  support force in the rudder horn, in N:

$$B_1 = C_R \frac{b}{c}$$

support force in the neck bearing, in N:

$B_2 = C_R - B_1$

For b and c see **Fig 14.**

5.4.4

The projected bearing surface A_b ("bearing height" × "external diameter of liner"), in mm^2, is not to be less than

$$A_b = \frac{B}{q}$$

where:

B : Support force, in N

q : Permissible surface pressure according to **Table 3.**

5.4.5

Stainless and wear resistant steels, bronze and hot-pressed bronze-graphit materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

5.4.6

The bearing height is to be equal to the bearing diameter, however, is not to exceed 1.2 times the bearing diameter. Where the bearing depth is less than the bearing diameter, higher specific surface pressures may be allowed.

Table 3: Surface pressure *q* of bearing materials

Bearing material	q, in N/mm^2
Lignum vitae	2.5
White metal, oil lubricated	4.5
Synthetic material(1)	5.5
Steel(2), bronze and hot-pressed bronze-graphite materials	7.0

(1) Synthetic materials to be of approved type.
Surface pressures exceeding 5.5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2.
(2) Stainless and wear resistant steel in an approved combination with stock liner. Higher surface pressures than 7 N/mm^2 may be accepted if verified by tests.

The wall thickness of pintle bearings in sole piece and rudder horn is to be approximately equal to one fourth of the pintle diameter.

5.5 Pintles

5.5.1

Pintles are to have scantlings complying with the conditions given in **[4.4]** and **[4.6].** The pintle diameter, in mm, is not to be less than:

$$d_a = 0.35\sqrt{B_1 k_r}$$

where:

B_1 : Support force, in N

k_r : Material factor defined in **[1.4.2].**

5.5.2

The thickness of any liner or bush, in mm, is neither to be less than:

$$t = 0.01\sqrt{B_1}$$

nor than the minimum thickness defined in **[5.4.1].**

5.5.3

Where pintles are of conical shape, the taper on diameter is to comply with the following:

- 1:8 to 1:12, if keyed by slugging nut
- 1:12 to 1:20, if mounted with oil injection and hydraulic nut

5.5.4

The pintles are to be arranged in such a manner as to prevent unintentional loosening and falling out. For nuts and threads the requirements of **[4.4.5]** and **[4.5.2]** apply accordingly.

5.6 Criteria for bearing clearances

5.6.1

For metallic bearing material the bearing clearance, in mm, is to be not less:

$$\frac{d_b}{1000} + 1.0$$

where:

d_b : Inner diameter of bush, in mm.

5.6.2

If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties.

5.6.3

The clearance is not to be taken less than 1.5 mm on diameter. In case of self lubricating bushes going down below this value can be agreed to on the basis of the manufacturer's specification.

6. Design yield moment of rudder stock

6.1 General

6.1.1

The design yield moment of the rudder stock is to be determined by the following formula:

$$Q_F = 0.02664 \frac{D_t^3}{k_r}$$

D_t : Stock diameter, in mm, according to **[3.1]**.

Where the actual diameter D_{ta} is greater than the calculated diameter D_t, the diameter D_{ta} is to be used. However, D_{ta} applied to the above formula need not be taken greater than 1.145 D_t.

7. Stopper, locking device

7.1 Stopper

7.1.1

The motions of quadrants or tillers are to be limited on either side by stoppers. The stoppers and their foundations connected to the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock.

7.2 Locking device

7.2.1

Each steering gear is to be provided with a locking device in order to keep the rudder fixed at any position. This device as well as the foundation in the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock as specified in **[6]**. Where the ship's speed exceeds 12 knots, the design yield moment need only be calculated for a stock diameter based on a speed $V_0 = 12$ knots.

7.3

7.3.1

Regarding stopper and locking device see also the applicable requirements of the Society's Rules for Machinery Installations.

8. Propeller nozzles

8.1 General

8.1.1

The following requirements are applicable to propeller nozzles having an inner diameter of up to 5 m. Nozzles with larger diameters will be specially considered.

8.1.2

Special attention is to be given to the support of fixed nozzles at the hull structure.

8.2 Design pressure

8.2.1

The design pressure for propeller nozzles, in kN/m^2, is to be determined by the following formula:

$$p_d = c \cdot p_{d0}$$

$$p_{d0} = \varepsilon \frac{N}{Ap}$$

where:

N : Maximum shaft power, in kW

A_p : Propeller disc area, in m^2, taken equal to:

$$A_p = D^2 \frac{\pi}{4}$$

D : Propeller diameter, in m

ε : Factor obtained from the following formula:

$\varepsilon = 0.21 - 2 \cdot 10^{-4} \frac{N}{A_p}$, without being taken less than 0.1

c : Coefficient taken equal to (see **Fig 12**):

c = 1.0 in zone 2 (propeller zone)

c = 0.5 in zones 1 and 3

c = 0.35 in zone 4.

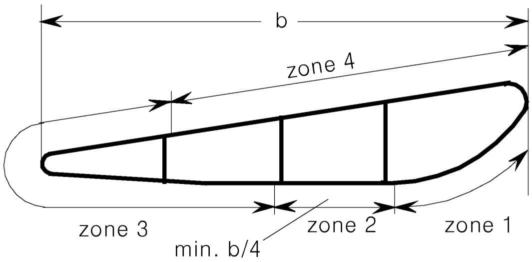


Fig 12: Zones of propeller nozzle

8.3 Plate thickness

8.3.1

The thickness of the nozzle shell plating, in mm, is not to be less than:

$t = t_0 + t_k$, without being taken less than 7.5

where:

t_0 : Thickness, in mm, obtained from the following formula:

$$t_0 = 5a\sqrt{p_d}$$

a : Spacing of ring stiffeners, in m

t_k : Corrosion allowance, in mm, taken equal to:

$t_k = 1.5$ if $t_0 \le 10$

$t_k = \min\left[0.1\left(\frac{t_0}{\sqrt{k}} + 0.5\right), 3.0\right]$ if $t_0 > 10$

8.3.2

The web thickness of the internal stiffening rings is not to be less than the nozzle plating for zone 3, however, in no case be less than 7.5 mm.

8.4 Section modulus

8.4.1

The section modulus of the cross section shown in **Fig 12** around its neutral axis, in cm^3, is not to be less than:

$$w = n d^2 b V_0^2$$

where:

d : Inner diameter of nozzle, in m

b : Length of nozzle, in m

n : Coefficient taken equal to:

$n = 1.0$, for rudder nozzles

$n = 0.7$, for fixed nozzles.

8.5 Welding

8.5.1

The inner and outer nozzle shell plating is to be welded to the internal stiffening rings as far as practicable by double continuous welds. Plug welding is only permissible for the outer nozzle plating.

9. Rudder horn and sole piece scantlings

9.1 Sole piece

9.1.1

The section modulus of the sole piece related to the z-axis, in cm^3, is not to be less than:

$$W_z = \frac{B_1 \cdot x \cdot k}{80}$$

where:

B1 : As defined in **[3.3]**. For rudders with two supports the support force is approximately $B_1 = C_R/2$, when the elasticity of the sole piece is ignored.

x : Distance, in m, of the respective cross section from the rudder axis, with:

$x_{min} = 0.5 \ell_{50}$

$x_{max} = \ell_{50}$

ℓ_{50} : As defined in **Fig 13** and **[3.3.2].**

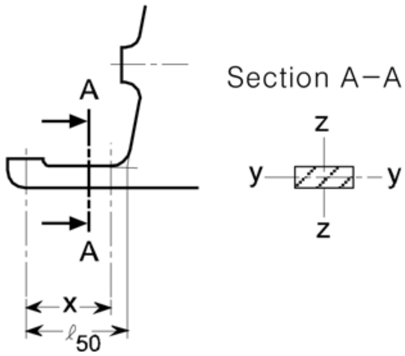


Fig 13: Sole piece

9.1.2

The section modulus related to the y-axis is not to be less than:

- where no rudder post or rudder axle is fitted

$$W_y = \frac{W_z}{2}$$

- where a rudder post or rudder axle is fitted

$$W_y = \frac{W_z}{3}$$

9.1.3

The sectional area, in mm^2, at the location $x = \ell_{50}$ is not to be less than:

$$A_s = \frac{B_1}{48} k$$

9.1.4

The equivalent stress taking into account bending and shear stresses, in N/mm^2, at any location within the length ℓ_{50} is not to exceed:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{115}{k}$$

where:

$$\sigma_b = \frac{B_1 x}{W_z}$$

$$\tau = \frac{B_1}{A_s}$$

9.2 Rudder horn of semi spade rudders (case of 1-elastic support)

9.2.1

The distribution of the bending moment, in N.m, shear force, in N, and torsional moment, in N.m, is to be determined according to the following formulae:

- bending moment: $M_b = B_1 z$

$$M_{b\max} = B_1 d$$

- shear force: $Q = B_1$
- torsional moment: $M_T = B_1 e_{(z)}$

For determining preliminary scantlings the flexibility of the rudder horn may be ignored and the supporting force B_1, in N, be calculated according to the following formula:

$$B_1 = C_R \frac{b}{c}$$

where b, c, d, $e_{(z)}$ and z are defined in **Fig 14** and **Fig 15.**

b results from the position of the centre of gravity of the rudder area.

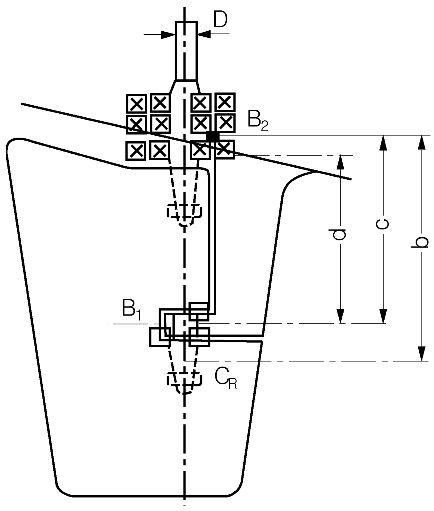


Fig 14: Dimensions of rudder horn

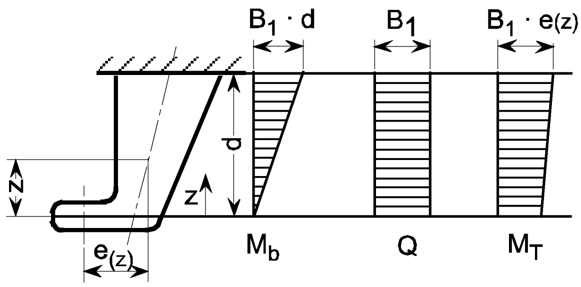


Fig 15: Rudder horn loads

9.2.2

The section modulus of the rudder horn in transverse direction related to the horizontal x-axis is at any location z, in cm^3, not to be less than:

$$W_x = \frac{M_b k}{67}$$

9.2.3

At no cross section of the rudder horn the shear stress, in N/mm^2, due to the shear force Q is to exceed the value:

$$\tau = \frac{48}{k}$$

The shear stress, in N/mm^2, is to be determined by the following formula:

$$\tau = \frac{B_1}{A_h}$$

where:

A_h : Effective shear area of the rudder horn, in mm^2, in y

9.2.4

The equivalent stress, in N/mm^2, at any location zof the rudder horn is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\left(\tau^2 + \tau_T^2\right)} = \frac{120}{k}$$

where:

$$\sigma_b = \frac{M_b}{W_x}$$

$$\tau_T = \frac{M_T}{2 A_T t_h} 10^3$$

A_T : Sectional area, in mm^2, enclosed by the rudder horn at the location considered

t_h : Thickness of the rudder horn plating, in mm.

9.2.5

When determining the thickness of the rudder horn plating the provisions of **[5.2]** to **[5.4]** are to be complied with. The thickness, in mm, is, however, not to be less than $2.4\sqrt{LK}$.

9.2.6

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to longitudinal girders, in order to achieve a proper transmission of forces, see **Fig 16.**

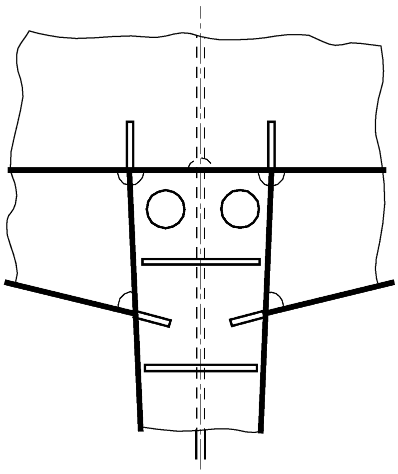


Fig 16: Connection of rudder horn to aft ship structure

9.2.7

Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number and must be of adequate thickness.

9.2.8

Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull. The thickness of these plate floors is to be increased by 50 % above the bottom thickness determined according to **Ch 6, Sec 1** or **Ch 9, Sec 2.**

9.2.9

The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

9.2.10

Where the transition between rudder horn and shell is curved, about 50 % of the required total section modulus of the rudder horn is to be formed by the webs in a section A-A located in the centre of the transition zone, i.e. 0.7 r above the beginning of the transition zone (See **Fig 17**).

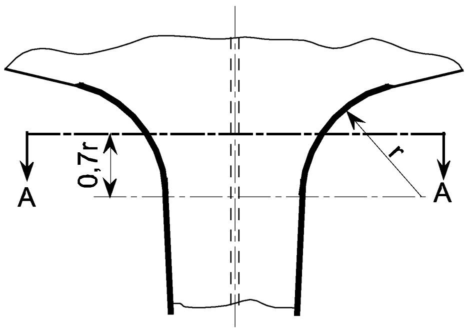


Fig 17: Transition between rudder horn and shell

9.3 Rudder horn of semi spade rudders (case of 2-conjugate elastic supports)

9.3.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formulae:

- between the lower and upper supports provided by the rudder horn:
  $$M_H = F_{A1}\, z$$
- above the rudder horn upper-support:
  $$M_H = F_{A1}\, z + F_{A2}\,(z - d_{lu})$$

where:

F_{A1} : Support force at the rudder horn lower-support, in N, to be obtained according to **Fig 5**, and taken equal to B_1

F_{A2} : Support force at the rudder horn upper-support, in N, to be obtained according to **Fig 5**, and taken equal to B_2

z : Distance, in m, defined in **Fig 19**, to be taken less than the distance d, in m, defined in the same figure

d_{lu} : Distance, in m, between the rudder-horn lower and upper bearings (according to **Fig 18,** $d_{lu} = d - \lambda$).

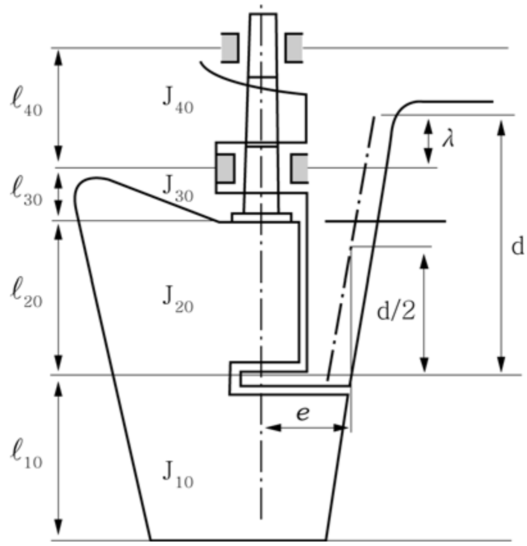


Fig 18: Geometrical parameters for the calculation of the bending moment in rudder horn

9.3.2 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

- between the lower and upper rudder horn bearings:

$$Q_H = F_{A1}$$

- above the rudder horn upper-bearing:

$$Q_H = F_{A1} + F_{A2}$$

where:

F_{A1}, F_{A2} : Support forces, in N.

9.3.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formulae:

- between the lower and upper rudder horn bearings:

$$M_T = F_{A1}\, e_{(z)}$$

- above the rudder horn upper-bearing:

$$M_T = F_{A1}\, e_{(z)} + F_{A2}\, e_{(z)}$$

where:

F_{A1}, F_{A2} : Support forces, in N

$e_{(z)}$: Torsion lever, in m, defined in **Fig 19.**

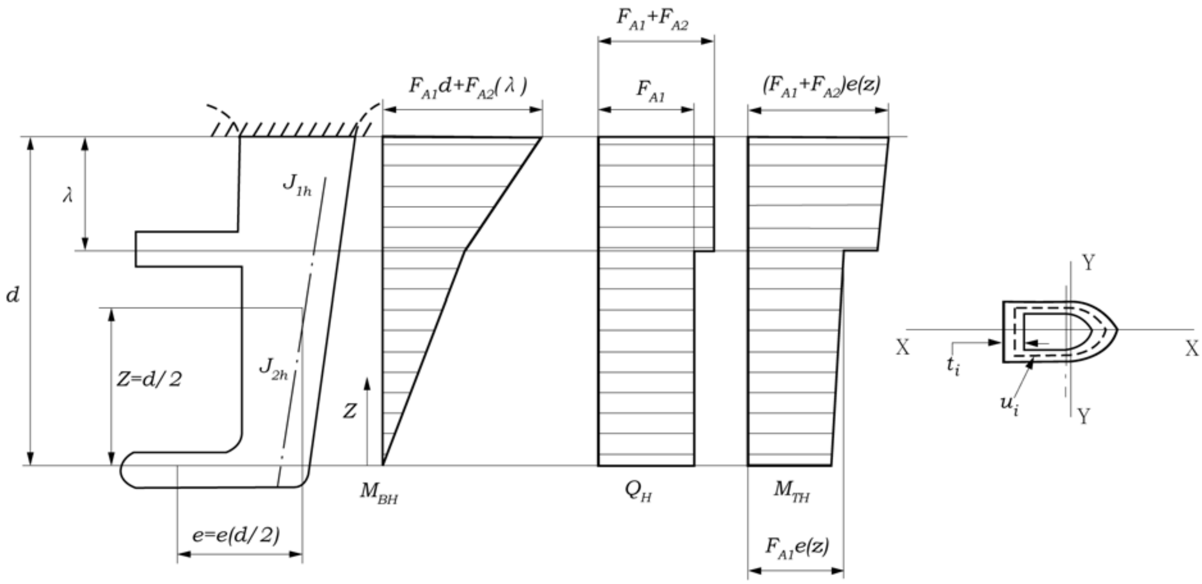


Fig 19: Geometry of rudder horn

9.3.4 Shear stress calculation

a) For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_s = \frac{F_{A1}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis

b) For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_s = \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis

where:

F_{A1}, F_{A2} : Support forces, in N

A_H : Effective shear sectional area of the rudder horn, in mm^2, in y-direction

M_T : Torque, in N.m

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T is obtained at the minimum value of t_H.

9.3.5 Bending stress calculation

For the generic section of the rudder horn within the length d, defined in **Fig 14**, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm^2, to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N.m

W_X : Section modulus, in cm3, around the X-axis (see **Fig 19**).

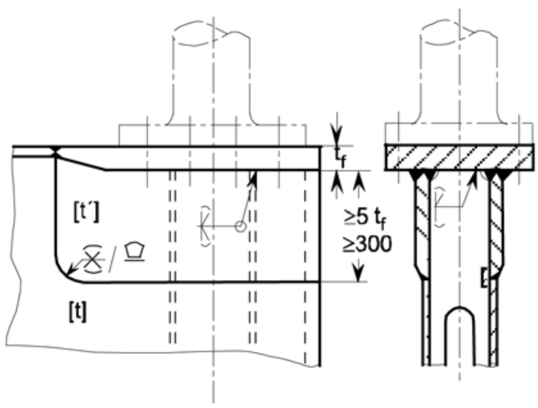
9.3.6 General remarks

Requirements **[9.2.5]** to **[9.2.10]** also apply to rudder horn with 2-conjugate elastic supports.

10. Rudder coupling flanges

10.1.1

Unless forged or cast steel flanges with integrally forged or cast welding flanges are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single or double-bevel welds as prescribed in **Ch 11, Sec 1** (see **Fig 20**).



t = thickness of rudder plating, in mm

t_f = actual flange thickness in mm

$t' = \frac{t_f}{3} + 5$ (mm) where, $t_f < 50$ mm

$t' = 3\sqrt{t_f}$ (mm) where, $t_f \geq 50$ mm

Fig 20: Horizontal rudder coupling flanges

10.1.2

Allowance is to be made for the reduced strength of the coupling flange in the thickness direction. In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

10.1.3

The welded joint between the rudder stock (with thickened collar, see **Ch 11, Sec 2**) and the flange is to be made in accordance with **Fig 21.**

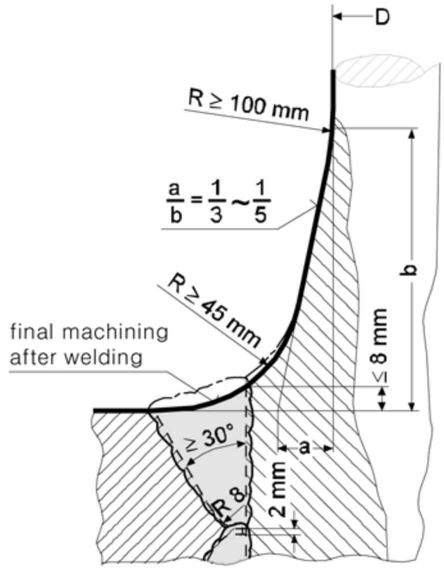


Fig 21: Welded joint between rudder stock and coupling flange

11. Azimuth propulsion system

11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see **Fig 22**):

- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

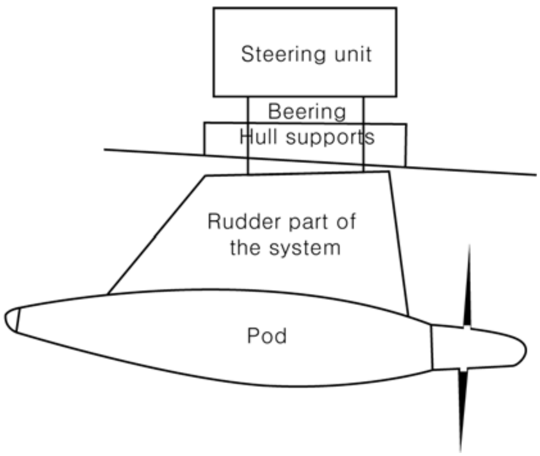


Fig 22: Azimuth propulsion system

11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the relevant requirements of the Society's Rules.

11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.
In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1

The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

- The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.
- The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in **[5.2.1]**, in which the term C_R/A is to be replaced by the lateral pressure calculated according to **[11.3].**

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in **Ch 6, Sec 1** or **Ch 9, Sec 2**, where the lateral pressure is to be calculated according to **[11.3].**

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to **[5.2.3]**, where the lateral pressure is to be calculated according to **[11.3].**

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in **Ch 6, Sec 2** or **Ch 9, Sec 2**, where the lateral pressure is to be calculated according to **[11.3].**

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in **[11.6.2].**
- The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered by the Designer in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see **[11.1.3]**)
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated, in $\mathrm{N/mm^2}$, for the load cases defined in **[11.6.2]**, is in compliance with the following formula:

$$\sigma_E \le \sigma_{ALL}$$

where:

σ_{ALL} : Allowable stress, in $\mathrm{N/mm^2}$, to be taken equal to the lesser of the following values:

$\sigma_{ALL} = 0.275\, R_m$

$\sigma_{ALL} = 0.55\, R_{eH}$

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out in accordance with the requirements in **[11.6.1].**

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in **[11.6.2].**

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports, in N/mm^2, calculated for the load cases defined in **[11.6.2]**, is in compliance with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

where:

σ_{ALL} : Allowable stress, in N/mm^2, equal to $65/k_r$

k_r : Material factor, defined in **[1.4.2]**

Values of σ_E greater than σ_{ALL} may be accepted by the Society on a case by case basis, depending on the localisation of σ_E and on the type of direct calculation analysis.

Section 2 – BULWARKS AND GUARD RAILS

1. General

1.1 Introduction

1.1.1

The requirements of this Section apply to the arrangement of bulwarks and guard rails provided at boundaries of the freeboard deck, superstructure decks and tops of the first tier of deckhouses located on the freeboard deck.

1.2 General

1.2.1

Efficient bulwarks or guard rails are to be fitted at the boundaries of all exposed parts of the freeboard deck and superstructure decks directly attached to the freeboard deck, as well as the first tier of deckhouses fitted on the freeboard deck and the superstructure ends.

1.2.2

The height of the bulwarks or guard rails is to be at least 1 m from the deck. However, where their height would interfere with the normal operation of the ship, a lesser height may be accepted, if adequate protection is provided and subject to any applicable statutory requirement.

1.2.3

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

1.2.4

In type B-100 ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.
Alternatively, freeing ports complying with **Ch 9, Sec 6, [5.5.2]** are to be fitted.

1.2.5

In ships with bulwarks and trunks of breadth not less than $0.6\,B$, which are included in the calculation of freeboard, open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of the exposed parts are to be fitted.
Alternatively, freeing ports complying with **Ch 9, Sec 6, [5.3.1]** are to be fitted.

1.2.6

In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

1.2.7

The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of **Ch 9, Sec 6, [5].**

2. Bulwarks

2.1 General

2.1.1

As a rule, plate bulwarks are to be stiffened at the upper edge by a suitable bar and supported either by stays or plate brackets spaced not more than 2.0 m apart.
The free edge of the stay or the plate bracket is to be stiffened.
Stay and brackets of bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.
As an alternative, the lower end of the stay and bracket may be supported by a longitudinal stiffener.

2.1.2

In type B-60 and B-100 ships, the spacing forward of 0.07 L from the fore end of brackets and stays is to be not greater than 1.2 m.

2.1.3

Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in **[2.2].**

2.1.4

As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.
Failing this, the detail of the connection will be examined by the Society.

2.2 Scantlings

2.2.1

The gross thickness of bulwarks on the freeboard deck not exceeding 1 m in height is to be not less than 6.5 mm.
Where the height of the bulwark is equal to or greater than 1.8 m, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark.
For bulwarks between 1 m and 1.8 m in height, their thickness is to be calculated by linear interpolation.

2.2.2

Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.2.3

At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating. Where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4

The gross section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 77 s h_B^2$$

where:

s : Spacing of stays, in m

hB : Height of bulwark, in m, measured from the top of the deck plating to the upper edge.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.
To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.
For stays with strengthening members not connected to the deck, the calculation of the required section modulus is considered by the Society on a case by case basis.
At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having a width not exceeding 600 mm may also be included in the calculation of the actual gross section modulus of stays.

2.2.5

Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in **[3.1.2].**
For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.2.6

In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the free-board regulations are to be complied with.

3. Guard rails

3.1 General

3.1.1

Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2

The opening below the lowest course is to be not more than 230 mm. The other courses are to be not more than 380 mm apart.

3.1.3

In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.4

Fixed, removable or hinged stanchions are to be fitted about 1.5 m apart. At least every third stanchion is to be supported by a bracket or stay.
Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.5

Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths. Wires are to be made taut by means of turnbuckles.

3.1.6

Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Section 3 - EQUIPMENT

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**
EN : Equipment number defined in **[2.1]**

1. General

1.1 General

1.1.1

The requirements in this Section apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc..
Therefore, the equipment complying with the requirements in this Section is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

1.1.2

The equipment complying with the requirements in this Section is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3

The equipment number *EN* formula for anchoring equipment required here under is based on an assumed current speed of 2.5 m/s, wind speed of 25 m/s and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

1.1.4

It is assumed that under normal circumstances a ship will use one anchor only.

2. Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to **[3.3.5]**), to be obtained from Table 1, based on their equipment number *EN*.
In general, stockless anchors are to be adopted.
For ships with *EN* greater than 16000, the determination of the equipment will be considered by the Society on a case by case basis.

Table 1: Equipment

Equipment number EN $A < EN \le B$		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Grade 1	Grade 2	Grade 3
50	70	2	180	220.0	14.0	12.5	
70	90	2	240	220.0	16.0	14.0	
90	110	2	300	247.5	17.5	16.0	
110	130	2	360	247.5	19.0	17.5	
130	150	2	420	275.0	20.5	17.5	
150	175	2	480	275.0	22.0	19.0	
175	205	2	570	302.5	24.0	20.5	
205	240	3	660	302.5	26.0	22.0	20.5
240	280	3	780	330.0	28.0	24.0	22.0
280	320	3	900	357.5	30.0	26.0	24.0
320	360	3	1020	357.5	32.0	28.0	24.0
360	400	3	1140	385.0	34.0	30.0	26.0
400	450	3	1290	385.0	36.0	32.0	28.0
450	500	3	1440	412.5	38.0	34.0	30.0
500	550	3	1590	412.5	40.0	34.0	30.0
550	600	3	1740	440.0	42.0	36.0	32.0
600	660	3	1920	440.0	44.0	38.0	34.0
660	720	3	2100	440.0	46.0	40.0	36.0
720	780	3	2280	467.5	48.0	42.0	36.0
780	840	3	2460	467.5	50.0	44.0	38.0
840	910	3	2640	467.5	52.0	46.0	40.0
910	980	3	2850	495.0	54.0	48.0	42.0
980	1060	3	3060	495.0	56.0	50.0	44.0
1060	1140	3	3300	495.0	58.0	50.0	46.0
1140	1220	3	3540	522.5	60.0	52.0	46.0
1220	1300	3	3780	522.5	62.0	54.0	48.0
1300	1390	3	4050	522.5	64.0	56.0	50.0
1390	1480	3	4320	550.0	66.0	58.0	50.0
1480	1570	3	4590	550.0	68.0	60.0	52.0
1570	1670	3	4890	550.0	70.0	62.0	54.0
1670	1790	3	5250	577.5	73.0	64.0	56.0
1790	1930	3	5610	577.5	76.0	66.0	58.0
1930	2080	3	6000	577.5	78.0	68.0	60.0
2080	2230	3	6450	605.0	81.0	70.0	62.0
2230	2380	3	6900	605.0	84.0	73.0	64.0
2380	2530	3	7350	605.0	87.0	76.0	66.0
2530	2700	3	7800	632.5	90.0	78.0	68.0
2700	2870	3	8300	632.5	92.0	81.0	70.0
2870	3040	3	8700	632.5	95.0	84.0	73.0
3040	3210	3	9300	660.0	97.0	84.0	76.0
3210	3400	3	9900	660.0	100.0	87.0	78.0
3400	3600	3	10500	660.0	102.0	90.0	78.0

Equipment number EN $A < EN \leq B$		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Grade 1	Grade 2	Grade 3
3600	3800	3	11100	687.5	105.0	92.0	81.0
3800	4000	3	11700	687.5	107.0	95.0	84.0
4000	4200	3	12300	687.5	111.0	97.0	87.0
4200	4400	3	12900	715.0	114.0	100.0	87.0
4400	4600	3	13500	715.0	117.0	102.0	90.0
4600	4800	3	14100	715.0	120.0	105.0	92.0
4800	5000	3	14700	742.5	122.0	107.0	95.0
5000	5200	3	15400	742.5	124.0	111.0	97.0
5200	5500	3	16100	742.5	127.0	111.0	97.0
5500	5800	3	16900	742.5	130.0	114.0	100.0
5800	6100	3	17800	742.5	132.0	117.0	102.0
6100	6500	3	18800	742.5		120.0	107.0
6500	6900	3	20000	770.0		124.0	111.0
6900	7400	3	21500	770.0		127.0	114.0
7400	7900	3	23000	770.0		132.0	117.0
7900	8400	3	24500	770.0		137.0	122.0
8400	8900	3	26000	770.0		142.0	127.0
8900	9400	3	27500	770.0		147.0	132.0
9400	10000	3	29000	770.0		152.0	132.0
10000	10700	3	31000	770.0			137.0
10700	11500	3	33000	770.0			142.0
11500	12400	3	35500	770.0			147.0
12400	13400	3	38500	770.0			152.0
13400	14600	3	42000	770.0			157.0
14600	16000	3	46000	770.0			162.0
(1) See **[3.2.4]**.							

2.1.2 Equipment number

The equipment number EN is to be obtained from the following formula:

$$EN = \Delta^{2/3} + 2hB + 0.1A$$

where:

Δ : Moulded displacement of the ship, in t, to the summer load waterline

h : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$h = a + \Sigma h_n$

When calculating h, sheer and trim are to be disregarded

a : Freeboard amidships from the summer load waterline to the upper deck, in m

h_n : Height, in m, at the centreline of tier "n" of superstructures or deckhouses having a breadth greater than $B/4$. Where a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less, the upper house is to be included and the lower ignored

A : Area, in m^2, in profile view, of the parts of the hull, superstructures and houses above the summer load waterline which are within the length L and also have a breadth greater than $B/4$

Fixed screens or bulwarks 1.5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in **Fig 1** is to be included.
The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

3. Equipment

3.1 General

3.1.1

All anchoring equipment, towing bitts, mooring bollards, fairlead cleats and eyebolts are to be so constructed and attached to the hull that, in use up to design loads, the integrity of the ship will not be impaired.

3.1.2

The anchoring arrangement is to be such as to prevent the cable from being damaged and fouled. Adequate arrangement is to be provided to secure the anchor under all operational conditions.

3.2 Anchors

3.2.1 General

The scantlings of anchors are to be in compliance with the following requirements.
Anchors are to be constructed and tested in compliance with approved plans.

3.2.2 Ordinary anchors

The required mass for each anchor is to be obtained from **Table 1.**
The individual mass of a main anchor may differ by ±7 % from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in **Table 1.**
The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60 % of the total mass of the anchor.
Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80 % of the mass required in **Table 1** for a stockless anchor. The mass of the stock is to be not less than 25 % of the mass of the anchor without the stock but including the connecting shackle.

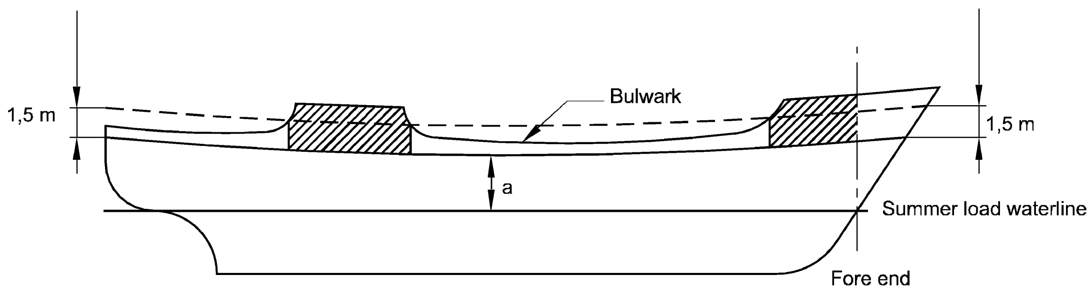


Fig 1: Effective area of bulwarks or fixed screen to be included in the equipment number

3.2.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to the applicable requirements of the Society's Rules for Materials, do not require prior adjustment or special placement on the sea

bottom.
Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75 % or 50 %, respectively, of that required for ordinary stockless anchors in **Table 1.**
The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

3.2.4 Third anchor

Where three anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for use.
The third anchor is intended as a spare and is not required for the purpose of classification.

3.2.5 Test for high holding power anchors approval

For approval and/or acceptance as a HHP anchor, comparative tests are to be performed on various types of sea bottom.
Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.
For approval and/or acceptance as a HHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0.1 times the minimum size tested.

3.2.6 Test for very high holding power anchors approval

For approval and/or acceptance as a VHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass. The holding power test load is to be less than or equal to the proof load of the anchor, specified in the applicable requirements of the Society’s Rules for Materials.
For approval and/or acceptance as a VHHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested, relevant to the bottom, middle and top of the mass range.

3.2.7 Specification for test on high holding power and very high holding power anchors

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case by case basis.
Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or VHHP) of the one to be tested may be accepted by the Society on a case by case basis.
For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.
The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case by case basis.
Three tests are to be carried out for each anchor and type of sea bottom.
The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.
Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.3 Chain cables for anchors

3.3.1 Material

The chain cables are classified as grade 1, 2 or 3 depending on the type of steel used and its manufacture.
The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of the Society's Rules for Materials.
Chain cables made of grade 1 may not be used with high holding power and very high holding power anchors.

3.3.2 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in the applicable requirements of the Society's Rules for Materials.
The diameter of stud link chain cables is to be not less than the value in **Table 1.**

3.3.3 Studless link chain cables

For ships with *EN* less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in the applicable requirements of the Society's Rules for Materials and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in **[3.3.1].**

3.3.4 Chain cable arrangement

Chain cables are to be made by lengths of 27.5 m each, joined together by Dee or lugless shackles.
The total length of chain cable, required in **Table 1**, is to be divided in approximately equal parts between the two anchors ready for use.
Where different arrangements are provided, they are considered by the Society on a case by case basis.
Where the ship may anchor in areas with current speed greater than 2.5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.3.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m
- wire rope for one of the two anchors, for ship length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1.5 times the corresponding required length of stud link chain cables, obtained from **Table 1**, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see **[3.3.2]**).
A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.4 Attachment pieces

3.4.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.
A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in **[3.4.2]**, is to be omitted.
Where the various lengths of chain cable are joined by means of lugless shackles and therefore no spe-

cial end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

3.4.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in **Table 2.** Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having a diameter equal to 1.2 *d*
- increased stud link, having a diameter equal to 1.1 *d*

Where different compositions are provided, they will be considered by the Society on a case by case basis.

Table 2: Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1.4 *d*
Open end link	1.2 *d*
Increased stud link	1.1 *d*
Common stud link	*d*
Lugless shackle	*d*
where: *d* : Diameter, in mm, of the common link.	

3.4.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of the applicable requirements of the Society's Rules for Materials.

3.4.4 Spare attachment pieces

A spare pear-shaped lugless end shackle or a spare attachment piece is to be provided for use when the spare anchor is fitted in place.

3.5 Towlines and mooring lines

3.5.1 General

The towlines having the characteristics defined in **Table 3** are intended as those belonging to the ship to be towed by a tug or another ship.

3.5.2 Materials

Towlines and mooring lines may be of wire, natural or synthetic fibre or a mixture of wire and fibre. The breaking loads defined in **Table 3** refer to steel wires or natural fibre ropes.
Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in the applicable requirements of the Society's Rules for Materials.

3.5.3 Steel wires

Steel wires are to be made of flexible galvanised steel and are to be of types defined in **Table 4.**
Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have

not less than 186 threads in addition to the metallic core.

Table 3: Towlines and mooring lines

Equipment number EN $A < EN \leq B$		Towline(1)		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N(2)	Length of each line, in m	Breaking load, in kN
50	70	180	98.1	3	80	34
70	90	180	98.1	3	100	37
90	110	180	98.1	3	110	39
110	130	180	98.1	3	110	44
130	150	180	98.1	3	120	49
150	175	180	98.1	3	120	54
175	205	180	112	3	120	59
205	240	180	129	4	120	64
240	280	180	150	4	120	69
280	320	180	174	4	140	74
320	360	180	207	4	140	78
360	400	180	224	4	140	88
400	450	180	250	4	140	98
450	500	180	277	4	140	108
500	550	190	306	4	160	123
550	600	190	338	4	160	132
600	660	190	371	4	160	147
660	720	190	406	4	160	157
720	780	190	441	4	170	172
780	840	190	480	4	170	186
840	910	190	518	4	170	201
910	980	190	550	4	170	216
980	1060	200	603	4	180	230
1060	1140	200	647	4	180	250
1140	1220	200	692	4	180	270
1220	1300	200	739	4	180	284
1300	1390	200	786	4	180	309
1390	1480	200	836	4	180	324
1480	1570	220	889	5	190	324
1570	1670	220	942	5	190	333
1670	1790	220	1024	5	190	353
1790	1930	220	1109	5	190	378
1930	2080	220	1168	5	190	402
2080	2230	240	1259	5	200	422
2230	2380	240	1356	5	200	451
2380	2530	240	1453	5	200	481
2530	2700	260	1471	6	200	481
2700	2870	260	1471	6	200	490
2870	3040	260	1471	6	200	500

Equipment number EN $A < EN \leq B$		Towline[1]		Mooring lines		
A	B	Minimum length, in m	Breaking load, in kN	N[2]	Length of each line, in m	Breaking load, in kN
3040	3210	280	1471	6	200	520
3210	3400	280	1471	6	200	554
3400	3600	280	1471	6	200	588
3600	3800	300	1471	6	200	612
3800	4000	300	1471	6	200	647
4000	4200	300	1471	7	200	647
4200	4400	300	1471	7	200	657
4400	4600	300	1471	7	200	667
4600	4800	300	1471	7	200	677
4800	5000	300	1471	7	200	686
5000	5200	300	1471	8	200	686
5200	5500	300	1471	8	200	696
5500	5800	300	1471	8	200	706
5800	6100	300	1471	9	200	706
6100	6500			9	200	716
6500	6900			9	200	726
6900	7400			10	200	726
7400	7900			11	200	726
7900	8400			11	200	735
8400	8900			12	200	735
8900	9400			13	200	735
9400	10000			14	200	735
10000	10700			15	200	735
10700	11500			16	200	735
11500	12400			17	200	735
12400	13400			18	200	735
13400	14600			19	200	735
14600	16000			21	200	735

(1) The towline is not compulsory. It is recommended for ships having length not greater than 180 m.
(2) See **[3.5.4]**.

Table 4: Steel wire composition

Breaking load BL, in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm^2	Composition of wire
$BL < 216$	72	1420 ÷ 1570	6 strands with 7-fibre core
$216 < BL < 490$	144	1570 ÷ 1770	6 strands with 7-fibre core
$BL > 490$	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

3.5.4 Number of mooring lines

When the breaking load of each mooring line is greater than 490 kN, either a greater number of mooring lines than those required in **Table 3** having lower strength, or a lower number of mooring lines than those required in **Table 3** having greater strength may be used, provided the total breaking load of all lines aboard the ship is greater than the value defined in **Table 3.**
In any case, the number of lines is to be not less than 6 and the breaking load of each line is to be greater than 490 kN.

3.5.5 Length of mooring lines

The length of individual mooring lines may be reduced by up to 7 % of the length defined in **Table 3**, provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in **Table 3.**

3.5.6 Equivalence between the breaking loads of synthetic and natural fibre ropes

Generally, fibre ropes are to be made of polyamide or other equivalent synthetic fibres.
The equivalence between the breaking loads of synthetic fibre ropes B_{LS} and of natural fibre ropes B_{LN} is to be obtained, in kN, from the following formula:

$$B_{LS} = 7.4\delta (B_{LN})^{8/9}$$

where:

δ : Elongation to breaking of the synthetic fibre rope, to be assumed not less than 30 %.

3.6 Hawse pipes

3.6.1

Hawse pipes are to be built according to sound marine practice.
Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.
For this purpose chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

3.6.2

In order to obtain an easy lead of the chain cables, the hawse pipes may be provided with rollers. These rollers are to have a nominal diameter not less than 10 times the size of the chain cable where they are provided with full imprints, and not less than 12 times its size where provided with partial imprints only.

3.6.3

All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened to the Surveyor’s satisfaction.

3.7 Windlass

3.7.1 General

The windlass, which is generally single, is to be power driven and suitable for the size of chain cable and the mass of the anchors.
The windlass is to be fitted in a suitable position in order to ensure an easy lead of the chain cables to and through the hawse pipes. The deck in way of the windlass is to be suitably reinforced.

3.7.2 Assumptions for the calculation of the continuous duty pull

The calculation of the continuous duty pull P_C that the windlass unit prime mover is to be able to supply is based on the following assumptions:

- ordinary stockless anchors
- wind force equal to 6 on Beaufort Scale
- water current velocity 3 knots
- anchorage depth 100 m
- P_C includes the influences of buoyancy and hawse pipe efficiency; the latter is assumed equal to 70 %
- the anchor masses assumed are those defined in the applicable requirements of the Society's Rules for Materials, excluding tolerances
- only one anchor is assumed to be raised at a time.

Owing to the buoyancy, the chain masses assumed are smaller than those defined in the applicable requirements of the Society's Rules for Materials, and are obtained, per unit length of the chain cable, in kg/m, from the following formula:

$$m_L = 0.0218\, d^2$$

where d is the chain cable diameter, in mm.

3.7.3 Calculation of the continuous duty pull

According to the assumptions in **[3.7.2]**, the windlass unit prime mover is to be able to supply for a least 30 minutes a continuous duty pull P_C to be obtained,i n kN, from **Table 5.**

Table 5: Continuous duty pull

Material of chain cables	Continuous duty pull, in kN
Mild steel	$P_C = 0.0375\, d^2$
High tensile strength steel	$P_C = 0.0425\, d^2$
Very high tensile strength steel	$P_C = 0.0475\, d^2$
where: d : Chain cable diameter, in mm.	

3.7.4 Temporary overload capacity

The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.
The temporary overload capacity, or short term pull, is to be not less than 1.5 times the continuous duty pull P_C and it is to be provided for at least two minutes.
The speed in this overload period may be lower than the nominal speed specified in **[3.7.5].**

3.7.5 Nominal hoisting speed

The nominal speed of the chain cable when hoisting the anchor and cable, to be assumed as an average speed, is to be not less than 0.15 m/s.
The speed is to be measured over two shots of chain cable during the entire trip; the trial is to commence with 3 shots (82.5 m) of chain fully submerged.

3.7.6 Windlass brake

A windlass brake is to be provided having sufficient capacity to stop the anchor and chain cable when

paying out the latter with safety, in the event of failure of the power supply to the prime mover. Windlasses not actuated by steam are also to be provided with a non-return device.
A windlass with brakes applied and the cable lifter declutched is to be able to withstand a pull of 45 % of the breaking load of the chain without any permanent deformation of the stressed parts or brake slip.

3.7.7 Chain stoppers

Where a chain stopper is fitted, it is to be able to withstand a pull of 80 % of the breaking load of the chain.
Where a chain stopper is not fitted, the windlass is to be able to withstand a pull of 80 % of the breaking load of the chain without any permanent deformation of the stressed part or brake slip.

3.7.8 Green sea loads

Where the height of the exposed deck in way of the item is less than 0.1 L or 22 m above the summer load waterline, whichever is the lesser, the securing devices of windlasses located within the forward quarter length of the ship are to resist green sea forces.
The green sea pressure and associated areas are to be taken equal to (see **Fig 2**):

- 200 $\mathrm{kN/m^2}$ normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction
- 150 $\mathrm{kN/m^2}$ parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction,

where:

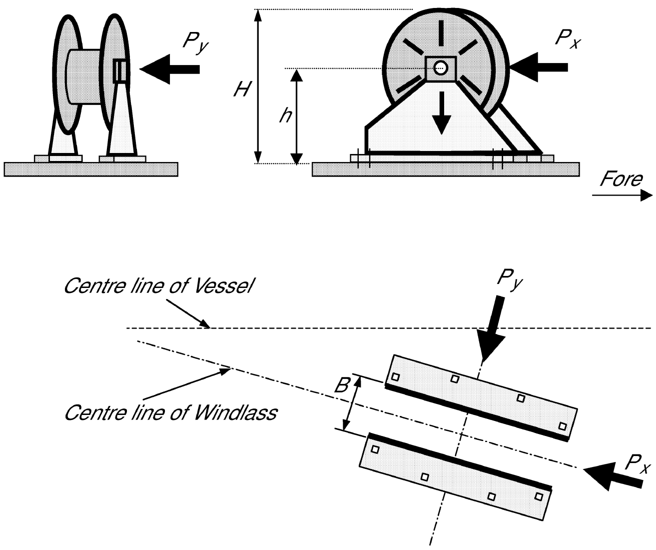
f : Coefficient taken equal to

$$f = 1 + \frac{B}{H}$$, but not greater than 2.5

B : Width of windlass measured parallel to the shaft axis,

H : Overall height of windlass.

Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.



Note: Py to be examined from both inboard and outboard directions separately - see [3.7.8]. The sign convention for y i is reversed when Py is from the opposite direction as shown.

Fig 2: Direction of forces and weight

3.7.9 Forces in the securing devices of windlasses due to green sea loads

Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated by considering the green sea loads specified in **[3.7.8].**
The windlass is supported by N bolt groups, each containing one or more bolts (see also **Fig 3**).
The axial force R_i in bolt group (or bolt) i, positive in tension, is to be obtained, in kN, from the following formulae:

- $R_{xi} = P_x h_{xi} A_i / I_x$
- $R_{yi} = P_y h_{yi} A_i / I_y$
- $R_i = R_{xi} + R_{yi} - R_{si}$

where:

P_x : Force, in kN, acting normal to the shaft axis

P_y : Force, in kN, acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group i

h : Shaft height, in cm, above the windlass mounting

x_i, y_i : X and Y co-ordinates, in cm, of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force

A_i : Cross-sectional area, in cm^2, of all bolts in group I

I_x, I_y : Inertias, for N boltg roups, equal to:

$$I_x = \sum A_i x_i^2$$

$$I_y = \sum A_i y_i^2$$

R_{si} : Static reaction force, in kN, at bolt group i, due to weight of windlass.

Shear forces F_{xi}, F_{yi} applied to the bolt group i, and the resultant combined force F_i are to be obtained, in kN, from the following formulae:

- $F_{xi} = (P_x - \alpha g M)/N$
- $F_{yi} = (P_y - \alpha g M)/N$
- $F_i = (F_{xi}{}^2 + F_{yi}{}^2)^{0,5}$

where:

α : Coefficient of friction, to be taken equal to 0.5

M : Mass, in t, of windlass

N : Number of bolt groups.

Axial tensile and compressive forces and lateral forces calculated according to these requirements are also to be considered in the design of the supporting structure.

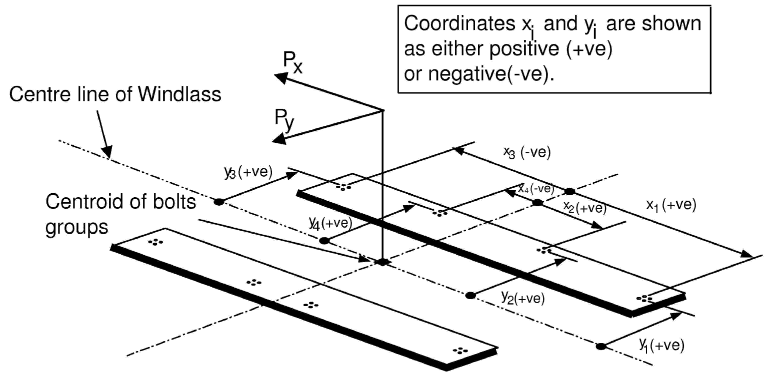


Fig 3: Sign convention

3.7.10 Strength criteria for windlass subject to anchor and chain loads

The stresses on the parts of the windlass, its frame and stopper are to be less than the yield stress of the material used.
For the calculation of the above stresses, special attention is to be paid to:

- stress concentrations in keyways and other stress raisers
- dynamic effects due to sudden starting or stopping of the prime mover or anchor chain
- calculation methods and approximation.

3.7.11 Strength criteria for securing devices of windlass

Tensile axial stresses in the individual bolts in each bolt group *i* are to be calculated according to the requirements specified in **[3.7.9]**. The horizontal forces F_{xi} and F_{yi}, to be calculated according to the requirements specified in **[3.7.9]**, are normally to be reacted by shear chocks.
Where "fitted" bolts are designed to support these shear forces in one or both directions, the equivalent Von Mises stress σ, in $\mathrm{N/mm^2}$, in the individual boltis to comply with following formula:

$$\sigma \leq 0.5\sigma_{BPL}$$

where σ_{BPL} is the stress in the bolt considered as being loaded by the proof load.
Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.7.12 Connection with deck

The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.8 Chain stoppers

3.8.1

A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. A chain stopper is to be capable of withstanding a pull of 80 % of the breaking load of the chain cable. The deck at the chain stopper is to be suitably reinforced.
For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

3.8.2

Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.9 Chain locker

3.9.1

The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.9.2

Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.9.3

The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.
Generally, such attachments are to be able to withstand a force not less than 15 % of the breaking load of the chain cable.
In an emergency, the attachments are to be easily released from outside the chain locker.

3.9.4

Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

3.10 Fairleads and bollards

3.10.1

Fairleads and bollards of suitable size and design are to be fitted for towing, mooring and warping operations. ⚓

Chapter 11

Construction and Testing

Section 1 - CONSTRUCTION

1. Structural details

1.1 Cut-outs, plate edges

1.1.1

The free edges (cut surfaces) of cut-outs, hatch corners, etc. are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc. are not to be welded out, but are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.
Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as laid down in above. This also applies to cutting drag lines, etc., in particular to the upper edge of shear strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

1.1.2

The hatch opening corners are to be machine cut.

1.2 Cold forming

1.2.1

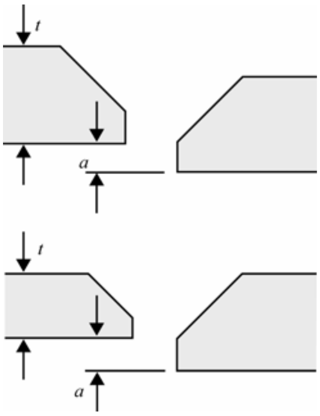
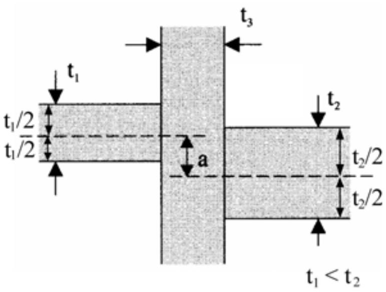
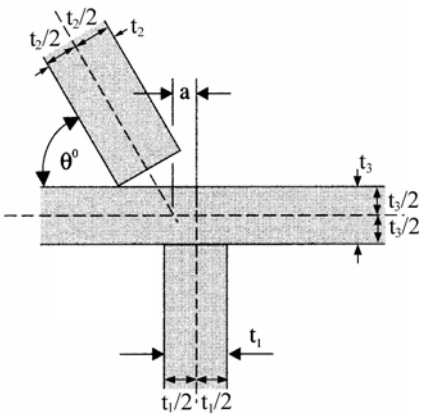
For cold forming (bending, flanging, beading) of corrugated bulkhead the inside bending radius is to be not less than $2\,t$ (t = as-built thickness).
In order to prevent cracking, flame cutting flash or sheering burrs are to be removed before cold forming. After cold forming all structural components and, in particular, the ends of bends (plate edges) are to be examined for cracks. Except in cases where edge cracks are negligible, all cracked components are to be rejected. Repair welding is not permissible.

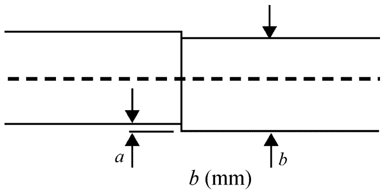
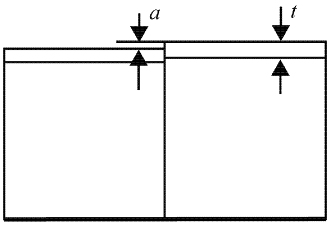
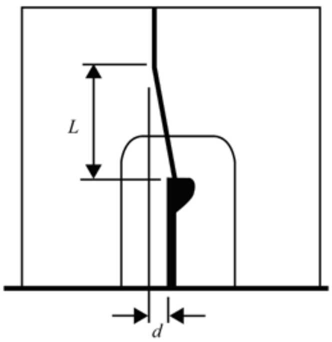
1.3 Assembly, alignment

1.3.1

The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. As far as possible, major distortions of individual structural components are to be corrected before further assembly.
Structural members are to be aligned following the IACS recommendation No.47 provisions given in Table 1 or according to the requirements of a recognised fabrication standard that has been accepted by the Classification Society. In the case of critical components, control drillings are to be made where necessary, which are then to be welded up again on completion.
After completion of welding, straightening and aligning are to be carried out in such a manner that the material properties are not influenced significantly. In case of doubt, the Society may require a procedure test or a working test to be carried out.

Table 1: Alignment (t, t_1 and t_2: as-built thickness)

Detail	Standard	Limit	Remarks
Alignment of butt welds 		$a \le 0.15t$ strength member $a \le 0.2t$ other but maximum 4.0 mm	t is the lesser plate thickness
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substituted for t_1.
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substitute for t_1.
Note: “strength” means the following elements: strength deck, inner bottom, bottom, lower stool, lower part of transverse bulkhead, bilge hopper and side frames of single side bulk carriers.			

Detail	Standard	Limit	Remarks
Alignment of face plates of T longitudinal 	Strength member $a \leq 0.04b$	a = 8.0 mm	
Alignment of height of T-bar, L-angle bar or bulb 	Strength member $a \leq 0.15t$ Other $a \leq 0.2t$	a = 3.0 mm	
Alignment of panel stiffener 	$d \leq L/50$		
Note: "strength" means the following elements: strength deck, inner bottom, bottom, lower stool, lower part of transverse bulkhead, bilge hopper and side frames of single side bulk carriers.			

Section 2 – WELDING

1. General

1.1 Application

1.1.1

The requirements of this Section apply to the preparation, execution and inspection of welded connections in hull structures.

1.1.2

Welding of hull parts is to be carried out by approved welders only.

1.1.3

Welding procedures and welding consumables approved for the types of connection and parent material in question are to be used.

1.1.4

Welding of connections is to be executed according to the approved plans.

1.1.5

The quality standard adopted by the shipyard is to be submitted to the Society and it applies to all welded connections unless otherwise specified on a case by case basis.

1.1.6

Completed weld joints are to be to the satisfaction of the attending Surveyor.

1.1.7

Non destructive examination (NDE) for weld is to be carried out at the position indicated by the test plan in order to ensure that the welds are free from cracks and internal harmful imperfections and defects.

1.2 Welding consumables and procedures

1.2.1

Welding consumables adopted are to be approved by the Society. The requirements for the approval of welding consumables are given in the Society's Rules or guide for welding.

1.2.2

The welding procedures adopted are to be approved by the Society. The requirements for the approval of welding procedures are given in the Society's Rules or guide for welding.

1.2.3

Suitable welding consumables are to be selected depending on the kind and grade of materials. The requirements of the selection of welding consumables are given in the Society's Rules or guide for welding.

1.3 Welders and NDE operators

1.3.1 Welders

Manual and semi-automatic welding is to be performed by welders certified by the Society as specified in the Society's Rules or guide for welding.

1.3.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained and certified by the Society as specified in the Society's Rules or guide for welding.

1.3.3 NDE operator

NDE is to be carried out by qualified personnel certified by the Society or by recognized bodies in compliance with appropriate standards.

1.4 Documentation to be submitted

1.4.1

The welding application plan to be submitted for approval has to contain the necessary data relevant to the fabrication by welding of the structures, kinds of welding procedure applied, welding position, etc.

1.4.2

The NDE plan to be submitted for approval has to contain the necessary data relevant to the locations and number of examinations, welding procedure(s) applied, method of NDE applied, etc.

2. Types of welded connections

2.1 General

2.1.1

The type of welded connections and the edge preparation are to be appropriate to the welding procedure adopted.

2.2 Butt welding

2.2.1 General

Butt connections of plating are to be full penetration, welded on both sides except where special welding procedures approved by the Society is applied.

2.2.2 Welding of plates with different thicknesses

In the case of welding of plates with a difference in as-built thickness equal to or greater than 4 mm, the thicker plate is normally to be tapered. The taper has to have a length of not less than 3 times the difference in as-built thickness.

2.2.3 Edge preparation, root gap

Edge preparations and root gaps are to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.3 Tee or cross joints

2.3.1 General

The connections of primary supporting members and stiffener webs to plating as well as plating abutting on another plating, are to be made by fillet welding or deep penetration weld, as shown in **Fig 1.**

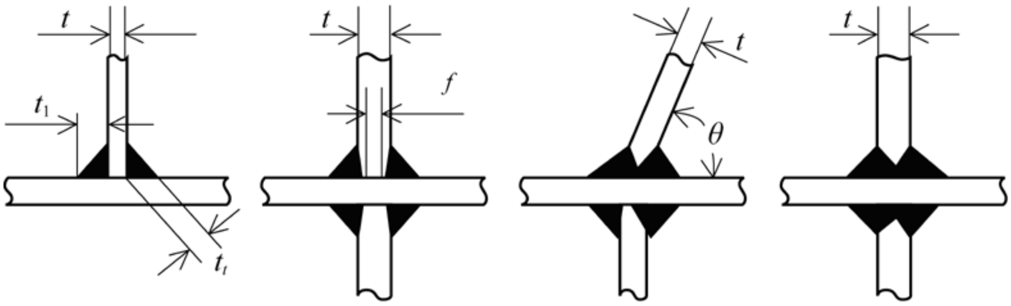


Fig 1: Tee or cross joints

t	:	As-built thickness of abutting plate, in mm
f	:	Unwelded root face, in mm, taken as $f \le t/3$
t_ℓ	:	Leg length of the fillet weld, in mm
t_t	:	Throat thickness, in mm.

2.4 Full penetration welds

2.4.1 Application

Full penetration welds are to be used in the following connections:

- rudder horns and shaft brackets to shell structure
- rudder side plating to rudder stock connection areas
- vertical corrugated bulkhead to inner bottom plating that are situated in the cargo area and arranged without transverse lower stool
- vertical corrugated bulkhead to top plating of transverse lower stool
- pillars to plating member, in case the stress acting on the pillar is tension (i.e. engine room, fore peak and deckhouses)
- edge reinforcement or pipe penetrations both to strength deck, sheer strake and bottom plating within $0.6\,L$ amidships, when the dimension of the opening exceeds 300 mm
- abutting plate panels forming boundaries to sea below summer load waterline.

2.4.2

In case where shedder plates are fitted at the lower end of corrugated bulkhead, the shedder plates are to be welded to the corrugation and the top plate of the transverse lower stool by one side penetration welds or equivalent.

2.4.3

The transverse lower stool side plating is to be connected to the transverse lower stool top plating and the inner bottom plating by full penetration welds. Deep penetration welds may be accepted.

2.4.4

The supporting floors are to be connected to the inner bottom plating by full penetration welds. Deep penetration welds may be accepted.

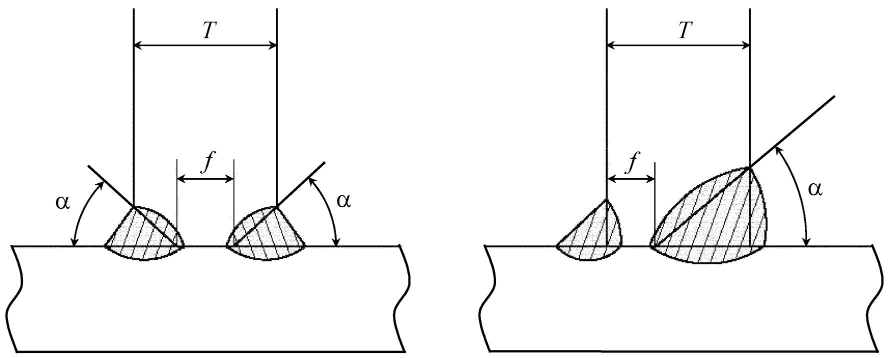
2.4.5

Generally, adequate groove angle between 40 and 60 degrees and root opening is to be taken and if necessary back gouging for both side welding is required.

2.5 Deep penetration weld

2.5.1

Deep penetration weld is defined as **Fig 2.**



- Root face (f) : 3 mm to T/3 mm
- Groove angle (α) : 40° to 60°

Fig 2: Deep penetration weld

2.6 Fillet welds

2.6.1 Kinds and size of fillet welds and their applications

Kinds and size of fillet welds for as-built thickness of abutting plating up to 50 mm are classed into 5 categories as given in **Table 1** and their application to hull construction is to be as required by **Table 2.** In addition, for zones "*a*" and "*b*" of side frames as shown in **Ch 3, Sec 6, Fig 19**, the weld throats are to be respectively 0.44 t and 0.4 t, where t is as-built thickness of the thinner of two connected members.

Table 1: Categories of fillet welds

Category	Kinds of fillet welds	As-built thickness of abutting plate, t, in mm(1)	Leg length of fillet weld, in mm(2)	Length of fillet welds, in mm	Pitch, in mm
F0	Double continuous weld	t	0.7 t	-	-
F1	Double continuous weld	$t \le 10$	0.5 t + 1.0	-	-
		$10 \le t < 20$	0.4 t + 2.0	-	-
		$20 \le t$	0.3 t + 4.0	-	-
F2	Double continuous weld	$t \le 10$	0.4 t + 1.0	-	-
		$10 \le t < 20$	0.3 t + 2.0	-	-
		$20 \le t$	0.2 t + 4.0	-	-
F3	Double continuous weld	$t \le 10$	0.3 t + 1.0	-	-
		$10 \le t < 20$	0.2 t + 2.0		
		$20 \le t$	0.1 t + 4.0		
F4	Intermittent weld	$t \le 10$	0.5 t + 1.0	75	300
		$10 \le t < 20$	0.4 t + 2.0		
		$20 \le t$	0.3 t + 4.0		

(1) t is as-built thickness of the abutting plate, in mm. In case of cross joint as specified in **Fig 1**, t is the thinner thickness of the continuous member and the abutting plate, to be considered independently for each abutting plate.

(2) Leg length of fillet welds is made fine adjustments corresponding to the corrosion addition t_c specified in **Ch 3, Sec 3, Table 1** as follows:

+1.0mm	for $t_c > 5$
+0.5mm	for $5 \ge t_c > 4$
+0.0mm	for $4 \ge t_c > 3$
-0.5mm	for $t_c \le 3$

(3) Leg length is rounded to the nearest half millimetre.

Table 2: Application of fillet welds

Hull area	Connection: Of		Connection: To		Category
General, unless otherwise specified in the table(1)	Watertight plate		Boundary plating		F1
	Brackets at ends of members				F1
	Ordinary stiffener and collar plates		Deep tank bulkheads		F3
			Web of primary supporting members and collar plates		F2
	Web of ordinary stiffener		Plating (Except deep tank bulkhead)		F4
			Face plates of built-up stiffeners	At ends (15 % of span)	F2
				Elsewhere	F4
	End of primary supporting members and ordinary stiffeners without brackets		Deck plate, shell plate, inner bottom plate, bulkhead plate		F0
	End of primary supporting members and ordinary stiffeners with brackets		Deck plate, shell plate, inner bottom plate, bulkhead plate		F1
Bottom and double bottom	Ordinary stiffener		Bottom and inner bottom plating		F3
	Center girder		Shell plates in strengthened bottom forward		F1
			Inner bottom plate and shell plate except the above		F2
	Side girder including intercostal plate		Bottom and inner bottom plating		F3
	Floor		Shell plates and inner bottom plates	At ends, on a length equal to two frame spaces	F2
			Center girder and side girders in way of hopper tanks		F2
			Elsewhere		F3
	Bracket on center girder		Center girder, inner bottom and shell plates		F2
	Web stiffener		Floor and girder		F3
Side and inner side in double side structure	Web of primary supporting members		Side plating, inner side plating and web of primary supporting members		F2
Side frame of single side structure	Side frame and end bracket		Side shell plate		See **Ch 3, Sec 6, Fig 19**
	Tripping bracket		Side shell plate and side frame		F1
Deck	Strength deck	$t \geq 13$	Side shell plating within 0.6 L midship		Deep penetration
			Elsewhere		F1
		$t < 13$	Side shell plating		F1
	Other deck		Side shell plating		F2
			Ordinary stiffeners		F4
	Ordinary stiffener and intercostal girder		Deck plating		F3
	Hatch coamings		Deck plating	At corners of hatchways for 15 % of the hatch length	F1
				Elsewhere	F2
	Web stiffeners		Coaming webs		F4

Hull area	Connection Of	Connection To		Category
Bulkheads	Non-watertight bulkhead structure	Boundaries	Swash bulkheads	F3
	Ordinary stiffener	Bulkhead plating	At ends (25 % of span), where no end brackets are fitted	F1
Primary supporting members(1)	Web plate	Shell plating, deck plating, inner bottom plating, bulkhead	At end (15 % of span)	F1
			Elsewhere	F2
		Face plate	In tanks, and located within 0.125 L from fore peak	F2
			Face area exceeds 65 cm^2	F2
			Elsewhere	F3
After peak	Internal members	Boundaries and each other		F2
Seating	Girder and bracket	Bed plate	In way of main engine, thrust bearing, boiler bearers and main generator engines	F1
		Girder plate	In way of main engine and thrust bearing	F1
		Inner bottom plate and shell	In way of main engine and thrust bearing	F2
Super-structure and deck houses	External bulkhead	Deck		F1
	Ordinary stiffeners	Side wall and deck plate	At end (15 % of span)	F3
			Elsewhere	F4(2)
	End section of ordinary stiffener and Primary supporting member	Without brackets	Side wall and web of primary supporting members	F1
		With bracket		F2
Pillar	Pillar	Heel and head		F1
Ventilator	Coaming	Deck		F1
Rudder	Rudder frame	Vertical frames forming main piece		F1
		Rudder plate		F3
		Rudder frames except above		F2

(1) For Hatch cover, weld sizes F1, F2 and F3 instead of F0, F1 and F2, respectively, are to be used.
(2) Where the one side continuous welding is applied, the weld size F3 is to be applied.
(3) The interior bulkheads are not included in this category. The welding of the interior bulkheads is to be subjected to the discretion of the Society.

2.6.2 Intermittent welds

Where double continuous fillet welds in lieu of intermittent welds are applied, leg length of fillet welds is to be of category F3.

2.6.3 Size of fillet weld for abutting plating with small angle

Where the angle between an abutting plate and the connected plate is not 90 degrees as shown in **Fig 3**, the size of fillet welds for the side of larger angle is to be increased in accordance with the following formula:

$$t_\ell{}' = t_\ell \frac{1}{\sqrt{2}\sin\left(\frac{\varphi}{2}\right)}$$

where:

t_ℓ : Leg length of the fillet weld, in mm, as defined in **[2.3.1]**

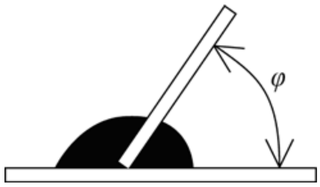


Fig 3: Connecting angle

2.6.4 Deep penetration welds

The leg length of fillet welds of deep penetration type may be reduced by 15 % of that required in **Table 1**, depending on the welding procedure test.

2.7 Lap joint welds

2.7.1 General

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the followings:

- peripheral connections of doublers
- internal structural elements subject to very low stresses.

2.7.2 Fillet welds

Lap joints are to have the fillet size of category F1.

2.8 Slot welds

2.8.1 General

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within $0.6L$ amidships.

2.8.2 Size of fillet welds

The slot welds are to have adequate shape to permit a thoroughly fused bead to be applied all around the bottom edge of the opening. The size of fillet welds is to be category F1 and spacing of slots is to be as determined by the Society on a case by case basis.

3. Connection details

3.1 Bilge keel connection

3.1.1

The intermediate flat, through which the bilge keel is connected to the shell, according to **Ch 3, Sec 6, [6.5.2]**, is to be welded to bilge plating and bilge keel.

3.1.2

The butt welds of the intermediate flat and bilge keel are to be full penetration and shifted from the shell butts.
The butt welds of the bilge plating and those of the intermediate flat are to be flush in way of cross-

ing, respectively, with the intermediate flat and with the bilge keel.

3.1.3

Along the longitudinal edges, the intermediate flat is to be continuously fillet welded with a throat thickness "*a*" of 0.3 times its thickness. At the ends of intermediate flat, the throat thickness "*a*" at the end faces is to be increased to 0.5 times the intermediate flat thickness but is to be less than the bilge plating thickness (see **Fig 4**).
The welded transition at the end faces of the doubling plates to the plating should form with the latter an angle of 45° or less.

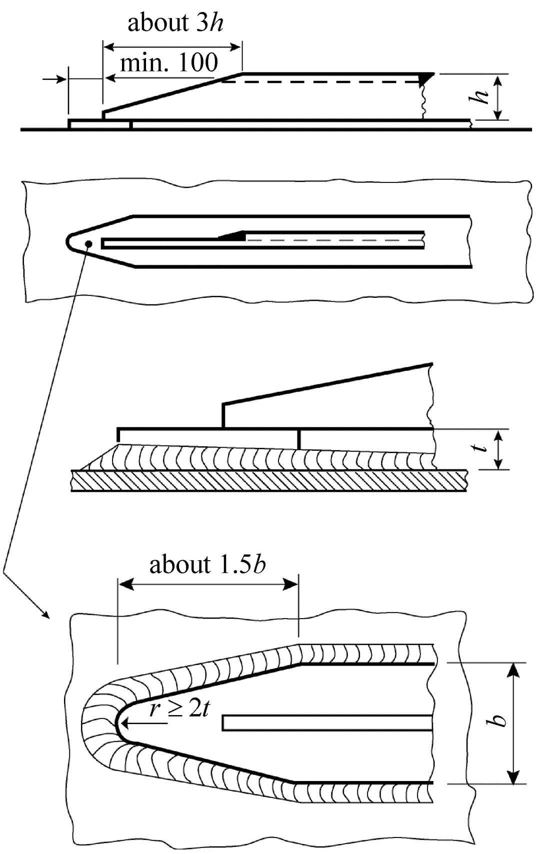


Fig 4: Bilge keel welding arrangement

Section 3 – TESTING OF COMPARTMENTS

1. General

1.1 Definitions

1.1.1 Shop primer

Shop primer is a thin coating applied after surface preparations and prior to fabrication as a protection against corrosion during fabrication.

1.1.2 Protective coating

Protective coating is a final coating protecting the structure from corrosion.

1.1.3 Structural testing

Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of tank), hydropneumatic testing may be carried out instead. When hydropneumatic testing is performed, the conditions should simulate, as far as practicable, the actual loading of the tank.

1.1.4 Hydropneumatic testing

Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank with water up to its top and applying an additional air pressure. The value of additional air pressure is at the discretion of the Society, but is to be at least as defined in **[2.2].**

1.1.5 Leak testing

Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

1.1.6 Hose testing

Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and to other compartments which contribute to the watertight integrity of the hull.

1.2 Application

1.2.1

The following requirements determine the testing conditions for:

- tanks, including independent tanks,
- watertight or weathertight structures.

1.2.2

The purpose of these tests is to check the tightness and/or the strength of structural elements at time of ship construction and on the occasion of major repairs.

1.2.3

Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work not impair the strength and tightness of the structure.

2. Testing methods

2.1 Structural testing

2.1.1

Structural testing may be carried out after application of the shop primer.

2.1.2

Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

- all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating,
- leak testing is carried out prior to the application of the protective coating.

2.1.3

In absence of leak testing, protective coating should be applied after the structural testing of:

- all erection welds, both manual and automatic,
- all manual fillet weld connections on tank boundaries and manual penetration welds.

2.2 Leak testing

2.2.1

Where leak testing is carried out, in accordance with **Table 1**, an air pressure of 0.15×10^5 Pa is to be applied during the test.

2.2.2

Prior to inspection, it is recommended that the air pressure in the tank is raised to 0.20×10^5 Pa and kept at this level for about 1 hour to reach a stabilized state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

2.2.3

The Society may accept that the test is conducted after the pressure has reached a stabilized state at 0.20×10^5 Pa, without lowering pressure, provided they are satisfied of the safety of the personnel involved in the test.

2.2.4

Welds are to be coated with an efficient indicating liquid.

2.2.5

A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure. The U-tube should have a cross section larger than that of the pipe supplying air.
In addition, test pressure is also to be verified by means of one master pressure gauge. The Society may accept alternative means which are considered to equivalently reliable.

2.2.6

Leak testing is to be carried out, prior to the application of protective coating, on all fillet weld connections on tank boundaries, penetrations and erection welds on tank boundaries excepting welds may be automatic processes. Selected locations of automatic erection welds and pre-erection manual or automatic welds may be required to be similarly tested at the discretion of the Surveyor taking account of the quality control procedures operating in the shipyard. For other welds, leak testing may be carried out, after the protective coating has been applied, provided that these welds were carefully inspected visually to the satisfaction of the Surveyor.

2.2.7

Any other recognized method may be accepted to the satisfaction of the Surveyor.

2.3 Hose testing

2.3.1

When hose testing is required to verify the tightness of the structures, as defined in **Table 1**, the minimum pressure in the hose, at least equal to 0.20×10^5 Pa, is to be applied at a maximum distance of 1.5 m. The nozzle diameter is not to be less than 12 mm.

2.4 Hydropneumatic testing

2.4.1

When hydropneumatic testing is performed, the same safety precautions as for leak testing are to be adopted.

2.5 Other testing methods

2.5.1

Other testing methods may be accepted, at the discretion of the Society, based upon equivalency considerations.

3. Testing requirements

3.1 General

3.1.1

General testing requirements for testing are given in **Table 1.** ⚓

Table 1: General testing requirements

Item number	Structural to be tested	Type of testing	Structural test pressure	Remarks
1	Double bottom tanks	Structural testing (1)	The greater of the following: • head of water up to the top of overflow • head of water up to the bulkhead deck	Tank boundaries tested from at least one side
2	Double side tanks	Structural testing (1)	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	Tank boundaries tested from at least one side
3	Tank bulkheads, deep tanks	Structural testing (1)	The greater of the following: (2) • head of water up to the top of overflow • 2.4 m head of water above highest point of tank • setting pressure of the safety relief valves, where relevant	Tank boundaries tested from at least one side
	Fuel oil tanks	Structural testing		
4	Ballast holds	Structural testing (1)	The greater of the following: • head of water up to the top of overflow • 0.90 m head of water above top of hatch	
5	Fore peak and after peak used as tank	Structural testing	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	Tank of the after peak carried out after the stern tube has been fitted
	Fore peak not used as tank	Refer to SOLAS Ch II.1 Reg.14		
	Aft peak not used as tank	Leak testing		
6	Cofferdams	Structural testing (3)	The greater of the following: • head of water up to the top of overflow • 2.4 m head of water above highest point of tank	
7	Watertight bulkheads	Refer to SOLAS Ch II.1 Reg.14 (4)		
8	Watertight doors below freeboard or bulkhead deck	Refer to SOLAS Ch II.1 Reg.18		
9	Double plate rudder	Leak testing		
10	Shaft tunnel clear of deep tanks	Hose testing		
11	Shell doors	Hose testing		

12	Watertight hatchcovers of tanks	Hose testing		
13	Watertight hatchcovers and closing appliances	Hose testing		
14	Chain locker, located aft of collision bulkhead	Structural testing	Head of water up to the top	
15	Independent tanks	Structural testing	Head of water up to the top of overflow, but not less than 0.9 m	
16	Ballast ducts	Structural testing	Ballast pump maximum pressure	

(1) Leak or hydropneumatic testing may be accepted under the conditions specified in **[2.2]**, provided that at least one tank for each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent vessels of series of identical newbuildings. This relaxation does not apply to cargo space boundaries in tankers and combination carriers and tanks for segregated cargoes or pollutants. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.

(2) Where applicable, the highest point of tank is to be measured to the deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tanks is to be taken at the top of hatch.

(3) Leak or hydropneumatic testing may be accepted under the conditions specified in **[2.2]** when, at the Society discretion, the latter is considered significant also in relation to the construction techniques and the welding procedures adopted.

(4) When hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc.) already installed, it may be replaced, at the Society discretion, by a careful visual inspection of all the crossings and weld joints; where necessary, dye penetrant test or ultrasonic test may be required.

Chapter 12

Additional Class Notations

Section 1 – GRAB ADDITIONAL CLASS NOTATION

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

M_{GR} : Mass of unladen grab, in tons

s : Spacing, in m, of ordinary stiffeners, measured at mid-span

1. Basic concepts

1.1 Application

1.1.1

The additional class notation GRAB [X] is assigned, in accordance with **Ch 1, Sec 1, [3.2]**, to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to [X] tons, in compliance with the requirements of this Section.

1.1.2

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

2. Scantlings

2.1 Plating

2.1.1

The net thickness of plating of inner bottom, hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3.0 m above the lowest point of the inner bottom, excluding bilge wells, is to be taken as the greater of the following values:

- t , as obtained according to requirements in **Ch 6** and **Ch 7**
- t_{GR} , as defined in **[2.1.2]** and **[2.1.3].**

2.1.2

The net thickness t_{GR}, in mm, of the inner bottom plating is to be obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 50)\sqrt{sk}$$

2.1.3

The net thickness t_{GR}, in mm, of hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3.0 m above the lowest point of the inner bottom, excluding bilge wells, is to be obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 42)\sqrt{sk}$$ ⚓

Chapter 13

Ships in Operation, Renewal Criteria

Section 1 – MAINTENANCE OF CLASS

1. General

1.1 Application

1.1.1

The survey requirements for the maintenance of class of bulk carriers are given in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers.
Thickness measurements are a major part of surveys to be carried out for the maintenance of class, and the analysis of these measurements is a prominent factor in the determination and extent of the repairs and renewals of the ship's structure.

1.1.2

This Chapter is intended to provide Owners, companies performing thickness measurements and Society's Surveyors with a uniform procedure in order to fulfil rule requirements for thickness measurements. In particular, it will enable all the above-mentioned parties to carry out:

- the planning and preparation
- the determination of extent and location
- the analysis

of the thickness measurements.

1.1.3

This Chapter also takes into account specific requirements for thickness measurements relevant to close-up surveys within the scope of the Enhanced Survey Program (ESP) of single side skin bulk carriers and double side skin bulk carriers.

1.2 Definitions

1.2.1 Local corrosion

Local corrosion is pitting corrosion, grooving, edge corrosion, necking effect or other corrosions of very local aspect.

1.2.2 Substantial corrosion

Substantial corrosion is an extent of corrosion such that assessment of the corrosion pattern indicates gauged (or measured) thickness between $t_{renewal}$ and $t_{renewal} + t_{reserve}$.

Section 2 - THICKNESS MEASUREMENTS AND ACCEPTANCE CRITERIA

Symbols

For symbols not defined in this Section, refer to **Ch 1, Sec 4.**

$t_{renewal}$: Renewal thickness; Minimum allowable thickness, in mm, below which renewal of structural members is to be carried out

$t_{renewal} = t_{as\_built} - t_C - t_{voluntary\_addition}$

$t_{reserve}$: Reserve thickness; Thickness, in mm, to account for anticipated thickness diminution that may occur during a survey interval of 2.5 year. ($t_{reserve}$ = 0.5 mm)

t_C : Corrosion addition, in mm, defined in **Ch 3, Sec 3**

t_{as_built} : As built thickness, in mm, including $t_{voluntary\_addition}$,if any

$t_{voluntary\_addition}$: Voluntary thickness addition; Thickness, in mm, voluntarily added as the Owner's extra margin for corrosion wastage in addition to t_C

t_{gauged} : Gauged thickness, in mm, on one item, i.e average thickness on one item using the various measurements taken on this same item during periodical ship's in service surveys.

1. Application

1.1 General

1.1.1

This section provides the following information:

- references to rule requirements and some additional information on the extent of the thickness measurements to be performed during surveys (see **[2.1]** and **[2.2]**)
- locations of the measurements for the main parts of the ship (see **[2.3]**)
- how to apply the acceptance criteria (see **[3]**).

Tables are also given to detail the above items. The sketches are given as an example to illustrate the requirements.

2. Rule requirements for the extent of measurements and the determination of locations

2.1 General

2.1.1

For the maintenance of class, thickness measurements are required during intermediate and class renewal surveys and may be required during annual surveys.
Table 1 gives the references to the minimum requirements for thickness measurements related to the different types of surveys.

Table 1: References to rule requirements related to thickness measurements

Class renewal survey	Intermediate survey	Annual survey
<u>**Outside the cargo length area:**</u> UR Z7: • systematic measurements and suspect areas. • where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction.	<u>**Outside the cargo length area:**</u> UR Z7: • thickness measurements to be taken if deemed necessary by the Surveyor. • where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction.	<u>**Outside the cargo length area:**</u> UR Z7: • areas of substantial corrosion identified at previous class renewal or intermediate surveys; • where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction.
<u>**Within the cargo length area:**</u> a) single side skin bulk carriers: UR Z10.2: • planning and general requirements • measurements of elements subjected to close-up survey • extent of systematic thickness measurements • according to the different locations, where substantial corrosion is found b) double side skin bulk carriers: UR Z10.5: • planning and general requirements • measurements of elements subjected to close-up survey • extent of systematic thickness measurements • according to the different locations, where substantial corrosion is found	<u>**Within the cargo length area:**</u> a) single side skin bulk carriers: UR Z10.2: *Ships 10 years of age or less:* • for cargo holds • for salt ballast tanks • according to the different locations, where substantial corrosion is found *Ships over 10 years of age:* • see references given for class renewal survey • according to the different locations, where substantial corrosion is found b) double side skin bulk carriers: UR Z10.5: *Ships 10 years of age or less:* • for cargo holds • for salt ballast tanks • according to the different locations, where substantial corrosion is found *Ships over 10 years of age:* • see references given for class renewal survey • according to the different locations, where substantial corrosion is found	<u>**Within the cargo length area:**</u> a) single side skin bulk carriers: UR Z10.2: • for cargo holds and when deemed necessary by the Surveyor • for salt ballast tanks and when deemed necessary by the Surveyor • according to the different locations, where substantial corrosion is found b) double side skin bulk carriers: UR Z10.5: • for cargo holds and when deemed necessary by the Surveyor • for salt ballast tanks and when deemed necessary by the Surveyor • according to the different locations, where substantial corrosion is found

2.2 Class renewal survey

2.2.1

The thickness measurements required by the Rules consist of:

- systematic thickness measurements in order to assess the global and local strength of the ship
- thickness measurements as indicated in the program of close-up survey
- measurements of elements considered as suspect areas
- additional measurements on areas determined as affected by substantial corrosion.

2.2.2

For the determination of close-up surveys and relevant thickness measurements as well as the areas considered as suspect areas, reference is to be made to the relevant Sections of the following IACS Unified Requirements:

- for the hull structure and piping systems in way of cargo holds, cofferdams, pipe tunnels, void spaces, fuel oil tanks within the cargo length area and all ballast tanks:
  - UR Z10.2 “Hull surveys of single skin bulk carriers”
  - UR Z10.5 “Hull surveys of double skin bulk carriers”
- for the remainder of the ship outside the cargo length area:
  - UR Z7.

2.3 Number and locations of measurements

2.3.1 Number of measurements

Considering the extent of thickness measurements as required by the Rules and indicated in **[2.1]** and **[2.2]**, the locations of the points to be measured are given for the most important items of the structure.

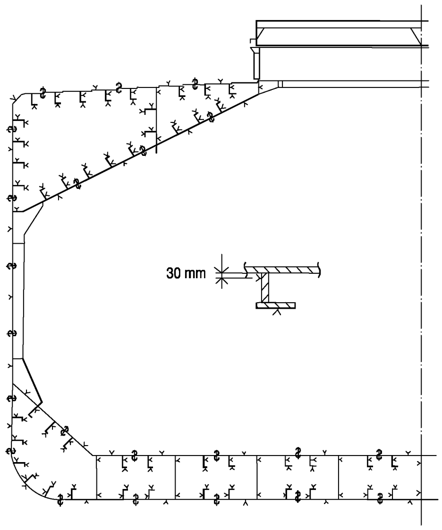
2.3.2 Locations of measurements

Table 2 provides explanations and/or interpretations for the application of those requirements indicated in the Rules which refer to both systematic thickness measurements related to the calculation of global hull girder strength and specific measurements connected to close-up surveys.
Fig 1 to **Fig 5** are provided to facilitate the explanations and/or interpretations given in **Table 2**, to show typical arrangements of single side skin bulk carriers and double side skin bulk carriers.

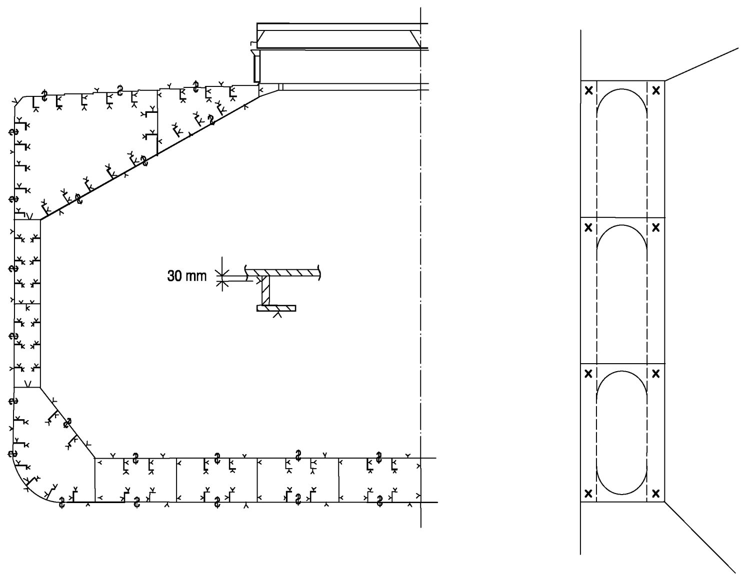
Table 2: Interpretations of rule requirements for the locations and number of points to be measured

Item	Interpretation	Figure reference
Selected plates on deck, tank top, bottom, double bottom and wind-and-water area	«Selected» means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	
All deck, tank top and bottom plates and wind-and-water strakes	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	
Transverse section	Single side skin bulk carrier: A transverse section includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom; inner bottom and hopper side plating, longitudinal bulkhead and bottom plating in top wing tanks. Double side skin bulk carrier: A transverse section includes all longitudinal members such as plating, longitudinals and girders at the deck, sides, bottom, inner bottom, hopper sides, inner sides and top wing inner sides.	Fig 1 for single and double side skin bulk carriers
Cargo hold hatch covers and coamings		Fig 2
Selected internal structure such as floors and longitudinals, transverse frames, web frames, deck beams, girders	The internal structural items to be measured in each space internally surveyed are to be at least 10% outside the cargo length area	

Item	Interpretation	Figure reference
Transverse section of deck plating outside line of cargo hatch openings	Two single points on each deck plate (to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion) between the ship sides and hatch coamings in the transverse section concerned	
Selected areas of all deck plating inside line of hatch openings	«Selected» means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion «All deck plating» means at least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	Extent of areas is shown in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers
Selected side shell frames in cargo holds for single side skin bulk carriers	25 % of frames: one out of four frames should preferably be chosen throughout the cargo hold length on each side «Selected frames» means at least 3 frames on each side of cargo holds	Extent of areas is shown in UR Z10.2 for single side skin bulk carriers. Locations of points are given in **Fig 3** for single side skin bulk carriers
Transverse frame in double skin tank		**Fig 1**
Transverse bulkheads in cargo holds	Includes bulkhead plating, stiffeners and girders, including internal structure of upper and lower stools, where fitted. Two selected bulkheads: one is to be the bulkhead between the two foremost cargo holds and the second may be chosen in other positions	Areas of measurements are shown in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers. Locations of points are given in **Fig 4.**
One transverse bulkhead in each cargo hold	This means that the close-up survey and related thickness measurements are to be performed on one side of the bulkhead; the side is to be chosen based on the outcome of the overall survey of both sides. In the event of doubt, the Surveyor may also require (possibly partial) close-up survey on the other side	Areas of measurements are shown in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers. Locations of points are given in **Fig 4.**
Transverse bulkheads in one topside/side ballast tank	The ballast tank is to be chosen based on the history of ballasting among those prone to have the most severe conditions	Locations of points are given in **Fig 5.**
Transverse webs in ballast tanks	One of the representative tanks of each type (i.e. topside or hopper or side tank) is to be chosen in the forward part	Extent of areas is shown in UR Z10.2 for single side skin bulk carriers and in UR Z10.5 for double side skin bulk carriers. Locations of points are given in **Fig 3.**



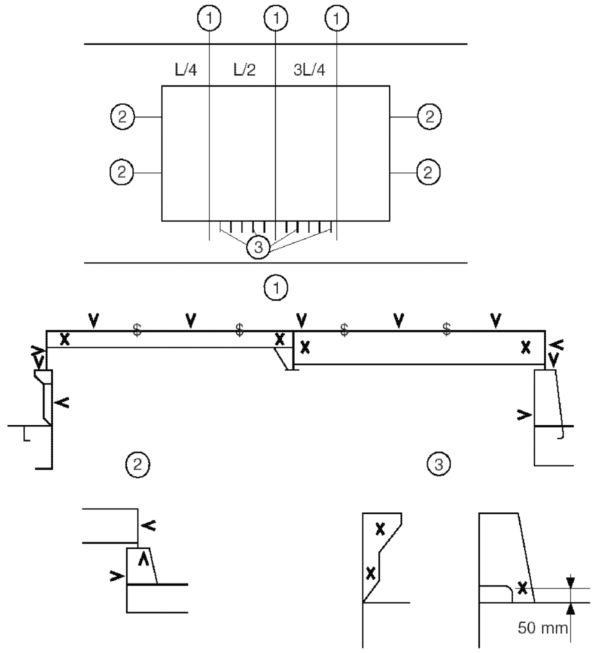
Single side bulk carriers



Double side bulk carrier

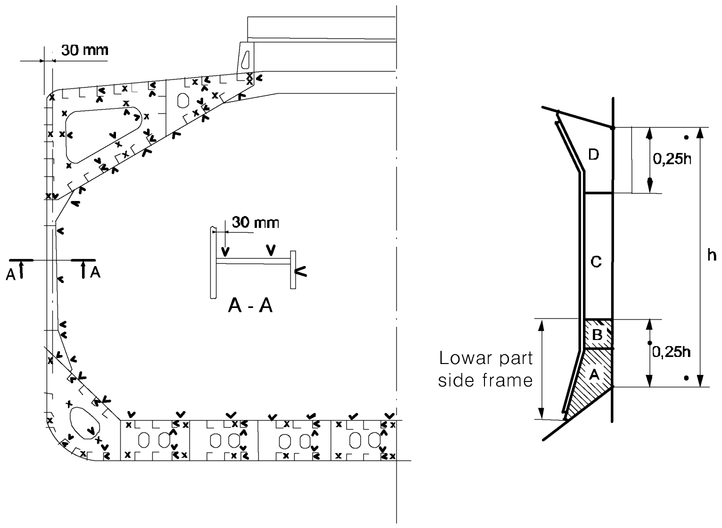
Note : Measurements are to be taken on both port and starboard sides of the selected transverse section.

Fig 1: Transverse section of bulk carrier



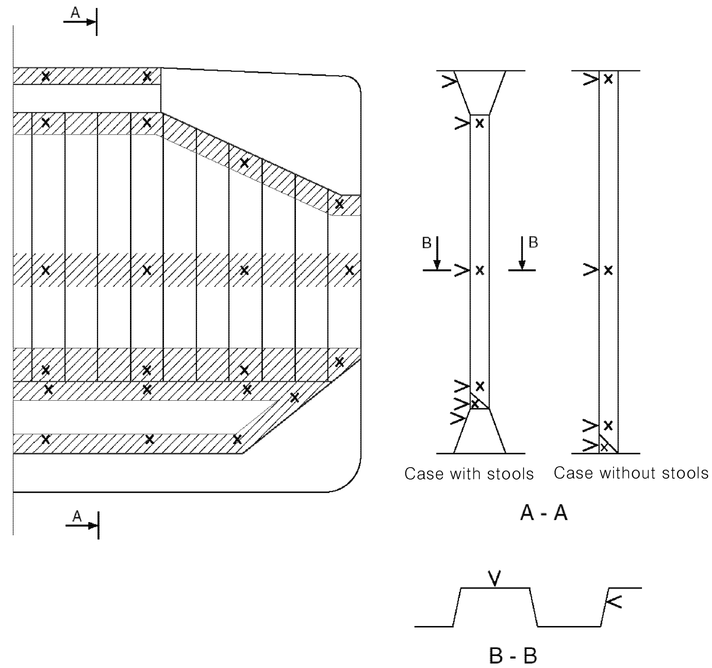
Notes :
1. Three sections at L/4, L/2, 3L/4 of hatch cover length, including:
   - one measurement of each hatch cover plate and skirt plate
   - measurements of adjacent beams and stiffeners
   - one measurement of coaming plates and coaming flange, each side
2. Measurements of both ends of hatch cover skirt plate, coaming plate and coaming flange
3. One measurement of one out of three hatch coaming brackets and bars, on both sides and both ends

Fig 2: Locations of measurements on hatch covers and coamings



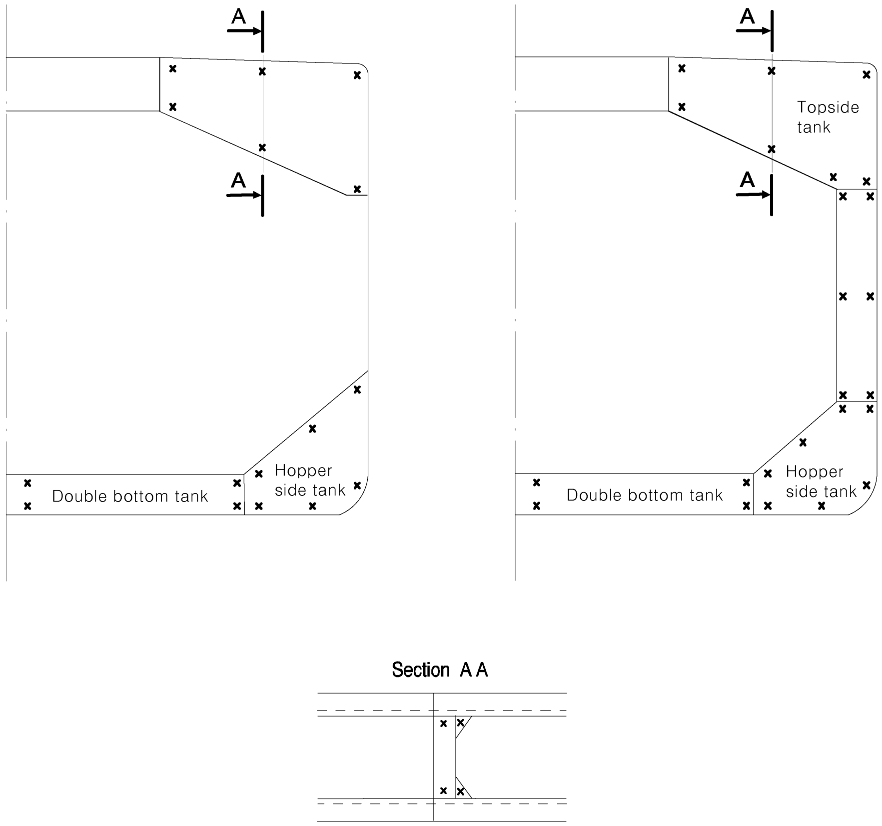
Note : The gauging pattern for web plating is to be a three point pattern for zones A, C and D, and a two point pattern for zone B (see figure). The gauging report is to reflect the average reading. The average reading is to be compared with the allowable thickness. If the web plating has general corrosion then this pattern is to be expanded to a five point pattern.

Fig 3: Locations of measurements on structural members in cargo holds and ballast tanks of single side skin bulk carriers



Note : Measurements to be taken in each shaded area as per views A-A and B-B

Fig 4: Locations of measurements on cargo hold transverse bulkheads



Note : Measurements to be taken in each vertical section as per view A-A

Fig 5: Locations of measurements on transverse bulkheads of topside, hopper, double hull and double bottom tanks

3. Acceptance Criteria

3.1 Definitions

3.1.1 Deck zone

The deck zone includes all the following items contributing to the hull girder strength above the horizontal strake of the topside tank or above the level corresponding to $0.9\,D$ above the base line if there is no topside tank:

- strength deck plating
- deck stringer
- sheer strake
- side shell plating
- top side tank sloped plating, including horizontal and vertical strakes
- longitudinal stiffeners connected to the above mentioned platings.

3.1.2 Bottom zone

The bottom zone includes the following items contributing to the hull girder strength up to the upper level of the hopper sloping plating or up to the inner bottom plating if there is no hopper tank:

- keel plate
- bottom plating
- bilge plate
- bottom girders
- inner bottom plating
- hopper tank sloping plating
- side shell plating
- longitudinal stiffeners connected to the above mentioned platings.

3.1.3 Neutral axis zone

The neutral axis zone includes the plating only of the items between the deck zone and the bottom zone, as for example:

- side shell plating
- inner hull plating, if any

3.2 Local strength criteria

3.2.1 Items for the local strength criteria

The items to be considered for the local strength criteria are those of the deck zone, the bottom zone and the neutral axis zone, as defined in **[3.1]**, and the additional following items:

- hatch coaming plating
- hatch coaming brackets
- hatch cover top plating
- hatch cover skirt plating
- hatch cover stiffeners
- transverse bulkheads plating
- transverse bulkheads stiffener web
- transverse bulkheads stiffener flange
- side shell frames web
- side shell frames flange

- side shell frames brackets
- web of topside and hopper tank web frames
- flange of topside and hopper tank web frames
- floors plating and stiffeners
- forward and aft peak bulkheads plating
- forward and aft peak bulkheads stiffener web
- forward and aft peak bulkheads stiffener flange
- stringers and girders.

3.2.2 Renewal thickness for corrosion other than local corrosion

For each item, steel renewal is required when the gauged thickness t_{gauged} is less than the renewal thickness, as specified in the following formula:

$$t_{gauged} < t_{renewal}$$

Where the gauged thickness t_{gauged} issuchas:

$$t_{renewal} < t_{gauged} < t_{renewal} + t_{reserve}$$

coating applied in accordance with the coating manufacturer's requirements or annual gauging may be adopted as an alternative to the steel renewal. The coating is to be maintained in good condition.

3.2.3 Renewal thickness for local corrosion

If pitting intensity in an area where coating is required, according to **Ch 3, Sec 5**, is higher than 15 % (see **Fig 6**), thickness measurements are to be performed to check the extent of pitting corrosion. The 15 % is based on pitting or grooving on only one side of a plate.
In cases where pitting is exceeding 15 %, as defined above, an area of 300 mm or more, at the most pitted part of the plate, is to be cleaned to bare metal and the thickness is to be measured in way of the five deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded.
The minimum remaining thickness in pits, grooves or other local areas as defined in **Ch 13, Sec 1, [1.2.1]** is to be greater than:

- 75 % of the as-built thickness, in the frame and end brackets webs and flanges
- 70 % of the as-built thickness, in the side shell, hopper tank and topside tank plating attached to the each side frame, over a width up to 30 mm from each side of it,

without being greater than $t_{renewal}$.

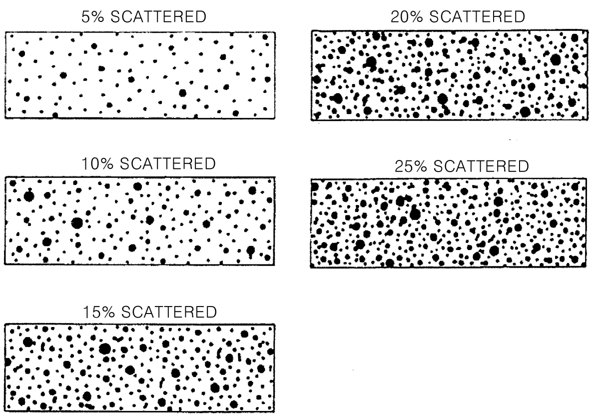


Fig 6: Pitting intensity diagrams (from 5 % to 25 % intensity)

3.3 Global strength criteria

3.3.1 Items for the global strength criteria

The items to be considered for the global strength criteria are those of the deck zone, the bottom zone and the neutral axis zone, as defined in **[3.1].**

3.3.2 Renewal thickness

The global strength criteria is defined by the assessment of the bottom zone, deck zone and neutral axis zone, as detailed below.

a) bottom zone and deck zone:

The current hull girder section modulus determined with the thickness measurements is not to be less than 90 % of the section modulus calculated according to **Ch 5, Sec 1** with the gross offered thicknesses.

Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the gauged items area of the considered zones, are not to be less than 90 % of the sectional area of the corresponding zones determined with the gross offered thicknesses.

b) neutral axis zone:

The current sectional area of the neutral axis zone, which is the sum of the gauged platings area of this zone, is not to be less than 85% of the gross offered sectional area of the neutral axis zone.

If the actual wastage of all items, of a given transverse section, which contribute to the hull girder strength is less than 10 % for the deck and bottom zones and 15 % for the neutral axis zone, the global strength criteria of this transverse section is automatically satisfied and its checking is no more required. ⚓

Rules for the Classification of Steel Ships

PART 11 COMMON STRUCTURAL RULES FOR BULK CARRIERS

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Rules for the Classification of Steel Ships

Part 12

Common Structural Rules for Double Hull Oil Tankers

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COMMON STRUCTURAL RULES FOR DOUBLE HULL OIL TANKERS

Foreword

1. This version of the Rules is effective as of 1st July 2010.

2. This version incorporates changes made to the 1 July 2008 consolidated edition.

2.1 Note that changes included in Rule Change Notice 1 to the 1 July 2008 consolidated edition are effective from 1 February 2010.

3. The Rules contain two parts, one part that is for information and does not constitute specific requirements and one part giving structural rules for double hull oil tankers of 150 m or greater. Subjects for information are given in *Section 1 - Introduction* and *Section 2 - Rule Principles*. Specific rule requirements are given in *Section 3* to *12* and the Appendices.

4. The following table provides a revision history of the Rules.

	Amendment Type / No.	Approval Date	Effective Date*	Reference Rule Edition
1	Corrigenda 1	7 Apr 2006	1 Apr 2006	1 Jan 2006 edition
2	Corrigenda 2	27 July 2006	1 Apr 2006	1 Jan 2006 edition
3	Rule Change Notice 1	29 Sept 2006	1 Apr 2007	1 Jan 2006 edition
4	Corrigenda 3	19 Nov 2007	1 Apr 2006	1 Jan 2006 edition
5	Rule Change Notice 2	25 Feb 2008	1 July 2008	1 Jan 2006 edition
6	Corrigenda 1 (1 July 2008 consolidated edition)	2 July 2008	1 July 2008	1 July 2008 consolidated edition
7	Rule Change Notice 1 (1 July 2008 consolidated edition)	11 Nov 2009 (Amended version)[1]	1 Feb 2010	1 July 2008 consolidated edition

	Amendment Type / No.	Approval Date	Effective Date*	Reference Rule Edition
8	Rule Change Notice 2 (1 July 2008 consolidated edition)	12 Apr 2010	1 July 2010	1 July 2008 consolidated edition

* For effective date, refer to the implementation statements of relevant Corrigenda / Rule Changes.

1) RCN 1 to July 2008 edition was originally approved on 28 January 2009, however following input from industry, IACS Council decided to postpone the original implementation date of 1 July 2009 until such time as a technical study was completed.

   In November 2009, following further technical review, IACS Council agreed an amended version of RCN 1 to enter into force on 1 February 2010.

Note: When the word '(void)' appears in the text, it means that the concerned part has been deleted. This is to keep the numbering of the remainder unchanged.

Table of Contents

Section 1

Introduction

1 Introduction to Common Structural Rules for Oil Tankers

1.1 General

1.1.1 Applicability

1.1.1.1 These Rules apply to double hull oil tankers of 150 m length, *L*, and upward classed with the Society and contracted for construction[(1)] on or after 1 April 2006. The definition of the rule length, *L*, is given in **Sec 4/1.1.1.1.**

1.1.1.2 Generally, for double hull tankers of less than 150 m in length, *L*, the Rules of the individual Classification Society are to be applied.

1.1.1.3 Ships contracted for construction before the effective date of these Rules are to comply with the Rules of the individual Classification Society.

Note
The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contracted for construction", see IACS Procedural Requirement (PR) No.29.

1.2 Application of Individual Classification Rules

1.2.1 Regions of the ship which these Rules do not cover

1.2.1.1 For regions of the structure which these Rules do not cover, the relevant requirements of the individual Classification Society's Rules are to be applied.

1.3 Guidance on Rule Structure

1.3.1 Framework

1.3.1.1 The Rules are structured in Sections giving instructions for detailed application and requirements which are applied in order to satisfy the Rule objectives. The acceptable procedures for the structural analysis required by the Rules are given in the Appendices.

1.3.2 Numbering and cross-references

1.3.2.1 The system for numbering of Sections and Sub-Sections is given in **Table 1.1.1.**

Table 1.1.1
Section Numbering

Order	Levels	Example
1	Section name (displayed in the header)	Section 1 - Introduction
2	Sub-Section	1 Introduction To The Common Structural⋯
3	Sub-Section 2	1.1 General
4	Sub-Section 3	1.1.1 Development of the rules
5	Paragraph number	1.1.1.1 An important part of the classification process is the development of rule⋯

1.3.2.2 The system for the numbering of Tables and Figures is given in **Table 1.1.2.**

Table 1.1.2
Numbering of Tables and Figures

Table location in document	Example of numbering
Section 5, Sub-Section 1, 2nd table in sub-section	Table 5.1.2
Section 1, Sub-Section 12, 5th table in sub-section	Table 1.12.5
Section 10, Sub-Section 4, 3rd table in sub-section	Table 10.4.3
Figure location in document	
Section 5, Sub-Section 1, 2nd figure in sub-section	Fig 5.1.2
Section 1, Sub-Section 12, 5th figure in sub-section	Fig 1.12.5
Section 10, Sub-Section 4, 3rd figure in sub-section	Fig 10.4.3

1.3.2.3

1.3.2.4 Cross-references within a Section (local) are represented as a Sub-Section or Paragraph number, e.g. **4.2** or **4.2.1.1.** See **Table1.1.3.**

1.3.2.5 Cross-references outside a Section (global) are represented as Section no./Sub-Section or Paragraph number, e.g. **Sec 4/2.1.1.3.** See **Table1.1.3.**

Table 1.1.3
How Cross-References are Applied

Location of reference	Example of cross-reference	
Local (within a Section)		
Text in Sub-Section 4.2	See 4.2	in 4.2
Text in Sub-Section 6.2.2	See 6.2.2	in 6.2.2
Text in Paragraph 5.1.2.1	See5.1.2.1	in 5.1.2.1
Global(outside a section)		
Text in Section 6, Sub-Section 4.2	Sec 6/4.2	
Text in Section 6, Sub-Section 6.2.2	Sec 6/6.2.2	
Text in Section 6, Paragraph 5.1.2.1	Sec 6/5.1.2.1	

1.3.3 General organization of the Rules

1.3.3.1 The general organization of the Rules is shown in **Fig 1.1.1**

Fig 1.1.1
Schematic Layout of the Rules

Topic	Section
Introduction	1
Rule Principles	2
Rule Application	3
Basic Information	4
Structural Arrangement	5
Materials and Welding	6
Loads	7

Topic	Section
Machinery general structure	8/4.1
Machinery bottom structure	8/4/2
Machinery side structure	8/4.3
Machinery deck structure	8/4.4
Machinery internal structure	8/4.5-4.8
Aft end general structure	8/5.1
Aft end bottom structure	8/5.2
Aft end shell structure	8/5.3
Aft end deck structure	8/5.4
Aft end internal structure	8/5.5-5.7

Topic	Section
Hull girder strength	8/1
Hull envelope plating	8/2.2
Hull envelope framing	8/2.3
Inner bottom	8/2.4
Bulkheads	8/2.5
Primary support members	8/2.6
Sloshing	8/6.2
Hull girder ultimate strength	9/1
Strength assessment (FEM)	9/2
Fatigue strength	9/3

Topic	Section
General structure	8/3.1
Bottom structure	8/3.2
Side structure	8/3.3
Deck structure	8/3.4
Internal structure	8/3.5-3.9
Bottom slamming	8/6.3
Bow impact	8/6.4

Topic	Section
Hull openings and closing arrangements	11/1
Crew protection	11/2
Support structure and structural appendages	11/3
Equipment	11/4
Testing procedures	11/5
Ship in operation renewal criteria	12

Section 2

Rule Principles

1 Introduction

1.1 Rule Principles

1.1.1 Rule objectives

1.1.1.1 The objectives of the Rules are to establish requirements to reduce the risks of structural failure in order to help improve the safety of life, environment and property and to provide adequate durability of the hull structure for the design life.

1.1.2 General

1.1.2.1 The sub-sections contain:

(a) the General Assumptions; pertaining to the design, construction and operation of the ship and gives information on the responsibilities of Classification Societies, builders and owners

(b) the Design Basis; which specifies the premises that the design principles of the Rules are based on, in terms of design parameters and assumptions about the ship operation

(c) the Design Principles; which define the fundamental principles used for the structural requirements in the Rules with respect to loads, structural capacity and assessment criteria

(d) the Application of the Design Principles; which describes how the design principles and methods are applied and what criteria are used to demonstrate that the structure meets the objective.

2 General Assumptions

2.1 General

2.1.1 International and national regulations

2.1.1.1 Ships are to be designed, constructed and operated in compliance with the regulatory framework prescribed internationally by the International Maritime Organization and implemented by National Administrations.

2.1.1.2 The Rules are based on the assumptions that all applicable statutory requirements are complied with.

2.1.1.3 The Rules incorporate the IACS unified requirements as shown in **Table 2.2.1.**

2.1.2 Classification Societies

2.1.2.1 Classification Societies develop and publish the standards for the hull structure and essential engineering systems. Classification Societies verify compliance with the classification requirements and the applicable international regulations when authorised by a National Administration during design, construction and operation of a ship.

Table 2.2.1
IACS Unified Requirements Applicable to Oil Tankers

Number	Title
A1	*Equipment*
A2	*Shipboard fittings and supporting hull structures associated with towing and mooring on conventional vessels*
S1	*Requirements for Loading Conditions, Loading Manuals and Loading Instruments*
S2	*Definitions of ship's length* L *and block coefficient* C_b
S3	*Strength of end bulkheads of superstructures and deckhouses*
S4	*Criteria for use of high tensile steel with yield points of 315* $\mathrm{N/mm^2}$ *and 355* $\mathrm{N/mm^2}$ *(with respect to longitudinal strength)*
S5	*Calculation of midship section moduli for conventional ship for ship's scantlings*
S6	*Use of steel grades for various hull members - ships of 90 m in length and above*
S7	*Minimum longitudinal strength Standards*
S11	*Longitudinal strength Standard*
S13	*Strength of bottom forward in oil tankers*
S14	*Testing procedures of Watertight Compartments*
S26	*Strength and securing of Small Hatches on the Exposed Fore Deck*
S27	*Strength Requirements for Fore Deck Fittings and Arrangements*

2.1.3 Responsibilities of Classification Societies, builders and owners

2.1.3.1 These Rules address the hull structural aspects of classification and do not include requirements related to the verification of compliance with the Rules during construction and operation. The verification of compliance with these Rules is the responsibility of all parties and requires that proper care and conduct is shown by all parties involved in its implementation. These responsibilities include:

(a) general aspects:

- relevant information and documentation involved in the design, construction and operation is to be communicated between all parties in a clear and efficient manner. The builder is responsible for providing design documentation according to requirements specified in the Rules. Other requirements for information and documentation are specified by the requirements and approval procedures of the individual Classification Societies
- quality systems are applied to the design, construction, operation and maintenance activities to assist compliance with the requirements of the Rules.

(b) design aspects:

- it is the responsibility of the owner to specify the intended use of the ship, and the responsibility of the builder to ensure that the operational capability of the design fulfils the owner's requirements as well as the structural requirements given in the Rules
- the builder shall identify and document the operational limits for the ship so that the ship can be safely and efficiently operated within these limits
- verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations
- the design is performed by appropriately qualified, competent and experienced personnel
- the classification society is responsible for a technical appraisal of the design plans and related documents for a ship to verify compliance with the appropriate classification rules.

(c) construction aspects:

- the builder is responsible for ensuring that adequate supervision and quality control is provided during the construction
- construction is to be carried out by qualified and experienced personnel
- workmanship, including alignment and tolerances, is to be in accordance with acceptable shipbuilding standards
- the Classification Society is responsible for surveying to verify that the construction and quality control are in accordance with the plans and procedures.

(d) operational aspects:

- the owner is to ensure that the operations personnel are aware of, and comply with, the operational limitations of the ship
- the owner is to provide operations personnel with sufficient training such that the ship is properly handled to ensure that the loads and resulting stresses imposed on the structure are minimised
- the owner is to ensure that the ship is maintained in good condition and in accordance with the Classification Society survey scheme and also in accordance with the international and national regulations and requirements
- the Classification Society is responsible for surveying to verify that the vessel maintains its condition of class in accordance with the Classification Society survey scheme.

3 Design Basis

3.1 General

3.1.1 The design basis

3.1.1.1 This Sub-Section specifies the design parameters and the assumptions about the ship operation that are used as the basis of the design principles of the Rules.

3.1.1.2 The Rules are applicable for ships in compliance with the specified design basis. Special consideration will be given to deviations from this design basis.

3.1.1.3 The design basis used for the design of each ship is to be documented and submitted to the Classification Society as part of the design review and approval. All deviations from the design basis are to be formally advised to the Classification Society.

3.1.2 Arrangement and layout

3.1.2.1 The Rules cover typical double hull tankers of greater than or equal to 150 m in length and with arrangements as follows:

(a) engine room and deck house located aft of the cargo tank region, and

(b) in addition to the inner skin two longitudinal oil-tight bulkheads with no centreline longitudinal bulkhead, or

(c) in addition to the inner skin one centreline longitudinal oil-tight bulkhead.

3.1.2.2 The ship's structure is assumed to be:

(a) constructed of welded steel structures

(b) composed of stiffened plate panels

(c) longitudinally framed with full transverse bulkheads and intermediate web frames.

3.1.2.3 The typical arrangements covered by the Rules are shown in **Fig 2.3.1** and assume that the structural arrangements include:

(a) narrow double side structure and double bottom structure with breadth/depth in accordance with statutory requirements

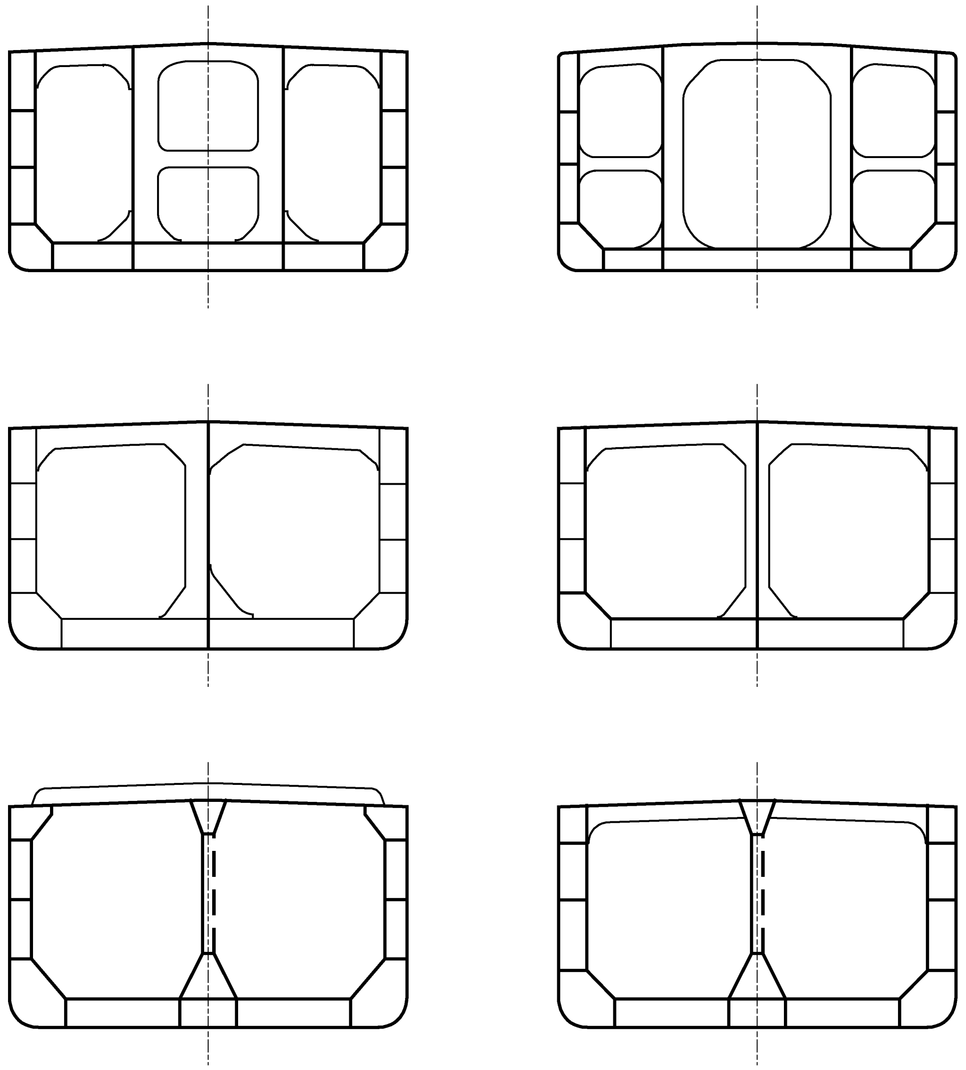
(b) single deck ships

(c) side longitudinal, centreline longitudinal or transverse bulkheads of plane, corrugated or double skin construction

(d) the number and location of bulkheads are arranged to comply with the statutory requirements

The cross sections shown in **Fig 2.3.1** are typical examples only and other variations of cross tie and web frame arrangements are also covered.

Fig 2.3.1
Typical Arrangements of Double Hull Tankers



3.1.2.4 The Rules assume the following hull form with respect to environmental loading:

(a) full form ship with block coefficient (C_b) greater than 0.7

(b) the ship length breadth ratio (L/B) greater than 5

(c) ship breadth depth ratio (B/D) less than 2.5

(d) the metacentric height (GM) not greater than $0.12B$ for homogeneously full load conditions, and $0.33B$ for ballast conditions.

3.1.3 Design life

3.1.3.1 A nominal design life of 25 years is assumed for selecting appropriate ship design parameters. The specified design life is the nominal period that the ship is assumed to be exposed to operating conditions. However, the ship's actual service life may be longer or shorter depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

3.1.4 Design speed

3.1.4.1 The design maximum service speed is to be specified by the designer. The Rules assume that the ship is able to operate at this service speed on a continuous basis, but this does not relieve the responsibilities of the owner and personnel to properly handle the ship and reduce speed or change heading in severe weather, see **2.1.3.1(d)**

3.1.5 Operating conditions

3.1.5.1 The ship is to be capable of carrying the intended cargo with the necessary flexibility in operation to fulfil its design role. Specification of cargo loading conditions as required by the Rules and any additional cargo loading conditions required by the owner are the responsibility of the designer.

3.1.5.2 The Rules assume the following:

(a) a minimum set of specified loading conditions as defined in the Rules are examined. These are to include both seagoing and harbour loading conditions

(b) in addition to the minimum set of specified loading conditions, all relevant additional loading conditions covering the intended ship's service which result in increased still water shear force, bending moments or increased local static loadings are to be submitted for review

(c) the Trim and Stability Booklet, Loading Manual and loading computer systems specify the operational limitations to the ship and these comply with the appropriate statutory and classification requirements

(d) all cargo tanks are from a local strength point of view including sloshing designed for unrestricted filling for a cargo density as specified in **3.1.8**. Limitations to loading patterns resulting in full or empty adjacent tanks as specified in the Rules and the Loading Manual do however apply for primary support members and hull girder shear force and bending moments

3.1.6 Operating draughts

3.1.6.1 The design operating draughts are to be specified by the designer and are to be used to derive the appropriate structural scantlings. All operational loading conditions in the Loading Manual are to comply with the specified design operating draughts. The following design operating draughts are as a minimum to be considered:

(a) the maximum and minimum mean operational draughts

(b) maximum scantling draught for the assessment of structure

(c) minimum draughts forward for the assessment of bottom slamming, with and without ballast tanks in way filled

(d) maximum mean draught for a condition with all cargo tanks abreast empty

(e) maximum mean draught for a condition with empty centre or wing cargo tank.

3.1.7 External environment

3.1.7.1 To cover worldwide trading operations and also to deal with the uncertainty in the future trading pattern of the ship and the corresponding wave conditions that will be encountered, a severe wave environment is used for the design assessment. The rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

3.1.7.2 The effects of wind and current on the structure are considered to be negligible and hence are not explicitly included.

3.1.7.3 The Rules do not include the effects of ice.

3.1.7.4 The Rules assume that the structural assessment of hull strength members is valid for the following design temperatures:

(a) lowest daily mean temperature in air is -10 °C

(b) lowest daily mean temperature in sea water is 0 °C

Ships operating for long periods in areas with lower daily mean air temperature may be subject to additional requirements as specified by the individual Classification Society.

3.1.8 Internal environment (cargo and water ballast tanks)

3.1.8.1 A specific gravity (SG) of 1.025, or a higher value if specified by the designer, is to be used for oil cargoes for the strength assessment of cargo tank structures.

3.1.8.2 For the fatigue assessment of cargo tank structures, a representative mean cargo density throughout the ship's life is to be used. The representative mean density is to be taken as 0.9 tonnes/m^3 or the cargo density from the homogeneous full load condition at the full load design draught T_{full}, if this is higher.

3.1.8.3 A SG of 1.025 is to be used for water ballast.

3.1.8.4 The Rules are based on the following design temperatures for the cargo:
(a) maximum cargo temperature is 80 °C
(b) minimum cargo temperature is 0 °C.

3.1.8.5 The design aspects and assumption upon which corrosion additions in the Rules are specified areas follows:
(a) the corrosion additions are based on a combination of experience and a statistical evaluation of historical corrosion measurements. The corrosion additions are based on the carriage of a mixture of crude and other oil products with various degrees of corrosive properties
(b) the corrosion additions are based on the design life, see **3.1.3.1**
(c) ballast tanks are coated. Requirements for coating application and maintenance are excluded from the Rules.

3.1.8.6 The values for corrosion additons and wastage allowance are specified in **Sec 6/3** and **Sec 12** respectively.

3.1.9 Structural construction and inspection

3.1.9.1 The structural requirements included in the Rules are developed with the assumption that construction and repair will follow acceptable shipbuilding and repair standards and tolerances. The Rules may require that additional attention is paid during construction and repair of critical areas of the structure.

3.1.9.2 Tank strength and tightness testing are to be carried out as a part of the verification scheme.

3.1.9.3 The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure will be subject to periodical survey in accordance with individual Classification Society Rules and Regulations. All structural elements are to be arranged to allow access for inspection, see **Sec 5/5**. It is assumed that close-up inspection of the critical areas will be carried out on a regular basis.

3.1.10 Owner's extras

3.1.10.1 Owner's specification of requirements above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:
(a) vibration analysis
(b) maximum percentage of high strength steel
(c) additional scantling dimensions above that required by the Rules
(d) additional design margin on the loads specified by the Rules, etc
(e) improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent
(f) combinations of cargo loading patterns and draughts exceeding the Rule specified conditions
(g) higher cargo density for fatigue evaluation for ships intended to carry high density cargo in part load conditions on a regular basis.

Owner's extras are not covered by these Rules. Owner's extras that may affect the structural design are to be clearly specified in the design documentation.

4 Design Principles

4.1 Overall Principles

4.1.1 Introduction

4.1.1.1 This Sub-Section defines the underlying design principles of the Rules in terms of loads, structural capacity models and assessment criteria and also construction and in-service aspects.

4.1.2 General

4.1.2.1 The Rules are based on the following overall principles:

(a) the safety of the structure can be demonstrated by addressing the potential structural failure mode(s) when the vessel is subjected to operational loads and environmental loads/conditions

(b) the design complies with the design basis, see **Sec 3**

(c) the structural requirements are based on a consistent set of loads that represent typical worst possible loading scenarios

(d) the structural requirements with respect to loads, capacity models and assessment criteria are presented in a modular format so that each component of the requirement is clearly identified

4.1.2.2 The ship's structure is designed such that:

(a) it has inherent redundancy. The ship's structure works in a hierarchical manner and, as such, failure of structural elements lower down in the hierarchy should not result in immediate consequential failure of elements higher up in the hierarchy

(b) permanent deformations are minimised. Permanent deformations of local panel or individual stiffened plate members may be acceptable provided that this does not affect the structural integrity, containment integrity or the performance of structural or other systems

(c) the incidence of in-service cracking is minimised, particularly in locations which; affect the structural integrity or containment integrity, affect the performance of structural or other systems or are difficult to inspect and repair

(d) it has adequate structural redundancy to survive in the event that the structure is accidentally damaged; for example, minor impact leading to flooding of any compartment.

4.2 Loads

4.2.1 Load scenarios

4.2.1.1 The loads used for assessment of the structure covers the load scenarios encountered by the ship during operation at sea and in harbour.

4.2.2 Design load combinations

4.2.2.1 Design load combinations combine local and global load components to represent identified load scenarios. The design load combinations should be sufficiently severe and varied so as to encompass all scenarios that can reasonably occur during normal operation.

4.2.2.2 The design load combinations for the hull and structural members consider the most unfavourable combination of load effects in order to maintain a consistent safety level for all combinations.

4.2.2.3 The design load combinations are based on one of the following combinations of static and dynamic loads depending on the type of load and the load scenario being considered:

(a) Static design load combinations (S)

covers application of all relevant static loads and typically covers load scenarios in harbour, tank testing or similar operations

(b) Static plus Dynamic design load combination (S+D)

covers application of all relevant static loads plus a realistic combination of simultaneously occurring dynamic load components and typically covers load scenarios for seagoing operations

(c) Impact design load combination

covers application of impact loads such as bottom slamming and bow impact encountered during seagoing operation. It is usually sufficient to ignore other static and dynamic load components in association with an impact load event.

(d) Sloshing design load combination

covers application of sloshing loads encountered during seagoing operations

(e) Fatigue design load

covers application of all relevant dynamic loads

(f) Accidental design load combination (A)

covers application of accidental loads where these loads are not considered as occurring during normal operations

4.2.3 Load categorisation

4.2.3.1 The design load combinations are composed of many different types of loads, which are categorised as shown in **Table 2.4.1.**

Table 2.4.1
Load Categorisations

Operational Loads	Lightship weight	Steel weight and outfit Machinery and permanent equipment
	Buoyancy loads	Buoyancy of the ship
	Variable loads	Cargo Ballast water Stores and consumables Personnel Temporary equipment
	Other loads	Tug and berthing loads Towing loads Anchor and mooring loads Lifting appliance loads
Environmental loads	Cyclic loading due to wave action including inertia loads	Dynamic wave pressures
		Dynamic loads and dynamic tank pressures due to ship accelerations
	Impact loads or resonant loads	Wave impacts Bottom slamming Liquid sloshing in tanks Green sea loads
Accidental loads		Flooding of compartments
Deformation loads		Thermal loads Deformations due to construction

4.2.3.2 Operational loads generally are static loads. They are grouped into lightship weight, buoyancy loads, variable loads and other loads. The operational loads occur as a consequence of the operation and handling of the ship.

4.2.3.3 Environmental loads are dynamic loads due to external influences. The environmental loads covered by the Rules are loads due to wave action.

4.2.3.4 Accidental loads include loads that result as a consequence of an accident or operational mishandling of the ship. The accidental loads covered by the Rules are increased tank pressures due to flooding of compartments.

4.2.3.5 Deformation loads are caused by thermal loads and residual stresses. The load effects from deformation loads are not covered by the Rules.

4.2.4 Characteristic load values

4.2.4.1 The characteristic values of the load components that are applied in the Rules are dependant on the design load combination being considered. The characteristic loads are typical values and are given by:

(a) for operational loads the characteristic loads are the expected or specified values

(b) for environmental loads the characteristic load is typically a load value which has a low probability of occurrence, i.e. an ‘extreme’ value.

4.2.5 Operational loads

4.2.5.1 The characteristic values of the static sea pressure on the hull due to the buoyancy are based on the draught at the loading condition under consideration.

4.2.5.2 The characteristic values of the static tank pressure are based on the filling height and the specific gravity of the cargo/ballast, and include allowances for possible overpressure due to the height of air pipes, pressure relief valve settings and capacity of pumps.

4.2.5.3 The characteristic values of the loads due to personnel, stores and consumables, temporary equipment and permanent equipment are based on specified values.

4.2.5.4 The characteristic values for tug, berthing, towing and mooring loads are based on specified values.

4.2.6 Environmental loads

4.2.6.1 The Rule formulations for wave loads, as given in **Sec 7/3**, are based on the envelope values calculated in accordance with **4.2.6.2** and calibrated with feedback from service experience and model tests.

4.2.6.2 The general principles for the derivation of the wave load values are:

(a) the application of load values is consistent for all similar load scenarios

(b) the characteristic load value is selected to suit the purpose of the application of the load and the selected structural assessment method, e.g. for strength assessment the expected lifetime maximum load is applied while for fatigue assessment an average value representing the expected load history is applied

(c) load calculations are performed using 3-D linear hydrodynamic computational tools. The effects of speed are considered

(d) the derivation of characteristic wave loads is based on a long term statistical approach which includes representation of the wave environment (North Atlantic scatter diagram), probability of ship/wave heading and probability of load value exceedance based on IACS Rec.34. All of which result in envelope values

(e) non-linear effects are considered for the expected lifetime maximum loads.

4.2.6.3 The combination of dynamic loads considers all simultaneously occurring dynamic load components. In deriving the simultaneously occurring loads, one particular load component is maximised or minimised and the relative magnitude of all simultaneously occurring dynamic load components is specified by the application of dynamic load combination factors (DLCF) based on the envelope load value. These dynamic load combination factors are based on the application of the equivalent design wave approach and are given as tabulated values.

4.2.6.4 The formulations of the load values for bottom slamming, bow impact loads and green sea loads take account of the following factors:

(a) vessel draught

(b) hull form

(c) heading
(d) forward speed
(e) location of deck houses/superstructure
(f) geometry of structural elements.

4.2.6.5 A slamming impact load results in a transient dynamic response in the structure. The formulation of the impact loads considers the impact load as an equivalent static load acting on the associated exposed hull surface.

4.2.6.6 The effect of green water on the deck structure along the entire vessel's length is considered. The green water loads on fore and parallel mid bodies of a ship are determined based on model tests, ship motion analysis and service experience. The green sea loads for the aft body are consistent with the derivation for the fore and mid body green sea loads.

4.2.7 Accidental loads

4.2.7.1 The accidental load scenarios cover loads acting on local structure as a consequence of flooding in accordance with the assumptions made in IMO regulations. This relates to the assessment of the watertight subdivision boundaries.

4.2.7.2 Only static loads corresponding to the draught in the flooded condition are considered.

4.2.8 Deformation loads

4.2.8.1 Thermal loads within the limits specified by the design basis are considered negligible. It is assumed that care is taken to account for, and allow for, expected thermal expansion.

4.3 Structural Capacity Assessment

4.3.1 General

4.3.1.1 The basic principle in structural design is to apply the defined design loads, identify possible failure modes and employ appropriate capacity models to determine the required structural scantlings.

4.3.2 Capacity models for strength

4.3.2.1 The strength assessment method is to be capable of analysing the failure mode in question to the required degree of accuracy. Several assessment methods may be applicable, even for the same failure modes.

4.3.2.2 The following aspects are the basis for selection of strength capacity models:
(a) whether the structural member is also assessed at a higher level in the hierarchy and/or at a later stage by more accurate methods or by more accurate response calculations
(b) simplified capacity models where some of the stress components are neglected are to always give conservative results
(c) appropriate methodology to assess the failure mode
(d) probability level of the load
(e) capability of response calculations to represent the physical behaviour of the structure up to the given load level
(f) complexity of structure
(g) complexity of loads
(h) criticality of the structural member. This will primarily have an impact on the assessment criteria, but needs to be considered in conjunction with selection of the appropriate methodology for structural assessment.

4.3.2.3 The structural capacity assessment methods are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

4.3.2.4 The formulae used to determine stresses, deformations and capacity are appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

4.3.3 Capacity models for fatigue

4.3.3.1 The fatigue assessment method provides Rule requirements to safeguard structural details against fatigue failure.

4.3.3.2 The fatigue capacity model is based on a linear cumulative damage summation (Palmgren - Miner's rule) in combination with S-N curves, a characteristic stress range and an assumed long-term stress distribution curve.

4.3.3.3 The fatigue capacity assessment models are in either a prescriptive format or require the use of more advanced calculations such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

4.3.4 Net thickness approach

4.3.4.1 The philosophy behind the net thickness approach is to:

(a) provide a direct link between the thickness used for strength calculations during the new building stage and the minimum thickness accepted during the operational phase

(b) enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

4.3.4.2 The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas such as primary support members and the hull girder. Both the local and overall corrosion are used as a basis for the new building review and are to be confirmed during operation of the vessel.

4.3.4.3 The net thickness approach for the local corrosion is shown in **Fig 2.4.1(a)** and is in terms of new building thicknesses, given by:

(a) the local strength requirements are given by the net thickness ($t_{net\text{-}req}$) after rounding

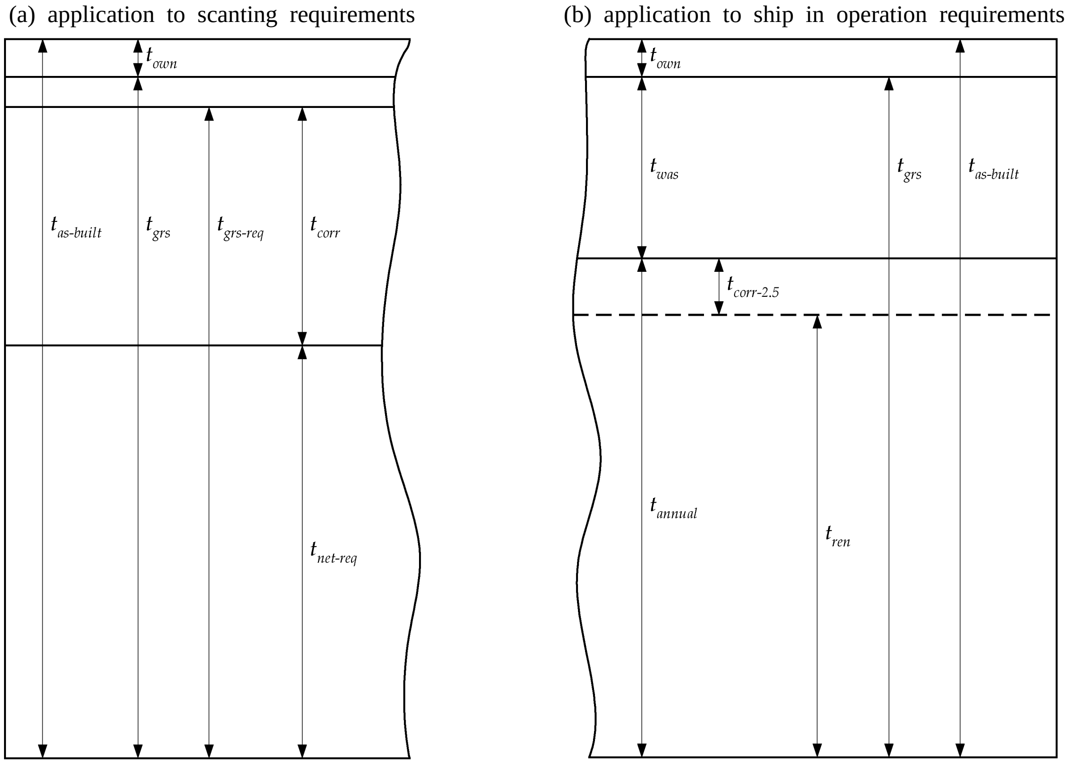
(b) the required gross thickness ($t_{grs\text{-}req}$) is given by adding the corrosion addition (t_{corr}) to the required rounded net thickness ($t_{net\text{-}req}$)

(c) the gross thickness (t_{grs}) is the actual thickness selected by the designer to fulfil the gross required thickness ($t_{grs\text{-}req}$) and is to be equal or greater than the required gross thickness ($t_{grs\text{-}req}$)

(d) the as built thickness is equal to the gross thickness (t_{grs}) plus any additional owners extra margin (t_{own})

(e) any additional thicknesses specified by the owner, as owners extra margin (t_{own}) are not to be included in the assessment of the required gross thickness ($t_{grs\text{-}req}$).

Fig 2.4.1
Net Thickness Approach for Local Wastage



4.3.4.4 The net thickness approach for determining the local renewal thickness during the ship in operation phase is shown in **Fig 2.4.1(b)** and is given by:

(a) the thickness at which annual surveys are required, t_{annual}, is obtained by subtracting the total wastage allowance (t_{was}) and the owners extra margin (t_{own}) from the as-built thickness ($t_{as\text{-}built}$)

(b) thickness at which renewal is required, t_{ren}, is obtained by subtracting the total wastage allowance (t_{was}), the thickness $t_{corr\text{-}2.5}$ and the owners extra margin (t_{own}) from the as-built thickness ($t_{as\text{-}built}$). Where $t_{corr\text{-}2.5}$ is the wastage allowance in reserve for corrosion occurring in the two and half years between Intermediate and Special surveys

(c) the total wastage allowance given is the rule specified wastage allowance (t_{was}) plus the wastage allowance in reserve ($t_{corr\text{-}2.5}$) plus any additional owners extra margin (t_{own})

(d) the rule specified wastage allowance (t_{was}) available before annual surveys are required is obtained by deducting the thickness $t_{corr\text{-}2.5}$ from the corrosion addition (t_{corr}).

The approach calls for a general 2.5 year survey interval when the gauged thickness is greater than the "thickness at which annual surveys are required" (t_{annual}), and a 1 year survey interval when the gauged thickness is less than the "thickness at which annual surveys are required" (t_{annual}).

4.3.4.5 The overall average corrosion for primary support members and the hull girder cross-section is given by deducting half the local corrosion addition (0.5 t_{corr}) from all structural elements comprising the respective cross-sections.

4.3.4.6 The assessment of local scantlings is performed based on the hull girder stresses given by the net hull girder properties, e.g. based on a global overall average corrosion of the hull girder, and the local stresses based on the net thickness of the local member under consideration, e.g. based on full local corrosion. It is assumed that the structure may corrode locally to the maximum allowed and that the hull girder may reduce to the maximum allowed overall hull girder corrosion.

4.3.4.7 The assessment of global (hull girder and primary support member) scantlings is based on the overall global corrosion, e.g. half the full local corrosion for all structural members simultaneously. The assumption is that the full local corrosion will not occur globally and hence a lesser average value of assumed corrosion is appropriate. Individual structural elements may corrode to the maximum corrosion addition and this is taken into account in the buckling assessment.

4.3.4.8 As fatigue is an accumulative assessment the scantlings and stresses used for the assessment are to be taken as the representative mean value over the design life. The mean corrosion over the design life is given as half the corrosion assumed for scantling strength assessment. Local stresses are thus calculated based on half the full local corrosion addition and hull girder stresses are calculated based on half the overall global corrosion. Half the global overall corrosion is found by deduction of one quarter of the full local corrosion addition of all structural elements simultaneously.

4.3.4.9 The actual amount of wastage allowed in service is taken as:

(a) locally: the full corrosion addition less an amount for typical wastage between the survey periods

(b) globally: the full global overall corrosion addition less an amount for typical wastage between the survey periods. The global wastage is monitored in service by evaluating the current global characteristics of the vessel.

4.3.5 Intact structure

4.3.5.1 All strength calculations are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is not assessed.

4.3.5.2 No benefit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

4.4 Materials and Welding

4.4.1 Materials

4.4.1.1 The Rule requirements associated with the selection of materials for structural components is based on the location, design temperature (see **3.1.7.4** and **3.1.8.4**), membrane, through thickness forces and criticality of the component. The requirements comply with **IACS UR S6**.

4.4.1.2 The Rule requirements are based on the assumption that the material is manufactured in accordance with the allowable under thickness rolling tolerances specified in **IACS UR W13**.

4.4.2 Welding

4.4.2.1 The Rule requirements for weld type, size and materials are based on the following considerations:

(a) joint type

(b) criticality of the joint

(c) magnitude, type and direction of the stresses in the joint

(d) material properties of the parent and weld material

(e) weld gap size.

4.5 Assessment/Acceptance Criteria

4.5.1 Design methods

4.5.1.1 The criteria for the assessment of the scantlings are based on one of the following design methods:

(a) Working Stress Design (WSD) method, also known as the permissible or allowable stress method

(b) Partial safety Factor (PF) method, also known as Load and Resistance Factor Design (LRFD).

4.5.1.2 For both WSD and PF, two design assessment conditions and corresponding acceptance criteria are given. These conditions are associated with the probability level of the combined loads, A and B:

(a) condition A is applicable to design load combinations based on 'expected' characteristic load values, typically covered by the static design load combinations

(b) condition B is applicable to design load combinations based on 'extreme' characteristic load values, typically covered by the static + dynamic load combinations.

4.5.1.3 The WSD method has the following composition:

$$W_{stat} \le \eta_1 R \quad \text{for condition A}$$

$$W_{stat} + W_{dyn} \le \eta_2 R \quad \text{for condition B}$$

Where:

W_{stat} simultaneously occurring static loads (or load effects in terms of stresses)

W_{dyn} simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components

R characteristic structural capacity (e.g. yield stress or buckling capacity)

η_i permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure

4.5.1.4 The PF method has the following composition:

$$\gamma_{stat-1} W_{stat} + \gamma_{dyn-1} W_{dyn} \le \frac{R}{\gamma_R} \quad \text{for condition A}$$

$$\gamma_{stat-2} W_{stat} + \gamma_{dyn-2} W_{dyn} \le \frac{R}{\gamma_R} \quad \text{for condition B}$$

Where:

γ_{stat-i} partial safety factor that accounts for the uncertainties related to static loads

W_{stat} simultaneously occurring static loads (or load effects in terms of stresses)

γ_{dyn-i} partial safety factor that accounts for the uncertainties related to dynamic loads

W_{dyn} simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components

R characteristic structural capacity (e.g. yield stress, ultimate hull girder stress)

γ_R partial safety factor that accounts for the uncertainties related to structural capacity

4.5.1.5 The acceptance criteria for both the WSD method and PF method are calibrated for the various requirements such that consistent and acceptable safety level for all combinations of static and dynamic load effects are achieved.

4.6 Principle of Safety Equivalence

4.6.1 General

4.6.1.1 Novel designs deviating from the design basis or structural arrangements covered by the Rules will be subject to special consideration. The principle of equivalence is to be applied to the novel design, hence it must be demonstrated that the structural safety of the novel design is at least equivalent to that intended by the Rules.

4.6.1.2 The principle of equivalence may be applied to alternative calculation methods.

4.6.1.3 A systematic review process was undertaken in developing these Rules. This identified and evaluated the likely consequences of hazards due to operational and environmental influences on tanker structural configurations and arrangements covered by these Rules. For novel designs, dependent on the nature of the deviation, it may be necessary to conduct an independent systematic review to document equivalence with the Rules.

5 Application of Principles

5.1 Overview of the Application of Principles

5.1.1 General

5.1.1.1 This Sub-Section shows how the design principles described in **Sec 4** have been applied in the development of the rule requirements.

5.2 Structural Design Process

5.2.1 Overview of the structural design process

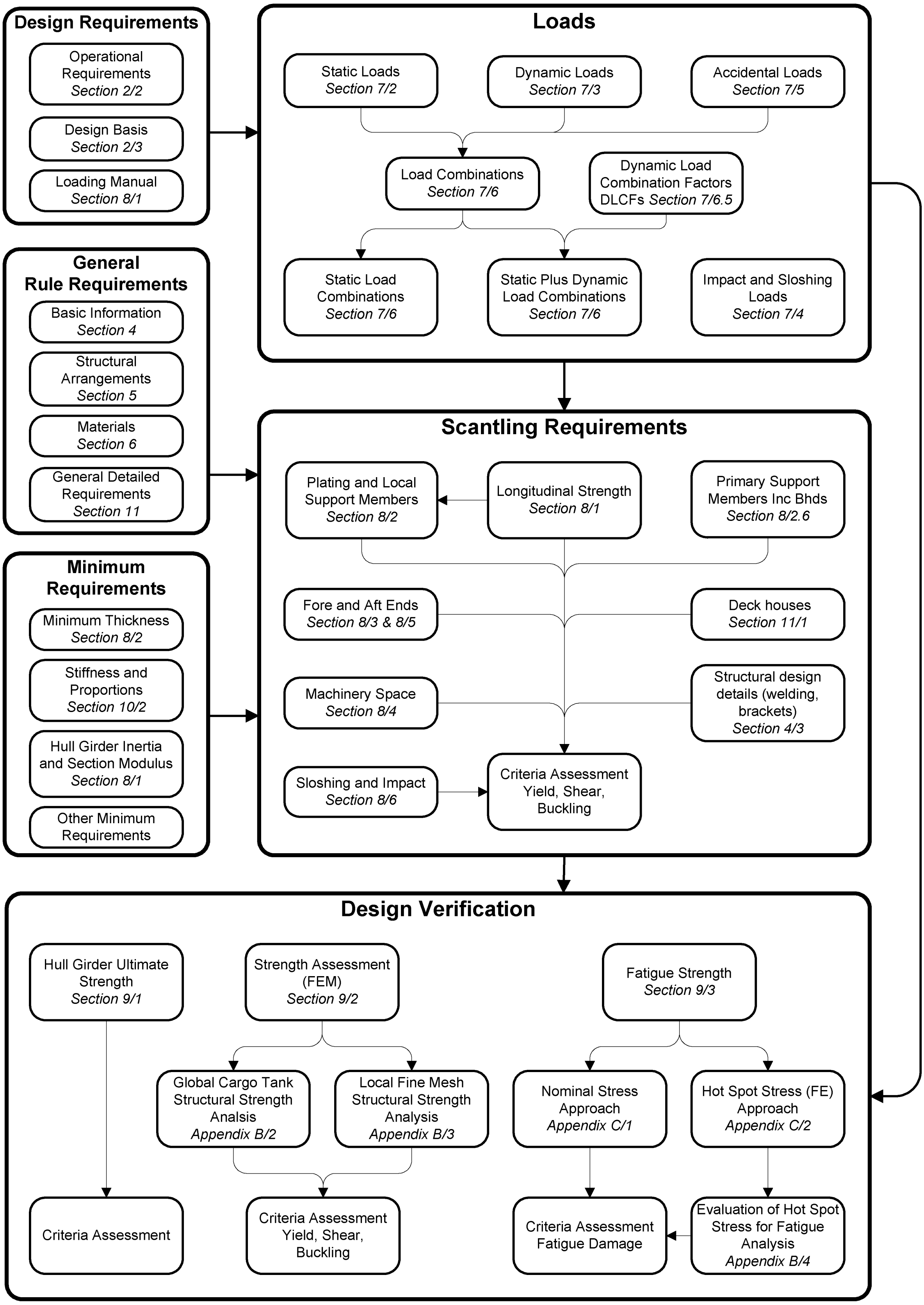
5.2.1.1 An overview of the structural design process applied in the Rules is shown in **Fig 2.5.1.**

5.2.1.2 The strength and acceptable safety of the hull and the structural elements is verified through the application of the following Rule requirements:

(a) prescriptive scantling requirements
- minimum requirements
- load-capacity based requirements

(b) design verification requirements based on load-capacity methods
- hull girder ultimate strength
- strength assessment using the Finite Element (FE) analysis
- fatigue assessment

Fig 2.5.1
Overview of Structural Design Process



5.3 Minimum Requirements

5.3.1 General

5.3.1.1 The minimum requirements are usually in one of the following forms:

(a) minimum thickness, which is independent of the yield stress, these are based on service experience and are usually expressed in the following format:

$t = A + BL$

Where:

A, B constants

L rule length, as defined in **Sec 4/1.1.1.1**

(b) minimum stiffness and proportion, which are based on prescriptive buckling requirements

5.4 Load-capacity Based Requirements

5.4.1 General

5.4.1.1 In general, the Working Stress Design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria where the Partial safety Factor (PF) method is applied. The partial safety factor format is applied for this highly critical failure mode to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

5.4.1.2 The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set, as given in **Table 2.5.3.** The table is schematic and only intended to give an overview.

5.4.1.3 The load scenarios addressed by the rules cover operations such as seagoing conditions, loading and unloading, tank testing conditions, ballast water exchange situations, special operations in harbour (e.g. propeller inspection afloat condition) and accidental flooding.

5.4.1.4 The design load combinations that represent the identified load scenarios are given in **Sec 7/6** and are denoted by S (static loads), S+D (static+dynamic loads), and A (accidental loads). In addition, the Rules address impact loads and sloshing loads as given in **Sec 7/4** and fatigue loads as given in **Sec 7/3.**

5.4.1.5 For the strength requirements, the considered loads cover the most severe operational loads that occur, hence the cargo tank finite element analysis and load-capacity based scantling requirements are based on rule loading conditions which simulate the worst possible loading conditions within the operating limits of the vessel.

5.4.1.6 For the fatigue requirements the considered loads cover an expected load history and representative loading conditions covering the ships' intended service are applied.

5.4.1.7 The acceptance criteria are categorised into three acceptance criteria sets. These are explained below and shown in **Tables 2.5.2** and **2.5.3.** The specific acceptance criteria set that is applied in the WSD rule requirements is dependent on the probability level of the characteristic combined load.

5.4.1.8 The acceptance criteria set AC1 is applied when the combined characteristic loads are frequently occurring, typically for the static design load combinations, but also applied for the sloshing design loads. This means that the loads occur on a frequent or regular basis. The allowable stress for a frequent load is lower than for an extreme load to take into account effects of:

(a) repeated yield

(b) allowance for some dynamics

(c) margins for operational mistakes.

5.4.1.9 The acceptance criteria set AC2 is typically applied when the combined characteristic loads are extreme values, e.g. typically for the static+dynamic design load combinations. High utilisation (η_i in **Table 2.5.1**) of the structural capacity (R_i in **Table 2.5.1**) is allowed in such cases because the considered loads are extreme loads with a low probability of occurrence.

5.4.1.10 The acceptance criteria set AC3 is typically applied for capacity formulations based on the plastic collapse models such as those that are applied to address bottom slamming and bow impact loads.

Table 2.5.1
Load Scenarios and Corresponding Rule Requirements

Load Scenarios		Rule Requirements			
Operation	Loads (that the vessel is exposed to and is to withstand)	Design Load Combination (specified in **Sec 7/6**) Ref. no	Notation	Design Format (specified in **Sec 8** and **9**) see Note 1	Acceptance Criteria Set (specified in **Sec 8** and **9**)
Seagoing operations					
Transit	Static and dynamic loads in heavy weather	1	S + D	1. $S_G + S_L + D_G + D_L \leq \eta_2 R_1$	AC2
				2. $\gamma_S S_G + \gamma_D D_G \leq R_2 / \gamma_{R2}$	AC2
	Impact loads in heavy weather	2	Impact	$S_L + D_{imp} \leq \eta_3 R_p$	AC3
	Internal sloshing loads	3	Sloshing	$S_L + D_{slh} \leq \eta_1 R_1$	AC1
	Cyclic wave loads	4	Fatigue	$DM \leq \sum \eta_i / N_i$	-
BWE by flow through or sequential methods	Static and dynamic loads in heavy weather	5	S + D	$S_G + S_L + D_G + D_L \leq \eta_2 R_1$	AC2
Harbour and sheltered operations					
Loading, unloading and ballasting	Typical maximum loads during loading, unloading and ballasting operations	6	S	$S_G + S_L \leq \eta_1 R_1$	AC1
Tank testing	Typical maximum loads during tank testing operations	7	S	$S_G + S_{L1} \leq \eta_1 R_1$	AC1
Special conditions in harbour	Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions	8	S	$S_G + S_L \leq \eta_1 R_1$	AC1
Accidental condition					
Accidental flooding	Typically maximum loads on internal watertight subdivision structure due to accidental flooding	9	A	for water tight boundaries 1. $S_L \leq \eta_2 R_1$	AC2
				for collision bulkhead 2. $S_L \leq \eta_1 R_1$	AC1
Note 1. The symbols defined in this column are defined in the text of **5.4**					
Where: D_G dynamic global load D_L dynamic local load D_M cumulative fatigue damage ratio S_G static global load S_L static local load R_i structural capacity					

5.4.2 Design loads for scantling requirements and strength assessment (FEM)

5.4.2.1 The structural assessment of compartment boundaries, e.g. bulkheads, is based on the worst possible loading, hence conditions are assessed with a full tank on one side and an empty tank on the other side. The situation with the tank content reversed is also considered. Similarly the shell envelope is assessed for conditions at the deepest draught without internal filling and at the lowest draught with internal filling.

5.4.2.2 The standard loading patterns to be used in the strength assessment (FEM) are given in **Appendix B**, **Tables B.2.3** and **B.2.4** for tankers with two oil-tight longitudinal bulkheads and one centreline oil-tight longitudinal bulkhead respectively. The corresponding information for the scantling requirements is given in **Sec 8.**

5.4.2.3 To ensure consistency of approach, standardised rule values for parameters such as GM, R_{roll}, T_{sc} and C_b. are applied to calculate the rule load values.

5.4.2.4 The probability level of the dynamic global and local loads (D_G, D_L and D_{imp} in **Table 2.5.1**) is 10^{-8} and are derived using the long term statistical approach specified in **4.2.6.2.**

5.4.2.5 The probability level of the sloshing loads (D_{slh} in **Table 2.5.1**) is 10^{-4} which is a load that occurs frequently.

5.4.2.6 The design load combinations corresponding to the identified load scenarios produce realistic design load sets suitable for the design and verification of the structural capability. Design load sets apply all the applicable simultaneously acting static and dynamic local load components (S_L and D_L in **Table 2.5.1**, which are usually pressure load components) and static and dynamic global load components (S_G and D_G in **Table 2.5.1**, which is usually hull girder bending moment) for the design of a particular or group of structural members. The relevant design load sets for the scantling requirements are given in **Sec 8/2** to **8/5.** The design load sets for the Finite Element analysis are referred to as load cases and are given in **Appendix B.**

5.4.2.7 The simultaneously occurring dynamic loads are specified by applying a dynamic load combination factor to the envelope dynamic load values given in **Sec 7/3.** The dynamic load combination factors that define the dynamic load cases are given in **Sec 7/6.4** for the structural strength assessment (FE) and in **Sec 7/6.5** for the scantling requirements.

5.4.2.8 The dynamic load combination factors have been derived using the equivalent design wave approach to provide realistic simultaneously occurring dynamic loads components suitable for structural assessment.

5.4.2.9 For the determination of design loads for the hull girder ultimate strength requirement given in **Sec 9/1**, the operational loads (i.e. ship loading conditions)and the environmental loads (i.e. hull girder wave bending moments) are maximised for sagging conditions for seagoing conditions. The characteristic value for the still water hull girder sagging bending moments M_{sw} is based on the maximum value from the seagoing conditions specified in **Sec 8/1.** The characteristic value for the wave hull girder sagging bending moments M_{WV} is given in **Sec 7/3.**

5.4.3 Design loads for fatigue requirements

5.4.3.1 For the fatigue requirements given in **Sec 9/3** and **Appendix C**, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-4} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

5.4.3.2 The considered wave-induced loads include:

(a) hull girder loads (i.e., vertical and horizontal bending moments)

(b) dynamic wave pressures

(c) dynamic tank pressures.

5.4.3.3 The fatigue analysis is calculated for two representative loading conditions covering the ship’s intended operation. These two conditions are:

(a) full load homogeneous conditions at design draught

(b) normal ballast condition.

The proportion of the ship's sailing life in the full load condition is 50 % and in ballast 50 %. It is assumed that 15 % of the ships' life is in harbour/sheltered water. It is consequently assumed that the ship will be sailing in open waters in full load condition for 42.5 % of the ship's life and in the ballast condition for 42.5 % of the ship's life.

5.4.3.4 The load values are based on actual parameters corresponding to the applied loading conditions, e.g. *GM*, C_b, etc., and the applicable draughts at amidships is used. The actual values are taken from specified loading conditions in the loading manual.

5.4.3.5 The simultaneously occurring dynamic loads are accounted for by combination of stresses due to the various dynamic load components. The stress combination procedure is given in **Appendix C.**

5.4.3.6 Still water loads and static sea and tank pressures from the actual loading conditions are used to determine the mean stress effect.

5.4.4 Structural response analysis

5.4.4.1 In general, the following approaches are applied for determination of the structural response to the applied design load combinations

(a) Beam theory
- used for prescriptive requirements

(b) FE analysis
- coarse mesh for cargo hold model
- fine mesh for local models
- very fine mesh for fatigue assessment

5.4.5 Structural capacity assessment

5.4.5.1 The considered failure modes in the Rules are yield (plastic deformation), buckling, brittle fracture and fatigue. Structural failure due to yield and buckling is primarily controlled by the strength requirements, brittle fracture is primarily controlled by the requirements for material selection and welding, and fatigue failure is primarily controlled by the high cycle fatigue requirements.

5.4.5.2 Generally, the capacity models applied in the prescriptive rules, i.e., the scantling requirements in **Sec 8**, are based on simple beam theory and include elastic yield and plastic capacity models. The buckling capacity is assessed using simplified buckling capacity models or by a more theoretical non-linear analysis procedure.

5.4.5.3 The design verification requirements are based on a linear elastic finite element analysis, a detailed prescriptive fatigue assessment procedure and a simplified ultimate strength assessment procedure. There is also a finite element based fatigue assessment procedure for some structural members, such as the hopper knuckle.

5.4.5.4 The application of the net thickness approach to assess the structural capacity is specified in **Sec 6/3.3.**

5.4.6 Acceptance criteria

5.4.6.1 The acceptance criteria applied in the working stress design requirements are given as acceptance criteria sets shown in **Tables 2.5.2** and **2.5.3.** There are slight variations within each set depending on the relative contribution of local and global loads, static and dynamic loads and the structural member being considered. The specific acceptance criteria are given in the detailed rule requirements in **Sec 8** and **9/2.**

Table 2.5.2
Principal Acceptance Criteria – Rule Requirements

	Plate panels and Local Support Members		Primary Support Members		Hull girder members	
Acceptance criteria set	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC1:	70-80 % of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	70-75 % of yield stress	Control of stiffness and proportions. Pillar buckling	75 % of yield stress	NA
AC2:	90-100 % of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	85 % of yield stress	Control of stiffness and proportions. Pillar buckling	90-100 % of yield stress	Usage factor typically 0.9
AC3:	Plastic criteria	Control of stiffness and proportions	Plastic criteria	Control of stiffness and proportions	NA	NA

Table 2.5.3
Principal Acceptance Criteria – Design Verification – FE Analysis

	Global cargo tank analysis		Local fine mesh analysis
Acceptance criteria set	Yield	Buckling	Yield
AC1:	60-80 % of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	local mesh as 136 % of yield stress averaged stresses as global analysis
AC2:	80-100 % of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	local mesh as 170 % of yield stress averaged stresses as global analysis

5.4.6.2 The purpose of applying different sets is to achieve a consistent and acceptable safety level for all combinations of static and dynamic loads and to account for different capacity models.

5.5 Materials

5.5.1 General

5.5.1.1 Higher material properties are selected for highly critical structural elements which are subjected to high loads in order to reduce the risk of propagation of brittle fracture.

5.6 Application of Rule Requirements

5.6.1 Minimum requirements

5.6.1.1 These specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum are not allowed.

5.6.2 Load based prescriptive requirements

5.6.2.1 These provide scantling requirements for all plating, local support members, most primary support members and the hull girder and cover all structural elements including deckhouses, foundations for deck equipment, etc.

5.6.2.2 In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

5.6.3 Design verification – hull girder ultimate strength

5.6.3.1 The requirements for the ultimate strength of the hull girder are based on a Partial safety Factor (PF) method, see **4.5.** A safety factor is assigned to each of the basic variables, the still water bending moment, wave bending moment and ultimate capacity. The safety factors were determined using a structural reliability assessment approach, the long term load history distribution of the wave bending moment was derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

5.6.3.2 The purpose of the hull girder ultimate strength verification is to demonstrate that one of most critical failure modes of a double hull tanker is controlled.

5.6.4 Design verification – global finite element analysis

5.6.4.1 The global finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements. The analysis is required because the prescriptive requirements do not take into account the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy. Hence the global finite element analysis is necessary to verify the proposed scantlings.

5.6.4.2 A linear elastic three dimensional finite element analysis of the cargo region (a FE model length of three tanks is required) is carried out to assess and verify the structural response of the proposed hull girder and primary support members and assist in specifying the scantling requirements for the primary support members. The purpose with the finite element analysis is to verify that the stresses and buckling capability of the primary support members are within acceptable limits for the applied design loads.

5.6.5 Design verification – fatigue assessment

5.6.5.1 The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A prescriptive fatigue requirement is applied to details such as end connections of longitudinal stiffeners using an SN curve approach based on geometric details, i.e. Class F, F2, etc. A hot spot fatigue assessment procedure using finite element analysis is applied to details such as the hopper knuckle. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

5.6.6 Relationship between the prescriptive scantling requirements and the strength assessment (FEM)

5.6.6.1 The prescriptive minimum requirements define the minimum acceptable scantlings. These may not to be reduced by any form of alternative calculations such as load-capacity prescriptive requirements or strength analysis such as FEM.

5.6.6.2 The section modulus and/or shear area of a primary support member and/or the cross sectional area of a primary support member cross tie may be reduced to 85% of the prescriptive requirements provided that the reduced scantlings comply with the strength assessment (FEM).

5.6.6.3 The philosophy is that a coarse approach should be more conservative than a detailed approach. Hence, the prescriptive requirements are generally more conservative than the corresponding requirements based on strength assessment (FEM).

Section 3

Rule Application

1 Notations

1.1 Notations

1.1.1 General

1.1.1.1 Ships fully complying with the requirements of these Rules and the specific requirements of the assigning Classification Society relating to construction, survey and equipment will be eligible to be assigned with character symbols and a ship type notation appropriate to the assigning Classification Society.

1.1.1.2 In addition to **1.1.1.1**, ships fully complying with the requirements of these Rules will also be assigned the notation CSR.

2 Documentation, Plans and Data Requirements

2.1 Documentation and Data Requirements

2.1.1 Loading information

2.1.1.1 Loading guidance information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations is to be provided onboard the ship. The loading guidance information is to include an approved loading manual and loading computer system complying with the requirements given in **Sec 8/1.1.2** and **8/1.1.3** respectively.

2.1.2 Submission of calculation data and results

2.1.2.1 Where calculations have been carried out in accordance with the procedures given in the Appendices of these Rules, one copy of the following supporting information is to be submitted as applicable:

(a) reference to the calculation procedure and technical program used
(b) a description of the structural modelling
(c) a summary of the analysis parameters including properties and boundary conditions
(d) details of the loading conditions and the means of applying loads
(e) a comprehensive summary of calculation results
(f) sample calculations where appropriate.

2.1.2.2 In general, submission of large volumes of input and output data associated with programs, such as finite element analysis, will not be required.

2.1.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output resides with the designer.

2.1.3 Use of computer software for rule calculations

2.1.3.1 In general, any rule computation program recognised by the Classification Society may be employed to determine scantlings according to these Rules provided the implementation given in **5.1** is complied with.

2.1.3.2 A computer program that has been demonstrated to produce reliable results to the satisfaction of the Classification Society is regarded as a recognised program. Where the computer programs employed are not supplied or recognised by the Classification Society, full particulars of the computer program, including example calculation output, are to be submitted. It is recommended that the designers consult the Classification Society on the suitability of the computer programs intended to be used prior to the commencement of any analysis work.

2.2 Submission of Plans and Supporting Calculations

2.2.1 General

2.2.1.1 In general, the main categories and lists of information required are given in **2.2.2.** Additional requirements for some items are also given in subsequent sections as applicable.

2.2.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations. Additional copies may be required according to the individual Classification Society requirements.

2.2.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, materials, welding and loads imposed on the structure by equipment and systems as appropriate.

2.2.1.4 Plans are to include information related to the renewal thickness as specified in **Sec 12.**

2.2.2 Plans and supporting calculations

2.2.2.1 In general, plans covering the following items are to be submitted:

(a) main scantling plans:
- midship sections showing longitudinal and transverse structural members
- construction profiles/plans showing all main longitudinal structural elements along the ships length including decks, inner bottom, bulkheads, double side stringers and double bottom girders
- shell expansion
- main oil-tight and watertight transverse bulkheads including primary support members

(b) loading guidance information:
- preliminary loading manual
- final loading manual
- details of the design basis, see **Sec 8/1.1.2**
- test conditions for the loading instrument

(c) detailed construction plans:
- cargo tank construction plans showing the variations in detail arrangements and scantlings of double bottom floors, double side webs and other transverse primary support members
- fore end
- aft end
- engine room construction including the engine and thrust bearing seating
- deckhouses and superstructures

(d) detail design plans except where the information is already included on plans listed in **(a)** and **(c)**:
- sternframe
- hull penetration plans
- welding
- bilge keels
- booklet of standard design details
- anchoring and mooring equipment
- pillar and girder support arrangements for decks
- access arrangements through double bottom and side skin spaces in the cargo tank region
- details and arrangements of openings and attachments to the hull structure for means of access for inspection purposes

(e) plans detailing support structures except where the information is already included on plans listed in **(a)** to **(d)**:
- anchoring windlass and chain stopper
- mooring winches
- masts, derrick posts or cranes
- emergency towing equipment
- other deck equipment or fittings

2.2.2.2 The following supporting documents are to be submitted:

(a) general arrangement

(b) capacity plan

(c) lines plan or equivalent

(d) dry-docking plan, where developed

(e) freeboard plan or equivalent, showing freeboards and items relative to the conditions of assignment

2.2.2.3 The following supporting calculations are to be submitted:
(a) calculation of the equipment number.

2.2.2.4 Plans of items not covered by these Rules are to be submitted according to the individual Classification Society requirements.

2.2.3 Plans to be supplied onboard the ship

2.2.3.1 One copy of the following plans indicating the new-building and renewal thickness for each structural item:
(a) main scantling plans as given in **2.2.2.1(a)**
(b) one copy of the final approved loading manual, see **2.1.1**
(c) one copy of the final loading instrument test conditions, see **Sec 8/1.1.3**
(d) detailed construction plans as given in **2.2.2.1(c)**
(e) welding
(f) details of the extent and location of higher tensile steel together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels
(g) details and information on use of special materials, such as aluminium alloy, used in the hull construction.
(h) towing and mooring arrangements plan, see **Sec 11/3.1.6.16**

3 Scope of Approval

3.1 General

3.1.1 Rule application

3.1.1.1 Further to the information contained in **Sec 1/1.1.2** and **Sec 1/1.2.1**, the Rules cover the scantling requirements for the classification of new double hull tankers of 150 m or greater in length.

3.1.1.2 The attention of owners, designers, and builders is directed to the regulations of international, national, canal, and other authorities dealing with those requirements which may affect structural aspects, in addition to or in excess of the classification requirements.

3.1.1.3 Other aspects of the structural design not covered by these Rules are to be addressed using the rules of the individual Classification Society.

3.2 Classification

3.2.1 General

3.2.1.1 The documentation, plans and data requirements specified in **Sec 2** are to be submitted. Each in dividual Classification Society will review such documentation to verify compliance with the requirements.

3.2.1.2 An appropriate term to indicate that the plans, reports or documents have been reviewed for compliance with these Rules will be used according to the procedures of the individual Classification Society.

3.3 Requirements of National and International Regulations

3.3.1 Responsibility

3.3.1.1 It is the responsibility of the designer to ensure that the design complies with the current National and International regulations applicable to the vessel.

3.3.1.2 Classification Societies are not responsible for assessing compliance with International and National regulations as part of the general classification approval process. However, a Classification Society may enter into an agreement under which they are explicitly instructed to review and approve a vessel design for compliance with specified regulations. This approval may be accepted as proof of compliance on behalf of a Flag Administration provided the Classification Society has been designated as a suitable recognised by that Flag Administration in accordance with SOLAS Regulations XI/1.

3.3.2 Review procedure

3.3.2.1 When compliance is reviewed by the Flag Administration, the vessel is to be issued with certificates indicating compliance with National and International regulations by the Flag Administration. For ships with arrangements and equipment that are required to comply with the following requirements, and applicable amendments thereto, and where not issued by the Flag Administration, the applicable convention certificates are to be issued by the Classification Society or by an IACS member when authorised:

(a) International Convention on Load Lines, 1966

(b) International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1978

(c) International Convention for the Prevention of Pollution from Ships, 1973, and as modified by the Protocol of 1978 relating thereto.

For dual class ships, convention certificates may be issued by either Classification Society with which the ship is classed, provided this is recognised in a formal dual class agreement with the Classification Societies classing the ship and that both societies are authorised by the Flag Administration.

4 Equivalence Procedure

4.1 General

4.1.1 Rule applications

4.1.1.1 These Rules apply in general to double hull oil tankers of normal form, proportions, speed and structural arrangements. Relevant design parameters defining the assumptions made are given in **Sec 2/3.**

4.1.1.2 The Rules are applicable to steel ships of welded construction. Other materials for use in hull construction will be specially considered.

4.1.1.3 Special consideration will be given to the application of the Rules incorporating design parameters which are outside the design basis of **Sec 2/3**, for example:

(a) increased fatigue life

(b) increased corrosion additions

(c) increased cargo density.

4.1.2 Novel designs

4.1.2.1 Ships of novel design, i.e. those of unusual form, proportions, speed and structural arrangements outside those reflected in **Sec 2/3.1.2** of these Rules will be specially considered according to the contents of this sub-section.

4.1.2.2 Information is be submitted to the Classification Society to demonstrate that the structural safety of the novel design is at least equivalent to that intended by the Rules.

4.1.2.3 In such cases, the Classification Society is to be contacted at an early stage in the design process to establish the applicability of the Rules and additional information required for submission.

4.1.2.4 Dependent on the nature of the deviation, a systematic review may be required to document equivalence with the Rules.

4.1.3 Alternative calculation methods

4.1.3.1 Where indicated in specific sections of the Rules, alternative calculation methods to those shown in the Rules may be accepted provided it is demonstrated that the scantlings and arrangements are of at least equivalent strength to those derived using the Rule calculation method.

5 Calculation and Evaluation of Scantling Requirements

5.1 Determination of Scantling Requirements for Plates

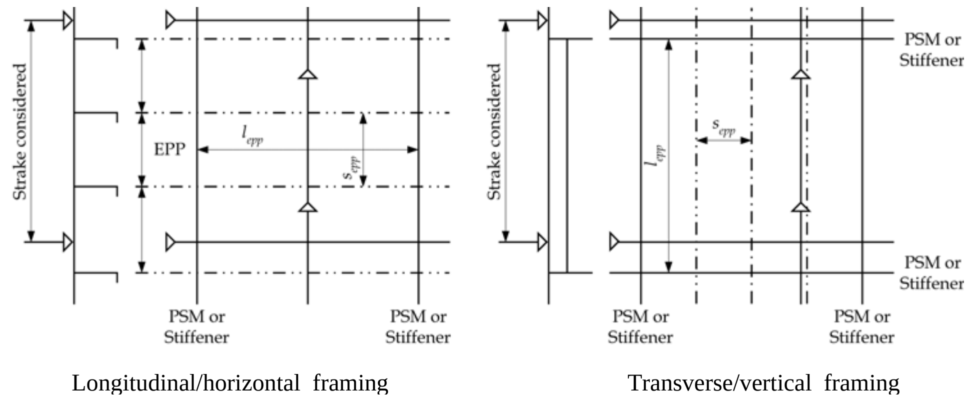
5.1.1 Determination of scantlings of plate strakes – idealisation of plate panels

5.1.1.1 Scantlings of plate strakes are to be derived based on the idealisation of the as-built structure as a series of Elementary Plate Panels (EPP).

5.1.1.2 An EPP is the unstiffened part of the plating between stiffeners. The plate panel length, l_{epp}, and breadth, s_{epp}, of the EPP are defined in relation to the longest and shortest plate edges respectively, as shown in **Fig 3.5.1.**

5.1.1.3 For strength assessment, the idealisation of EPP may be different and take into account the mesh arrangement in the FEM model.

Fig 3.5.1
Elementary Plate Panel Definition



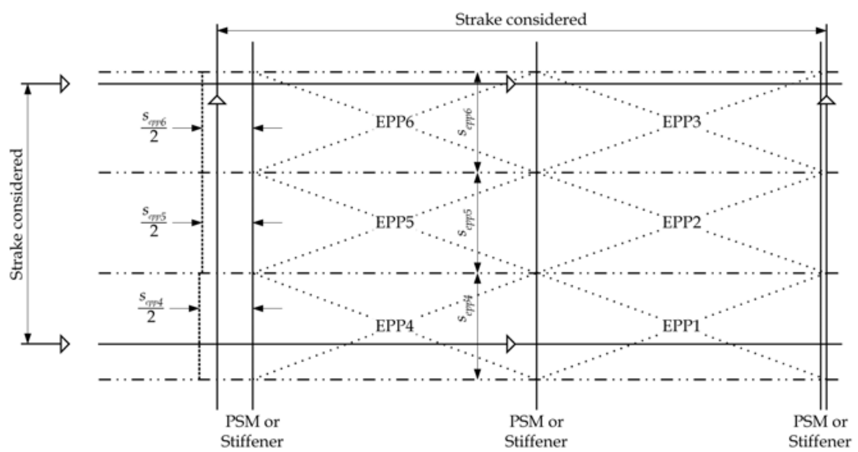
5.1.1.4 The required scantling of a plate strake is to be taken as the greatest value required for each EPP within that strake as given by:

(a) an EPP positioned entirely within the strake boundaries, e.g. EPP2 in **Fig 3.5.2**

(b) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the long edge of the EPP, e.g. EPP1, 3, 4 and 6 in **Fig 3.5.2**

(c) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the short edge of the EPP within more than half the EPP breadth, sepp, from the edge, e.g. EPP1 and EPP2 in **Fig 3.5.3(a).**

Fig 3.5.2
Determining Elementary Plate Panels for a Strake



5.1.2 Determination of scantlings of elementary plate panels for scantling requirements

5.1.2.1 The required scantling of each elementary plate panel is to be calculated based on a Load Calculation Point (LCP) defined as:

(a) for longitudinal framing, at the mid length of the EPP measured along the global x-axis at its lower edge. For horizontal plating the load calculation point is to be taken at the outboard y-value of the EPP. See **Fig 3.5.3(a)**

(b) for transverse framing, at the mid length of the EPP measured along the global x-axis at the lower edge of strake. For horizontal plating the load calculation point is to be taken at the outboard y-value of the EPP. See **Fig 3.5.3(b)**

(c) for horizontal framing on vertical transverse structure, at the lower edge of the elementary plate panel at the point of outboard y-value of the EPP. See **Fig 3.5.3(c)**

(d) for vertical framing on vertical transverse structure, at the greatest y-value of the lower edge of the EPP or at the lower edge of strake. See **Fig 3.5.3(d)**

5.1.2.2 Both the local pressure and hull girder stress used for the calculation of the local scantling requirements are to be taken at the LCP.

5.1.3 Determination of scantlings of elementary plate panels for hull girder strength

5.1.3.1 The required scantlings of the elementary plate panels are to satisfy the hull girder bending and hull girder shear requirements of **Sec 8/1.**

5.1.3.2 The required thickness of each elementary plate panel, with respect to buckling, is to be calculated based on stresses taken at the mid length of the EPP measured along the global x-axis.

5.1.3.3 The buckling evaluation is to be calculated using the stress distribution across the width of the panel defined with a reference stress taken at the edge with maximum stress and reduced stress at the other edge given as a fraction, Ψ, defined in **Table 10.3.1**, of the reference stress.

5.1.3.4 The required scantling of a plate strake is to be taken as the greatest value required for each EPP within that strake as given by:

(a) an EPP positioned entirely within the strake boundaries, e.g. EPP2 in **Fig 3.5.2**

(b) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the long edge of the EPP, e.g. EPP1, 3, 4 and 6 in **Fig 3.5.2**

(c) an EPP with a strake boundary weld seam bisecting it predominantly in the direction of the short edge of the EPP within more than half the EPP breadth, S_{epp}, from the edge, e.g. EPP1 and 2 in **Fig 3.5.3(a).**

5.1.4 Determination of scantlings of elementary plate panels for FEM strength assessment

5.1.4.1 The required scantlings of elementary plate panels are to be derived from the plate mesh element with maximum utilisation, see **Sec 9/2.**

Fig 3.5.3
Example of Load Calculation Point for Typical Structural Configurations

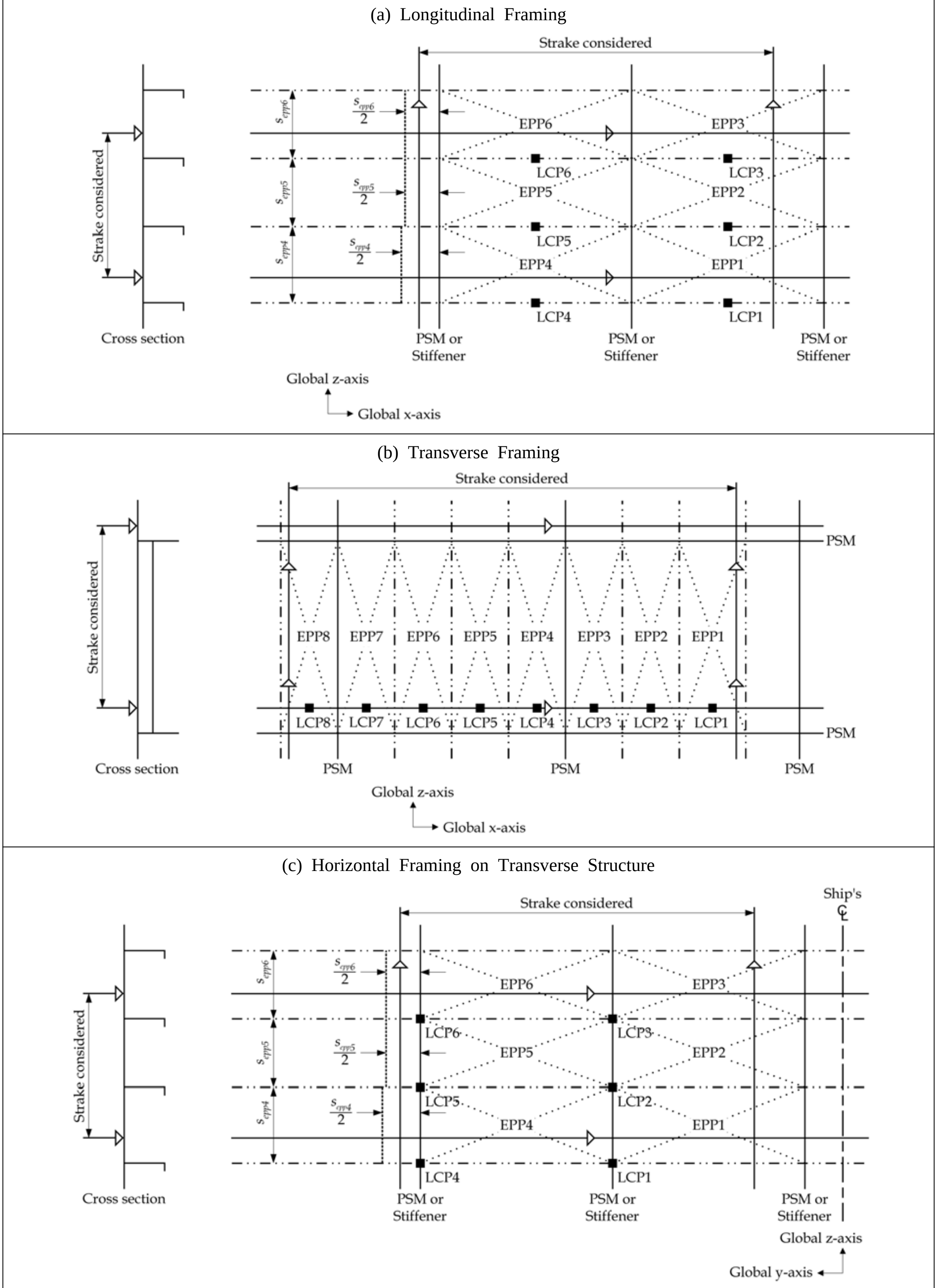
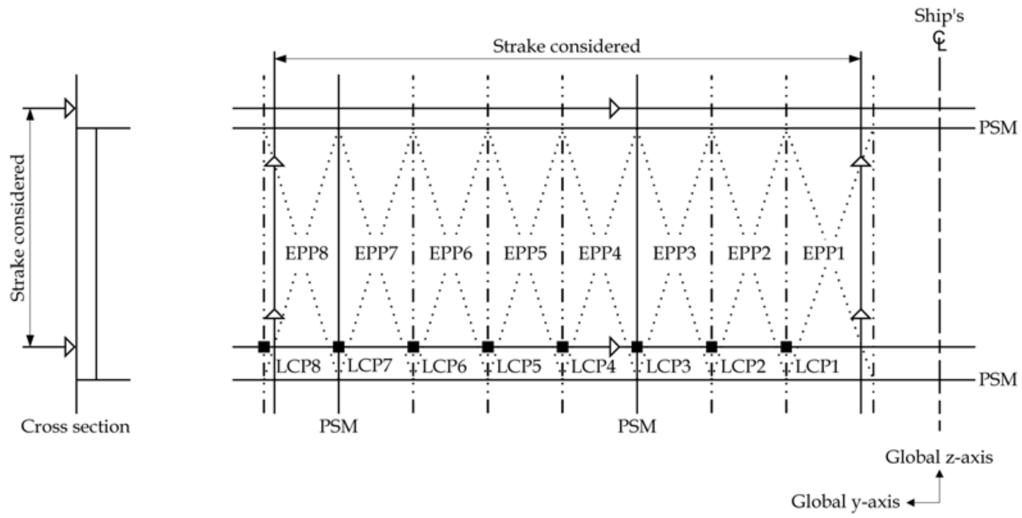


Fig 3.5.3 (Continued)
Example of Load Calculation Point for Typical Structural Configurations

(d) Vertical Framing on Transverse Structure



5.2 Determination of Scantlings of Stiffeners

5.2.1 Determination of scantlings of stiffeners – idealisation of stiffeners

5.2.1.1 Scantlings of individual stiffeners are to be derived based on the idealisation of the as-built structure as a series of stiffened panels.

5.2.1.2 A stiffened panel consists of a single idealised stiffener profile and effective plate flange supporting a boundary of one or more elementary plate panels. The arrangement of stiffened panels is based on the idealisation of the structure according to the elementary plate panel definition in **5.1.1.**

5.2.1.3 Scantlings of stiffeners based on requirements in **Sec 8** may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings.The scantling of the group is to be taken as the greater of the following:

(a) the average of the required scantling of all stiffeners within a group

(b) 90 % of the maximum scantling required for any one stiffener within the group.

The concept of grouping is not applicable to fatigue requirements as given in **Sec 9/3** and **Appendix C.**

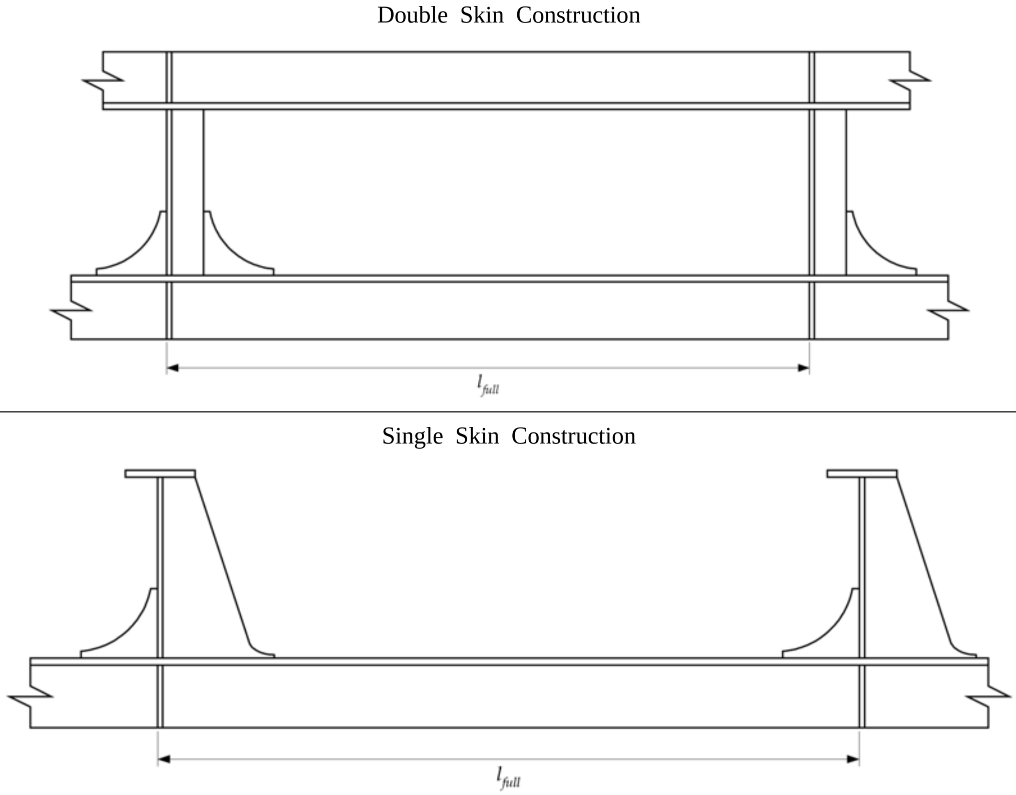
5.2.2 Determination of scantlings of stiffened panels for scantling requirements and fatigue

5.2.2.1 The required scantling of a stiffened panel is to be based on a pressure load calculation point defined as:

(a) mid point of the overall span, l_{full}, of the stiffener between primary support members, see **Fig 3.5.4**

(b) at the connection of the stiffener to the plating.

Fig 3.5.4
Definition of Overall Span of Stiffeners, l_{full}



5.2.2.2 For longitudinal and horizontal framing the design pressure is to be taken as the pressure at the mid point of the overall span.

5.2.2.3 For transverse and vertical framing the design pressure is to be taken as the greater of the following:

P_{ms} kN/m^2

$$\frac{(P_{end-1}+P_{end-2})}{2} \quad \text{kN/m}^2$$

Where:

P_{ms} calculated pressure at mid point of overall span, l_{full}, in kN/m^2

P_{end-1} calculated pressure at 1st end of overall span, in kN/m^2

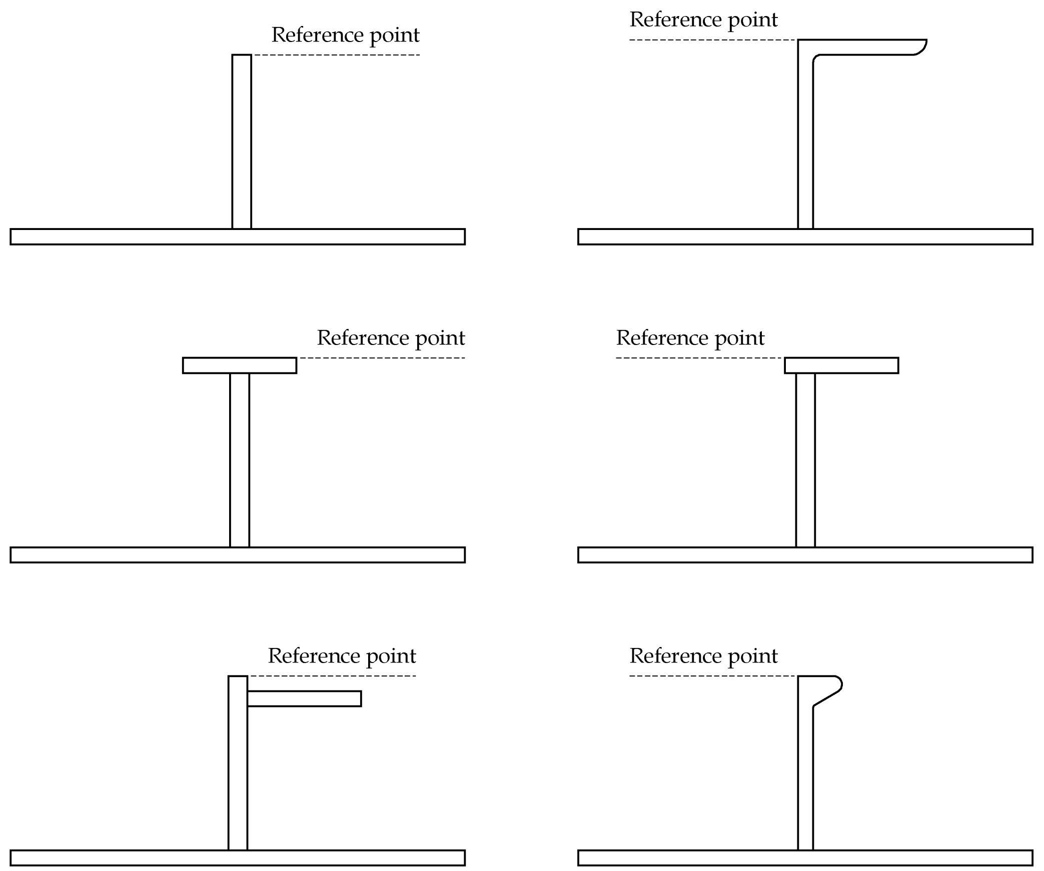
P_{end-2} calculated pressure at 2nd end of overall span, in kN/m^2

l_{full} overall span, in m, see **Fig 3.5.4**

5.2.2.4 The section modulus requirements given in these Rules relate to the reference point giving the minimum section modulus. In general, this will be on the outer surface of the faceplate. The reference point for calculation of section modulus for typical profiles is shown in **Fig 3.5.5.**

5.2.2.5 The hull girder stress used for calculation of local scantling requirements for stiffeners is to be taken at the reference point as shown in **Fig 3.5.5**

Fig 3.5.5
Reference Point for Calculation of Section Modulus and Hull Girder Stress for Local Scantling Assessment



5.2.3 Determination of scantlings of stiffened panels for hull girder buckling strength

5.2.3.1 The required scantling of a stiffened panel, with respect to buckling, is to be based on the axial stress calculated at the attachment point of the stiffener to the plate and at the mid length of the stiffener measured along the global x-axis.

5.2.3.2 The required scantling as given in **5.2.3.1** applies to stiffeners outside of a distance s from the support, where s is the stiffener spacing.

5.2.4 Determination of scantlings of stiffened panels for FEM strength assessment

5.2.4.1 The required scantlings of the stiffened panel are to be based on the derivation of applied stresses in accordance with **Sec 9/2.**

5.2.5 Shear area requirements of stiffeners

5.2.5.1 Requirements for the shear area and/or web thickness of stiffeners are given in **Sec 8.**

5.2.5.2 The requirements in **Sec 8** are to be calculated based on the load point defined in **5.2.2** and the effective span as given in **Sec 4/2.1.2.**

5.2.5.3 The requirements in **Sec 8** are to be evaluated against the actual shear area of the stiffener, based on the effective shear height of the stiffener as given in **Sec 4/2.4.2** and based on the specified minimum yield of the stiffener.

5.2.5.4 The effect of brackets may be included in the calculation of the effective span, but no part of the bracket is to be included in the calculation of the actual shear area.

5.2.6 Bending requirements of stiffeners

5.2.6.1 Requirements for the section modulus and moment of inertia of stiffeners are given in **Sec 8.**

5.2.6.2 The requirements in **Sec 8** are to be calculated based on the load point defined in **5.2.1** and the effective span as given in **Sec 4/2.1.1.**

5.2.6.3 The requirements in **Sec 8** are to be evaluated against the actual section modulus/moment of inertia of the stiffener. The stiffener web and flanges are to be included in the calculation of actual sectional properties.

5.2.6.4 The effect of brackets may be included in the calculation of the effective span, but no part of the bracket is to be included in the calculation of section modulus/moment of inertia.

5.2.6.5 When the stiffener is of a higher strength material than the attached plate, the yield stress used for the calculation of the section modulus requirements in **Sec 8** is in general not to be greater than 1.35 times the minimum specified yield stress of the attached plate. If the yield stress of the stiffener exceeds this limitation the following criterion is to be satisfied:

$$\sigma_{yd-stf} \leq \left(\sigma_{yd-plt} - |\sigma_{hg}|\right) \frac{Z_{net-plt}}{Z_{net}} + |\sigma_{hg}| \qquad \text{N/mm}^2$$

Where:

σ_{yd-stf} specified minimum yield stress of the material of the stiffener, in N/mm^2

σ_{yd-plt} specified minimum yield stress of the material of the attached plate, in N/mm^2

σ_{hg} maximum hull girder stress of sagging and hogging (S+D), in N/mm^2, as defined in **Table 8.2.5** and **Table 8.4.3** for stiffeners in cargo tank region and machinery spaces respectively and not to be taken as less than 0.4 σ_{yd-plt}

Z_{net} net section modulus, in way of face plate/free edge of the stiffener, in cm^3

$Z_{net-plt}$ net section modulus, in way of the attached plate of stiffener, in cm^3

5.2.7 Evaluation of slanted stiffeners

5.2.7.1 The shear area and section modulus requirements for local support members are valid about an axis parallel to the plate flange. If the angle φ_w between the stiffener web and the attached plating is less than 75 degrees, see **Fig 4.2.14**, then the actual shear area and section modulus is to be adjusted in accordance with **Sec 4/2.4.2** and **2.4.3.** The angle between the stiffener web, φ_w, and the attached plating is not to be less than 50 degrees.

5.3 Calculation and Evaluation of Scantling Requirements for Primary Support Members

5.3.1 Load application point for primary support members

5.3.1.1 The design pressure for primary support members is generally taken at the mid point of the load area. The design pressures for the primary support members are defined for individual members as given in **Sec 8.**

5.3.2 Shear requirements of primary support members

5.3.2.1 Requirements for shear area and/or web thickness of primary support members are given in **Sec 8.**

5.3.2.2 These requirements are to be calculated based on the load point defined in **5.3.1** and the effective span as given in **Sec 4/2.1.5.**

5.3.2.3 These requirements are to be evaluated against the actual shear area and the specified minimum yield of the web plate of the primary support member. The actual shear area of the primary support member is defined in **Sec 4/2.5.1.** The effect of brackets may be included in the calculation of effective span, but are not to be included in the calculation of actual shear area.

5.3.3 Bending requirements of primary support members

5.3.3.1 Requirements for section modulus and moment of inertia of primary support members are given in **Sec 8** and **Sec 10**, respectively.

5.3.3.2 These requirements are to be calculated based on the load point defined in **5.3.1** and the effective span as given in **Sec 4/2.1.4.**

5.3.3.3 These requirements are to be evaluated against the actual section modulus/moment of inertia of the primary support member. Web and flanges are included in the calculation of actual sectional properties. The effect of brackets may be included in calculation of effective span, but are not to be included in the calculation of section modulus/moment of inertia.

5.3.3.4 Where it is impracticable to fit a primary support member with the required web depth, then it is permissible to fit a member with reduced depth provided that the fitted member has equivalent moment of inertia or deflection to the required member. The required equivalent moment of inertia is to be based on an equivalent section given by the effective width of plating at mid span with required plate thickness, web of required depth and thickness and face plate of sufficient width and thickness to satisfy the required mild steel section modulus. All other rule requirements, such as minimum thicknesses, slenderness ratio, section modulus and shear area, are to be satisfied for the member of reduced depth. The equivalent moment of inertia may be also demonstrated by an equivalent member having the same deflection as the required member.

5.4 Rounding of Calculated Thickness

5.4.1 Required gross thickness

5.4.1.1 The minimum required gross thickness of any member to be fitted at the new-building stage, exclusive of any owners’ extras, is to be taken as the rounded net thickness required plus the appropriate corrosion addition.

5.4.1.2 The required net thickness is given by rounding the calculated net thickness to the nearest half millimetre. For example:

(a) for $10.75 \leq t_{calc\text{-}net} < 11.25$ mm the Rule required thickness is 11 mm

(b) for $11.25 \leq t_{calc\text{-}net} < 11.75$ mm the Rule required thickness is 11.5 mm.

Section 4

Basic Information

1 Definitions

1.1 Principal Particulars

1.1.1 *L*, rule length

1.1.1.1 *L*, the rule length, is the distance on the waterline at the scantling draught, from the forward side of the stem to the centreline of the rudder stock, in metres. *L* is not to be less than 96 %, and need not be greater than 97 %, of the extreme length on the summer load waterline. In ships with an unusual stern and bow arrangement the length, *L,* will be specially considered.

1.1.2 L_L, load line length

1.1.2.1 L_L, the load line length is defined in the International Convention on Load Lines.

1.1.3 Moulded breadth

1.1.3.1 *B*, the moulded breadth, is the maximum breadth of the ship, measured amidships to the moulded line of the frame, in metres.

1.1.4 Moulded depth

1.1.4.1 *D*, the moulded depth, is the vertical distance, in metres, amidships, from the moulded baseline to the moulded deck line of the uppermost continuous deck measured at deck at side. On vessels with a rounded gunwale, *D* is to be measured to the continuation of the moulded deck line.

1.1.5 Draughts

1.1.5.1 *T*, the draught in metres, is the summer load line draught for the ship in operation, measured from the moulded base line at amidships. Note this may be less than the maximum permissible summer load waterline draught.

1.1.5.2 T_{bal}, is the minimum design ballast draught, in metres, at which the strength requirements for the scantlings of the ship are met. The minimum design ballast draught is not to be greater than the minimum draught of ballast conditions including ballast water exchange operation, measured from the moulded base line at amidships, for any ballast loading condition in the loading manual including both departure and arrival conditions.

1.1.5.3 T_{bal-n}, the normal ballast draught in metres, is the draught at departure given for the normal ballast condition in the loading manual, measured from the moulded base line at amidships, see **Sec 8/1.1.2.3**. The normal ballast condition is the ballast condition in compliance with condition specified in **Sec 8/1.1.2.2 a).**

1.1.5.4 T_{full}, the full load design draught in metres, is the draught at departure given for the homogeneous full load condition in the loading manual, measured from the moulded base line at amidships, see **Sec 8/1.1.2.3.**

1.1.5.5 T_{sc}, is the maximum design draught, in metres, at which the strength requirements for the scantlings of the ship are met.

1.1.6 Amidships

1.1.6.1 Amidships is to be taken as the middle of the rule length, *L*.

1.1.7 Moulded displacement

1.1.7.1 Δ, the moulded displacement, in tonnes, corresponding to the underwater volume of the ship, at draught T_{sc}, in sea water with a density of 1.025 t/m^3.

1.1.8 Maximum service speed

1.1.8.1 *V*, the maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest sea-going draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

1.1.9 Block coefficient

1.1.9.1 C_b, the block coefficient at the scantling draught, is defined as:

$$C_b = \frac{\nabla}{L B_{WL} T_{sc}}$$

Where:

∇ moulded displacement volume at the scantling draught, in m^3

L rule length, as defined in **1.1.1.1**

B_{WL} moulded breadth measured amidships, in m, at the scantling draught waterline

T_{sc} scantling draught, as defined in **1.1.5.5**

1.1.9.2 C_{b-LC}, the block coefficient at considered loading condition, is defined as:

$$C_{b-LC} = \frac{\nabla_{LC}}{L B_{WL} T_{LC}}$$

Where:

∇_{LC} moulded displacement volume at the T_{LC}, in m^3

L rule length, as defined in **1.1.1.1**

B_{WL} moulded breadth measured amidships, in m, at the T_{LC}

T_{LC} draught at amidships, in m, in the loading condition being considered.

1.1.10 Length between perpendiculars

1.1.10.1 L_{pp}, the length between perpendiculars, is the distance, in metres, on the scantling draught waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post.

1.1.11 The forward perpendicular

1.1.11.1 F.P., the forward perpendicular, is the perpendicular at the intersection of the scantling draught waterline with the fore side of the stem. The F.P. is the forward end of the rule length, L.

1.1.12 The aft perpendicular

1.1.12.1 A.P., the aft perpendicular, is the perpendicular at the aft end of the rule length, L, measured from the F.P.

1.1.13 Load line block coefficient

1.1.13.1 C_{bL}, the load line block coefficient, is defined in the International Convention on Load Lines as follows:

$$C_{bL} = \frac{\nabla_L}{L_L B T_L}$$

Where:

∇_L moulded displacement volume at the moulded draught, T_L, in m^3

L_L load line length, as defined in **1.1.2.1**

B moulded breadth, in m, as defined in **1.1.3.1**

T_L the moulded draught measured to the waterline at 85 per cent of the least moulded depth, in m

1.1.14 Deadweight

1.1.14.1 DWT, is the deadweight of the ship, in tonnes, floating in water with a specific gravity of 1.025, at the summer load line draught.

1.2 Position 1 and Position 2

1.2.1 Position 1

1.2.1.1 Position 1 is defined as any location upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0.25 L_L.

1.2.2 Position 2

1.2.2.1 Position 2 is defined as any location upon exposed superstructure decks abaft the forward 0.25 L_L.

1.3 Type 'A' and Type 'B' Freeboard Ships

1.3.1 ICLL definition

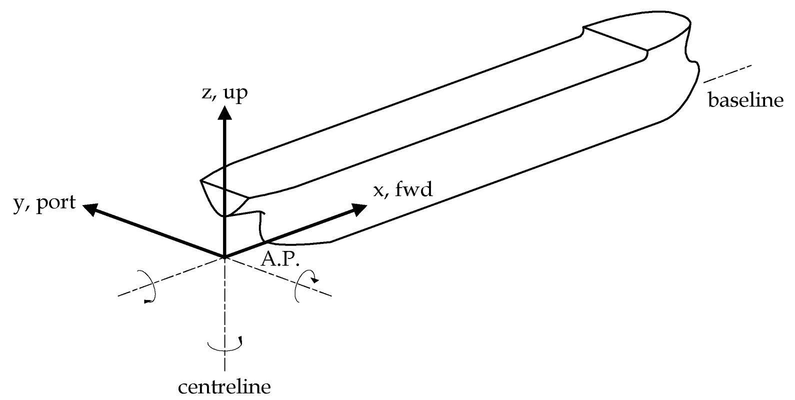
1.3.1.1 A Type 'A' or Type 'B' freeboard ship is as defined in the International Convention on Load Lines.

1.4 Coordinate System

1.4.1 Origin and orientation

1.4.1.1 The coordinate system used within these Rules is shown in **Fig 4.1.1.** Motions and displacements are considered positive in the forward, up and to port direction. Angular motions are considered positive in the clockwise direction about the x, y or z axis.

Fig 4.1.1
Coordinate System



1.5 Naming Convention

1.5.1 Bulkhead nomenclature

1.5.1.1 **Fig 4.1.2, 4.1.3** and **4.1.4** show the common structural nomenclature used within these Rules.

Fig 4.1.2
Corrugated Transverse Bulkhead Nomenclature

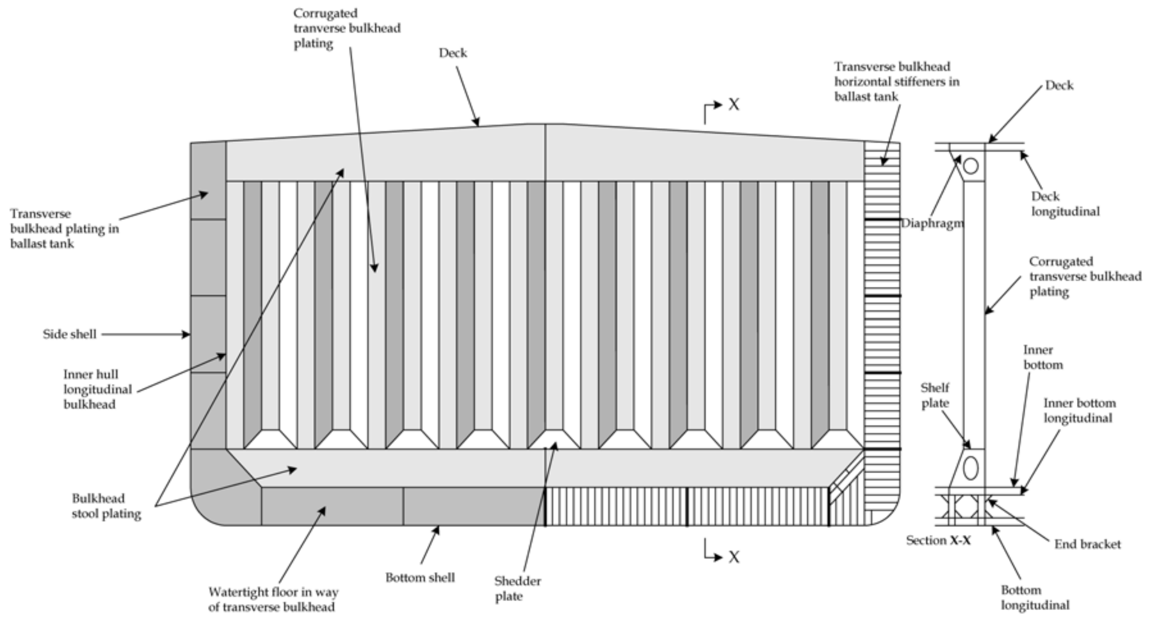


Fig 4.1.3
Flat Transverse Bulkhead Nomenclature

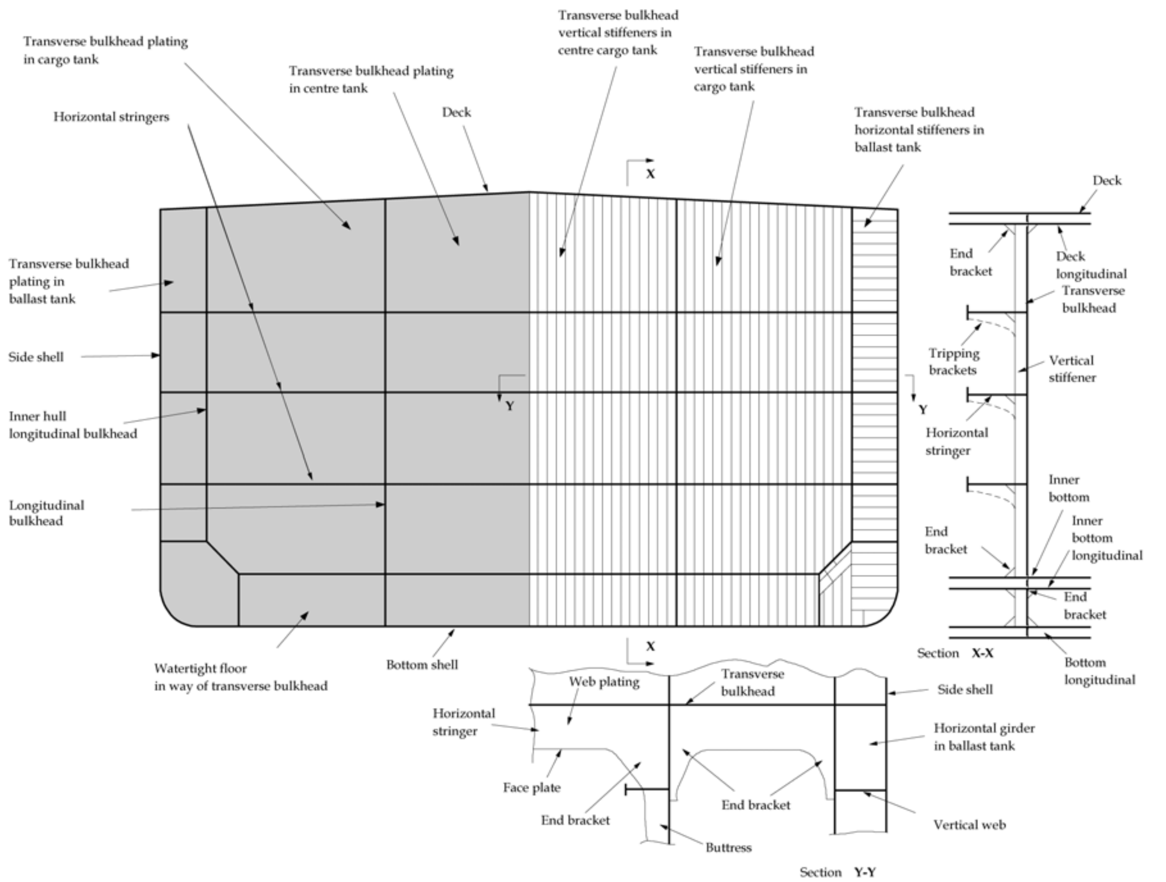
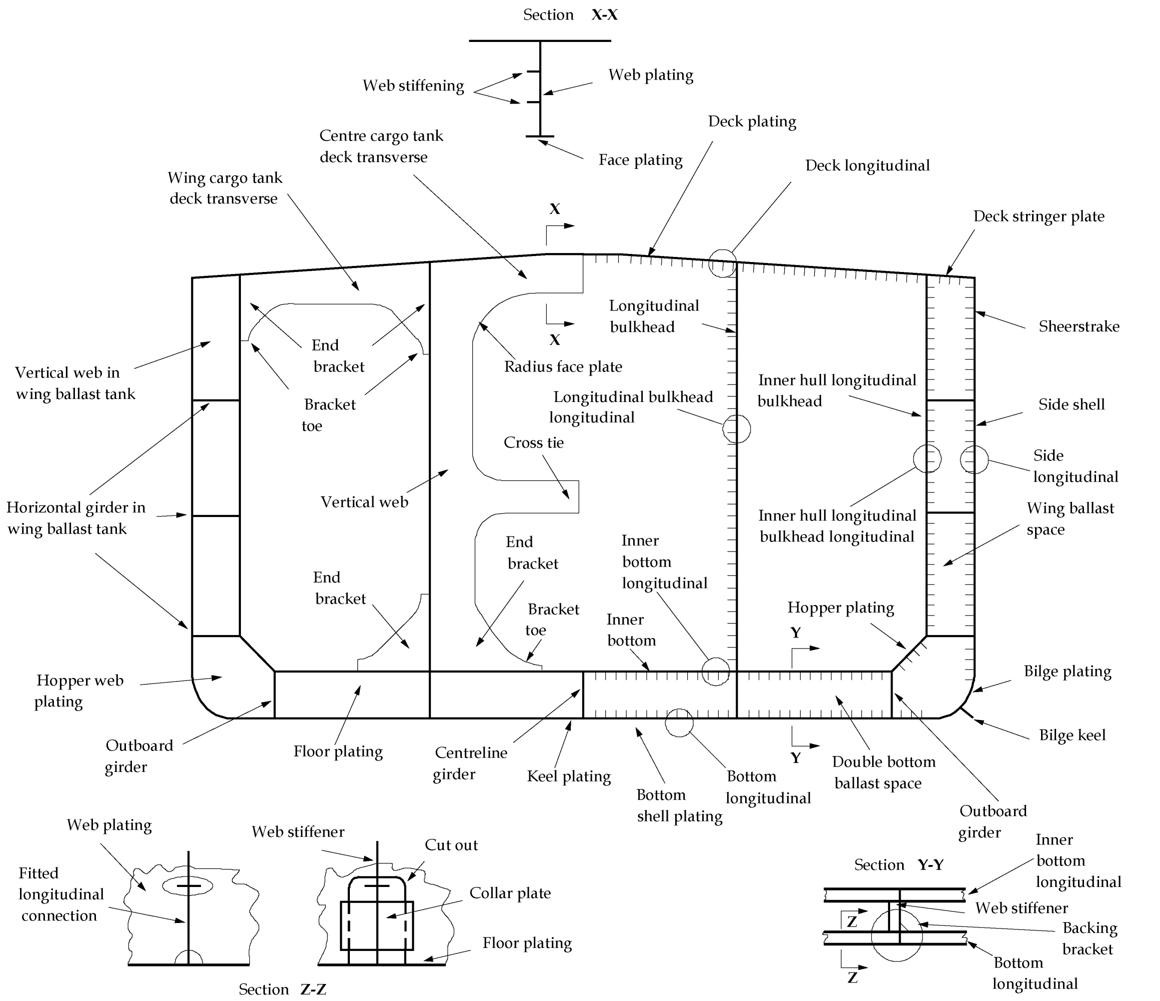


Fig 4.1.4
Mid Cargo Hold Transverse Section



1.6 Symbols

1.6.1 General

1.6.1.1 The symbols and subscripts used within these Rules are defined locally. The principal particulars, as defined in **1.1**, may be referred to within text without reference.

1.7 Units

1.7.1 General

1.7.1.1 The following units are used within these Rules. The units to be used within equations are given locally.

(a) General:

• dimensions/distances	m
• primary spacings	m
• secondary spacings	mm
• area	m^2
• volume	m^3
• mass	t

• velocity	m/s
• acceleration	m/s^2

(b) Hull girder properties:

• dimensions	m
• area	m^2
• section modulus	m^3
• moment of inertia	m^4
• moment of area	m^3

(c) Stiffener properties:

• dimensions	mm
• area	cm^2
• section modulus	cm^3
• inertia	cm^4
• length/effective length	m
• span	m

(d) Plating dimensions:

• breadth	mm
• length	m
• thickness	mm

(e) Loads:

• pressures	kN/m^2
• loads	kN
• bending moment	kNm
• shear force	kN

(f) Miscellaneous:

• yield strength	N/mm^2
• stress	N/mm^2
• deflections	mm
• modulus of elasticity	N/mm^2
• density	t/m^3
• displacement	t
• angle	deg
• calculated angle	rad
• period	s
• frequency	Hz
• ship speed	knots

1.8 Glossary

1.8.1 Definitions of terms

1.8.1.1 The terms in **Table4.1.1** are used within these Rules to describe the items which their respective definitions describe.

Table 4.1.1
Definitions of Terms

Terms	Definition
Accommodation deck	A deck used primarily for the accommodation of the crew
Accommodation ladder	A portable set of steps on a ship’s side for people boarding from small boats or from a pier
Aft peak	The area aft of the aft peak bulkhead
Aft peak bulkhead	The first main transverse watertight bulkhead forward of the stern
Aft peak tank	The compartment in the narrow part of the stern aft of the aft peak bulkhead
Anchor	a device which is attached to anchor chain at one end and lowered into the sea bed to hold a ship in position; it is designed to grip the bottom when it is dragged by the ship trying to float away under the influence of wind and current; usually made of heavy casting or casting
Ballast tank	A compartment used for the storage of water ballast
Bay	The area between adjacent transverse frames or transverse bulkheads
Bilge keel	A piece of plate set perpendicular to a ship’s shell along the bilges to reduce the rolling motion
Bilge plating	The area of curved plating between the bottom shell and side shell. To be taken as follows: From the start of the curvature at the lower turn of bilge on the bottom to the lesser of, the end of curvature at the upper turn of the bilge on the side shell or 0.2 D above the baseline/local centreline elevation
Bilge strake	The lower strake of bilge plating
Boss	The boss of propeller is the central part to which propeller blades are attached and through which the shaft end passes
Bottom shell	The shell envelope plating forming the predominantly flat bottom portion of the shell envelope including the keel plate
Bow	The structural arrangement and form of the forward end of the ship
Bower Anchor	An anchor carried at the bow of the ship
Bracket	An extra structural component used to increase the strength of a joint between two structural members
Bracket toe	The narrow end of a tapered bracket
Breakwater	Inclined and stiffened plate structure on a weather deck to break and deflect the flow of water coming over the bow
Breast hook	A triangular plate bracket joining port and starboard side structural members at the stem
Bridge	An elevated superstructure having a clear view forward and at each side, and from which a ship is steered
Bulb profile	A stiffener utilising an increase in steel mass on the outer end of the web instead of a separate flange
Bulkhead	A structural partition wall sub-dividing the interior of the ship into compartments
Bulkhead deck	The uppermost continuous deck to which transverse watertight bulkheads and shell are carried
Bulkhead stool	The lower or upper base of a corrugated bulkhead
Terms	Definition
Bulkhead structure	The transverse or longitudinal bulkhead plating with stiffeners and girders

Table 4.1.1
Definitions of Terms

Terms	Definition
Bulwark	The vertical plating immediately above the upper edge of the ship's side surrounding the exposed deck(s)
Bunker	A compartment for the storage of fuel oil used by the ship's machinery
Cable	A rope or chain attached to the anchor
Camber	The upward rise of the weather deck from both sides towards the centreline of the ship
Cargo tank bulkhead	A boundary bulkhead separating cargo tanks
Cargo area	The part of the ship that contains cargo tanks and cargo/slop tanks and adjacent areas including ballast tanks, fuel tanks, cofferdams, void spaces and also including deck areas throughout the entire length and breadth of the part of the ship over the mentioned spaces. It includes the collision bulkhead and the transverse bulkhead at the aft end of the cargo block.
Carlings	A stiffening member used to supplement the regular stiffening arrangement
Casing	The covering or bulkhead around or about any space for protection
Cellular construction	A structural arrangement where there are two closely spaced boundaries and internal diaphragm plates arranged in such a manner to create small compartments
Centreline girder	A longitudinal member located on the centreline of the ship
Chain	Connected metal rings or links used for holding anchor, fastening timber cargoes, etc.
Chain locker	A compartment usually at the forward end of a ship which is used to store the anchor chain
Chain pipe	A section of pipe through which the anchor chain enters or leaves the chain locker
Chain stopper	A device for securing the chain cable when riding at anchor as well as securing the anchor in the housed position in the hawse pipe, thereby relieving the strain on the windlass
Coaming	The vertical boundary structure of a hatch or skylight
Cofferdams	The spaces between two bulkheads or decks primarily designed as a safeguard against leakage of oil from one compartment to another
Collar plate	A patch used to, partly or completely, close a hole cut for a longitudinal stiffener passing through a transverse web
Collision bulkhead	The foremost main transverse watertight bulkhead
Companionway	A weathertight entrance leading from a ship's deck to spaces below
Compartment	An internal space bounded by bulkheads or plating
Confined space	A space identified by one of the following characteristics: limited openings for entry and exit, unfavourable natural ventilation or not designed for continuous worker occupancy
Corrugated bulkhead	A bulkhead comprised of plating arranged in a corrugated fashion
Cross ties	Large transverse structural members joining longitudinal bulkheads and used to support them against hydrostatic and hydrodynamic loads
Deck	A horizontal structure element that defines the upper or lower boundary of a compartment
Deck house	A decked structure other than a superstructure, located on the freeboard deck or above.
Deck structure	The deck plating with stiffeners, girders and supporting pillars
Terms	Definition

Table 4.1.1
Definitions of Terms

Terms	Definition
Deep tank	any tank which extends between two decks or the shell/inner bottom and the deck above or higher
Discharges	Any piping leading through the ship's sides for conveying bilge water, circulating water, drains etc.
Docking bracket	A bracket located in the double bottom to locally strengthen the bottom structure for the purposes of docking
Double bottom structure	The shell plating with stiffeners below the top of the inner bottom and other elements below and including the inner bottom plating
Doubler	Small piece of plate which is attached to a larger area of plate that requires strengthening in that location. Usually at the attachment point of a stiffener
Double skin member	Double skin member is defined as a structural member where the idealized beam comprises webs, with top and bottom flanges formed by attached plating
Duct keel	A keel built of plates in box form extending the length of the cargo tank. It is used to house ballast and other piping leading forward which otherwise would have to run through the cargo tanks
Enclosed superstructure	The superstructure with bulkheads forward and/or aft fitted with weather tight doors and closing appliances
Engine room bulkhead	A transverse bulkhead either directly forward or aft of the engine room
Face plate	The section of a stiffening member attached to the plate via a web and is usually parallel to the plated surface
Flange	The section of a stiffening member, typically attached to the web, but is sometimes formed by bending the web over. It is usually parallel to the plated surface
Flat bar	A stiffener comprising only of a web
Floor	A bottom transverse member
Forecastle	A short superstructure situated at the bow
Fore peak	The area of the ship forward of the collision bulkhead
Fore peak deck	A short raised deck extending aft from the bow of the ship
Freeboard deck	Generally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all exposed openings
Freeing port	An opening in the bulwarks to allow water shipped on deck to run freely overboard
Gangway	The raised walkway between superstructure, such as between the forecastle and bridge, or between the bridge and poop
Girder	A collective term for primary supporting structural members
Gudgeon	A block with a hole in the centre to receive the pintle of a rudder; located on the stern post, it supports and allows the rudder to swing
Gunwale	The upper edge of the ship's sides
Gusset	A plate, usually fitted to distribute forces at a strength connection between two structural members
Hatch ways	Openings, generally rectangular, in a ship's deck affording access into the compartment below

Table 4.1.1
Definitions of Terms

Terms	Definition
Hawse pipe	Steel pipe through which the hawser or cable of anchor passes, located in the ship's bow on either side of the stem, also known as spurling pipe
Hawser	Large steel wire or fibre rope used for towing or mooring
Hopper plating	Plating running the length of a compartment sloping between the inner bottom and vertical portion of inner hull longitudinal bulkhead
HP	Holland Profile
Terms	Definition
Independent tank	A self supporting tank
Inner hull	The innermost plating forming a second layer to the hull of the ship
Intercostal	Longitudinal member between the floors or frames of a ship; it is non-continuous
JIS	Japanese industrial standard profile
Keel	The main structural member or backbone of a ship running longitudinal along centreline of bottom. Usually a flat plate stiffened by a vertical plate on its centreline inside the shell
Knuckle	A discontinuity in a structural member
Lightening hole	A hole cut in a structural member to reduce its weight
Limber hole	A small drain hole cut in a frame or plate to prevent water or oil from collecting
Local support members	Local support members are defined as local stiffening members which only influence the structural integrity of a single panel, e.g. deck beams
Longitudinal centreline bulkhead	A longitudinal bulkhead located on the centreline of the ship
Longitudinal hull girder structural members	Structural members that contribute to the longitudinal strength of the hull girder, including: deck, side, bottom, inner bottom, inner hull longitudinal bulkheads including upper sloped plating where fitted, hopper, bilge plate, longitudinal bulkheads, double bottom girders and horizontal girders in wing ballast tanks
Longitudinal hull girder shear structural members	Structural members that contribute to strength against hull girder vertical shear loads, including: side, inner hull longitudinal bulkheads, hopper, longitudinal bulkheads and double bottom girders
Manhole	A round or oval hole cut in decks, tanks, etc., for the purpose of providing access
Margin plate	The outboard strake of the inner bottom and when turned down at the bilge the margin plate (or girder) forms the outer boundary of the double bottom
Notch	A discontinuity in a structural member caused by welding
Oil fuel tank	A tank used for the storage of fuel oil
Pillar	A vertical support placed between decks where the deck is unsupported by the shell or bulkhead
Pintle	Vertical pin on a rudder’s forward edge that enables the rudder to hang onto the stern post and swing when it fits into the gudgeon
Pipe tunnel	The void space running in the midships fore and aft lines between the inner bottom and shell plating forming a protective space for bilge, ballast and other lines extending from the engine room to the tanks
Poop	The space below an enclosed superstructure at the extreme aft end of a ship

Table 4.1.1
Definitions of Terms

Terms	Definition
Poop deck	The first deck above the shelter deck at the aft end of a ship
Primary support members	Members of the beam, girder or stringer type which ensure the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads
Rudder	A device, usually of an aerofoil or flat section, that is used to steer a ship. A common type has a vertical fin at the stern and is able to move from 35 degrees port to 35 degrees starboard; rudders are characterised by their area, aspect ratio, and shape
Terms	Definition
Scallop	A hole cut into a stiffening member to allow continuous welding of a plate seam
Scarfing bracket	A bracket used between two offset structural items
Scantlings	The physical dimensions of a structural item
Scupper	Any opening for carrying off water from a deck, either directly or through piping
Scuttle	A small opening in a deck or elsewhere, usually fitted with a cover or lid or a door for access to a compartment
Shedder plates	Slanted plates that are fitted to minimise pocketing of residual cargo in way of corrugated bulkheads
Sheer strake	The top strake of a ship’s side shell plating
Shelf plate	A horizontal plate located on the top of a bulkhead stool
Shell envelope plating	The shell plating forming the effective hull girder
Side shell	The shell envelope plating forming the side portion of the shell envelope above the bilge plating
Single skin member	Single skin member is defined as a structural member where the idealized beam comprises a web, with a top flange formed by attached plating and a bottom flange formed by a face plate
Skylight	A deck opening fitted with or without a glass port light and serving as a ventilator for engine room, quarters, etc.
Slop tank	A tank in an oil tanker which is used to collect the oil and water mixtures from cargo tanks after tank washing
Spaces	Separate compartments including tanks
Stay	Bulwark and hatch coaming brackets
Stem	The piece of bar or plating at which a ship's outside plating terminates at forward end
Stern frame	The heavy strength member in single or triple screw ships, combining the rudder post
Stern tube	A tube through which the shaft passes to the propeller; and acts as an after bearings for the shafting and may be water or oil lubricated
Stiffener	A collective term for secondary supporting structural members
Stool	A structure supporting tank bulkheads
Strake	A course, or row, of shell, deck, bulkhead, or other plating
Strength deck	The uppermost continuous deck
Stringer	Horizontal girders linking vertical web frames

Table 4.1.1
Definitions of Terms

Terms	Definition
Stringer plate	The outside strake of deck plating
Superstructure	A decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0.04B.
Tank top	The horizontal plating forming the bottom of a cargo tank
Towing pennant	A long rope which is used to effect the tow of a ship
Transom	The structural arrangement and form of the aft end of the ship
Transverse ring	All transverse material appearing in a cross-section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse girder
Transverse web frame	The primary transverse girders which join the ships longitudinal structure
Tripping bracket	A bracket used to strengthen a structural member under compression, against torsional forces
‘Tween deck	An abbreviation of between decks, placed between the upper deck and the tank top in the cargo tanks
Terms	Definition
Ullage	The quantity represented by the unoccupied space in a tank
Void	An enclosed empty space in a ship
Wash bulkhead	A perforated or partial bulkhead in a tank
Watertight	Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed
Weather deck	A deck or section of deck exposed to the elements which has means of closing weather-tight, all hatches and openings
Weathertight	Weathertight means that in any sea conditions water will not penetrate into the ship
Web	The section of a stiffening member attached perpendicular to the plated surface
Wind and water strakes	The strakes of a ship's side shell plating between the ballast and the deepest load water-line
Windlass	A machine for lifting and lowering the anchor chain
Wing tank	The space bounded by the inner hull longitudinal bulkhead and side shell

2 Structural Idealisation

2.1 Definition of Span

2.1.1 Effective bending span of local support members

2.1.1.1 The effective bending span, l_{bdg}, of a stiffener is defined for typical arrangements in **2.1.1.3** to **2.1.1.7.** Where arrangements differ from those shown in **Fig 4.2.1** through **Fig 4.2.8**, span definition may be specially considered.

2.1.1.2 The effective bending span may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective bending span is to be taken as the full length of the stiffener between primary member supports.

2.1.1.3 If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between primary member supports unless a backing bracket is fitted, see **Fig 4.2.2.**

2.1.1.4 The effective bending span may only be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted to the attached plating on the side opposite to that of the stiffener are not to be considered as effective in reducing the effective bending span.

2.1.1.5 The effective bending span, l_{bdg}, for stiffeners forming part of a double skin arrangement is to be taken as shown in **Fig 4.2.1.**

2.1.1.6 The effective bending span, l_{bdg}, for stiffeners forming part of a single skin arrangement is to be taken as shown in **Fig 4.2.2.**

2.1.1.7 For stiffeners supported by a bracket on one side of primary support members, the effective bending span is to be taken as the full distance between primary support members as shown in **Fig 4.2.2(a)**. If brackets are fitted on both sides of the primary support member, the effective bending span is to be taken as in **Fig 4.2.2(b), (c)** and **(d).**

Fig 4.2.1
Effective Bending Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

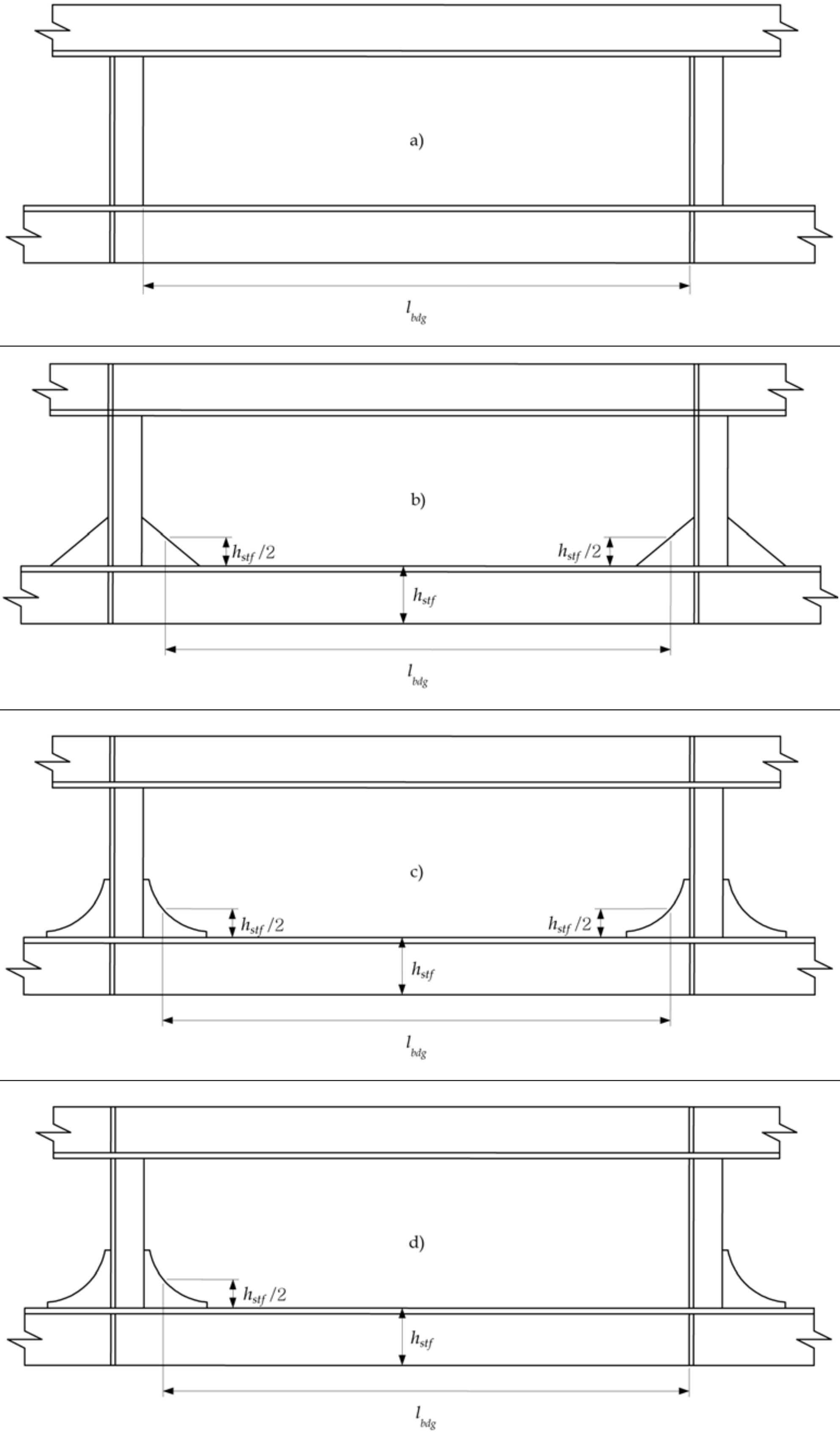
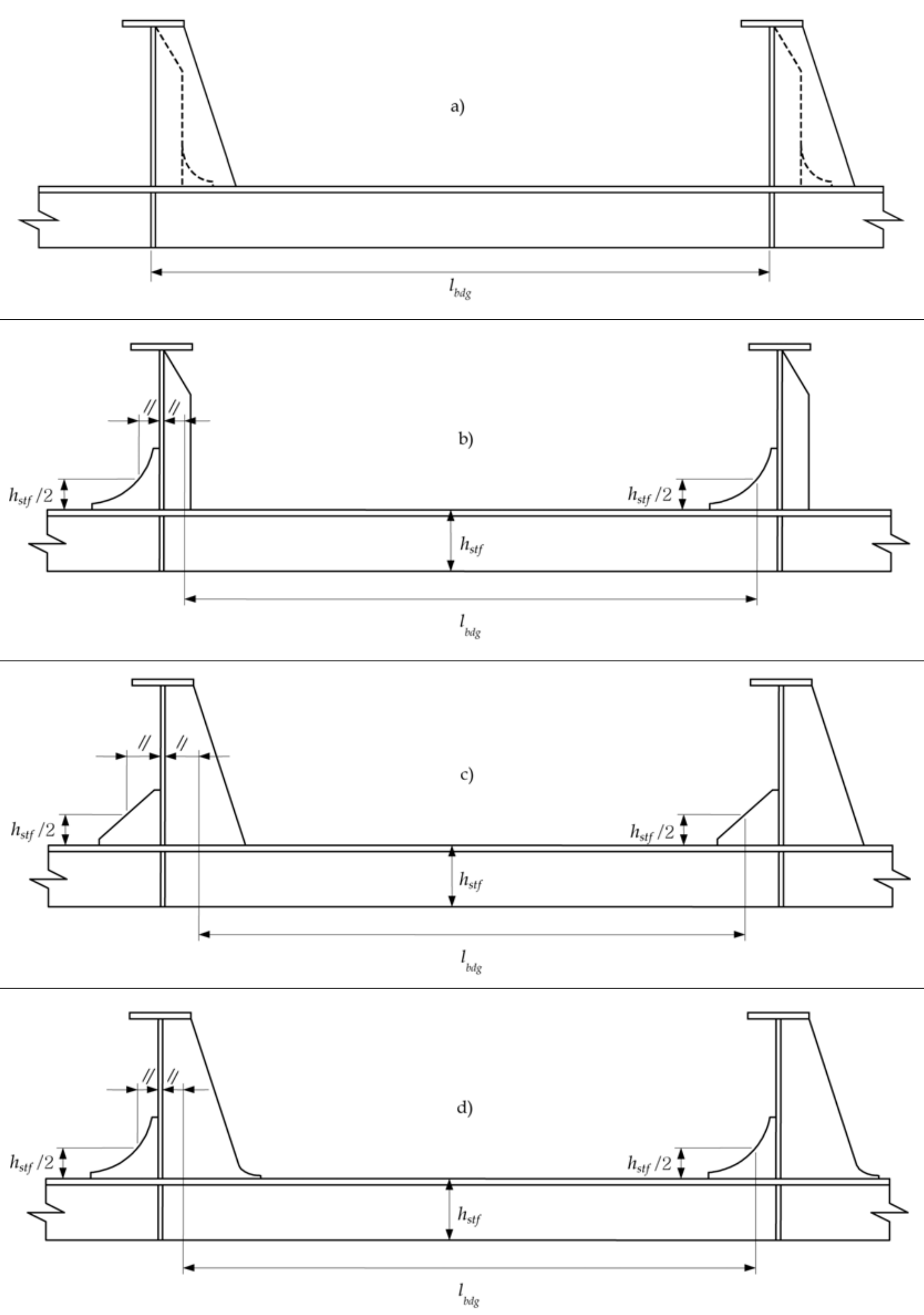
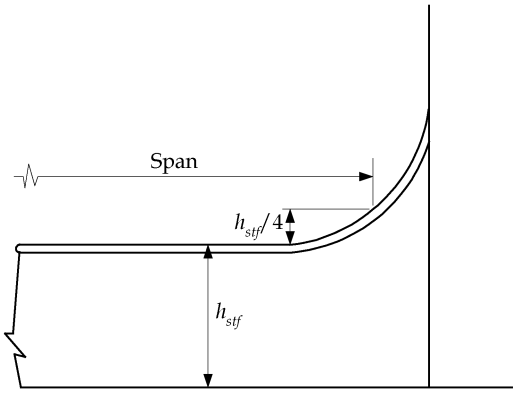


Fig 4.2.2
Effective Bending Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)



2.1.1.8 Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, see **Fig 4.2.3.**

Fig 4.2.3
Effective Bending Span for Local Support Members with Continuous Face Plate along Bracket Edge



2.1.1.9 For the calculation of the span point, the bracket length is not to be taken greater than 1.5 times the length of the arm on the bulkhead or base.

2.1.2 Effective shear span of local support members

2.1.2.1 The effective shear span, l_{shr}, of a stiffener is defined for typical arrangements in **2.1.2.5** to **2.1.2.7.** Effective bending span for other arrangements will be specially considered.

2.1.2.2 The effective shear span may be reduced due to the presence of brackets provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length as given in **2.1.2.4.**

2.1.2.3 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener the effective shear span may be calculated using the longer effective bracket arm.

2.1.2.4 The effective shear span may be reduced by a minimum of s/4000 m at each end of the member, regardless of support detail, hence the effective shear span, l_{shr}, is not to be taken greater than:

$$l_{shr} \le l - \frac{s}{2000} \quad \text{m}$$

Where:

l full length of the stiffener between primary support members, in m

s stiffener spacing, in mm, as defined in **2.2.1**

2.1.2.5 The effective shear span, l_{shr}, for stiffeners forming part of a double skin arrangement is to be taken as shown in **Fig 4.2.4.**

2.1.2.6 The effective shear span, l_{shr}, for stiffeners forming part of a single skin arrangement is to be taken as shown in **Fig 4.2.5.**

Fig 4.2.4
Effective Shear Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

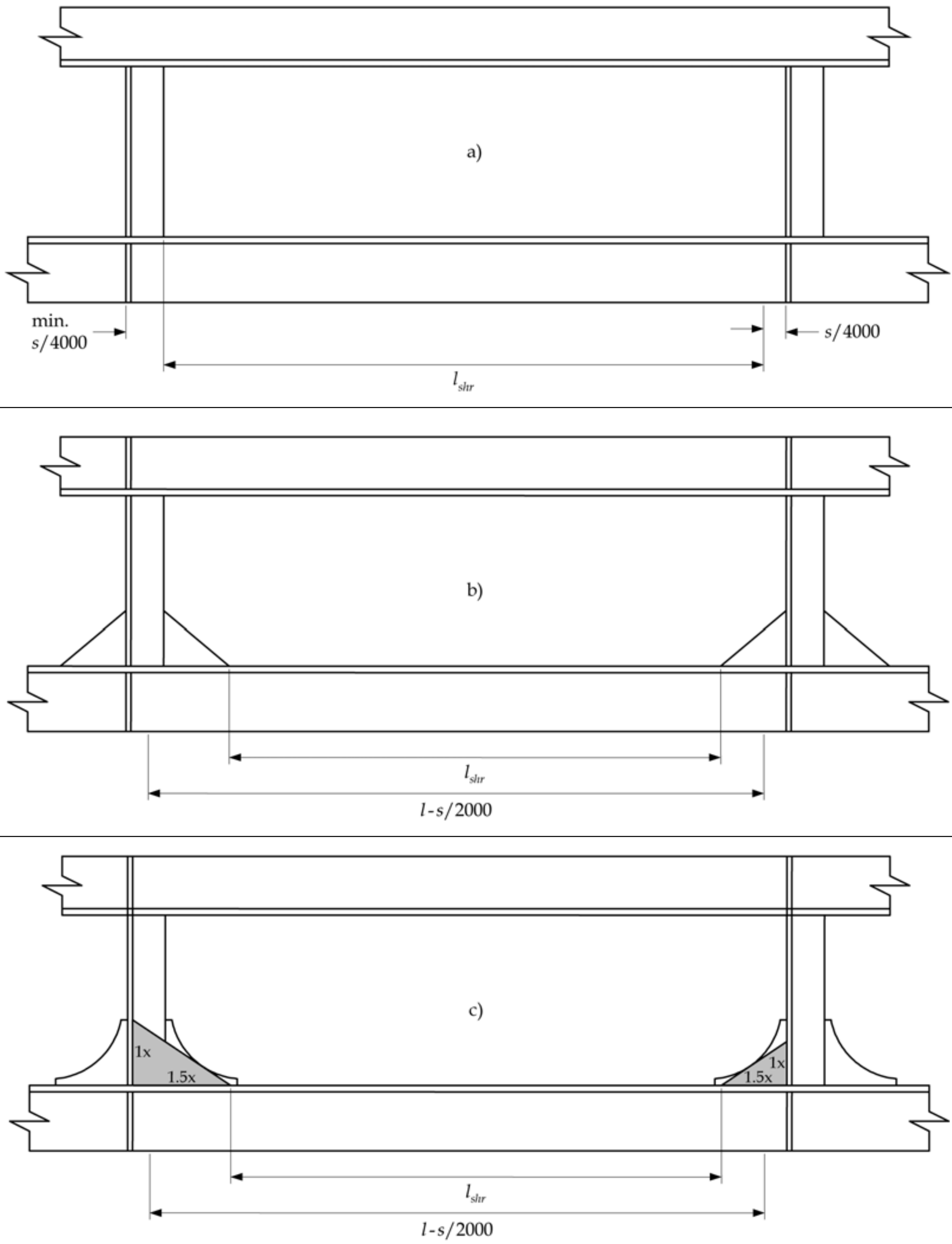


Fig 4.2.5
Effective Shear Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)

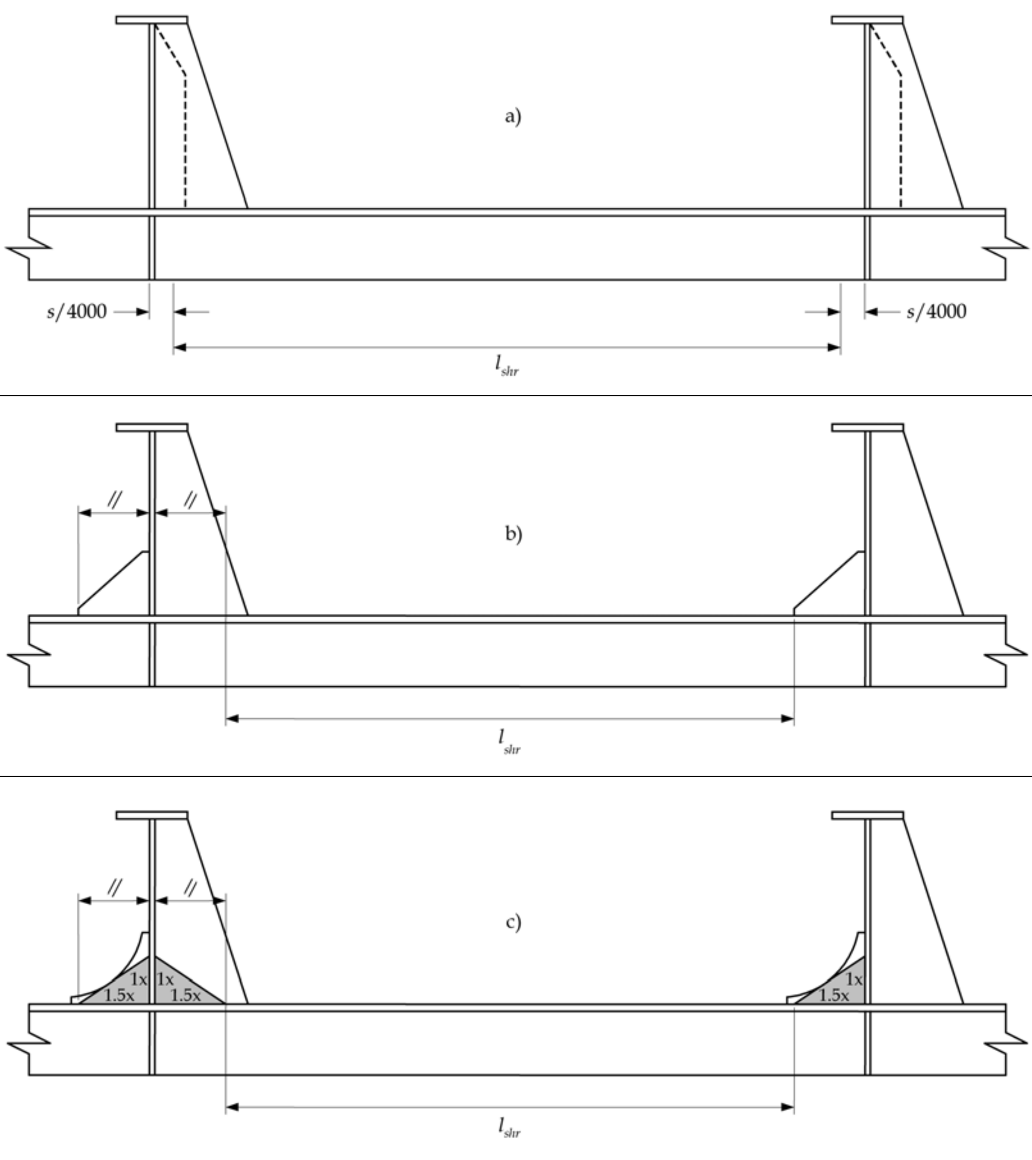
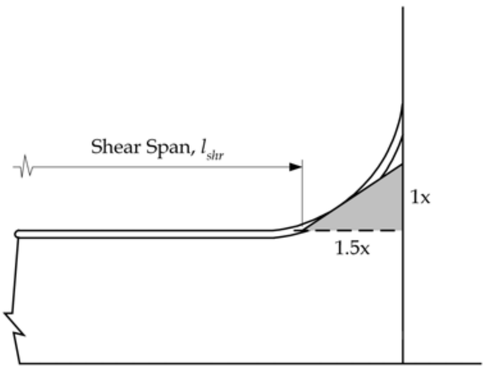


Fig 4.2.6
Effective Shear Span for Local Support Members with Continuous Face Plate along Bracket Edge



2.1.2.7 Where the face plate of the stiffener is continuous along the curved edge of the bracket, the effective shear span is to be taken as shown in **Fig 4.2.6.**

2.1.2.8 For curved and/or long brackets (high length/height ratio) the effective bracket length is to be taken as the maximum inscribed 1:1.5 bracket as shown in **Fig 4.2.4(c)** and **Fig 4.2.5(c).**

2.1.3 Effect of hull form shape on span of local support members

2.1.3.1 The full length of the stiffener between primary support members, l, is to be measured along the flange for stiffeners with a flange, and along the free edge for flat bar stiffeners. For curved stiffeners the span is defined as the chord length between span points. The calculation of the effective span is to be in accordance with requirements given in **2.1.1.**

2.1.4 Effective bending span of primary support members

2.1.4.1 The effective bending span, l_{bdg}, of a primary support member may be taken as less than the full length of the member between supports provided that suitable end brackets are fitted.

2.1.4.2 For arrangements where the primary support member face plate is not carried continuously around the edge of the bracket, i.e. the bracket is welded to the primary support member, the span point at each end of the member, between which the effective bending span is measured, is to be taken at the point where the depth of end bracket measured from the face of the member is equal to one half the depth of the member, as shown in **Fig 4.2.7(b).** The effective bracket used to define the span point is to be taken as given in **2.1.4.4.**

2.1.4.3 For brackets where the face plate of the primary support member is continuous along the face of the bracket, i.e. the bracket is integral part of the primary support member, the span point is to be taken at the position where the depth of the bracket is equal to one quarter the depth of the member, see **Fig 4.2.7(a), (c)** and **(d).** The effective bracket used to define the span point is to be taken as given in **2.1.4.4.**

2.1.4.4 The effective bracket is defined as the maximum size of triangular bracket with a length to height ratio of 1.5 that just fits inside the as fitted bracket, for curved brackets the tangent point is to be used to define the fit, see **Fig 4.2.7** for examples.

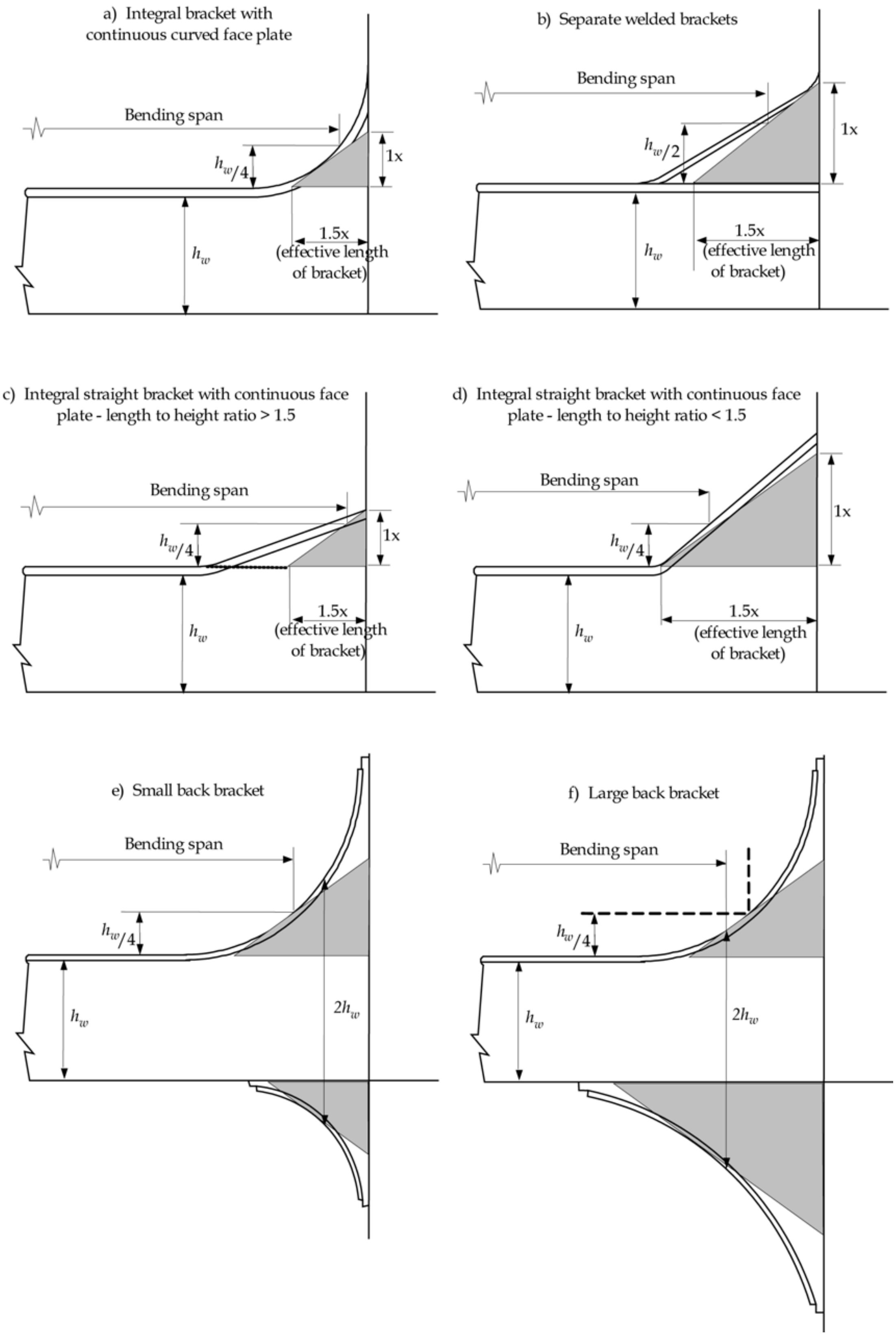
2.1.4.5 For straight brackets with a length to height ratio greater than 1.5, the span point is to be taken to the effective bracket; for steeper brackets the span point is to be taken to the as fitted bracket.

2.1.4.6 For curved brackets the span point is to be measured taken to the fitted bracket at span positions above the tangent point between fitted bracket and effective bracket. For span positions below the tangent point the span point is to be measured to the effective bracket.

2.1.4.7 For arrangements where the primary support member face plate is carried on to the bracket and backing brackets are fitted the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary support member. Arrangements with small and large backing brackets are shown in **Fig 4.2.7(e)** and **(f).**

2.1.4.8 For arrangements where the height of the primary support member is maintained and the face plate width is increased towards the support the effective bending span may be taken to a position where the face plate breadth reaches twice the nominal breadth.

Fig 4.2.7
Effective Span of Primary Support Member for Bending Assessment

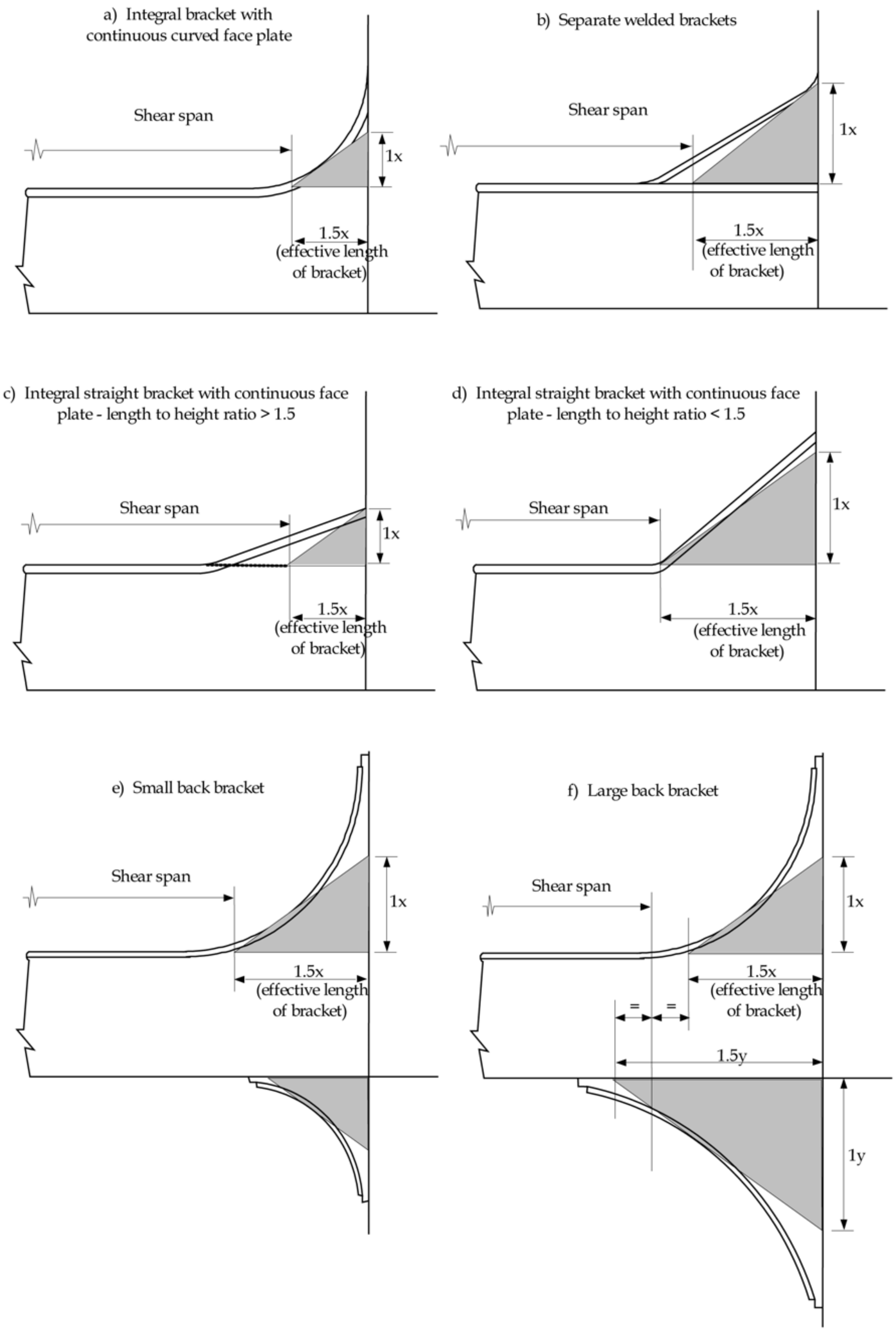


2.1.5 Effective shear span of primary support members

2.1.5.1 The span point at each end of the primary support member, between which the shear span is measured, is to be taken at the toe of the effective brackets supporting the member, where the toes of effective brackets are as shown in **Fig 4.2.8.** The effective bracket used to define the toe point is given in **2.1.4.4.**

2.1.5.2 For arrangements where the effective backing bracket is larger than the effective bracket in way of face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in **Fig 4.2.8(f).**

Fig 4.2.8
Effective Span of Primary Support Member for Shear Assessment



2.2 Definition of Spacing and Supported Breadth

2.2.1 Supported load breadth of local support members

2.2.1.1 The mean of the stiffener spacings on each side is to be used for the calculation of the effective plate flange of stiffeners and the load breadth supported by a stiffener, s, see **Fig 4.2.9.**

2.2.2 Spacing and supporting load breadth of primary support members

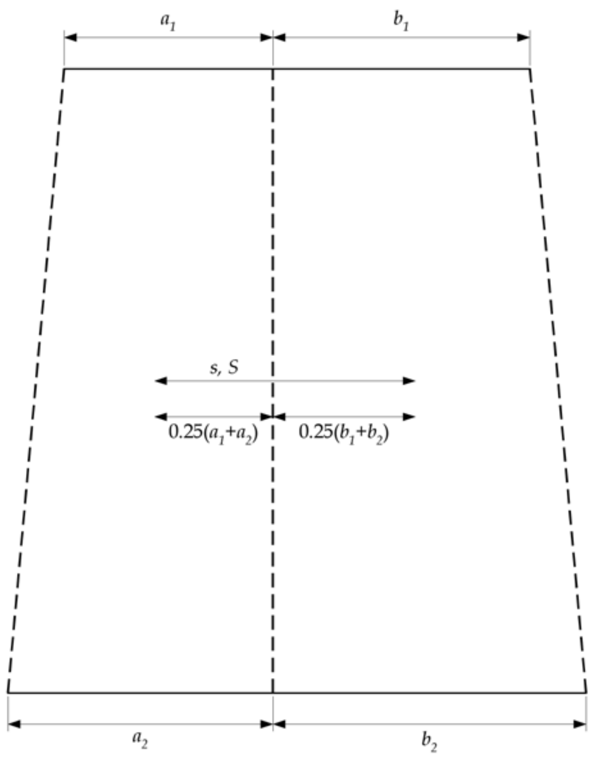
2.2.2.1 Primary support member spacing, S, for the calculation of the effective plate flange of primary support members is to be taken as the mean spacing between adjacent primary support members, as shown in **Fig 4.2.9.**

2.2.2.2 Unless specifically defined elsewhere in the Rules, the loading breadth supported by a girder is defined as half the sum of the primary support member spacing on each side, see **Fig 4.2.9.**

2.2.3 Effective spacing of curved plating

2.2.3.1 For curved plating the stiffener spacing or the primary support member spacing, s or S, is to be measured on the mean chord between members.

Fig 4.2.9
Supported Load Breadth and Breadth of Attached Plating for Local and Primary Support Members



Note
1. The mean breadth is to be taken as $0.25\ (a_1+a_2+b_1+b_2)$, where a_1, a_2, b_1, b_2 are the spacings between local and primary support members at ends as appropriate.

2.3 Effective Breadth of Plating

2.3.1 Effective breadth of attached plate of local support members for strength evaluation

2.3.1.1 The effective breadth as defined in **2.3.1.2** is applicable to the scantling requirements of stiffeners as given in **Sec 8.**

2.3.1.2 The effective breadth of the attached plate, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as the mean stiffener spacing, s, as given in **2.2.1.** However, where the attached plate net thickness, t_{p-net}, is less than 8 mm, the effective breadth is not to be taken greater than 600 mm.

2.3.2 Effective breadth of attached plate and flanges of primary support members for strength evaluation

2.3.2.1 The effective breadths as defined in **2.3.2.2** to **2.3.2.4** are applicable to the scantling requirements of primary support members as given in **Sec 8**.

2.3.2.2 At the end of the span where no effective end bracket is fitted, the effective breadth of attached plate, b_{eff}, for calculating the section modulus and/or moment of inertia of a primary support member is to be taken as:

$$b_{eff} = 0.67\,S\sin\left[\frac{\pi}{6}\left(\frac{l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2S}\right)\right] \text{ m} \quad \text{for} \quad \left(\frac{l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2S}\right)\le 3$$

$$b_{eff} = 0.67S \text{ m} \quad \text{for} \quad \left(\frac{l_{bdg}\,(1-\frac{1}{\sqrt{3}})}{2S}\right)> 3$$

Where:

S mean spacing of primary support member as defined in **2.2.2** at position considered, in m

l_{bdg} effective bending span, as defined in **2.1.4**, in m

Note sin( ) is to be calculated in radians

2.3.2.3 At mid span, the effective breadth of attached plate, b_{eff}, for calculating the section modulus and/or moment of inertia of a primary support member is to be taken as:

$$b_{eff} = S\sin\left[\frac{\pi}{18}\left(\frac{l_{bdg}}{S\sqrt{3}}\right)\right] \text{ m} \quad \text{for} \quad \left(\frac{l_{bdg}}{S\sqrt{3}}\right)\le 9$$

$$b_{eff} = 1.0S \text{ m} \quad \text{for} \quad \left(\frac{l_{bdg}}{S\sqrt{3}}\right)> 9$$

Where:

S mean spacing of primary support member as defined in **2.2.2** at position considered, in m

l_{bdg} effective bending span, as defined in **2.1.4**, in m

Note sin( ) is to be calculated in radians

2.3.2.4 At the end of the span where an effective end bracket is fitted, the effective breadth of attached plate, b_{eff}, for calculating the section modulus of a primary support member is to be taken as the mean values of those given by **2.3.2.2** and **2.3.2.3**. A bracket is considered effective when the length as defined in **Fig 4.2.7** is equal or greater than 0.1 l_{bdg}.

2.3.2.5 The free flange of primary support members of single skin construction may generally be considered fully effective provided tripping bracket arrangements are fitted as required in **Sec 10/2.3.3**. For curved face plates see **2.3.4**.

2.3.3 Effective breadth of attached plate of local support members for fatigue strength evaluation

2.3.3.1 The effective breadths as defined in **2.3.3.2** and **2.3.3.3** are applicable to the fatigue strength evaluation of local support members as given in **Sec 9/3** and **Appendix C**.

2.3.3.2 At the ends of the span and in way of end brackets and supports, the effective breadth of attached plating, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as:

$$b_{eff} = 0.67\, s\, \sin\left[\frac{\pi}{6}\left(\frac{1000 l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right)\right] \text{ mm} \qquad \text{for } \left(\frac{1000 l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right) \le 3$$

$$b_{eff} = 0.67 s \text{ mm} \qquad \text{for } \left(\frac{1000 l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right) > 3$$

Where:

s stiffener spacing, in mm, as defined in **2.2.1**

l_{bdg} effective bending span, as defined in **2.1.1**, in m

Note sin( ) is to be calculated in radians

2.3.3.3 At mid span, the effective breadth of attached plate, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as:

$$b_{eff} = s\, \sin\left[\frac{\pi}{18}\left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right)\right] \text{ mm} \qquad \text{for } \left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right) \le 9$$

$$b_{eff} = 1.0\, s \text{ mm} \qquad \text{for } \left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right) > 9$$

Where:

s stiffener spacing, in mm, as defined in **2.2.1**

l_{bdg} effective bending span, as defined in **2.1.1**, in m

Note sin( ) is to be calculated in radians

2.3.4 Effective area of curved face plates or attached plating of primary support members

2.3.4.1 The effective area as defined in **2.3.4.2** and **2.3.4.3** is applicable to primary support members as follows:

(a) deriving the effective net area of curved face plates and curved attached plating for calculating the section modulus of primary support members for the scantling requirements in **Sec 8**

(b) deriving the effective net area of curved face plates, modelled by beam elements, for the strength assessment (FEM) in **Sec 9/2** and **Appendix B**.

2.3.4.2 The effective net area of curved face plates or attached plating of primary support members, $A_{eff\text{-}net50}$, is to be taken as:

$$A_{eff-net50} = C_f t_{f-net50} b_f \quad \text{mm}^2$$

Where:

C_f flange efficiency coefficient as shown in **Fig 4.2.10**

$= C_{f1} \frac{\sqrt{r_f\, t_{f-net50}}}{b_1}$ but not to be taken greater than 1.0

C_{f1} $= \frac{0.643\,(\sinh\beta\cosh\beta + \sin\beta\cos\beta)}{\sinh^2\beta + \sin^2\beta}$ for symmetrical and unsymmetrical face plates, see Curve 1 in **Fig 4.2.10**

$= \frac{0.78\,(\sinh\beta + \sin\beta)(\cosh\beta - \cos\beta)}{\sinh^2\beta + \sin^2\beta}$ for attached plating of box girders with two webs, see Curve 2 in **Fig 4.2.10**

$= \frac{1.56\,(\cosh\beta - \cos\beta)}{\sinh\beta + \sin\beta}$ for attached plating of box girders with multiple webs, see Curve 3 in **Fig 4.2.10**

β $\frac{1.285\, b_1}{\sqrt{r_f\, t_{f-net50}}}$ rad

b_1 $= 0.5(b_f - t_{w-net50})$ for symmetrical face plates

$= b_f$ for unsymmetrical face plates

$= s_w - t_{w-net50}$ for attached plating of box girders

s_w spacing of supporting webs for box girders, in mm

$t_{f-net50}$ net flange thickness

$= t_{f-grs} - 0.5\, t_{corr}$ mm

for calculation of C_f and β for unsymmetrical face plates $t_{f-net50}$ is not to be taken greater than $t_{w-net50}$

t_{f-grs} gross flange thickness, in mm

$t_{w-net50}$ net web plate thickness

$= t_{w-grs} - 0.5\, t_{corr}$ mm

t_{w-grs} gross web thickness, in mm

t_{corr} corrosion addition, as given in **Sec 6/3.2**

r_f radius of curved face plate or attached plating, in mm

b_f breadth of face plate or attached plating, in mm

2.3.4.3 The effective net area of curved face plates supported by radial brackets, or attached plating supported by cylindrical stiffeners, $A_{eff-net50}$, is given by:

$$A_{eff-net50} = \left(\frac{3 r_f\, t_{f-net50} + C_f\, s_r^2}{3 r_f\, t_{f-net50} + s_r^2}\right) t_{f-net50}\, b_f \quad \text{mm}^2$$

Where:

C_f as defined in **2.3.4.2**

$t_{f-net50}$ net flange thickness, as defined in **2.3.4.2**

s_r spacing of tripping brackets or web stiffeners or stiffeners normal to the web plating, in mm, see **Fig 4.2.11**

b_f breadth of face plate or attached plating, in mm, see **Fig 4.2.11**

r_f radius of curved face plate or attached plating, in mm, see **Fig 4.2.11**

Fig 4.2.10
Effective Width of Curved Face Plates for Alternative Structural Configurations

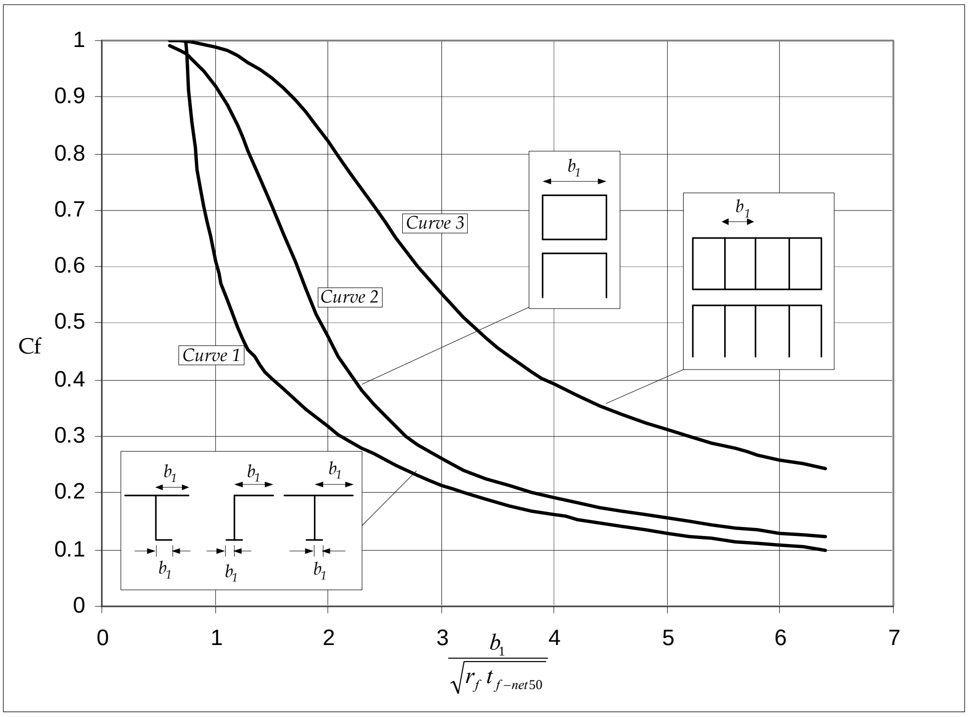
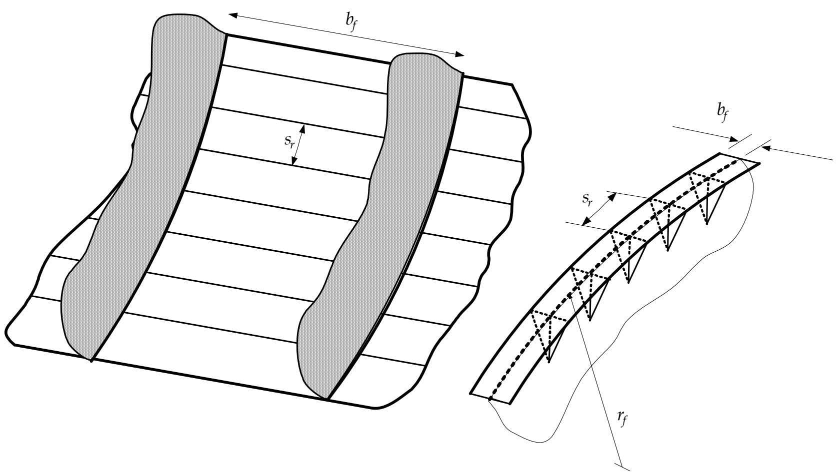


Fig 4.2.11
Curved Shell Panel and Face Plate



2.3.4.4 The effective area given in **2.3.4.2** and **2.3.4.3** is only applicable to face plates and attached plating of primary support members. This is not to be applied for the area of web stiffeners parallel to the face plate.

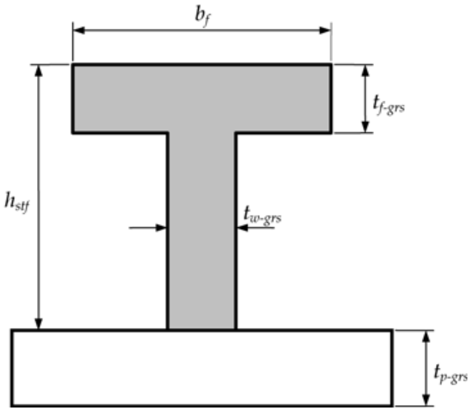
2.4 Geometrical Properties of Local Support Members

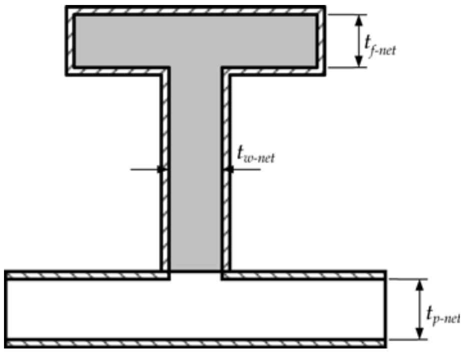
2.4.1 Calculation of net section properties for local support members

2.4.1.1 The net section modulus, moment of inertia and shear area properties of local support members are to be calculated using the net thicknesses of the attached plate, web and flange.

2.4.1.2 The description of the net dimensions for typical profiles is given in **Fig 4.2.12**.

Fig 4.2.12
Net Sectional Properties of Local Support Members

<table>
<tr><td rowspan="2">Profile</td><td>Reduction Methodology</td></tr>
<tr><td>Local Support Members</td></tr>
<tr><td>

T − Profile</td><td>
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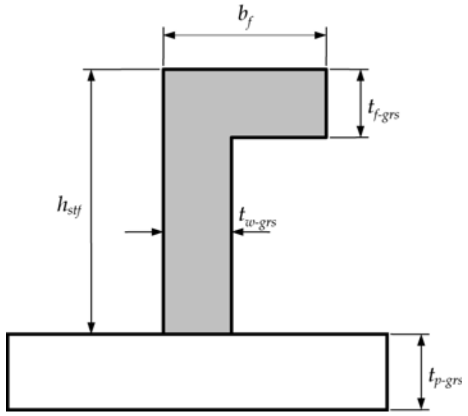
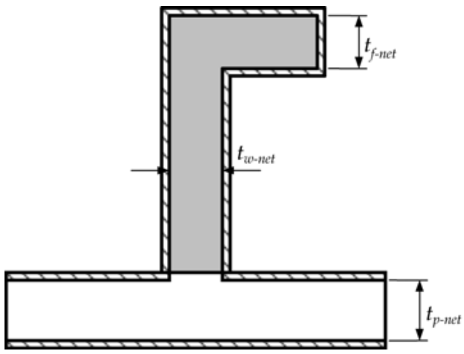
<tr><td>

L − Profile</td><td>
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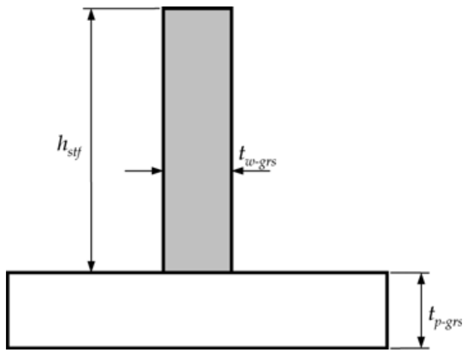
<tr><td>

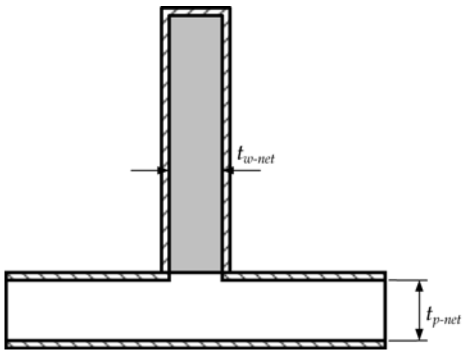
Flat bar − Profile</td><td>
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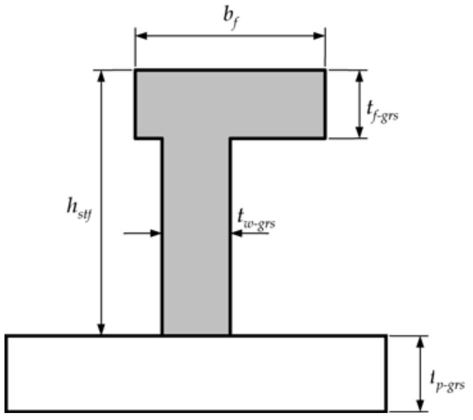
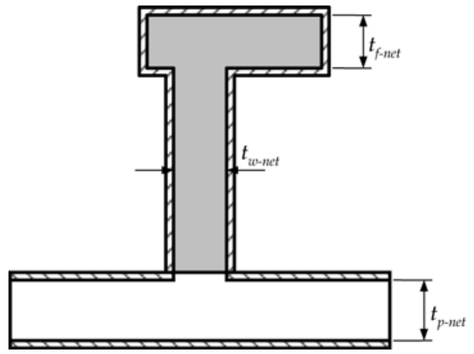
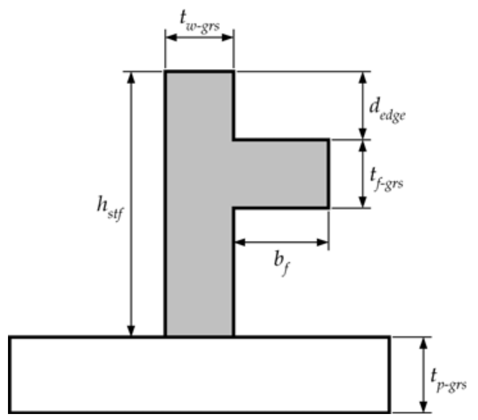
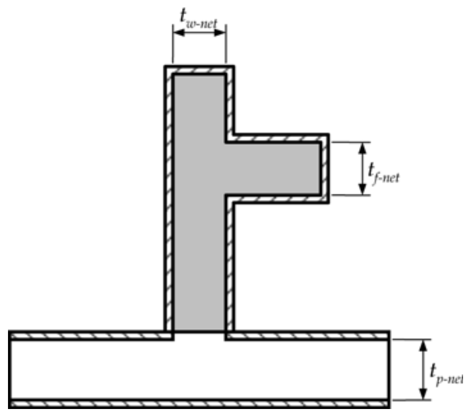
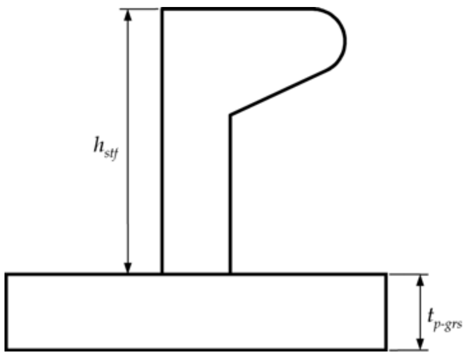
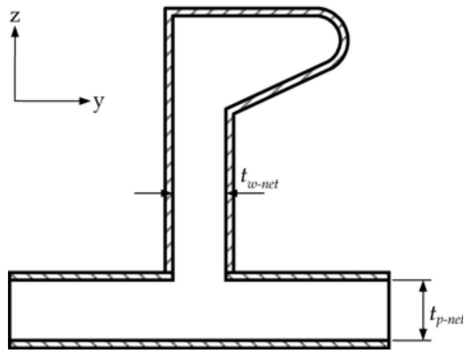
Fig 4.2.12 (Continued)
Net Sectional Properties of Local Support Members

 L2 − Profile	
 L3 − Profile	
 Bulb Profile and Similar Profiles	 The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position of the profile is to be determined assuming the corrosion magnitude 0.5 t_{corr} deducted from the surface of the profile cross-section

2.4.1.3 (void)

2.4.1.4 (void)

2.4.1.5 (void)

Fig 4.2.13
(void)

Table 4.2.1
(void)

Table 4.2.2
(void)

2.4.2 Effective elastic sectional properties of local support members

2.4.2.1 The net elastic shear area, $A_{shr\text{-}el\text{-}net}$, of local support members is to be taken as:

$$A_{shr-el-net} = \frac{(h_{stf} + t_{p-net})t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

Where:

h_{stf} stiffener height, including face plate, in mm. See also **2.4.1.2**

$t_{p\text{-}net}$ net thickness of attached plate, in mm

$t_{w\text{-}net}$ net web thickness, in mm

φ_w angle between the stiffener web and attached plating, see **Fig 4.2.14**, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

2.4.2.2 The effective shear depth of stiffeners, d_{shr}, is to be taken as:

$$d_{shr} = (h_{stf} + t_{p-net})\sin \varphi_w \quad \text{mm}$$

Where:

h_{stf} stiffener height, including face plate, in mm. See also **2.4.1.2**

$t_{p\text{-}net}$ net thickness of attached plate, in mm

φ_w angle between the stiffener web and attached plating, see **Fig 4.2.14**, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

2.4.2.3 The elastic net section modulus, $Z_{el-\varphi\text{-net}}$ of local support members is to be taken as:

$$Z_{el-\varphi-net} = Z_{stf-net}\sin \varphi_w \quad \text{cm}^3$$

Where:

$Z_{stf\text{-}net}$ net section modulus of corresponding upright stiffener, i.e. when φ_w is equal to 90 degrees, in cm^3. See also **2.4.1.2**

φ_w angle between the stiffener web and attached plating, see **Fig 4.2.14**, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

2.4.3 Effective plastic section modulus and shear area of stiffeners

2.4.3.1 The net plastic shear area, $A_{shr\text{-}pl\text{-}net}$, of local support members is to be taken as:

$$A_{shr-pl-net} = \frac{(h_{stf} + t_{p-net})\, t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

Where:

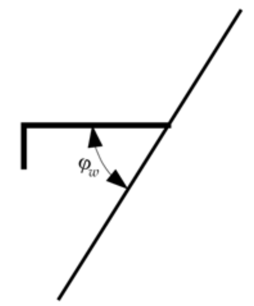
h_{stf} stiffener height, including face plate, in mm. See also **2.4.1.2**

$t_{p\text{-}net}$ net thickness of attached plate, in mm

$t_{w\text{-}net}$ net web thickness, in mm

φ_w angle between the stiffener web and the plate flange, see **Fig 4.2.14**, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

Figure 4.2.14
Angle between Stiffener Web and Plate Flange



2.4.3.2 The effective net plastic section modulus, Z_{pl-net}, of local support members is to be taken as:

$$Z_{pl-net} = \frac{f_w\, d_w^{\,2}\, t_{w-net} \sin\varphi_w}{2000} + \frac{(2\gamma - 1) A_{f-net} \left(h_{f-ctr} \sin\varphi_w - b_{f-ctr} \cos\varphi_w\right)}{1000} \quad \text{cm}^3$$

Where:

f_w web shear stress factor
= 0.75 for flanged profile cross-sections with n = 1 or 2
= 1.0 for flanged profile cross-sections with n = 0 and for flat bar stiffeners

n number of moment effective end supports of each member
= 0, 1 or 2
A moment effective end support may be considered where:
(a) the stiffener is continuous at the support
(b) the stiffener passes through the support plate while it is connected at it's termination point by a carling (or equivalent) to adjacent stiffeners
(c) the stiffener is attached to a abutting stiffener effective in bending (not a buckling stiffener) or bracket. The bracket is assumed to be bending effective when it is attached to another stiffener (not a buckling stiffener).

d_w depth of stiffener web, in mm:
= h_{stf} - t_{f-net} for T, L (rolled and built up) and L2 profiles
= h_{stf} for flat bar and L3 profiles
to be taken as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

h_{stf} stiffener height, in mm, see **Fig 4.2.12**

γ $= 0.25\left(1+\sqrt{3+12\beta}\right)$

β = 0.5 for all cases, except L profiles without a mid span tripping bracket

$$= \frac{10^6 t^2_{w-net}\, f_b\, l_f^2}{80\, b_f^2\, t_{f-net}\, h_{f-ctr}} + \frac{t_{w-net}}{2 b_f}$$

but not to be taken greater than 0.5 for L (rolled and built-up) profiles without a mid span tripping bracket

A_{f-net} net cross-sectional area of flange, in mm^2:
= $b_f\ t_{f-net}$ in general

= 0 for flat bar stiffeners

b_f breadth of flange, in mm, see **Fig 4.2.12**. For bulb profiles, see **Table 4.2.3** and **Table 4.2.4**

$b_{f\text{-}ctr}$ distance from mid thickness of stiffener web to the centre of the flange area:

$= 0.5(b_f - t_{w-grs})$ for rolled angle profiles

=0 for T profiles

as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

$h_{f\text{-}ctr}$ height of stiffener measured to the mid thickness of the flange:

= h_{stf} - 0.5 $t_{f\text{-}net}$ for profiles with flange of rectangular shape except for L3 profiles

= h_{stf} - d_{edge} - 0.5 $t_{f\text{-}net}$ for L3 profiles

as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

d_{edge} distance from upper edge of web to the top of the flange, in mm. For L3 profiles, see **Fig 4.2.12**

f_b = 1.0 in general

= 0.8 for continuous flanges with end bracket(s). A continuous flange is defined as a flange that is not sniped and continuous through the primary support member

= 0.7 for non-continuous flanges with end bracket(s). A non-continuous flange is defined as a flange that is sniped at the primary support member or terminated at the support without aligned structure on the other side of the support

l_f length of stiffener flange between supporting webs, in m, but reduced by the arm length of end bracket(s) for stiffeners with end bracket(s) fitted

$t_{f\text{-}net}$ net flange thickness, in mm

= 0 for flat bar stiffeners

as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

$t_{w\text{-}net}$ net web thickness, in mm

φ_w angle between the stiffener web and the plate flange, see **Fig 4.2.14**, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

Table 4.2.3
Characteristic Flange Data for HP Bulb Profiles (see Fig 4.2.15)

h_{stf} (mm)	d_w (mm)	$b_{f-grs}{}^*$ (mm)	$t_{f-grs}{}^*$ (mm)	b_{f-ctr} (mm)	h_{f-ctr} (mm)
200	171	40	14.4	10.9	188
220	188	44	16.2	12.1	206
240	205	49	17.7	13.3	225
260	221	53	19.5	14.5	244
280	238	57	21.3	15.8	263
300	255	62	22.8	16.9	281
320	271	65	25.0	18.1	300
340	288	70	26.4	19.3	318
370	313	77	28.8	21.1	346
400	338	83	31.5	22.9	374
430	363	90	33.9	24.7	402

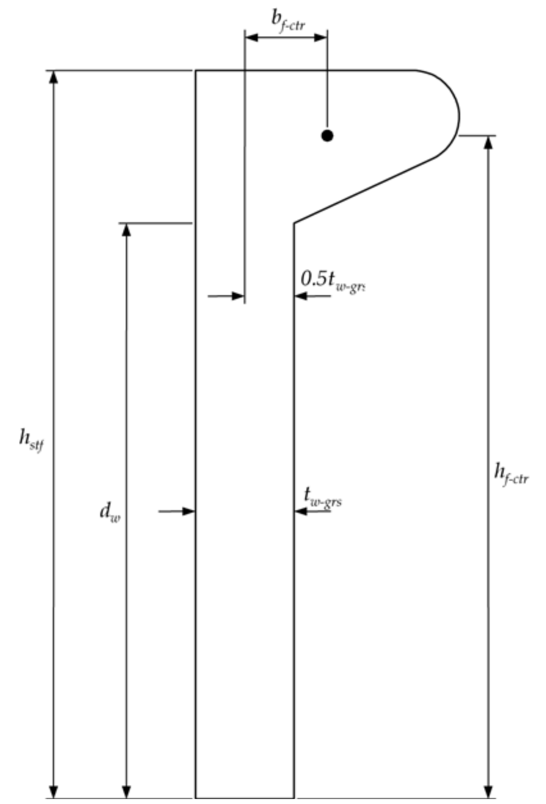
Note
1. Characteristic flange data converted to net scantlings are given as:
$b_f \cong b_{f-grs}{}^* + 2t_{w-net}$
$t_{f-net} = t_{f-grs}{}^* - t_{corr}$
$t_{w-net} = t_{w-grs} - t_{corr}$

Table 4.2.4
Characteristic Flange Data for JIS Bulb Profiles (see Fig 4.2.15)

h_{stf} (mm)	d_w (mm)	$b_{f-grs}{}^*$ (mm)	$t_{f-grs}{}^*$ (mm)	b_{f-ctr} (mm)	h_{f-ctr} (mm)
180	156	34	11.9	9.0	170
200	172	39	13.7	10.4	188
230	198	45	15.2	11.7	217
250	215	49	17.1	12.9	235

Note
1. Characteristic flange data converted to net scantlings are given as:
$b_f \cong b_{f-grs}{}^* + 2t_{w-net}$
$t_{f-net} = t_{f-grs}{}^* - t_{corr}$
$t_{w-net} = t_{w-grs} - t_{corr}$

Fig 4.2.15
Characteristic Data for Bulb Profiles



2.5 Geometrical Properties of Primary Support Members

2.5.1 Effective shear area of primary support members

2.5.1.1 For calculation of the shear area of primary support members the web height, h_w, is to be taken as the moulded height of the primary support member.

2.5.1.2 For single and double skin primary support members, the effective net shear area, $A_{shr\text{-}net50}$, is to be taken as:

$$A_{shr-net50} = 0.01\, h_n\, t_{w-net50} \sin\varphi_w \quad \text{cm}^2$$

Where:

h_n for a single skin primary support member, see **Fig 4.2.16**, the effective web height, in mm, is to be taken as the lesser of:

(a) h_w

(b) $h_{n3} + h_{n4}$

(c) $h_{n1} + h_{n2} + h_{n4}$

for a double skin primary support member, the same principle is to be adopted in determining the effective web height.

h_w web height of primary support member, in mm

h_{n1}, h_{n2}, h_{n3}, h_{n4} as shown in **Fig 4.2.16**

$t_{w\text{-}net50}$ net web thickness

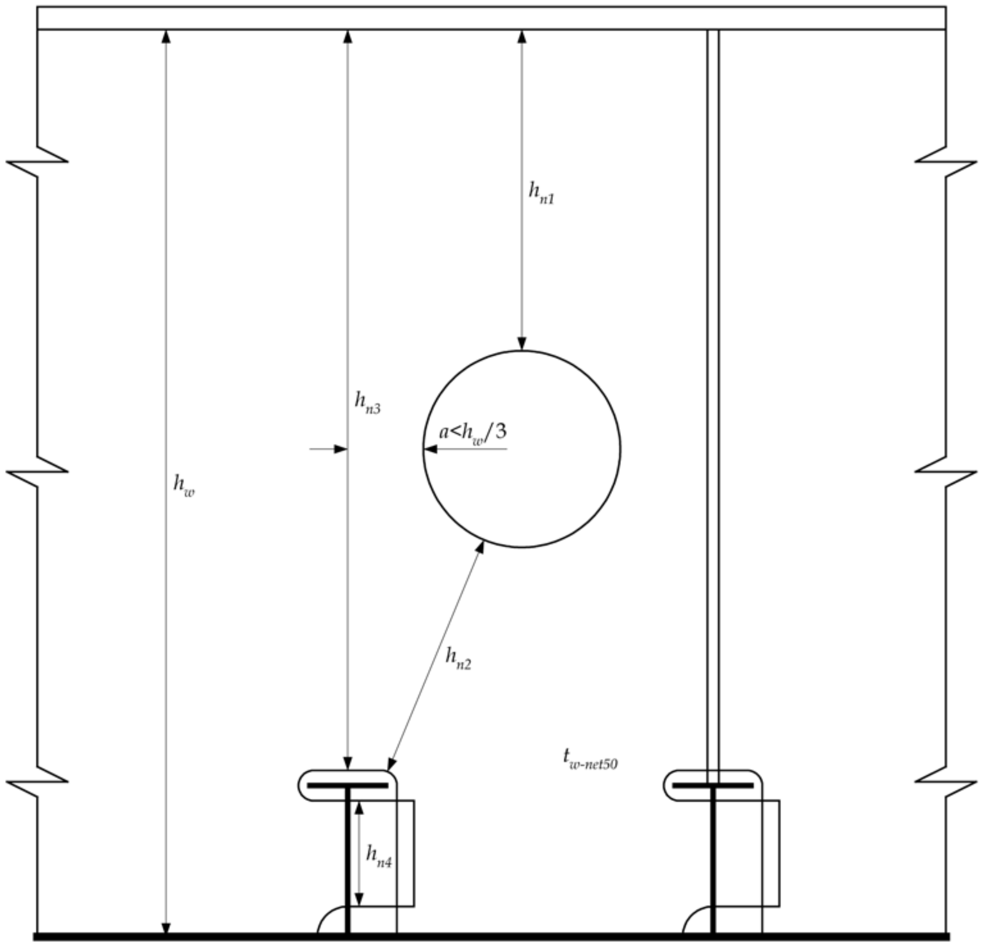
$= t_{w\text{-}grs} - 0.5\, t_{corr}$ mm

$t_{w\text{-}grs}$ gross web thickness, in mm

t_{corr} corrosion addition, as given in **Sec 6/3.2**, in mm

φ_w angle between the web and attached plating, see **Fig 4.2.14**, in degrees. φ_w is to be taken as 90 degrees if the angle is greater than or equal to 75 degrees

Fig 4.2.16
Effective Shear Area in way of Openings



Note
The figure shows effective web height for a single skin primary support member. The effective web height of a double skin primary support member follows the same principles.

2.5.1.3 Where an opening is located at a distance less than $h_w/3$ from the cross-section considered, h_n is to be taken as the smaller of the net height and the net distance through the opening. See **Fig 4.2.16.**

2.5.1.4 Where a girder flange of a single skin primary support member is not parallel to the axis of the attached plating, the effective net shear area, $A_{shr-net50}$, is to be taken as:

$$A_{shr-net50} = 0.01 h_n t_{w-net50} + 1.3 A_{f-net50} \sin 2\theta \sin\theta \quad \text{cm}^2$$

Where:

$A_{f-net50}$ net flange/face plate area

$= 0.01 b_f t_{f-net50}$ cm^2

b_f breadth of flange or face plate, in mm

$t_{f-net50}$ net flange thickness

$= t_{f-grs} - 0.5 t_{corr}$ mm

$t_{f\text{-}grs}$ gross flange thickness, in mm

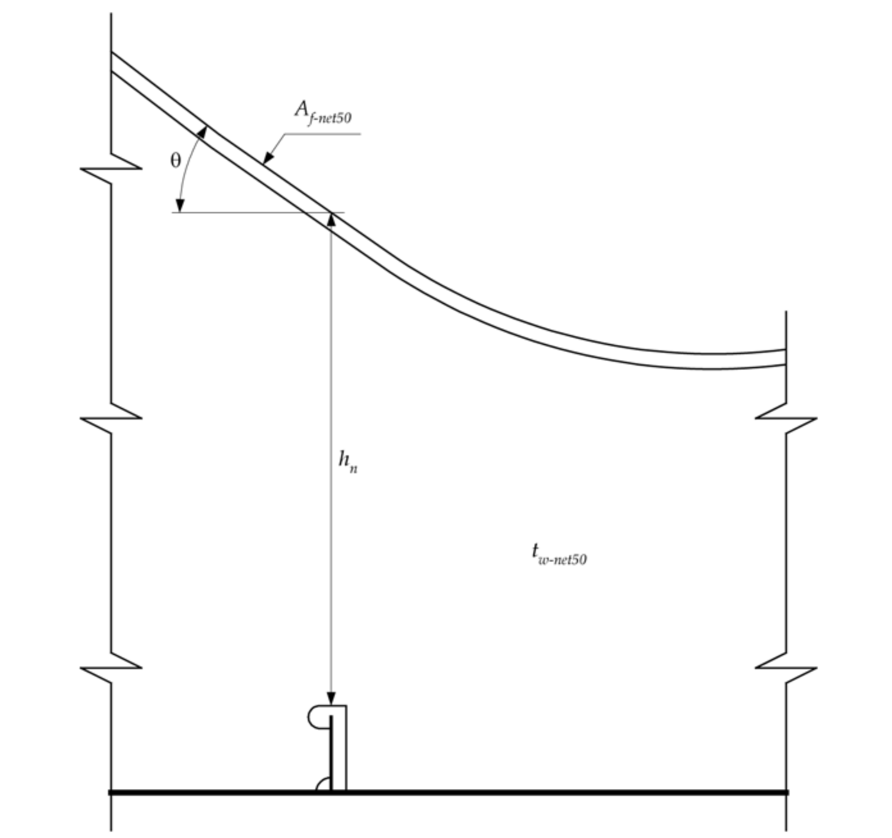
t_{corr} corrosion addition, as given in **Sec 6/3.2**, in mm

θ angle of slope of continuous flange, see **Fig 4.2.17**

$t_{w\text{-}net50}$ net web thickness, as defined in **2.5.1.2**, in mm

h_n effective web height, as defined in **Fig 4.2.16**, in mm

Fig 4.2.17
Effective Shear Area in way of Brackets



2.5.2 Effective section modulus of primary support members

2.5.2.1 The net section modulus of primary support members is to be calculated using the net thicknesses of the attached plate, web and face plate (or top attached plate for double skin girders), where the net thicknesses are to be taken as:

$t_{w-net50} = t_{w-grs} - 0.5t_{corr}$ mm, for the net web thickness

$t_{p-net50} = t_{p-grs} - 0.5t_{corr}$ mm, for the net lower attached plate thickness

$t_{f-net50} = t_{f-grs} - 0.5t_{corr}$ mm, for the net upper attached plate or face plate

Where:

$t_{w\text{-}grs}$ gross web thickness, in mm

$t_{p\text{-}grs}$ gross thickness of lower attached plate, in mm

$t_{f\text{-}grs}$ gross thickness of upper attached plate or face plate, in mm

t_{corr} corrosion addition, as given in **Sec 6/3.2**, in mm

Note
See **2.3.4** for curved face plates of primary support members

Where angle between the primary support member web and the plate flange is less than 75 degrees, the section modulus is to be directly calculated

2.6 Geometrical Properties of the Hull Girder Cross-Section

2.6.1 Vertical hull girder section modulus

2.6.1.1 The effective vertical hull girder section modulus, Z_v, at any vertical distance, z, above the baseline is defined by:

$$Z_v = \frac{I_v}{|z - z_{NA}|} \quad \text{m}^3$$

where:

I_v vertical hull girder moment of inertia, of all longitudinally continuous members in cross section under consideration, after deduction of openings as given in **2.6.3**, in m^4

z distance from the structural member under consideration to the baseline, in m

z_{NA} distance from the baseline to the horizontal neutral axis of the hull girder cross-section, in m

2.6.1.2 For calculation of the vertical net hull girder section modulus for the strength assessment, $Z_{v\text{-}net50}$, required by **Sec 8**, the vertical net hull girder moment of inertia and position of horizontal neutral axis is to be calculated based on gross thickness minus the corrosion addition 0.5 t_{corr} of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Sec 6/3.2**.

2.6.1.3 For calculation of vertical net hull girder section modulus for the fatigue assessment, $Z_{v\text{-}net75}$, required by **Sec 9/3**, the vertical net hull girder moment of inertia and position of horizontal neutral axis is to be calculated based on gross thickness minus the corrosion addition 0.25 t_{corr} of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Sec 6/3.2**.

2.6.2 Horizontal hull girder section modulus

2.6.2.1 The effective horizontal hull girder section modulus, Z_h, at any transverse coordinate, y, is to be taken as:

$$Z_h = \frac{I_h}{|y - y_{NA}|} \quad \text{m}^3$$

where:

I_h horizontal hull girder moment of inertia, of all longitudinally continuous members in cross section under consideration, after deduction of openings as given in **2.6.3**, in m^4

y transverse coordinate, in m

y_{NA} distance from the centreline to the vertical neutral axis of the hull girder cross section, in m

2.6.2.2 For calculation of the horizontal net hull girder section modulus for the strength assessment, $Z_{h\text{-}net50}$, required by **Sec 8**, the horizontal net hull girder moment of inertia and position of vertical neutral axis is to be calculated based on gross thickness minus the corrosion addition 0.5 t_{corr} of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Sec 6/3.2**.

2.6.2.3 For calculation of the horizontal net hull girder section modulus for fatigue assessment, $Z_{h\text{-}net75}$, as required in **Sec 9/3**, the net horizontal hull girder moment of inertia and position of vertical neutral axis is to be calculated based on gross thickness minus the corrosion addition 0.25 t_{corr} of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Sec 6/3.2**.

2.6.3 Effective area for calculation of hull girder moment of inertia and section modulus

2.6.3.1 The effective hull girder sectional area includes all the longitudinally continuous structural members after deduction of openings. The structural members given in **2.6.3.2** are not to be included in the effective hull girder sectional area. The definition of openings to be deducted and deduction free openings are given in **2.6.3.4** − **2.6.3.9**. The definition of effective area in way of non-continuous bulkheads and decks is given in **2.6.3.10**.

2.6.3.2 The following structural members are not to be considered as effectively contributing to the hull girder sectional area as they do not provide sufficient structural continuity and are therefore to be excluded in the calculation:

(a) superstructures which do not form a strength deck

(b) deck houses

(c) vertically corrugated bulkheads

(d) bulwarks and gutter plates

(e) bilge keels

(f) sniped or non-continuous longitudinal stiffeners if the cross-section under consideration is closer than twice the height of the stiffener from the end of the stiffener.

2.6.3.3 The following definitions of opening are to be applied:

(a) large openings are openings exceeding 2.5 m in length and/or 1.2 m in breadth, where the length is measured along the global x-axis of the ship as defined in **Fig 4.1.1**

(b) small openings are openings that are not large openings i.e. manholes, lightening holes, etc.

(c) isolated openings are openings spaced not less than 1m apart in the ship's transverse/vertical direction

2.6.3.4 Large openings and small openings that are not isolated are to be deducted from the sectional area used in the section modulus calculation.

2.6.3.5 Isolated small openings in longitudinal stiffeners or girders are to be deducted if their depth exceeds 25 % of the web depth.

2.6.3.6 When several openings are located in or adjacent to the same cross-section, the total equivalent breadth of the combined openings, Σb_{ded}, is to be deducted, see **2.6.3.7** to **2.3.6.8** and **Fig 4.2.18**.

2.6.3.7 Isolated small openings need not be deducted provided that the sum of their breadths, or shadow area breadths, in one transverse section does not reduce the hull girder section modulus at deck or baseline by more than 3 %. Alternatively isolated small openings need not to be deducted provided the total equivalent breadth of small openings, Σb_{sm}, is less than:

$$\Sigma b_{sm} = 0.06(B_{sect} - \Sigma b_{ded}) \quad \text{m}$$

Where:

Σb_{sm} total equivalent breadth of small openings, see **Fig 4.2.18**

$= b_{sm1} + b_{sm2} + b_{sm3}$ m

B_{sect} the breadth of the ship at the section being considered, in m

Σb_{ded} total equivalent breadth of combined openings specified in **2.6.3.7**, in m

The effect of the shadow area of deductible openings is to be taken into account.

2.6.3.8 When calculating the total equivalent breadth of small openings, Σb_{sm}, each opening is assumed to have a longitudinal shadow area, see **Fig 4.2.18**. This shadow area is obtained by drawing two tangent lines with an angle of 15 degrees to the longitudinal axis of the ship.

2.6.3.9 Full or partial compensation of openings may be provided by increasing the sectional area of the plating, longitudinal stiffeners or girders, or other suitable structure. The compensation area is to extend well beyond the forward and aft end of the opening. Any local edge reinforcement of the opening is not to be included in the effective area of the hull girder section modulus calculations. Compensation is not necessary for openings which are not required to be deducted in accordance with **2.6.3.7**.

2.6.3.10 When calculating the ineffective area in way of large openings and in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in **Fig 4.2.19**. The shadow area, which indicates the area that is not effective, is obtained by drawing two tangent lines with an angle of 15 degrees to the longitudinal axis of the ship.

Fig 4.2.18
Calculation of equivalent Breadth

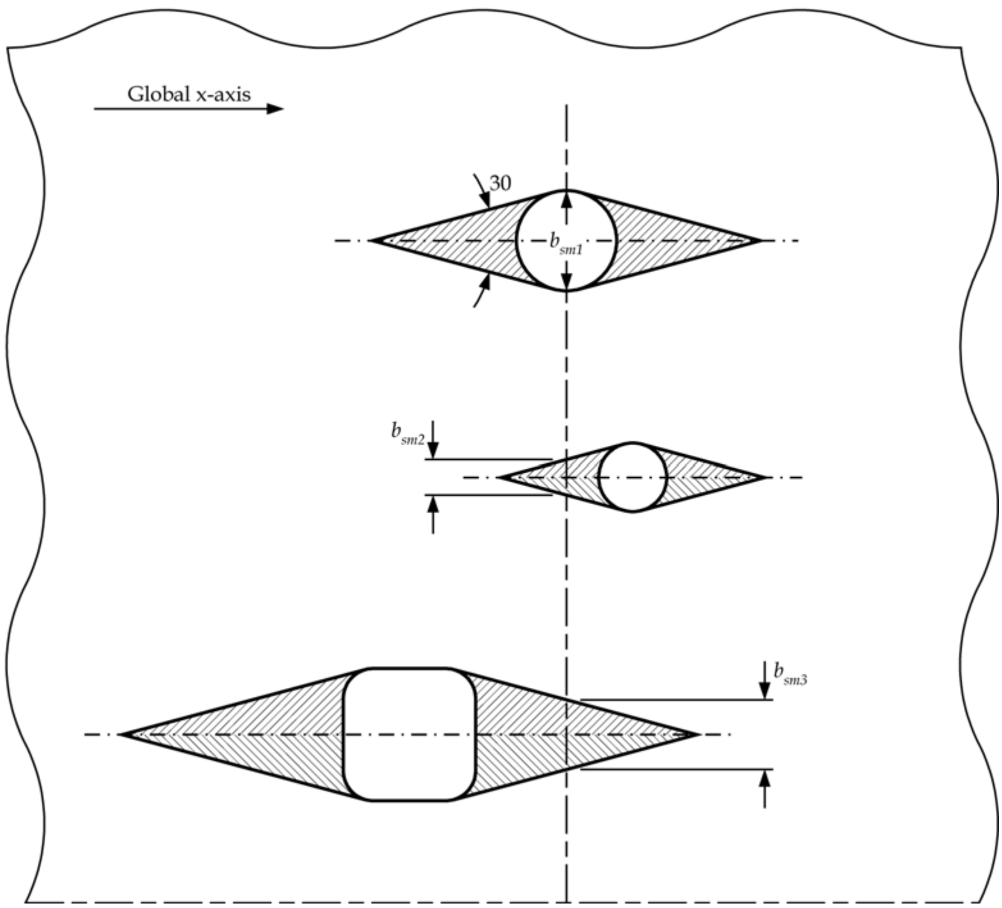
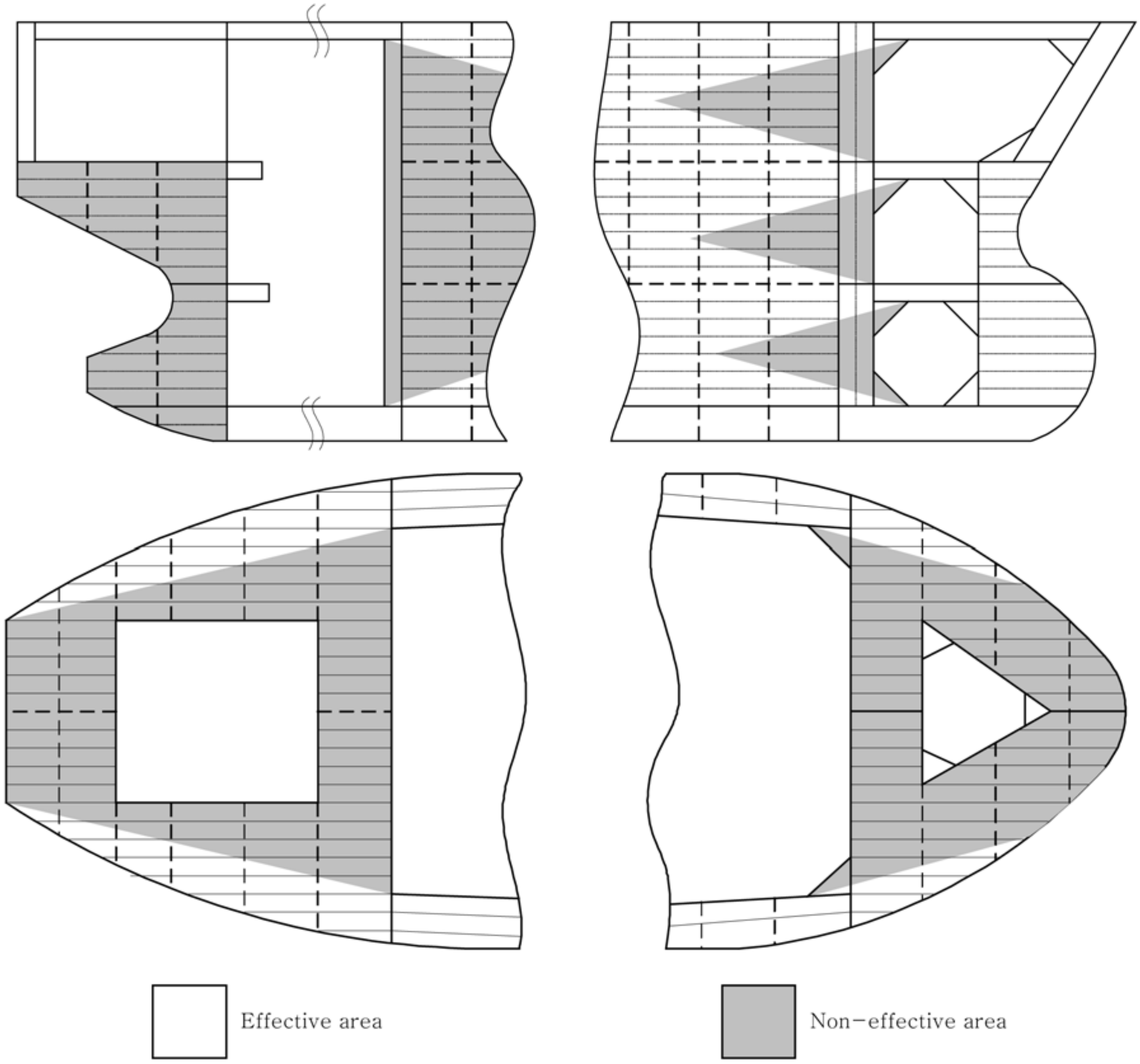


Fig 4.2.19
Effective Area in way of Non-Continuous Decks and Bulkheads



2.6.4 Effective vertical hull girder shear area

2.6.4.1 The effective net hull girder vertical shear area includes the net plating area of the side shell including the bilge, the inner hull including the hopper side and the outboard girder under and the longitudinal bulkheads including the double bottom girders in line.

2.6.4.2 For calculation of the net hull girder vertical shear area, the net plating area is to be calculated based on the net thickness, t_{net50}, given by the gross thickness minus the corrosion addition 0.5 t_{corr} of all effective structural members given in **2.6.4.1**. Where t_{corr} is as defined in **Sec 6/3.2.**

2.6.4.3 For longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the shear force calculation is to be based on the projected area onto the vertical plane. See **Fig 4.2.20.**

2.6.4.4 The calculation of the net effective shear area for vertical and horizontal corrugated bulkheads is to be based on the net effective equivalent thickness, $t_{cg\text{-}net50}$, given by:

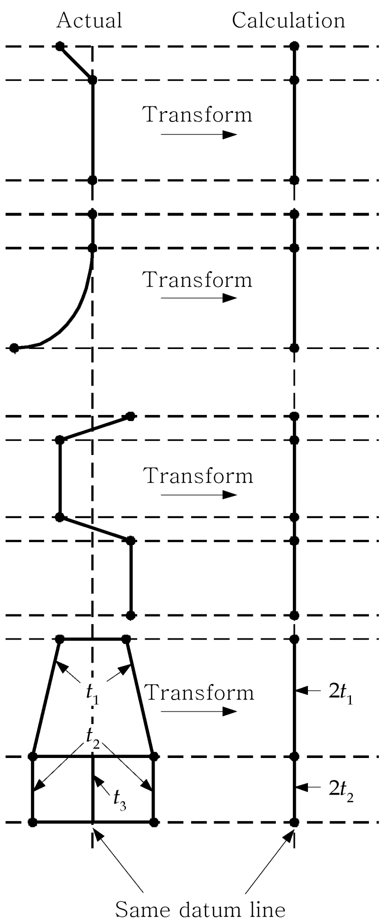
$$t_{cg-net50} = \left[0.5\left(t_{w-grs} + t_{f-grs}\right)\frac{b_{cg}}{b_{w-cg} + b_{f-cg}}\right] - 0.5t_{corr} \quad \text{mm}$$

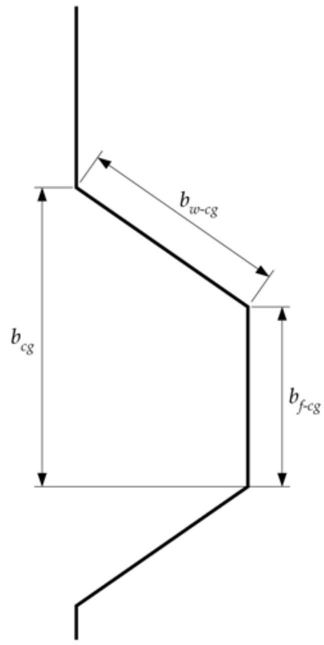
Where:

$t_{w\text{-}grs}$	gross corrugation web thickness, in mm
$t_{f\text{-}grs}$	gross corrugation flange thickness, in mm
b_{cg}	projected length of one corrugation, in mm, as defined in **Fig 4.2.20**
$b_{w\text{-}cg}$	breadth of corrugation web, in mm, as defined in **Fig 4.2.20**
$b_{f\text{-}cg}$	breadth of corrugation flange, in mm, as defined in **Fig 4.2.20**
t_{corr}	corrosion addition, as defined in **Sec 6/3.2**

2.6.4.5 The equivalent net corrugation thickness, $t_{cg\text{-}net50}$, is only applicable for the calculation of the effective area, $A_{eff\text{-}net50}$, and shear force distribution factor, f_i, as defined in **Sec 8/1.3.2.2.**

Fig 4.2.20
Effective Shear Area





3 Structure Design Details

3.1 Standard Construction Details

3.1.1 Details to be submitted

3.1.1.1 A booklet of standard construction details is to be submitted for review. It is to include the following:

(a) the proportions of built-up members to demonstrate compliance with established standards for structural stability, see **Sec 10**

(b) the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue; such as:

- details of the ends, at the intersections of members and associated brackets
- shape and location of air, drainage, and/or lightening holes
- shape and reinforcement of slots or cut-outs for internals
- elimination or closing of weld scallops in way of butts, 'softening' of bracket toes, reduction of abrupt changes of section or structural discontinuities
- proportion and thickness of structural members to reduce fatigue response due to engine, propeller or wave induced cyclic stresses, particularly for higher strength steels.

3.2 Termination of Local Support Members

3.2.1 General

3.2.1.1 In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

3.2.1.2 Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.

3.2.1.3 All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in **3.2.3** to **3.2.5.**

3.2.2 Longitudinal members

3.2.2.1 All longitudinals are to be kept continuous within the $0.4L$ amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding is to be specially considered.

3.2.2.2 Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

3.2.3 Bracketed connections

3.2.3.1 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings sufficient to compensate for the non-continuous stiffener flange or non-continuous stiffener.

3.2.3.2 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, the section modulus is less than that required for the stiffener.

3.2.3.3 Minimum net bracket thickness, $t_{bkt\text{-}net}$, is to be taken as:

$$t_{bkt-net} = \left(2 + f_{bkt}\sqrt{Z_{rl-net}}\right)\left(\sqrt{\frac{\sigma_{yd-stf}}{\sigma_{yd-bkt}}}\right) \quad \text{mm,}$$

but is not to be less than 6 mm and need not be greater than 13.5 mm

Where:

f_{bkt} 0.2 for brackets with flange or edge stiffener

0.3 for brackets without flange or edge stiffener

Z_{rl-net} net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

σ_{yd-stf} specified minimum yield stress of the material of the stiffener, in N/mm^2

σ_{yd-bkt} specified minimum yield stress of the material of the bracket, in N/mm^2

3.2.3.4 Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by **3.2.4**. The end brackets are to have arm lengths, l_{bkt}, not less than:

$$l_{bkt} = c_{bkt}\sqrt{\frac{Z_{rl-net}}{t_{bkt-net}}} \quad \text{mm, but is not to be less than:}$$

- 1.8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see **Fig 4.3.1(c)**
- 2.0 times for other cases, see **Fig 4.3.1(a), (b)** and **(d)**

Where:

c_{bkt} 65 for brackets with flange or edge stiffener

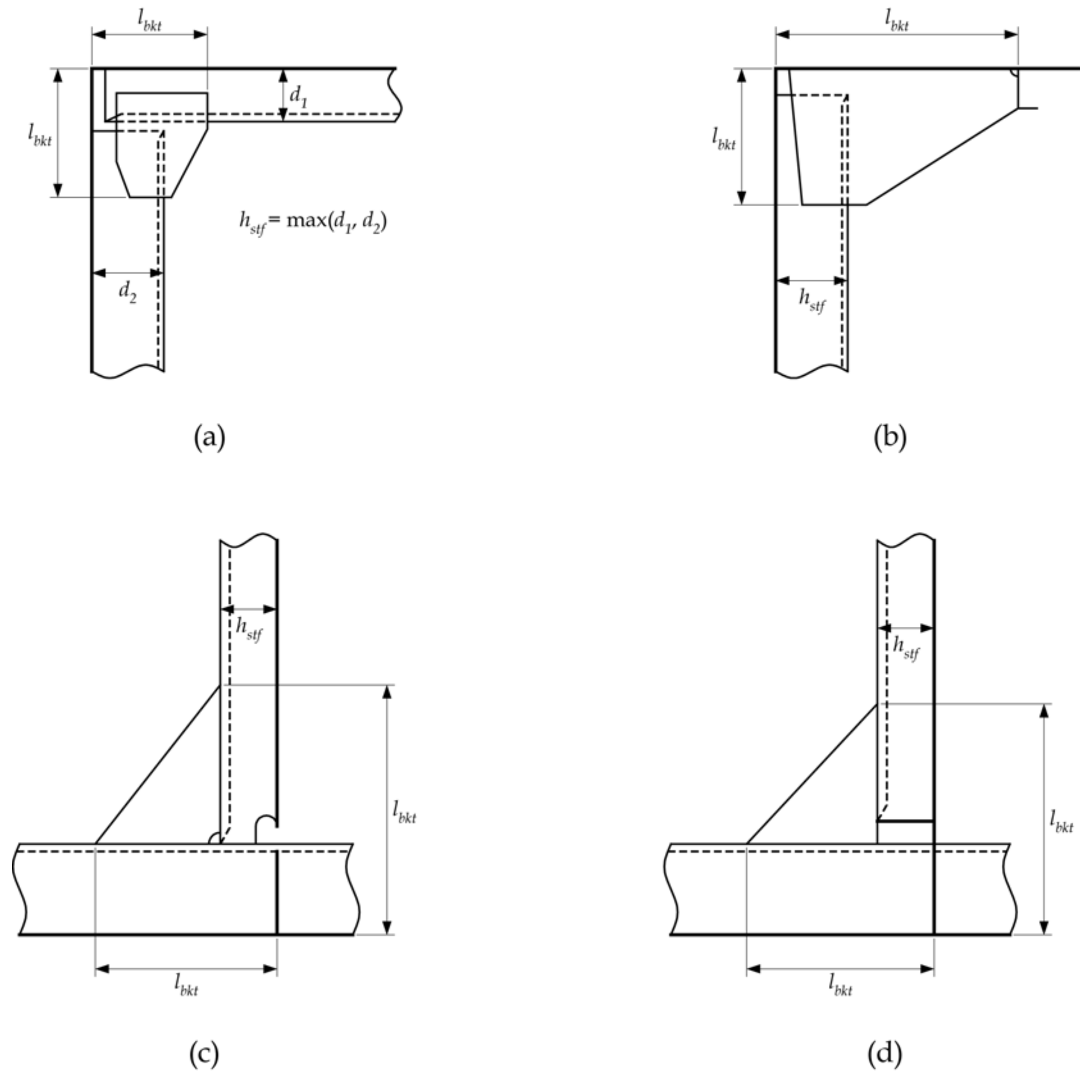
70 for brackets without flange or edge stiffener

Z_{rl-net} net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$t_{bkt-net}$ minimum net bracket thickness, as defined in **3.2.3.3**

3.2.3.4bis In case of different arm lengths the lengths of the arms, measured from the plating to the toe of the bracket, are to be such that the sum of them is greater than 2 l_{bkt} and each arm not to be less than 0.8 l_{bkt}, where l_{bkt} is as defined in **3.2.3.4.**

Fig 4.3.1
Bracket Arm Length



Note:

- For stiffeners of configuration (b) that are not lapped, the bracket arm length l_{bkt} is not to be less than the stiffener height h_{stf}.
- For stiffener arrangements similar to (c) and (d) where the smaller attached stiffener, labelled as h_{stf}, is connected to a primary support member or bulkhead, the height of the bracket is not to be less than the height of the attached stiffener, h_{stf}.

3.2.3.5 The proportions and edge stiffening of brackets are to be in accordance with the requirements of **Sec 10/2.4**. Where an edge stiffener is required, the depth of stiffener web, d_w, is not to be less than:

$$d_w = 45\left(1 + \frac{Z_{rl-net}}{2000}\right) \quad \text{mm, but is not to be less than 50 mm}$$

Where:

Z_{rl-net} net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

3.2.4 Bracketless connections

3.2.4.1 Local support members, for example longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of **3.2.2** and **3.2.3.**

3.2.4.2 Where alternative connections are adopted, the proposed arrangements will be specially considered.

3.2.4.3 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.2.5 Sniped ends

3.2.5.1 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e. structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, t_{p-net}, is not less than:

$$t_{p-net} = c_1 \sqrt{\left(1000l - \frac{s}{2}\right)\frac{sPk}{10^6}}$$

Where:

l stiffener span, in m

s stiffener spacing, in mm, as defined in **2.2**

P design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

a) **Table 8.2.5** in the cargo tank region

b) **Sec 8/3.9.2.2** in the area forward of the forward cargo tank, and in the aft end

c) **Sec 8/4.8.1.2** in the machinery space

k higher strength steel factor, as defined in **Sec 6/1.1.4**

c_1 coefficient for the design load set being considered, to be taken as:

= 1.2 for acceptance criteria set AC1

= 1.1 for acceptance criteria set AC2

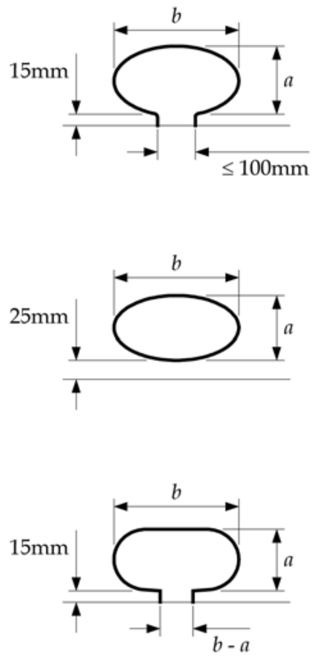
3.2.5.2 Bracket toes and sniped end members are, in general, to be kept within 25 mm of the adjacent member. The maximum distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 degrees. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

3.2.5.3 The end attachments of non-load bearing members may be snipe ended. The sniped end is to be not more than 30 degrees and is generally to be kept within 50 mm of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15 mm.

3.2.6 Air and drain holes and scallops

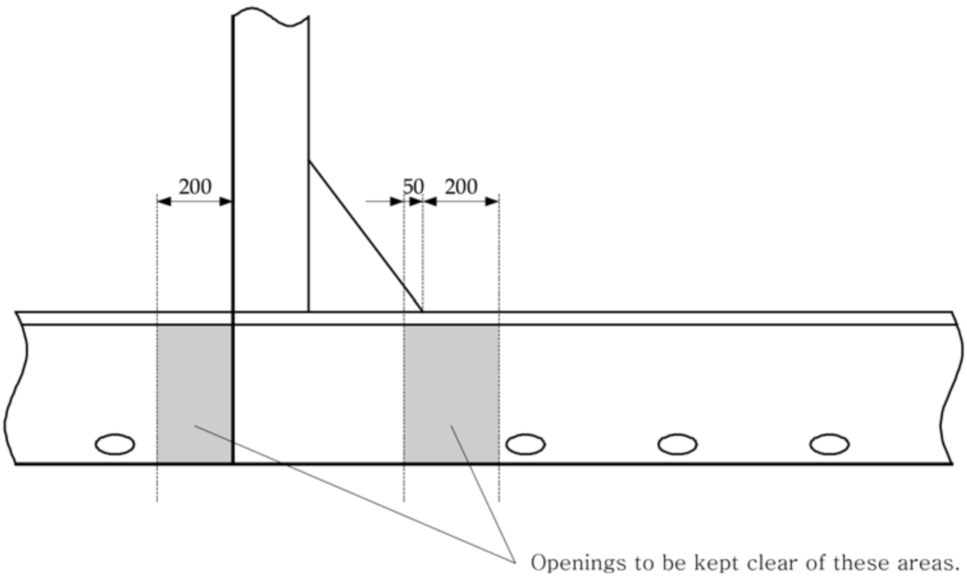
3.2.6.1 Air, drain holes, scallops and block fabrication butts are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the mid-span and 50 mm measured along the length in the opposite direction. See **Fig 4.3.2(b)**. In areas where the shear stress is less than 60 percent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. **Fig 4.3.2(a)** shows some examples of air and drain holes and scallops. In general, the ratio of a/b, as defined in **Fig 4.3.2(a)**, is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

Fig 4.3.2(a)
Examples of Air and Drain Holes and Scallops



Note
The details shown in this figure are for guidance and illustration only.

Figure 4.3.2(b)
Location of Air and Drain Holes



3.2.7 Special requirements

3.2.7.1 Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width b as shown in **Fig 4.3.2(a)**, are not permitted in longitudinal strength members or within 20 % of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

3.3 Termination of Primary Support Members

3.3.1 General

3.3.1.1 Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and, wherever possible, a complete ring system.

3.3.1.2 The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

3.3.2 End connection

3.3.2.1 Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

3.3.2.2 The ends of brackets are generally to be soft-toed. The free edges of the brackets are to be stiffened. Scantlings and details are given in **3.3.3.**

3.3.2.3 Where primary support members are subject to concentrated loads additional strengthening may be required, particularly if these are out of line with the member web.

3.3.2.4 In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied provided that there is adequate support of the adjoining face plates.

3.3.3 Brackets

3.3.3.1 In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1.5 times the web depth. The thickness of the bracket is, in general, not to be less than that of the girder web plate.

3.3.3.2 For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the mid point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the bracket toes.

3.3.3.3 Where a wide face plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face plate abuts against a thinner one and the difference in thickness is greater than 4 mm, the taper of the thickness is not to be greater than 1 in 3.

3.3.3.4 Face plates of brackets (typical brackets similar to those indicated in **Fig 4.2.7b**) are to have a net cross-sectional area, $A_{f\text{-}net}$, which is not to be less than:

$$A_{f-net} = l_{bkt-edge} t_{bkt-net} \quad \text{cm}^2$$

Where:

$l_{bkt\text{-}edge}$ length of free edge of bracket, in m. For brackets that are curved the length of the free edge may be taken as the length of the tangent at the midpoint of the free edge. If $l_{bkt\text{-}edge}$ is greater than 1.5 m, 40 percent of the face plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0.15 m from the edge

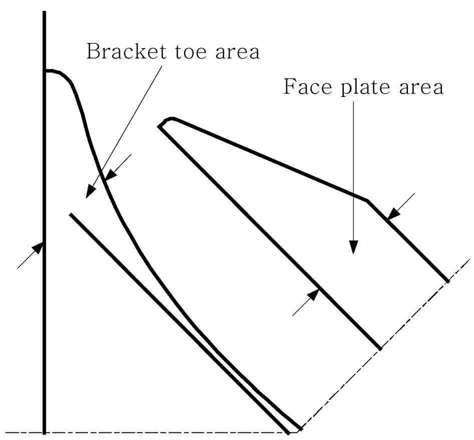
$t_{bkt\text{-}net}$ minimum net bracket thickness, in mm, as defined in **3.2.3.3**

3.3.4 Bracket toes

3.3.4.1 The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15mm. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face plate, it is to be sniped and tapered at an angle not greater than 30°.

3.3.4.2 Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face plates are welded adjacent to the edge of primary support member brackets, adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face plate is to be not less than 60 percent of the full cross-sectional area of the face plate, see **Fig 4.3.3.**

Fig 4.3.3
Bracket Toe Construction



Note
The details shown in this figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

3.4 Intersections of Continuous Local Support Members and Primary Support Members

3.4.1 General

3.4.1.1 Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimize stress concentrations around the perimeter of the opening and on the attached web stiffeners.

3.4.1.2 Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with “full” collar plates, see **Fig 4.3.4.**

3.4.1.3 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of **3.4.3**, and in areas of significant stress concentrations, e.g., in way of primary support member toes. See **Fig 4.3.5** for typical lug arrangements.

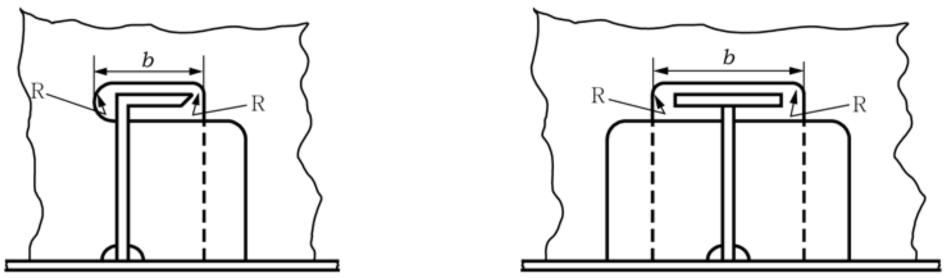
3.4.1.4 When, in the following locations, the calculated direct stress, σ_w, in the primary support member web stiffener according to **3.4.3.5** exceeds 80 % of the permissible values a soft heel is to be provided in way of the heel of primary support member web stiffeners:

(a) connection to shell envelope longitudinals below the scantling draught, T_{sc}

(b) connection to inner bottom longitudinals.

A soft heel is not required at the intersection with watertight bulkheads, where a back bracket is fitted or where the primary support member web is welded to the stiffener face plate. The soft heel is to have a keyhole, similar to that shown in **Fig 4.3.6(c)**.

Fig 4.3.4
Collars for Cut-outs in Areas of High Stress



R = 0.2b
(min. 25 mm)

3.4.2 Details of cut-outs

3.4.2.1 In general, cut-outs are to have rounded corners and the corner radii, R, are to be as large as practicable, with a minimum of 20 percent of the breadth, b, of the cut-out or 25 mm, whichever is greater, but need not be greater than 50 mm, see **Fig 4.3.4**. Consideration will be given to other shapes on the basis of maintaining equivalent strength and minimizing stress concentration.

3.4.3 Connection between primary support members and intersecting stiffeners (local support members)

3.4.3.1 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

3.4.3.2 The total load, W, transmitted through the connection to the primary support member is given by:

$$W = P s \left(S - \frac{s}{2000} \right) 10^{-3} \quad \text{kN}$$

Where:

P design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets, method to derive the design pressure and applicable acceptance criteria set are to be taken in accordance with the following criteria, which define the Acceptance Criteria Set to be used:

Table 8.2.5 in the cargo tank region

Sec 8/3.9.2.2 in the area forward of the forward cargo tank

Sec 8/3.9.2.2 in the aft end

Sec 8/4.8.1.2 in the machinery space

Sec 8/6.2.4.1 if subjected to sloshing loads

Sec 8/6.3.5.1 if subjected to bottom slamming loads

Sec 8/6.4.5.1 if subjected to bow impact loads

S primary support member spacing, in m, as defined in **Sec 4/2.2**

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

For stiffeners having different primary support member spacing, S, and/or different pressure, P, at each side of the primary support member, the average load for the two sides is to be applied, e.g. vertical stiffeners at transverse bulkhead.

3.4.3.3 The load, W_1, transmitted through the shear connection is to be taken as follows.

If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \quad \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_1 = W$$

Where:

W the total load, in kN, as defined in **3.4.3.2**

α_a panel aspect ratio, not to be taken greater than 0.25

$$= \frac{s}{1000S}$$

S primary support member spacing, in m

s stiffener spacing, in mm

A_{1-net} effective net shear area of the connection, to be taken as the sum of the components of connection:

$$A_{1d-net} + A_{1c-net} \quad \text{cm}^2$$

in case of a slit type slot connections area, A_{1-net}, is given by:

$$A_{1-net} = 2 l_d t_{w-net} 10^{-2} \quad \text{cm}^2$$

in case of a typical double lug or collar plate connection area, A_{1-net}, is given by:

$$A_{1-net} = 2 f_1 l_c t_{c-net} 10^{-2} \quad \text{cm}^2$$

A_{1d-net} net shear connection area excluding lug or collar plate, as given by the following and **Fig 4.3.5**:

$$A_{1d-net} = l_d t_{w-net} 10^{-2} \quad \text{cm}^2$$

l_d length of direct connection between stiffener and primary support member web, in mm

t_{w-net} net web thickness of the primary support member, in mm

A_{1c-net} net shear connection area with lug or collar plate, given by the following and **Fig 4.3.5**:

$$A_{1c-net} = f_1 l_c t_{c-net} 10^{-2} \quad \text{cm}^2$$

l_c length of connection between lug or collar plate and primary support member, in mm

t_{c-net} net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent primary support member web, in mm

f_1 shear stiffness coefficient:

= 1.0 for stiffeners of symmetrical cross section

= $140/w$ for stiffeners of asymmetrical cross section but is not to be taken as greater than 1.0

w the width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in **Fig 4.3.5**

$A_{w\text{-}net}$ effective net cross-sectional area of the primary support member web stiffener in way of the connection including backing bracket where fitted, as shown in **Fig 4.3.6**, in cm^2. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, $A_{w\text{-}net}$, is to be measured at the throat of the connection, as shown in **Fig 4.3.6.**

f_c the collar load factor defined as follows:

for intersecting stiffeners of symmetrical cross section:

= 1.85 for $A_{w\text{-}net} \le 14$
= $1.85 - 0.0441(A_{w\text{-}net} - 14)$ for $14 < A_{w\text{-}net} \le 31$
= $1.1 - 0.013(A_{w\text{-}net} - 31)$ for $31 < A_{w\text{-}net} \le 58$
= 0.75 for $A_{w\text{-}net} > 58$

for intersecting stiffeners of asymmetrical cross section:

$$= 0.68 + 0.0172 \frac{l_s}{A_{w-net}}$$

where:

l_s = l_c for a single lug or collar plate connection to the primary support member
= l_d for a single sided direct connection to the primary support member
= mean of the connection length on both sides, i.e., in the case of a lug or collar plus a direct connection, $l_s = 0.5(l_c + l_d)$

3.4.3.4 The load, W_2, transmitted through the primary support member web stiffener is to be taken as follows.

If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \quad \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_2 = 0$$

Where:

W the total load, in kN, as defined in **3.4.3.2**

α_a panel aspect ratio

$$= \frac{s}{1000 S}$$

S primary support member spacing, in m

s stiffener spacing, in mm

$A_{1\text{-}net}$ effective net shear area of the connection, in cm^2, as defined in **3.4.3.3**

f_c collar load factor, as defined in **3.4.3.3**

$A_{w\text{-}net}$ effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in **3.4.3.3**

3.4.3.5 The values of $A_{w\text{-}net}$, $A_{wc\text{-}net}$ and $A_{1\text{-}net}$ are to be such that the calculated stresses satisfy the fol-

lowing criteria:
for the connection to the primary support member web stiffener away from the weld:

$\sigma_w \le \sigma_{perm}$

for the connection to the primary support member web stiffener in way of the weld:

$\sigma_{wc} \le \sigma_{perm}$

for the shear connection to the primary support member web:

$\tau_w \le \tau_{perm}$

Where:

σ_w direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection:

$= \dfrac{10 W_2}{A_{w-net}}$ N/mm^2

σ_{wc} direct stress in the primary support member web stiffener in way of the weld connection:

$= \dfrac{10 W_2}{A_{wc-net}}$ N/mm^2

τ_w shear stress in the shear connection to the primary support member

$= \dfrac{10 W_1}{A_{1-net}}$ N/mm^2

A_{w-net} effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in **3.4.3.3**

A_{wc-net} effective net area of the web stiffener in way of the weld as shown in **Fig 4.3.6**, in cm^2

A_{1-net} effective net shear area of the connection, in cm^2, as defined in **3.4.3.3**

W_1 load transmitted through the shear connection, in kN, as defined in **3.4.3.3**

W_2 load transmitted through the web stiffener, in kN, as defined in **3.4.3.4**

σ_{perm} permissible direct stress given in **Table 4.3.1** for the applicable acceptance criteria, see **3.4.3.2**, in N/mm^2

τ_{perm} permissible shear stress given in **Table 4.3.1** for the applicable acceptance criteria, see **3.4.3.2**, in N/mm^2

3.4.3.5 bis 1 When total load, W, is bottom slamming or bow impact loads the following criteria apply in lieu of **3.4.3.3 - 3.4.3.5.**

$$0.9W \le \frac{\left(A_{1-net}\tau_{perm} + A_{w-net}\sigma_{perm}\right)}{10} \text{ kN}$$

A_{1-net} effective net shear area in cm^2 of the connection, as defined in **3.4.3.3.**

A_{w-net} effective net cross sectional area in cm^2 of the primary support member web stiffener in way of the connection including backing bracket where fitted, as defined in **3.4.3.3.**

σ_{perm} permissible direct stress given in **Table 4.3.1** for AC-3, in N/mm^2

τ_{perm} permissible shear stress given in **Table 4.3.1** for AC-3, in N/mm^2

3.4.3.6 Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of A_{w-net} as shown in **Fig 4.3.6.**

3.4.3.7 Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g., lapped connections between transverse and longitudinal local support members.

3.4.3.8 Fabricated stiffeners having their face plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

3.4.3.9 Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in **Fig 4.3.7**. The offset primary support member web stiffener is to be located in close proximity to the slot edge. See also **Fig 4.3.7**. The ends of the offset web stiffeners are to be suitably tapered and softened.

3.4.3.10 Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

3.4.3.11 The size of the fillet welds is to be calculated according to **Sec 6/5** based on the weld factors given in **Table 4.3.2.** For the welding in way of the shear connection the size is not to be less than that required for the primary support member web plate for the location under consideration.

Table 4.3.1
Permissible Stresses for Connection between Stiffeners and Primary Support Members

Item	Direct Stress, σ_{perm}, in N/mm^2			Shear Stress, τ_{perm}, in N/mm^2		
	Acceptance Criteria Set See **3.4.3.2**			Acceptance Criteria Set See **3.4.3.2**		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary support member web stiffener	$0.83\ \sigma_{yd}$ (3)	σ_{yd}	σ_{yd}	-	-	-
Primary support member web stiffener to intersecting stiffener in way of weld connection:						
double continuous fillet	$0.58\ \sigma_{yd}$ (3)	$0.70\ \sigma_{yd}$ (3)	σ_{yd}	-	-	-
partial penetration weld	$0.83\ \sigma_{yd}$ (2)(3)	σ_{yd} (2)	σ_{yd}	-	-	-
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0.50\sigma_{yd}$	$0.60\ \sigma_{yd}$	σ_{yd}	-	-	-
Shear connection including lugs or collar plates:						
single sided connection	-	-	-	$0.71\ \tau_{yd}$	$0.85\ \tau_{yd}$	τ_{yd}
double sided connection	-	-	-	$0.83\ \tau_{yd}$	τ_{yd}	τ_{yd}

Where:

τ_{perm} permissible shear stress, in N/mm^2
σ_{perm} permissible direct stress, in N/mm^2
σ_{yd} minimum specified material yield stress, in N/mm^2
τ_{yd} $\frac{\sigma_{yd}}{\sqrt{3}}$, in N/mm^2

Note

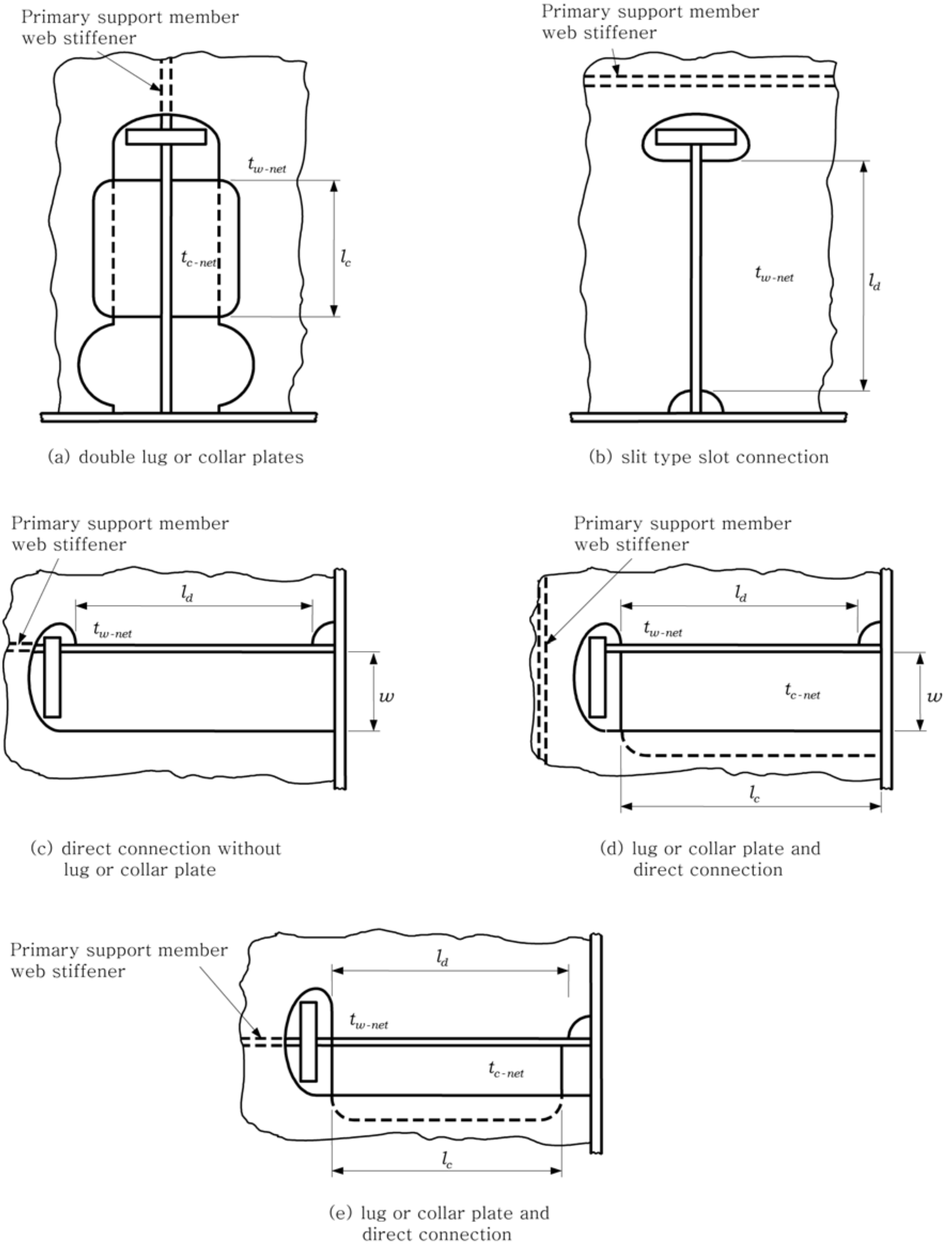
1. The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, see **3.4.3.11**.
2. The root face is not to be greater than one third of the gross thickness of the primary support member stiffener.
3. Allowable stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the primary support member web stiffener.

Table 4.3.2
Weld Factors for Connection between Stiffeners and Primary Support Members

Item	Weld factor
Primary support member stiffener to intersecting stiffener	$0.6\ \sigma_{wc}/\sigma_{perm}$ not to be less than 0.38
Shear connection inclusive lug or collar plate	0.38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	$0.6\ \tau_w/\tau_{perm}$ not to be less than 0.44

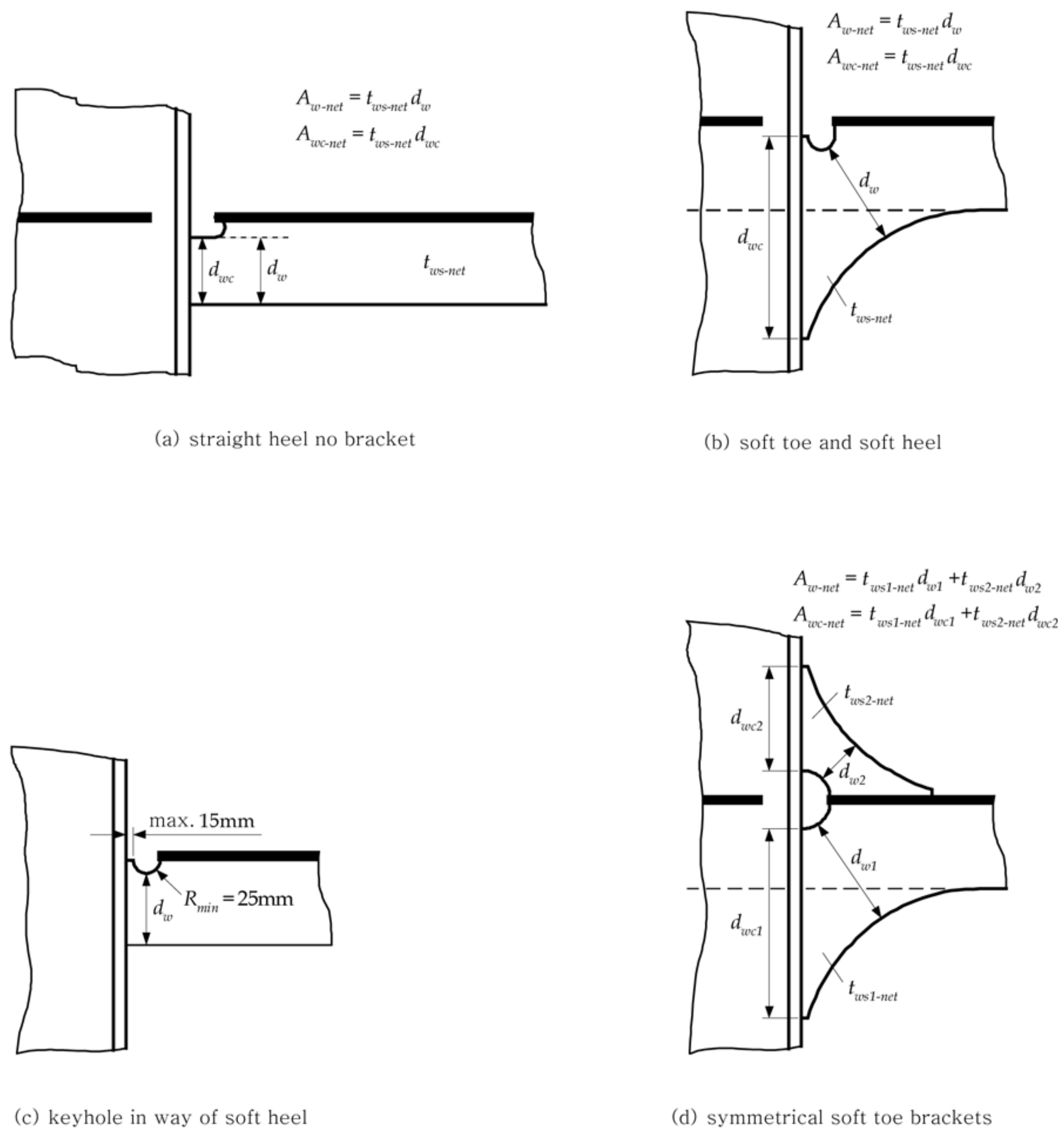
Where:
τ_w shear stress, as defined in **3.4.3.5**
σ_{wc} as defined in **3.4.3.5**
τ_{perm} permissible shear stress, in N/mm^2, see **Table 4.3.1**
σ_{perm} permissible direct stress, in N/mm^2, see **Table 4.3.1**

Fig 4.3.5
Symmetric and Asymmetric Cut outs



Note
The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig 4.3.6
Primary Support Member Web Stiffener Details



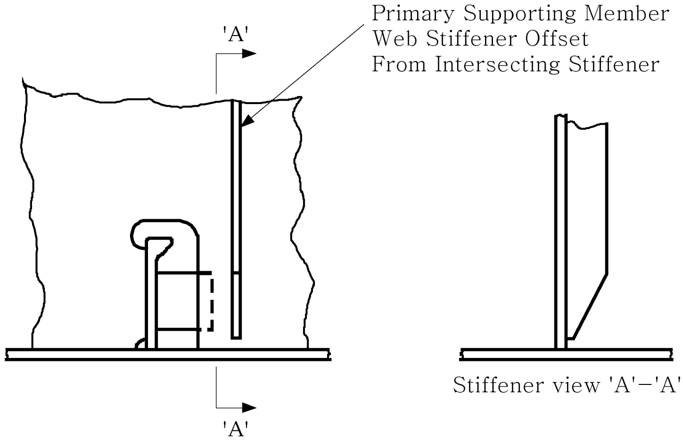
Where:

$t_{ws\text{-}net}$, $t_{ws1\text{-}net}$ and $t_{ws2\text{-}net}$	net thickness of the primary support member web stiffener/backing bracket, in mm
d_w, d_{w1} and d_{w2}	minimum depth of the primary support member web stiffener/backing bracket, in mm
d_{wc}, d_{wc1} and d_{wc2}	length of connection between the primary support member web stiffener/backing bracket and the local support stiffener, in mm

Note

Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, see **3.4.1.4**, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig 4.3.7
Offset Primary Support Member Web Stiffeners



3.5 Openings

3.5.1 General

3.5.1.1 Openings are to have well rounded corners.

3.5.1.2 Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

(a) in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end

(b) in floors or double bottom girders close to their span ends

(c) above the heads and below the heels of pillars.

Where larger openings than given by **3.5.2** or **3.5.3** are proposed, the arrangements and compensation required will be specially considered.

3.5.2 Manholes and lightening holes in single skin sections not requiring reinforcement

3.5.2.1 Openings cut in the web with depth of opening not exceeding 25 percent of the web depth and located so that the edges are not less than 40 percent of the web depth from the faceplate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 percent of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut outs for local support members.

3.5.3 Manholes and lightening holes in double skin sections not requiring reinforcement

3.5.3.1 Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required provided that the depth of the opening does not exceed 50 percent of the web depth and is located so that the edges are well clear of cut outs for the passage of local support members.

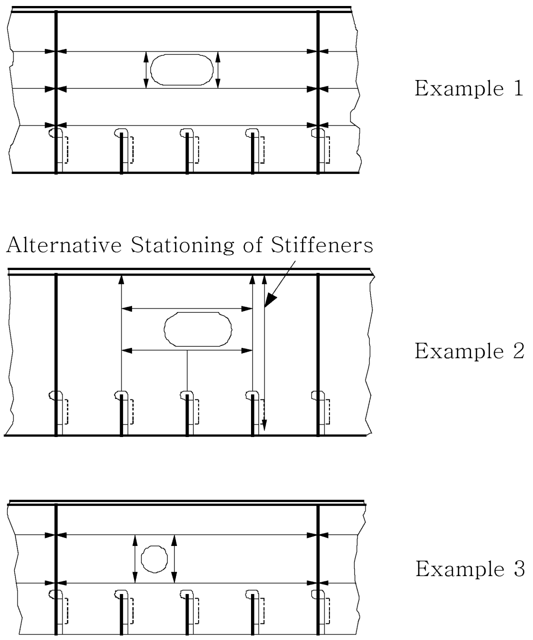
3.5.4 Manholes and lightening holes requiring reinforcement

3.5.4.1 Manholes and lightening holes are to be stiffened as required by **3.5.4.2** and **3.5.4.3**. The stiffening requirements of **3.5.4.2** and **3.5.4.3** may be modified where alternative arrangements are demonstrated as satisfactory with regards to stress and stability, in accordance with analysis methods described in **Sec 9/2**.

3.5.4.2 The web plate is to be stiffened at openings when the mean shear stress, as determined by application of the requirements of **Sec 8** or **Sec 9/2**, is greater than 50 N/mm^2 for acceptance criteria set AC1 or greater than 60 N/mm^2 for acceptance criteria set AC2. The stiffening arrangement is to ensure buckling strength as required by **Sec 10** under application of the loading as required in **Sec 8** or **Sec 9/2.**

3.5.4.3 On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm, and in both directions if length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners. See **Fig 4.3.8.**

Fig 4.3.8
Web Plate with Large Openings



3.6 Local Reinforcement

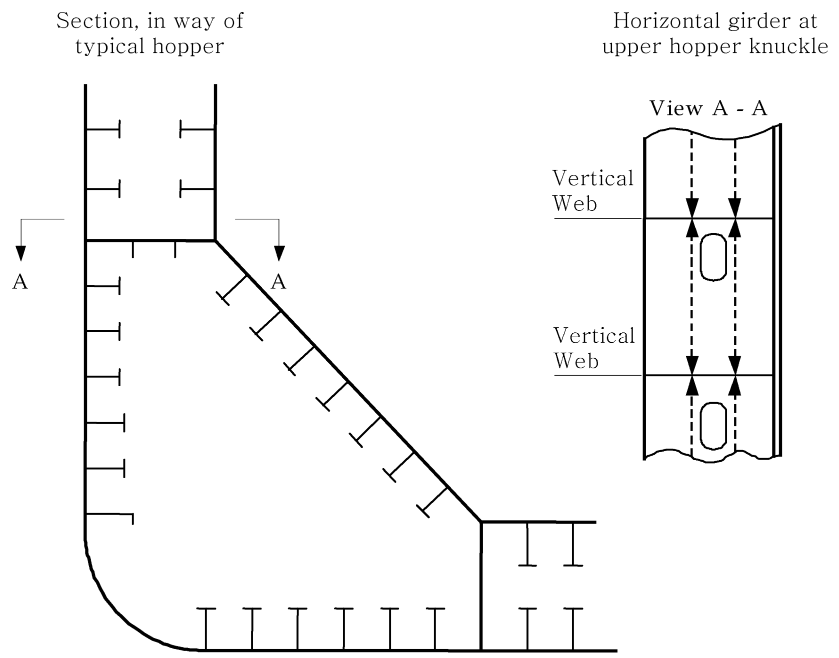
3.6.1 Reinforcement at knuckles

3.6.1.1 Whenever a knuckle in a main member (shell, longitudinal bulkhead etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear). See **Fig 4.3.9.**

3.6.1.2 In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

3.6.1.3 Generally, the distance between the knuckle and the support stiffening described in **3.6.1.1** is not to be greater than 50 mm.

Fig 4.3.9
Example of Reinforcement at Knuckles



3.6.2 Reinforcement for openings and attachments associated with means of access for inspection purposes

3.6.2.1 Local reinforcement is to be provided taking into account proper location and strength of all attachments to the hull structure for access for inspection purposes.

3.7 Fatigue Strength

3.7.1 General

3.7.1.1 Structural details are to be designed for compliance with the requirements of fatigue strength as specified in **Sec 9/3.**

Section 5

Structural Arrangement

1 General

1.1 Introduction

1.1.1 Scope

1.1.1.1 This section covers the general structural arrangement requirements for the ship, which are based on or derived from National and International regulations, see **Sec 2/2.1.1** and **3/3.3.**

2 Watertight Subdivision

2.1 Watertight Bulkhead Arrangement

2.1.1 General

2.1.1.1 All ships are to be provided with watertight bulkheads arranged to subdivide the hull into watertight compartments in accordance with the following requirements.

2.1.2 Minimum number and disposition of watertight bulkheads

2.1.2.1 The following watertight bulkheads are to be fitted on all ships:

(a) a collision bulkhead, see **2.2.1.1**

(b) an aft peak bulkhead

(c) a bulkhead at each end of the machinery space.

2.1.2.2 The bulkheads in the cargo tank region are to be spaced at uniform intervals so far as practicable.

2.1.2.3 The applicable number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of National regulations.

2.1.2.4 The number of openings in watertight bulkheads is to be kept to a minimum. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. Additional requirements apply to collision bulkheads in **Sec 8/3.6.2.**

2.2 Position of Collision Bulkhead

2.2.1 General

2.2.1.1 A collision bulkhead is to be fitted on all ships and is to extend to the freeboard deck. It is to be located between $0.05 L_L$ or 10 m, whichever is less, and $0.08 L_L$ aft of the reference point, where the load line length, L_L, is as defined in **Sec 4/1.1.2.1** and the reference point is as defined in **2.2.1.2.** Proposals for location of the collision bulkhead aft of $0.08 L_L$ will be specially considered.

2.2.1.2 For ships without bulbous bows the reference point is to be taken where the forward end of L_L coincides with the forward side of the stem, on the waterline which L_L is measured. For ships with bulbous bows, it is to be measured from the forward end of L_L a distance x forward; where x is to be taken as the lesser of the following:

(a) half the distance, from the forward end of L_L and the extreme forward end of the bulb extension

(b) $0.015 L_L$

(c) 3.0 m.

2.2.1.3 In general, the collision bulkhead is to be in one plane, however, the bulkhead may have steps or recesses provided they are in compliance with the limits prescribed in **2.2.1.1** and **2.2.1.2.**

2.3 Position of Aft Peak Bulkhead

2.3.1 General

2.3.1.1 An aft peak bulkhead, enclosing the stern tube and rudder trunk in a watertight compartment, is to be provided. Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, alternative arrangements will be specially considered. The aft peak bulkhead location on ships powered and/or controlled by equipment that do not require the fitting of a stern tube and/or rudder trunk will also be subject to special consideration.

2.3.1.2 The aft peak bulkhead may terminate at the first deck above the summer load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor.

3 Double Hull Arrangement

3.1 General

3.1.1 Protection of cargo tanks

3.1.1.1 Every tanker is to be provided with double bottom tanks and spaces, and double side tanks and spaces, in accordance with **3.2** and **3.3.** The double bottom and double side tanks and spaces, protect the cargo tanks or spaces, and are not to be used for the carriage of oil cargoes.

3.1.2 Capacity of ballast tanks

3.1.2.1 The capacity of the segregated ballast tanks shall be so determined that the ship may operate safely on ballast voyages without recourses to the use of cargo tanks for water ballast. The capacity of ballast shall be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballast only, the ships draught and trim can meet the requirements in **3.1.2.2** to **3.1.2.4.**

3.1.2.2 The moulded draught amidships, T_{mid}, excluding any hogging or sagging correction, is not to be less than:

$$T_{mid} = 2.0 + 0.02L \quad \text{m}$$

Where:

L rule length, as defined in **Sec 4/1.1.1.1**, in m

3.1.2.3 The draughts at the F.P. and A.P. are to correspond to those determined by the draught amidships, as given in **3.1.2.2**, and in association with a trim by the stern not greater than $0.015L$ (m).

3.1.2.4 The draught at the A.P. is not to be less than that required to obtain full immersion of the propeller(s).

3.1.3 Limitation of size and arrangement of cargo tanks

3.1.3.1 Cargo tanks are to be of a size and arrangement that hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

3.2 Double Bottom

3.2.1 Double bottom depth

3.2.1.1 The minimum double bottom depth, d_{db}, is to be taken as the lesser of:

$$d_{db} = \frac{B}{15} \quad \text{m, but not less than 1.0 m}$$

$$d_{db} = 2.0 \quad \text{m}$$

Where:

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

3.3 Double Side

3.3.1 Double side width

3.3.1.1 The minimum double side width, w_{ds}, is to be taken as the lesser of:

$$w_{ds} = 0.5 + \frac{DWT}{20000} \quad \text{m, but not less than 1.0 m}$$

$$w_{ds} = 2.0 \quad \text{m}$$

Where:

DWT deadweight of the ship, in tonnes, as defined in **Sec 4/1.1.14.1**

4 Separation of Spaces

4.1 Separation of Cargo Tanks

4.1.1 General

4.1.1.1 The cargo pump room, cargo tanks, slop tanks and cofferdams are to be positioned forward of machinery spaces. Main cargo control stations, control stations, accommodation and service spaces are to be positioned aft of cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces, but not necessarily aft of the oil fuel bunker tanks and ballast tanks.

4.2 Cofferdam Spaces

4.2.1 General

4.2.1.1 Cofferdam spaces are to be kept gas-tight. Where applicable, access requirements to permit internal inspections, are to be in accordance with **5.3.**

5 Access Arrangements

5.1 Access Into and Within Spaces in, and Forward of, the Cargo Tank Region

5.1.1 General

5.1.1.1 Access into and within spaces in, and forward of, the cargo tank region is to satisfy the *International Convention for the Safety of Life at Sea,1974*, as amended, Chapter II-1, Part A-1, Regulation 3-6, as required by the Flag Administration, for details and arrangements of openings and attachments to the hull structure. This will be reviewed in conjunction with the structural requirements. In addition, the requirements of **5.1.1.2** to **5.1.1.5** are to be complied with.

5.1.1.2 Where a duct keel or pipe tunnel is fitted provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. The duct keel or pipe tunnel is not to pass into machinery spaces. The aft access may lead from the pump room to the duct keel. Where an aft access is provided from the pump room to the duct keel, the access opening from the pump room to the duct keel is to be provided with an oil-tight cover plate or a watertight door. Mechanical ventilation is to be provided and such spaces are to be sufficiently ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for a sufficient period. In addition, the atmosphere in the tunnel is to be sampled by a gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

5.1.1.3 Where a watertight door is fitted in the pump room for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Classification Society and the following additional requirements:

(a) the watertight door is to be capable of being manually closed from outside the main pump room entrance, in addition to bridge operation. A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

(b) a notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the ship, except when access to the pipe tunnel is required.

5.1.1.4 At least one horizontal access opening of 600 mm by 800 mm clear opening is to be fitted in each horizontal girder in the vertical wing ballast space and weather deck to assist in rescue operations. Where an opening of 600 mm by 800 mm is not permitted due to structural arrangements, a 600 mm by 600 mm clear opening will be accepted.

5.1.1.5 Special consideration will be given to any proposals to fit permanent repair/maintenance access openings with oil-tight covers in cargo tank bulkheads. Attention is drawn to the relevant National regulations concerning load line and oil outflow aspects of such arrangements.

Section 6

Materials and Welding

1 Steel Grades

1.1 Hull Structural Steel

1.1.1 Scope

1.1.1.1 Materials used during construction are to comply with the Rules for Materials of the individual Classification Society. Use of other materials and the corresponding scantlings will be specially considered.

1.1.2 Strength

1.1.2.1 Steel having a specified minimum yield stress of 235 N/mm^2 is regarded as normal strength hull structural steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel.

1.1.3 Material grades

1.1.3.1 Material grades of hull structural steels are referred to as follows:
(a) A, B, D and E denote normal strength steel grades
(b) AH, DH and EH denote higher strength steel grades.

1.1.4 Higher strength steel factor

1.1.4.1 For the determination of hull girder section modulus, where higher strength hull structural steel is used, a higher strength steel factor, k is given in **Table 6.1.1.**

Table 6.1.1
Values of k

Specified minimum yield stress, N/mm^2	k
235	1.00
265	0.93
315	0.78
340	0.74
355	0.72
390	0.68

Note
1. Intermediate values are to be calculated by linear interpolation.

1.1.5 Through thickness property

1.1.5.1 Where tee or cruciform connections employ partial or full penetration welds, and the plate material is subject to significant tensile strain in a direction perpendicular to the rolled surfaces, consideration is to be given to the use of special material with specified through thickness properties, in accordance with the Rules for Materials of the individual Classification Society. These steels are to be designated on the approved plan by the required steel strength grade followed by the letter Z (e.g. EH36Z).

1.1.6 Steel castings and forgings

1.1.6.1 Steel castings or forgings that are used for stern frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items are to be in accordance with the Rules for Materials of the individual Classification Society.

1.2 Application of Steel Materials

1.2.1 Selection of material grades

1.2.1.1 Steel materials for particular locations are not to be of lower grades than those given in **Table 6.1.2** for the material class given in **Table 6.1.3.**

1.2.2 Applicable thickness

1.2.2.1 For application of **Table 6.1.2** and **Table 6.1.3**, the steel grade is to correspond to the as-built thickness.

1.2.3 Operation in areas with low air temperature

1.2.3.1 For ships intended to operate for long periods in areas with a lowest daily mean air temperature below −10 degrees C (i.e. regular service during winter to Arctic or Antarctic waters) the materials in exposed structures will be specially considered.

Table 6.1.2
Material Grades

Thickness, t in mm	Material Class		
	I	II	III
$t \leq 15$	A, AH	A, AH	A, AH
$15 < t \leq 20$	A, AH	A, AH	B, AH
$20 < t \leq 25$	A, AH	B, AH	D, DH
$25 < t \leq 30$	A, AH	D, DH	D, DH
$30 < t \leq 35$	B, AH	D, DH	E, EH
$35 < t \leq 40$	B, AH	D, DH	E, EH
$40 < t \leq 51$	D, DH	E, EH	E, EH

Table 6.1.3
Material Class or Grade of Structural Members

Structural member category	Material Class or Grade: Within 0.4 L Amidships	Material Class or Grade: Outside 0.4 L
○ Secondary - Longitudinal bulkhead strakes, other than those belonging to primary category - Deck plating exposed to weather other than that belonging to primary or special category - Side plating	Class I	Grade A(8)/AH
○ Primary - Bottom plating including keel plate - Strength deck plating, excluding that belonging to the special category(10)(11) - Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings(11) - Uppermost strake in longitudinal bulkheads(10) - Vertical strake (hatch side girder) and upper sloped strake in top wing tank	Class II	Grade A(8)/AH
○ Special - Sheer strake at strength deck(1)(2)(3)(10)(11) - Stringer plate in strength deck(1)(2)(3)(10)(11) - Deck strake at longitudinal bulkhead(2)(4)(10)(11) - Strength deck plating at outboard corners of cargo hatch openings(11) - Bilge strake(2)(6) - Continuous longitudinal hatch coamings(11)	Class III	Class II (Class I outside 0.6 L amidships)
○ Other Categories - Plating for stern frames, rudder horns and shaft brackets - Longitudinal strength members of strength deck plating for ships with single strength deck(11) - Strength members not referred to in above categories(9)	- Grade B/AH Grade A(8)/AH	Class II - Grade A(8)/AH

Note
1. Not to be less than E/EH within 0.4 L amidships in vessels with length, L, exceeding 250 m.
2. Single strakes required to be of material class III or E/EH are, within 0.4 L amidships, to have breadths not less than $800 + 5L$ mm, but need not be greater than 1800 mm.
3. A radius gunwale plate may be considered to meet the requirements for both the stringer plate and the sheer strake, provided it extends generally 600 mm inboard and vertically.
4. For tankers having a breadth, B, exceeding 70 m, the centreline strake and the strakes in way of the longitudinal bulkheads port and starboard, are to be class III.
5. (void)
6. To be not lower than D/DH within 0.6 L amidships of vessels with length, L, exceeding 250 m.
7. (void)
8. Grade B/AH to be used for plate thickness more than 40 mm. However, engine foundation heavy plates outside 0.6 L amidships may be of Grade A/AH.
9. The material class used for reinforcement and the quality of material (i.e. whether normal or higher strength steel) used for welded attachments, such as spill protection bars and bilge keel, is to be similar to that of the hull envelope plating in way. Where attachments are made to round gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.
10. The material class for deck plating, sheer strake and upper strake of longitudinal bulkhead within 0.4 L amidships is also to be applied at structural breaks of the superstructure, irrespective of position.
11. To be not lower than B/AH within 0.4 L amidships for ships with single strength deck.

1.2.4 Guidance for repairs

1.2.4.1 Where materials are used in the construction, which are not in accordance with the Rules for Materials of the individual Classification Society, a set of plans showing the following information, for each material, is to be placed aboard the vessel in addition to those normally retained on the vessel:

(a) material specification and applicable thickness

(b) welding procedure

(c) location and extent of application.

1.3 Aluminium Alloys

1.3.1 General

1.3.1.1 The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components will be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

1.3.1.2 Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

1.3.1.3 Material requirements and scantlings are to comply with the Rules for Materials of the individual Classification Society.

1.3.2 Incendiary sparking on impact with steel

1.3.2.1 Aluminium may, under certain circumstances give rise to incendiary sparking on impact with oxidized steel. A particular risk is where an aluminium component is dragged or rubbed against the uncoated steel structure creating a thin smear of aluminium on the surface. Subsequent high energy impact by a rusted component on that smear could generate an incendiary spark capable of igniting any surrounding inflammable gas. The following requirements are therefore to be complied with:

(a) aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided

(b) where fitted, aluminium fittings, units and supports, in tanks used for the carriage of oil, cofferdams and pump rooms are to satisfy the requirements of **2.1.2** for aluminium anodes

(c) the underside of heavy portable aluminium structures such as gangways, etc., is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

2 Corrosion Protection Including Coatings

2.1 Hull Protection

2.1.1 General

2.1.1.1 All dedicated seawater ballast tanks are to have an efficient corrosion prevention system, as required by **SOLAS Reg. II-1/3-2**, see **Sec 2/2.1.1.**

2.1.1.2 For ships contracted for construction on or after the date of IMO adoption of the amended **SOLAS Reg. II-1/3-2**, by which an IMO "Performance standard for protective coatings for ballast tanks and void spaces" will be made mandatory, the coatings of internal spaces subject to the amended SOLAS Regulation are to satisfy the requirements of the IMO performance standard.

2.1.1.3 Consistent with **IMO Resolution A.798(19)** and **IACS UI SC122**, the selection of the coating system, including coating selection, specification, and inspection plan, are to be agreed between the shipbuilder, coating system supplier and the owner, in consultation with the Classification Society, prior to commencement of construction. The specification for the coating system for these spaces is to be documented and this documentation is to be verified by the Classification Society and is to be in full compliance with the coating performance standard.

2.1.1.4 The shipbuilder is to demonstrate that the selected coating system with associated surface preparation and application methods is compatible with the manufacturing processes and methods.

2.1.1.5 The shipbuilder is to demonstrate that the coating inspectors have proper qualification as required by the IMO standard.

2.1.1.6 The attending surveyor of the Classification Society will not verify the application of the coatings but will review the reports of the coating inspectors to verify that the specified shipyard coating procedures have been followed.

2.1.1.7 Where anodes are fitted in ballast tanks, ballast tank anode distribution drawings are to be submitted for approval. Such drawings are to include details of the connections to the hull, e.g. welding details.

2.1.2 Internal cathodic protection systems

2.1.2.1 When a cathodic protection system is to be fitted to steel structures in tanks used for liquid cargo with flash point below 60°C, a plan of the fitting arrangement is to be submitted for approval. The arrangements will be considered for safety against fire and explosion. This approval also applies to adjacent tanks.

2.1.2.2 Permanent anodes in tanks made of, or alloyed with magnesium are not acceptable, except in tanks solely intended for water ballast that are not adjacent to cargo tanks. Impressed current systems are not to be used in cargo tanks due to the development of chlorine and hydrogen that can result in an explosion. Aluminium anodes are accepted, however, in tanks with liquid cargo with flash point below 60°C and in adjacent ballast tanks, aluminium anodes are to be located so a kinetic energy of not more than 275J is developed in the event of their loosening and becoming detached.

2.1.2.3 Aluminium anodes are to be located in such a way that they are protected from falling objects. They are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

2.1.2.4 All anodes are to be attached to the structure in such a way that they will remain securely fastened both initially and during service. The following methods are acceptable:

(a) steel core connected to the structure by continuous fillet welds of sufficient cross section

(b) attachment by properly secured through-bolts or other positive locking devices. Attachment by clamps fixed with setscrews is to be by approved means.

2.1.2.5 Anode steel cores bent and directly welded to the steel structure are to be of a material complying with the requirements for grade A of the Rules for Materials of the individual

Classification Society.

2.1.2.6 Anodes are to be attached to stiffeners or aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.1.2.7 Where cores or supports are welded to local support members or primary support members, they are to be kept clear of end supports, toes of brackets and similar stress raisers. Where they are welded to asymmetrical members, the welding is to be at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate, but well clear of the free edges. Generally, anodes are not to be fitted to a face plate of higher strength steel.

2.1.2.8 Tanks in which anodes are installed, are to have sufficient holes for the circulation of air to prevent gas from collecting in pockets.

2.1.3 Paint containing aluminium

2.1.3.1 Paint containing aluminium is not to be used in positions where cargo vapours may accumulate unless it has been shown by appropriate tests that the paint to be used does not increase the incendiary sparking hazard. Tests need not be performed for coatings with less than 10 percent aluminium by weight.

3 Corrosion Additions

3.1 General

3.1.1 Introduction

3.1.1.1 The required net thickness of steel structures is to be increased by the corrosion addition as specified in this Sub-Section.

3.1.1.2 The corrosion additions given in this Sub-Section are applicable to carbon-manganese steels, see **1.1**. Application of corrosion additions for other materials, such as stainless steel, is to be in accordance with the requirements of the individual Classification Society.

3.1.1.3 The application of the corrosion additions in rule calculations is given in **3.3.**

3.2 Local Corrosion Additions

3.2.1 General

3.2.1.1 The local corrosion additions, t_{corr}, for structural members are to be taken as:

$$t_{corr} = t_{was} + 0.5 \quad \text{mm}$$

Where:

t_{was} total wastage allowance of the considered structural member, in mm, as given in **Sec 12/1.4.2.2**

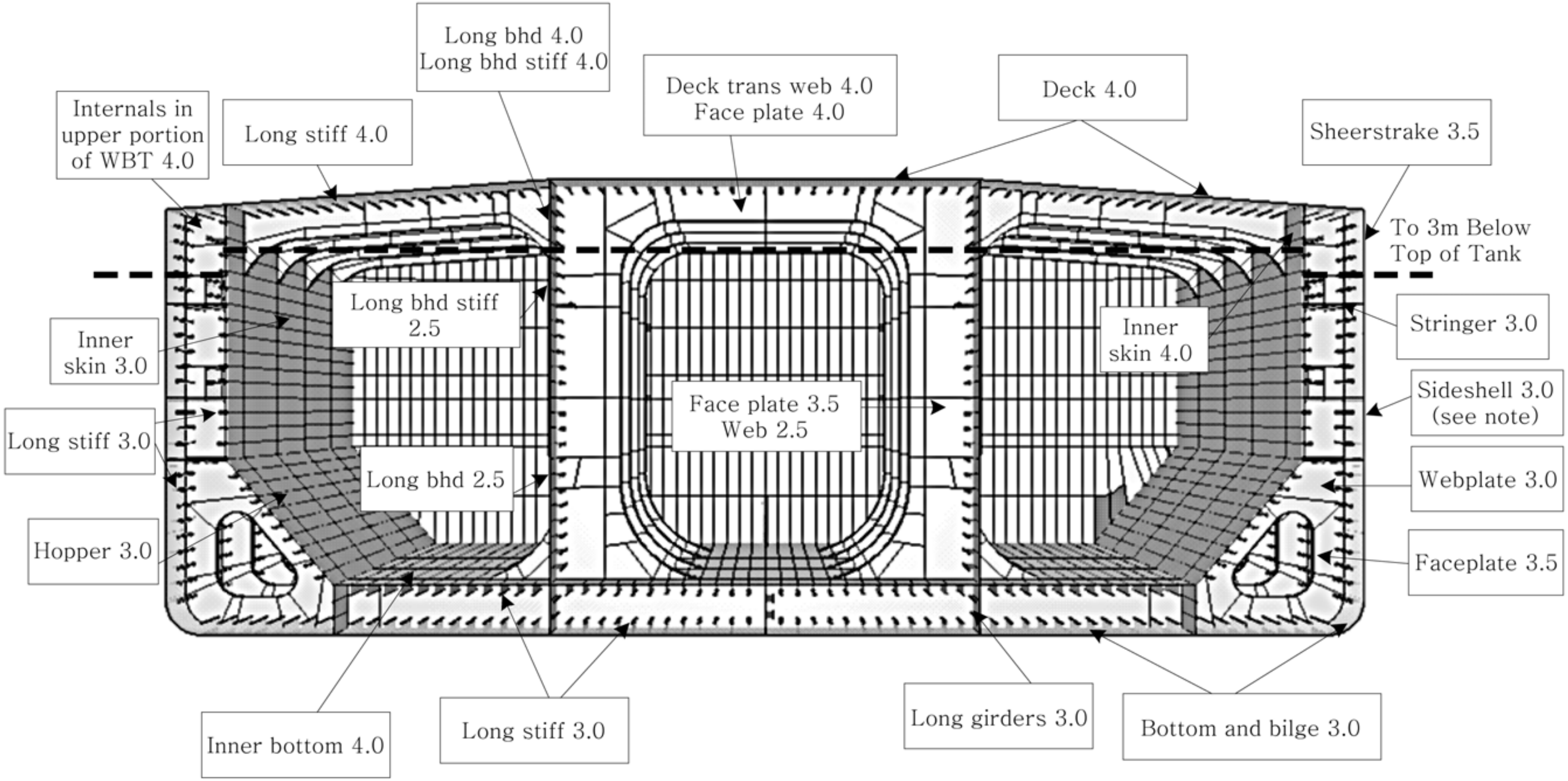
3.2.1.2 The local corrosion additions, t_{corr}, for typical structural elements in the cargo tank region are given in **Table 6.3.1** and **Fig 6.3.1.**

Table 6.3.1
Corrosion Addition, t_{corr}, for Typical Structural Elements Within the Cargo Tank Region

Category of contents			Corrosion Addition t_{corr}, in mm
Internal members and plate boundary between spaces with the same category of contents			
In and between ballast water tanks	Face plate of PSM	Within 3 m below top of tank(1)	4.5
		Elsewhere	3.5
	Other members	Within 3 m below top of tank(1)	4.0
		Elsewhere	3.0
	Stiffeners on boundaries to heated cargo tanks	Within 3 m below top of tank(1)	4.5
		Elsewhere	3.5
In and between cargo oil tanks	Face plate of PSM	Within 3 m below top of tank(1)	4.0
		Elsewhere	3.5
	Other members	Within 3 m below top of tank(1)	4.0
		Elsewhere	2.5
Exposed to atmosphere on both sides	Support members on deck		2.5
In and between void spaces	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, etc.		2.0
In and between dry spaces	Internals of deckhouses, machinery spaces, pump room, store rooms, steering gear space, etc.		1.5
Plate boundary between spaces having a different category			
Boundary between ballast tank and cargo oil tank	Unheated cargo tank	Within 3 m below top of tank(1)	4.0
		Inner bottom plating	4.0
		Elsewhere	3.0
	Heated cargo tank	Within 3 m below top of tank(1)	4.5
		Inner bottom plating	4.5
		Elsewhere	3.5
Boundary between ballast tank and atmosphere or sea	Weather deck plating		4.0
	Other members(2)	Within 3 m below top of tank(1)	3.5
		Elsewhere	3.0
Boundary between ballast tank and void or dry space	Within 3 m below top of tank(1)		3.0
	Elsewhere		2.5
Boundary between cargo tank and atmosphere	Weather deck plating		4.0
Boundary between cargo tank and void spaces	Within 3 m below top of tank(1)		3.0
	Elsewhere		2.5
Boundary between cargo tank and dry spaces	Within 3 m below top of tank(1)		3.0
	Elsewhere		2.0

Note
1. Only applicable to cargo and ballast tanks with weather deck as the tank top
2. 0.5 mm to be added for side plating in the quay contact region defined in **Sec 8/Fig 8.2.2**
3. Heated cargo oil tanks are defined as cargo tanks arranged with any form of heating capability

Fig 6.3.1
Corrosion Addition, t_{corr}, for Typical Structural Elements Within the Cargo Tank



Note
1. Corrosion additions are given for a standard configuration and without heated cargo
2. 0.5 mm to be added for side plating in the quay contact region defined in **Sec 8/Fig 8.2.2**

3.3 Application of Corrosion Additions

3.3.1 General

3.3.1.1 The application of corrosion additions described in **3.3.2** to **3.3.7** is to be applied unless otherwise specified in the specific rule requirements.

3.3.1.2 Compliance with the Rules may be performed either by:

(a) comparison of the proposed gross scantling with the gross required, in which case the applicable corrosion addition is added to the net requirement of the Rules

(b) comparison of the proposed net scantling with the net required, in which case the applicable corrosion addition is deducted from the gross proposed.

Methods (a) and (b) are suitable for assessment of thickness. Method (b) is the most suitable for assessment of section properties, e.g. section modulus, area and moment of inertia.

3.3.1.3 The gross scantlings specified in **3.3.2** to **3.3.7** used to derive the net scantlings are to exclude any owner's extra thicknesses, see also **Sec 2/4.3.4.3.**

3.3.2 Application for hull girder longitudinal strength calculations

3.3.2.1 The calculation of hull girder stresses for the assessment of longitudinal strength as given in **Sect 8/1** is to be based on the net hull girder sectional properties calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thickness of all structural elements comprising the hull girder cross-section.

3.3.2.2 The local buckling capacity of plates and stiffeners subject to hull girder stresses are to be calculated based on the net scantlings, as given in **Sec 8/1.4.2**. The net scantling is calculated by deducting the full corrosion addition, i.e. -1.0 t_{corr}, from the gross thickness.

3.3.3 Application for scantling assessment of plates and local support members

3.3.3.1 The required gross thickness for plates and local support members are calculated by adding the full corrosion addition, i.e. +1.0 t_{corr}, to the net thickness required in accordance with the scantling requirements in **Sec 4/3.4** and **8/2** to **8/7.**

3.3.3.2 The net sectional properties of local support members are calculated by deducting the full corrosion addition, i.e. -1.0 t_{corr}, from the web, flange and attached plate gross thicknesses as described in **Sec 4/2.4.1** and are to comply with required section modulus, moment of inertia and shear area as given in **Sec 4/3.4** and **8/2** to **8/7.**

3.3.3.3 The calculation of hull girder stresses for the strength assessment of members under combined local and global loading is to be based on the net hull girder sectional properties calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thickness of all structural elements comprising the hull girder cross-section.

3.3.3.4 The required minimum gross thickness of plates and local support members is calculated by adding the full corrosion addition, i.e. +1.0 t_{corr}, to the minimum net thickness requirements given in **Sec 8/2.1.5.**

3.3.4 Application of corrosion additions for scantling strength assessment of primary support members

3.3.4.1 The required gross thickness of primary support members is calculated by adding half the corrosion addition, i.e. +0.5 t_{corr}, to the net thickness required in accordance with the strength requirements in **Sec 8/2.6** and **8/3** to **8/7.**

3.3.4.2 The net sectional properties of primary support members are to be calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the web and flange gross thicknesses, and are to comply with the required section modulus, moment of inertia and area as given in **Sec 8/2.6** and **8/3** to **8/7.**

3.3.4.3 The required minimum gross thickness of primary support members is calculated by adding the full corrosion addition, i.e. +1.0 t_{corr}, to the minimum net thickness requirement given in **Sec 8/2.1.6.1, 8/3.1.4.1, 8/4.1.5.1, 8/5.1.4.1, 8/6.3.7.5, 8/6.4.5.4** and **10/2.3.**

3.3.5 Application of corrosion additions for hull girder ultimate strength analysis

3.3.5.1 The calculation of the hull girder ultimate capacity, M_u, as given in **Sec 9/1**, is to be based on the net hull girder sectional properties calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thickness of all structural elements comprising the hull girder cross-section.

3.3.5.2 The buckling capacity of the structural elements used to derive the hull girder ultimate capacity is to be calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thicknesses of the plates and stiffener webs and flanges.

3.3.6 Application of corrosion additions for strength assessment by finite element analysis

3.3.6.1 For the cargo tank structural strength analysis, as given in **Sec 9/2.2** and **Appendix B/2**, the finite element model is to be modelled with thicknesses calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thickness of all structural elements.

3.3.6.2 The local buckling capacity of plates and stiffeners are to be calculated by deducting the full corrosion addition, i.e. -1.0 t_{corr}, from the gross thickness.

3.3.6.3 The local fine mesh structural strength analysis models, as given in **Sec 9/2.3** and **Appendix B/3**, are to be modelled with thicknesses calculated by deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thickness. The specified fine mesh areas are to be modelled by deduction of the full corrosion addition, i.e. -1.0 t_{corr}, from the gross thickness.

3.3.7 Application of corrosion additions for fatigue strength assessment

3.3.7.1 The calculation of hull girder stresses for the fatigue strength assessment, as given in **Sec 9/3** and **Appendix C/1**, is to based on the net fatigue hull girder sectional properties, calculated by deducting a quarter of the corrosion addition, i.e. -0.25 t_{corr}, from the gross thickness of all structural elements comprising the hull girder cross section.

3.3.7.2 The calculation of stresses in local support members from lateral load for the fatigue strength assessment, as given in **Sec 9/3** and **Appendix C/1**, are to be based on deducting half the corrosion addition, i.e. -0.5 t_{corr}, from the stiffener web, flange and attached plate.

3.3.7.3 For hot spot stress (FE based) approach, as given in **Sec 9/3** and **Appendix C/2**, the FE model of the hopper knuckle is to be modelled with thickness calculated by deducting a quarter of the corrosion addition, i.e. -0.25 t_{corr}, from the gross thicknesses. The very fine mesh areas are to be modelled by deduction of half the corrosion addition, i.e. -0.5 t_{corr}, from the gross thickness.

3.3.7.4 As an alternative to **3.3.7.3**, the hopper fatigue FE model may be made in accordance with requirements for FE strength model, i.e. all areas at -0.5 t_{corr}, as described in **3.3.6.1.** However the calculated stress range is then to be corrected by the factor f_{model} as described in **Appendix C/2.4.2.7.**

4 Fabrication

4.1 General

4.1.1 Workmanship

4.1.1.1 All workmanship is to be of commercial marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of **Sub-Sec 5.** Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or any other composition.

4.1.2 Fabrication standard

4.1.2.1 Structural fabrication is to be carried out, in accordance with 'IACS Recommendation 47, Shipbuilding and Repair Quality Standard for New Construction' or a recognised fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction.

4.1.2.2 The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Classification Society, prior to the commencement of the fabrication/construction.

4.1.2.3 The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

(a) Cutting edge : the slope of the cut edge and the roughness of the cut edges

(b) Flanged longitudinals and brackets and built-up sections : the breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate

(c) Pillars : the straightness between decks, and cylindrical structure diameter

(d) Brackets and small stiffeners : the distortion at the free edge line of tripping brackets and small stiffeners

(e) Sub-assembly stiffeners : details of snipe end of secondary face plates and stiffeners

(f) Plate assembly : for flat and curved blocks the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate

(g) Cubic assembly : in addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks

(h) Special assembly : the distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, deviation of rudder from shaft centreline, twist of rudder plate, and flatness, breadth and length of top plate of main engine bed. The final boring out of the propeller boss and stern frame, skeg or solepiece, and the fit-up and alignment of the rudder, pintles and axles, are to be carried out after completing the major part of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

(i) Butt joints in plating : alignment of butt joint in plating

(j) Cruciform joints : alignment measured on the median line and measured on the heel line of cruciform joints

(k) Alignment of interior members : alignments of flange of T longitudinals, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut outs for continuous stiffeners in assembly and in erection joints

(l) Keel and bottom sighting : deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships

(m) Dimensions : dimensions of length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine

(n) Fairness of plating between frames : deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deck house deck and wall plating

(o) Fairness of plating in way of frames : deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames

4.2 Cold Forming

4.2.1 Special structural members

4.2.1.1 For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in **Table 6.1.3**, such as radius gunwales and bilge strakes) the inside bending radius, in cold formed plating, is not to be less than 10 times the gross plate thickness for carbon-manganese steels (hull structural steels, see **1.1**). The allowable inside bending radius may be reduced below 10 times the gross plate thickness, providing the additional requirements stated in **4.2.3** are complied with.

4.2.2 Other members

4.2.2.1 For main structural members, e.g. corrugated bulkheads and hopper knuckles, the inside bending radius, in cold formed plating, is not to be less than 4.5 times the gross plate thickness for carbon-manganese steels (hull structural steels, see **1.1**). The allowable inside bending radius may be reduced below 4.5 times the gross plate thickness, providing the additional requirements stated in **4.2.3** are complied with.

4.2.3 Additional requirements

4.2.3.1 When steel is formed below 650°C with a radius of less than 10 or 4.5 times the gross plate thickness for special and other members, respectively, supporting data is to be provided. As a minimum, the following additional requirements are to be complied with:

(a) the steel is to be of grade D/DH or higher

(b) the material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{grs}/(2r_{bdg}+t_{grs})$, where t_{grs} is the gross thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5 %, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

(c) 100 % visual inspection of the deformed area is to be carried out. In addition, random checks by magnetic particle testing are to be carried out.

The bending radius is in no case to be less than twice the gross plate thickness.

4.3 Hot Forming

4.3.1 Temperature requirements

4.3.1.1 Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 28°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with **4.3.2.1** these mechanical tests are not required.

4.3.1.2 Confirmation is required to demonstrate the mechanical properties after further heating meet the requirements specified by a procedure test using representative material, when considering further heating other than in **4.3.1.1** of thermo-mechanically controlled steels (TMCP plates) for forming and stress relieving.

4.3.2 Line or spot heating

4.3.2.1 Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature, on the surface, is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

4.4 Welding

4.4.1 General

4.4.1.1 All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables and is to comply with the Rules for Materials of the individual Classification Society.

4.4.2 Welding sequence

4.4.2.1 Consideration is to be given to the assembly sequence and the effect on the overall shrinkage of plate panels, assemblies, etc., resulting from the welding processes employed. Welding is to proceed systematically, with each welded joint being completed in the correct sequence, without undue interruption.

4.4.2.2 Where practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

4.4.2.3 Generally, the welding of stiffener members, including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimize angular distortion of the stiffener.

4.4.3 Arrangements at junctions of welds

4.4.3.1 Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of a size, and in a position, that a satisfactory return weld can be made.

4.4.4 Leak stoppers

4.4.4.1 Where structural members pass through the boundary of a tank, leakage into the adjacent space could be hazardous or undesirable, and full penetration welding is to be adopted for the members for at least 150mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in the member close to the boundary outside of the compartment, and carefully welded all around.

5 Weld Design and Dimensions

5.1 General

5.1.1 Scope

5.1.1.1 In general, weld sizes are based on the Rule gross thickness values.

5.1.1.2 Requirements for welding sequence, qualification of welders, welding procedures and welding consumables are given in **4.4.**

5.1.2 Plans and specifications

5.1.2.1 Plans and/or specifications showing weld sizes and weld details are to be submitted for approval for each new construction project.

5.1.2.2 Where reductions in weld sizes are proposed the requirements given in *5.9*aretobeappliedandthe-followingdetailsaretobeincludedintheweldingspecification:
(a) proposed weld gap size
(b) proposed welding consumable.

5.1.3 Tolerance requirements

5.1.3.1 The gaps between the faying surfaces of members being joined are to be kept to a minimum or in accordance with approved specification.

5.1.3.2 Where the gap between the members joined by fillet welds exceeds 2 mm, the weld size is to be increased in accordance with **5.7.1.6.**

5.1.4 Special precautions

5.1.4.1 Welding is to be based on approved welding procedure specifications where small fillets are used to attach heavy plates or sections. Special precautions, such as the use of preheating, low-hydrogen electrodes or low-hydrogen welding processes, are accepted.

5.1.4.2 When heavy structural members are attached to relatively light plating, the weld size and sequence may require modification.

5.2 Butt Joints

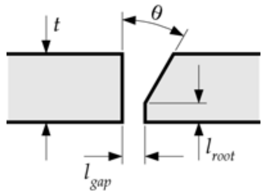
5.2.1 General

5.2.1.1 Joints in the plate components of stiffened panel structures are generally to be joined by butt welds. Typical types of butt welds with corresponding edge preparation are shown in **Fig 6.5.1.**

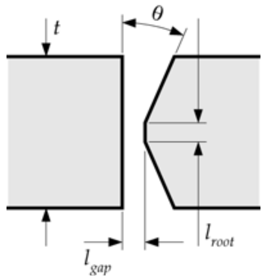
5.2.1.2 All types of butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound weld metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

Fig 6.5.1
Typical Butt Welds

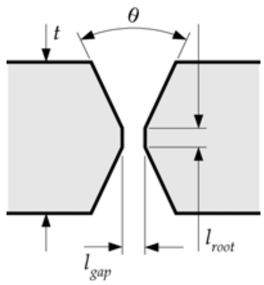
Single bevel butt



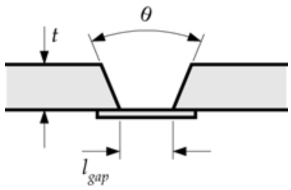
Double bevel butt



Double vee butt, uniform bevels



Single vee butt, one side welding with backing strip (temporary or permanent)



Note
1. The above figures are shown for guidance only. Actual details and dimensions are to be in accordance with a recognised fabrication standard. See **4.1.2.1**

5.2.2 Thickness difference in butt welds

5.2.2.1 Abrupt change of section is to be avoided where plates of different thicknesses are butt welded.

5.2.2.2 Where plates to be joined differ in thickness by more than 4 mm, a suitable transition taper is to be provided. The transition may be formed by tapering the thicker member, or by specifying a weld joint design which provides the required transition.

5.2.2.3 For the transverse butts in longitudinal strength members, the transition taper length is to be not less than three times the offset.

5.2.2.4 Differences in thickness greater than 4mm and without transition taper may be accepted for specific applications.

5.3 Tee or Cross Joints

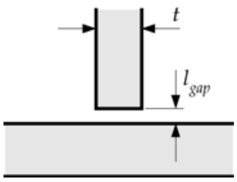
5.3.1 General

5.3.1.1 The connection of primary support members and stiffener web/end connections and joints formed by plating abutting on another plate panel is generally to be made by fillet welds sized in accordance with **5.7** and **Fig 6.5.2.** Examples of other typical tee or cross joint weld arrangements are shown in **Fig 6.5.3.**

5.3.1.2 Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate. See **5.3.4** and **Fig 6.5.3.**

Figure 6.5.2
Typical Tee or Cross Joint Fillet Welds

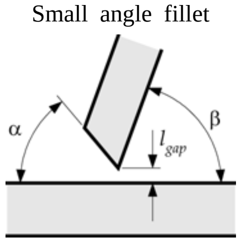
Tee fillet



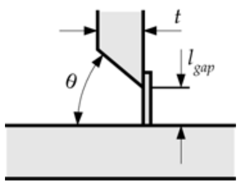
Note
1. The above figure is shown for guidance only. Actual details and dimensions are to be in accordance with a recognised fabrication standard. See **4.1.2.1.**

Figure 6.5.3
Other Typical Tee and Cross Joint Welds

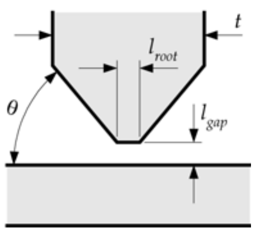
Small angle fillet



Single bevel tee with permanent backing



Double bevel tee symmetrical



Notes
1. The above figures are shown for guidance only. Actual details and dimensions are to be in accordance with a recognised fabrication standard. See **4.1.2.1.**

5.3.2 Continuous welding

5.3.2.1 Continuous welding is to be adopted in the following locations:

(a) all fillet welds where higher strength steel is used

(b) boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings

(c) boundaries of tanks and watertight compartments

(d) all structures in ballast and fresh water tanks and the ballast and fresh water tank bulkhead stiffeners

(e) all structures in the aft peak and the aft peak bulkhead stiffeners

(f) all structures in the fore peak tank/void

(g) all welding inside tanks intended for crude oil, petroleum products, chemicals, edible liquids or fresh water cargoes

(h) welding in way of all end connections, including end brackets, lugs, scallops, and at the orthogonal connections with other members

(i) all lap welds in the main hull

(j) primary support members and stiffener members to bottom shell in the 0.3 L forward region

(k) flat bar longitudinals to plating

(l) the attachment of minor fittings to higher strength steel plating and other connections or attachments.

5.3.3 Intermittent welding

5.3.3.1 Where continuous welding is not required, intermittent welding may be applied.

5.3.3.2 Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

5.3.4 Full or partial penetration corner or tee joints

5.3.4.1 Where high tensile stresses act through an intermediate plate (see **Fig 6.5.4**), increased fillet welds or penetration welds are to be used as required by **5.8.** Examples of such structures are:

(a) connection of hopper to inner hull

(b) longitudinal/transverse bulkhead primary support member end connections to the double bottom

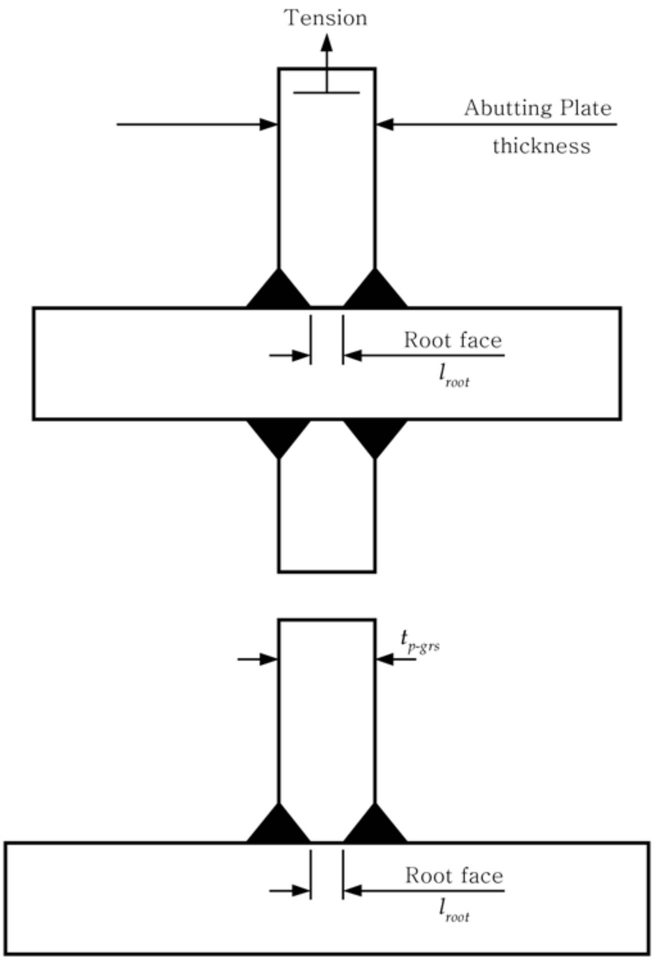
(c) connection of corrugated bulkhead lower stool side plates to shelf plate and inner bottom/hopper tank

(d) connections of gusset plates to corrugated bulkheads

(e) connection of double bottom floors, lower hopper tank webs and double bottom girders below corrugated bulkhead flanges and gusset plates for corrugated bulkheads configured without lower stools

(f) structural elements in double bottoms below bulkhead primary support members and stool plates.

Fig 6.5.4
Abutting Plate Panel



5.3.4.2 Full or partial penetration welds, with maximum root face, $l_{root} = t_{p\text{-}grs}/3$, where l_{root} is the weld root face length and $t_{p\text{-}grs}$ is the gross plate thickness, as shown in **Fig 6.5.4**, are to be used in the connection of hopper sloped plating to inner bottom.

5.3.4.3 Full penetration welds are to be used in the following connections:

(a) lower end of vertical corrugated bulkhead connections

(b) lower end of gusset plates fitted to corrugated bulkheads

(c) rudder horns and shaft brackets to shell structure

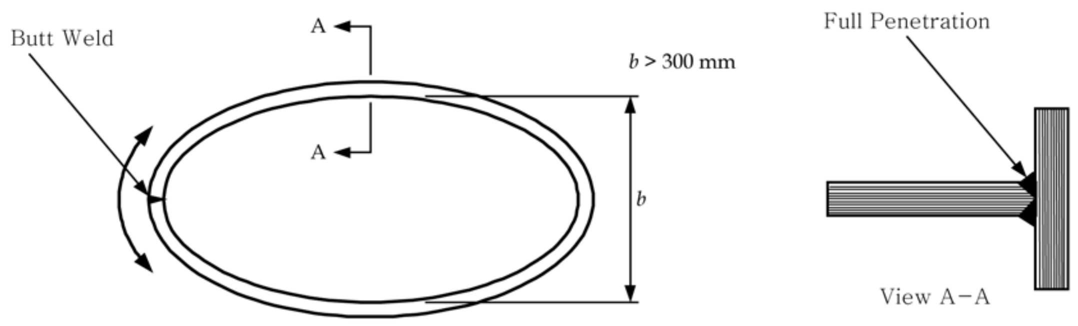
(d) rudder side plating to rudder stock connection areas

(e) edge reinforcements within 0.6 L amidships to the strength deck, sheer strake, bottom and bilge plating, when the transverse dimensions of the opening exceeds 300 mm, see **Fig 6.5.5**. Where collar plates are fitted in way of pipe penetrations, the collar plate is to be welded by a continuous fillet weld.

(f) abutting plate panels with gross plate thickness, $t_{p\text{-}grs}$, as shown in **Fig 6.5.4**, less than or equal to 12 mm, forming outer shell boundaries below the scantling draught, T_{sc}, including, but not limited to; sea chests, rudder trunks, and portions of transoms. For gross plate thickness, $t_{p\text{-}grs}$, greater than 12 mm, partial penetration welding with a maximum root face length $l_{root} = t_{p\text{-}grs}/3$ is acceptable.

(g) crane pedestals and associated bracketing and support structure, as required by **Sec 11/3.1.4.14.**

Fig 6.5.5
Examples of Suitable Edge Reinforcements



5.4 Lapped Joints

5.4.1 General

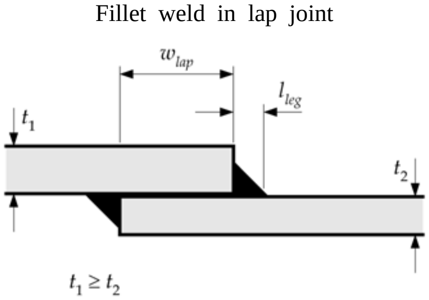
5.4.1.1 Overlaps may be adopted for end connections where the connection is not subject to high tensile or compressive loading.

5.4.1.2 Where overlaps are adopted, the width of the overlap, w_{lap}, is not to be less than three times, but not greater than four times, the gross thickness of the thinner of the plates being joined. See **Fig 6.5.6**. Where the gross thickness of the thinner plate being joined has a thickness of 25 mm or more the overlap will be subject to special consideration.

5.4.1.3 The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the gross thickness of the lug but need not be greater than 50 mm. The joints are to be positioned to allow adequate access for completion of sound welds.

5.4.1.4 The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

Fig 6.5.6
Lapped Joints



5.4.2 Overlapped end connections

5.4.2.1 Lapped end connections, where accepted by the Rules, are to have continuous welds on each edge with leg length, l_{leg}, as shown in **Fig 6.5.6**, such that the sum of the two leg lengths is not less than 1.5 times the gross thickness of the thinner plate.

5.4.3 Overlapped seams

5.4.3.1 Overlapped seams are to have continuous welds on both edges, of the sizes required by **Table 6.5.1** for the boundaries of tank or watertight bulkheads. Seams for plates with a gross thickness of 12.5 mm or less, which are clear of tanks, may have one edge with intermittent welds in accordance with **Table 6.5.1** for watertight bulkhead boundaries.

5.5 Slot Welds

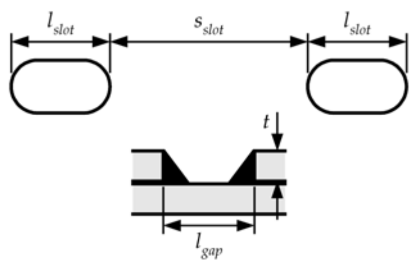
5.5.1 General

5.5.1.1 Slot welds may be specially approved for particular applications. Typical applications are indicated in **5.5.2** and **5.5.3**, and typical arrangements are shown in **Fig 6.5.7.**

5.5.1.2 Slots are to be well-rounded and have a minimum slot length, l_{slot}, of 75 mm and width, w_{slot}, of twice the gross plate thickness. Where used in the body of doublers and similar locations, such welds are in general to be spaced a distance, s_{slot}, of 2 l_{slot} to 3 l_{slot} but not greater than 250 mm.

Fig 6.5.7
Slot Welds

Slot welding



5.5.2 Closing plates

5.5.2.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot fillet welds to face plates fitted to the webs.

5.5.2.2 Slots are to be well rounded and have a minimum slot length, l_{slot}, of 90 mm and a minimum width, w_{slot}, of twice the gross plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance, s_{slot}, not greater than 140 mm. Slots are not to be filled with welding.

5.5.3 (void)

5.5.3.1 (void)

5.6 Stud Welds

5.6.1 General

5.6.1.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs is to be submitted for approval.

5.7 Determination of the Size of Welds

5.7.1 General

5.7.1.1 The following weld sizes are to be rounded to the nearest half millimetre.

5.7.1.2 The leg length, l_{leg}, as shown in **Fig 6.5.8**, of continuous, lapped or intermittent fillet welds, in association with the requirements of **5.7.2** to **5.7.5**, is not to be taken as less than:

(a) $l_{leg} = f_1 t_{p-grs}$

(b) $l_{leg} = f_{yd} f_{weld} f_2 t_{p-grs} + t_{gap}$

(c) l_{leg} as given in **Table 6.5.2**

Where:

f_1 = 0.30 for double continuous welding
= 0.38 for intermittent welding

t_{p-grs} the gross plate thickness, in mm. Is generally to be taken as that of the abutting member (member being attached). See **5.7.1.5**

f_{yd} correction factor taking into account the yield strength of the weld deposit:

$$= \left(\frac{1}{k}\right)^{0.5} \left(\frac{235}{\sigma_{weld}}\right)^{0.75}$$ but is not to be taken as less than 0.707

σ_{weld} minimum yield stress of the weld deposit, and is not to be less than:
305 N/mm² for welding of normal strength steel
375 N/mm² for welding of higher strength steels with yield strength of 265 to 355 N/mm²
400 N/mm² for welding of higher strength steel with yield strength of 390 N/mm²
See **5.9.4** for additional requirements that are to be applied where the weld size is determined based on a weld deposit yield strength that exceeds the specified minimum value

k higher strength steel factor, as defined in **1.1.4**. k is to be based on the material of the abutting member

f_{weld} weld factor depending on the type of structural member, see **5.7.2, 5.7.3** and **5.7.5**

f_2 correction factor for the type of weld:
1.0 for double continuous fillet
$\frac{s_{ctr}}{l_{weld}}$ for intermittent or chain welding

l_{weld} the actual length of weld fillet, clear of crater, in mm

s_{ctr} the distance between successive weld fillets, from centre to centre, in mm

t_{gap} allowance for weld gap (lesser gaps may be permitted, see **5.9.2**):
= 2.0 mm for $t_{p-grs} > 6.5$ mm
$= 2\left(1.25 - \frac{1}{f_2}\right)$ mm for $t_{p-grs} \le 6.5$ mm

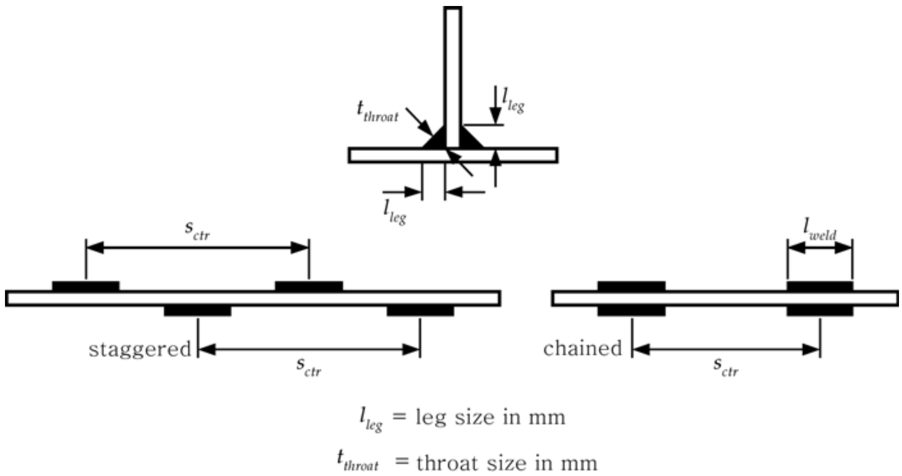
5.7.1.3 The throat size is not to be less than $l_{leg}/\sqrt{2}$, where the leg length, l_{leg}, is as shown in **Fig 6.5.8.**

5.7.1.4 The leg size for matched fillet welds either side of an intersection with intermittent welding is not to be greater than 0.62 t_{p-grs} or 6.5 mm, whichever is the lesser.

5.7.1.5 Where the gross web thickness of the abutting longitudinal stiffener is greater than 15 mm and exceeds the thickness of the table member (e.g. plating), the welding is to be double continuous and the leg length of the weld is to be not less than the greatest of the following:
(a) 0.3 times the gross thickness of the table member. The table member thickness used need not be greater than 30 mm
(b) 0.27 times the gross thickness of the abutting member plus 1.0 mm. The leg size need not be greater than 8.0 mm
(c) as given by **Table 6.5.2** for stiffeners to plating.

5.7.1.6 Where the gap between members being joined exceeds 2 mm and is not greater than 5 mm, the weld leg size is to be increased by the amount of the opening in excess of 2 mm. Where the opening between members is greater than 5 mm, corrective measures are to be taken, in accordance with an approved welding procedure specification.

Fig 6.5.8
Weld Definitions



5.7.2 Welding of fillet joints of main structural components

5.7.2.1 General weld factors for the connections of the structural components of the hull are given in **Table 6.5.1.**

5.7.2.2 Where components of the hull form a part of a double skin primary support member the requirements of **5.7.4** are also to be applied.

5.7.2.3 Where high tensile stresses act through an intermediate plate (see **Fig 6.5.4**), increased fillet welds or penetration welds are to be used as required by **5.8.**

5.7.3 Welding of primary support members

5.7.3.1 Weld factors for the connections of the web plating of primary support members are given in **Table 6.5.4.**

5.7.3.2 Where the minimum weld size is determined by the requirements of **5.7.1.2(b)** the weld connections to shell, decks or bulkheads are to take account of the material lost in the cut out where stiffeners pass through the member. In cases where the web plating and the width of the notch exceeds 15 percent of the stiffener spacing, the size of the weld leg length is to be multiplied by:

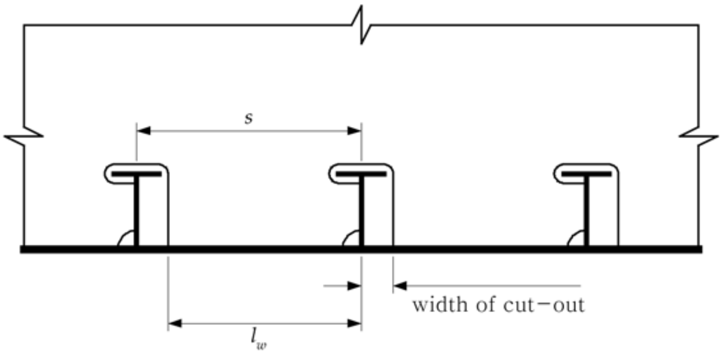
$$\frac{0.85s}{l_w}$$

Where:

s stiffener spacing, in mm

l_w length of web plating between notches, in mm, see **Fig 6.5.9**

Fig 6.5.9
Lost Material in Web Cut-outs for Stiffeners



5.7.4 Welding of end connections of primary support members

5.7.4.1 Welding of end connections of primary support members (i.e. transverse frames and girders) is to be such that the weld area, A_{weld}, is to be equivalent to the Rule gross cross-sectional area of the member. In terms of weld leg length, l_{leg}, this is to be taken as by:

$$l_{leg} = 1.41 f_{yd} \frac{h_w t_{p-grs}}{l_{dep}} \quad \text{mm}$$

Where:

h_w web height of primary support member, in mm, see **Fig 6.5.10**

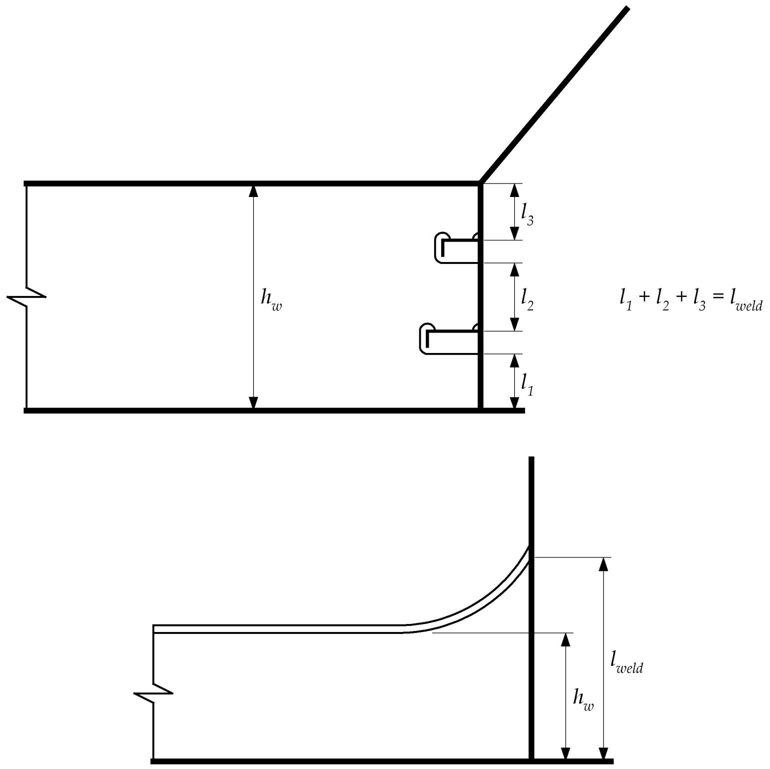
t_{p-grs} rule gross thickness of the primary support member, in mm

l_{dep} total length of deposit of weld metal, in mm. Generally this can be taken as twice l_{weld} shown in **Fig 6.5.10** for a double continuous fillet weld

f_{yd} correction factor taking into account the yield strength of the weld deposit, as defined in **5.7.1.2**

In no case is the size of weld to be less than that calculated in accordance with **5.7.1.2**, using a minimum weld factor, f_{weld}, of 0.48 in tanks or 0.38 elsewhere.

Fig 6.5.10
End Connection of Primary Support Members



Note
1. The length l_{weld} is the length of the welded connection. The total length of the weld deposit l_{dep} is, for double continuous fillet welds, twice the length of the welded connection l_{weld}

5.7.5 Welding at the ends of stiffeners

5.7.5.1 Welding of longitudinals to plating is to be double continuous at the ends of the longitudinals. In way of transverses the length of the double continuous weld is to be equal the depth of the longitudinal, or the depth of the end bracket, whichever is greater.

5.7.5.2 For deck longitudinals, a matched pair of welds is required at the intersection of longitudinals with transverses.

5.7.5.3 The welding of stiffener (i.e. longitudinals, beams and bulkhead stiffeners) end connections is to be not less than as required by **Table 6.5.5.** Where two requirements are given, the greater is to be complied with. The area of weld, A_{weld}, indicated in **Table 6.5.5**, is to be applied to each arm of the bracket or lapped connection.

5.7.5.4 Where a longitudinal strength member is cut at a primary support structure and the continuity of strength is provided by brackets, the weld area, A_{weld}, based on the effective throat times the length of the weld, is to be not less than the gross cross-sectional area of the member. If the longitudinal strength member is of high strength steel, the weld area, A_{weld}, is to be multiplied by f_{yd},, the correction factor taking into account the yield strength of the weld deposit as defined in **5.7.1.2.**

5.7.5.5 Where the stiffener member passes through, and is supported by the web of a primary support member, the weld connection is to be in accordance with the requirements of **Sec 4/3.4.3.11.**

5.7.5.6 Where intermittent welding is permitted, unbracketed stiffeners of shell, watertight and oil-tight bulkheads, and house fronts are to have double continuous welds for one-tenth of their length at each end. Unbracketed stiffeners of non-tight structural bulkheads, deck house sides and aft ends are to have a pair of matched intermittent welds at each end.

5.8 Weld for Structures Subject to High Tensile Stresses

5.8.1 Minimum leg size

5.8.1.1 Where high tensile stresses act through an intermediate plate, see **Fig 6.5.11**, the minimum leg length, l_{leg}, of double continuous welds is to be taken as:

$$l_{leg} = 1.92\left(\frac{235}{\sigma_{weld}}\right)^{0.75}\left[0.2 + \left(\frac{\sigma}{270} - 0.25\right)\frac{l_{root}}{t_{p-grs}}\right]t_{p-grs} + 2.0 \quad \text{mm}$$

Where:

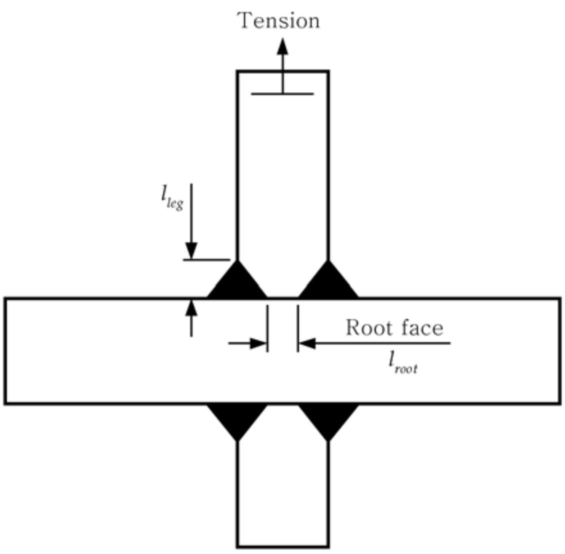
σ maximum tensile stress in plate being attached, in N/mm^2

l_{root} root face length, in mm

t_{p-grs} gross thickness of plate being attached, in mm

σ_{weld} as defined in **5.7.1.2**, where σ_{weld} is limited to the maximum value permitted by the limits imposed on correction factor taking into account the yield strength of the weld deposit, f_{yd}, as defined in **5.7.1.2**

Fig 6.5.11
Welds Subject To High Tensile Stresses



5.9 Reduced Weld Size

5.9.1 General

5.9.1.1 Reduction in fillet weld sizes that are required by **5.7** may be specially approved in accordance with either **5.9.2, 5.9.3** or **5.9.4.**

5.9.1.2 Where any of the methods for reduction of the weld size are adopted, the specific requirements giving justification for the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld leg length and the required weld leg length given by **5.7** without the permitted leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

5.9.2 Controlled gaps

5.9.2.1 Where quality control facilitates working to a gap between members of 1mm or less, a reduction in fillet weld leg size of 0.5 mm is permitted.

5.9.3 Deep penetration welding

5.9.3.1 Where an approved automatic deep penetration procedure is used and quality control facilitates are working to a gap between members of 1mm or less, the weld factors given in **Tables 6.5.1, 6.5.2(c)** and **(d), 6.5.4** and **6.5.5** may be reduced by 15 percent. Reductions of up to 20 percent, but not more than the fillet weld leg size of 1.5 mm, will be accepted provided that the Shipyard is able to consistently meet the following requirements:

(a) the welding is performed to a suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps

(b) the penetration at the root is at least the same amount as the reduction into the members being attached

(c) demonstrate that an established quality control system is in place.

5.9.4 Controlled welding consumables

5.9.4.1 Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than the minimums specified in **5.7.1.2** and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

5.10 End Connections of Pillars and Cross Ties

5.10.1 Effective weld area

5.10.1.1 The end connections of pillars and cross ties are to have an effective fillet weld area (weld throat multiplied by weld length) not less than:

$$A_{weld} = f_3 \left(\frac{235}{\sigma_{weld}} \right)^{0.75} A_{grs} P \qquad \text{cm}^2$$

Where:

A_{grs} gross cross-sectional area, for the pillar or cross tie, in m^2

P design pressure load, for the structure under consideration, in kN/m^2

σ_{weld} minimum yield stress of the deposit, as given in **5.7.1.2**, where σ_{weld} is limited to the maximum value permitted by the limits imposed on f_{yd} in **5.7.1.2**

f_3 = 0.05 when pillar or cross tie is in compression only

= 0.14 when pillar or cross tie is in tension

5.11 Alternatives

5.11.1 General

5.11.1.1 The foregoing are considered minimum requirements for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

5.11.1.2 The leg length limits given in **Table 6.5.2** are to be complied with in all cases.

Table 6.5.1
Weld Factors

Items	Weld Factor f_{weld}	Remarks
(1) General application		except as required by items 2-11
Watertight boundaries	0.43	
Non-tight plate boundaries	0.18	
Strength deck plating to shell	see **Table 6.5.3**	
Other decks to shell and bulkheads (except where forming tank boundaries)	0.30	generally continuous
Stiffeners to plating (clear of end connections)	0.13	in dry spaces
	0.18	in tanks
Stiffeners to plating for 0.1 span at ends	0.21	or extent of end bracket if greater
Panel stiffeners	0.13	
Overlapped welds generally	0.36	
Longitudinals, with gross web thickness greater than 15 mm, to plating	see **5.7.1.5**	t_{p-grs} defined in **5.7.1.5**
(2) Bottom construction in cargo tank region		(1)
Non-tight centre girder: to keel	0.30	
to inner bottom	0.28	no scallops
Non-tight boundaries of floors and girders	0.15	mid half span
	0.24	end quarters span
Floors and girder to inner bottom in way of:		
vertical primary supporting members	0.43	(1)
Connection between floors and girders	0.36	(1)
End connection of floors and girders	0.43	(1)
Docking brackets	0.30	
(3) Side construction in cargo tank region		including bilge hopper tanks, (1)
Vertical webs to inner hull bulkhead		
in way of deck transverse/bracket	0.43	
in way of cross tie, as applicable	0.36	
Elsewhere	0.24	
Vertical webs to shell	0.24	
Vertical webs end connection	0.43	(1)
(4) Cargo tank bulkhead construction		including pump room and cofferdam, (1)
Longitudinal and transverse oil-tight bulkhead boundaries:		
to deck, inner bottom and bottom shell	0.51	
at sides	0.43	
Vertical corrugation		
at upper end	0.51	
at lower end	see **5.3.4**	
Non-tight bulkhead boundaries	0.24	
Primary support members	see **Table 6.5.4**	
Connection between primary support members	0.49	

Table 6.5.1 (Continued)
Weld Factors

Items	Weld Factor f_{weld}	Remarks
(5) Structures in machinery space		
Centre girder to keel and inner bottom	0.36	
Floors to centre girder in way of:		
Engines	0.36	
thrust and boiler bearers	0.36	
Floors to main engine foundation girders Floors/girders to shell and inner bottom Main engine foundation girders to top plate and primary hull structure	0.36 0.24 Partial penetration	 edge to be prepared with maximum root 0.33 t_{p-grs} deep penetration
Foundation:		
auxiliary diesels (> 350kw)	0.40	
boiler and other auxiliaries	0.35	
Brackets supporting engine foundation	0.21	
(6) Construction in 0.25 L forward		
In way of flat of bottom:		
floors to shell and inner bottom	0.18	
girders to shell and inner bottom	0.28	
Bottom longitudinals to shell:		
flat of bottom forward	0.30	
Elsewhere	0.18	
side shell stringers to shell	0.24	
Fore peak construction:		
internal structures	0.18	
(7) Aft peak construction		
Internal structure:		
below water line	0.30	
above waterline	0.18	
(8) Superstructures and deck houses		
Connection of external bulkhead to deck		
first and second tier erections	0.28	
Elsewhere	0.15	
Internal bulkheads	0.12	

Table 6.5.1 (Continued)
Weld Factors

Items	Weld Factor f_{weld}	Remarks
(9) Closing Arrangements		
Hatch coaming to deck	0.43	
Cleats and fittings	0.60	minimum weld factor. Where $t_{p-grs} > 11.5$ mm, l_{leg} need not exceed 0.62 t_{p-grs}. Penetration welding may be required depending on design
Hatch covers:		
oil-tight joints	0.46	
watertight joints:		
Outside	0.46	
Inside	0.18	
Hatch covers:		
at end of stiffener (unbracketed)	0.38	(2)
at end of stiffener (bracketed)	0.38	
Elsewhere	0.12	
(10) Deck Equipment		(3)
Masts, derrick posts, crane pedestals, etc., to deck	0.43	
Deck machinery seats to deck	0.20	
Mooring equipment seats	0.43	
(11) Miscellaneous fittings and equipment		
Rings for access hole type covers to ship	0.43	
Frames of shell and weathertight doors	0.43	
Stiffening of shell and weathertight doors	0.24	
Ventilators, air pipes, etc., coaming to deck	0.43	
Ventilators, etc., fittings	0.24	
Scuppers and discharge to deck	0.55	
Bulwark stays to deck	0.24	
Bulwark attachment to deck	0.43	
Guard rails, stanchions, etc., to deck	0.43	
Bilge keel ground bars to shell	see **Table 11.3.1**	
Bilge keels to ground bars	see **Table 11.3.1**	
Fabricated anchors	full penetration	

Note
1. The weld size is to be increased for areas with high tensile stress, see **5.8.**
2. Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length, at the ends, equal to the end depth of the member.
3. Weld factors are minimum values.

Table 6.5.2
Leg Size

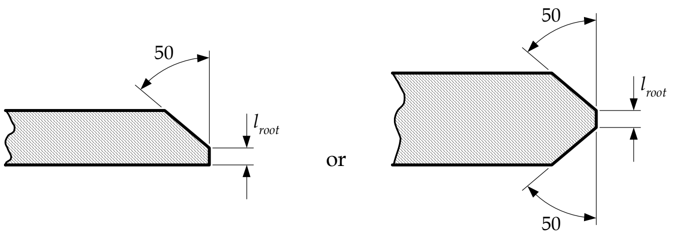
Item	Minimum Leg Size[1], mm
(a) Gross plate thickness t_{p-grs} < 6.5 mm[5]	
Hand or automatic welding	4.0
Automatic deep penetration welding	4.0
(b) Gross plate thickness t_{p-grs} > 6.5 mm[5]	
Hand or automatic welding	4.5
Automatic deep penetration welding	4.0
(c) Welds within 3m below top of ballast and cargo tanks[2][4]	6.5
(d) All welds in cargo tank region, except in (c)[4]	6.0

Note
1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.
2. Only applicable to cargo and ballast tanks with weather deck as the tank top.
3. See **5.9** for provisions to reduce minimum leg size.
4. A reduction to 5.5 mm leg size for the secondary structural elements such as carling, buckling stiffeners and tripping brackets may be applied without additional gap control.
5. For superstructure and deck houses, the minimum leg length may be taken as 3.5 mm.

Table 6.5.3
Weld Connection of Strength Deck Plating to Sheer Strake

Stringer gross plate thickness, in mm	Weld type
t_{p-grs} < 15	Double continuous fillet weld with a leg size of 0.60 t_{p-grs} + 2.0 mm
15 < t_{p-grs} < 20	Single vee preparation to provide included angle of 50° with root face length l_{root} < $t_{p-grs}/3$ in conjunction with a continuous fillet weld with a weld factor of 0.35 or Double vee preparation to provide included angle of 50° with root face length l_{root} < $t_{p-grs}/3$
t_{p-grs} > 20	Double vee preparation to provide included angle of 50° with root face length l_{root} < $t_{p-grs}/3$, but not to be greater than 10 mm

Where t_{p-grs} = gross thickness of stringer plate, in mm



single vee preparation double vee preparation

Note
1. Welding procedure, including joint preparation, is to be specified and approved for individual builders.
2. Where structural members pass through the boundary of a tank a leak stopper is to be arranged in accordance with **4.4.4.**
3. Alternative connections will be specially considered.

Table 6.5.4
Connection of Primary Support Members

Primary Support Member gross face area, in cm^2		Position(1)	Weld factor, f_{weld}			
			In tanks		In dry spaces	
Greater than	Not greater than		To face plate	To plating	To face plate	To plating
	30.0	At ends	0.20	0.26	0.20	0.20
		Remainder	0.12	0.20	0.12	0.15
30.0	65.0	At ends	0.20	0.38	0.20	0.20
		Remainder	0.12	0.26	0.12	0.15
65.0	95.0	At ends	0.42	0.59(3)	0.20	0.30
		Remainder	0.30(2)	0.42	0.15	0.20
95.0	130.0	At ends	0.42	0.59(3)	0.30	0.42
		Remainder	0.30(2)	0.42	0.20	0.30
130.0		At ends	0.59(3)	0.59(3)	0.42	0.59(3)
		Remainder	0.42	0.42	0.30	0.42

Note
1. The weld factors 'at ends' are to be applied for 0.2 times the overall length of the member from each end, but at least beyond the toe of the member end brackets. On vertical webs, the increased welding may be omitted at the top, but is to extend at least 0.3 times overall length from the bottom.
2. Weld factor 0.38 to be used for cargo tanks.
3. Where the web plate thickness is increased locally to meet shear stress requirements, the weld size may be based on the gross web thickness clear of the increased area, but is to be not less than weld factor of 0.42 based on the increased gross thickness.
4. In regions of high stress, see **5.3.4, 5.7.4** and **5.8.**

Table 6.5.5
Stiffener End Connection Welds

Connection	Weld area, A_{weld}, in cm^2	Weld Factor, f_{weld}(1)
(1) Stiffener welded direct to plating	$0.25\,A_{stf-grs}$ or $6.5\ cm^2$ whichever is the greater	0.38
(2) Bracketless connection of stiffeners, stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1.2\sqrt{Z_{grs}}$	0.26
(b) in tank	$1.4\sqrt{Z_{grs}}$	0.38
(c) main frame to tank side bracket in $0.15\,L$ forward	as (a) or (b)	0.38
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0.38

Where:

$A_{stf-grs}$ gross cross sectional area of the stiffener, in cm^2

A_{weld} weld area, in cm^2, and is calculated as total length of weld, in cm, times throat thickness, in cm (Where the gap exceeds 2 mm the weld size is to be increased. See **5.7.1.6**)

Z_{grs} the gross section modulus required, in cm^3, of the stiffener on which the scantlings of the bracket are based

Note
1. For minimum weld fillet sizes, see **Table 6.5.2.**

Section 7

Loads

1 Introduction

1.1 General

1.1.1 Application

1.1.1.1 This section provides in detail the loads and load combinations for the scantling calculations. The loads cover load scenarios in harbour and at sea, see **Sec 2/5.4**, dividing the loads into static load components, dynamic load components, sloshing loads and impact loads.

1.2 Definitions

1.2.1 Coordinate system

1.2.1.1 The applied coordinate system *x, y, z* is as defined in **Sec 4/1.4.1.1.**

1.2.1.2 The direction of the incident waves are specified by the angle b between the *x*-axis and the propagating wave direction as shown in **Fig 7.1.1**. Examples given:

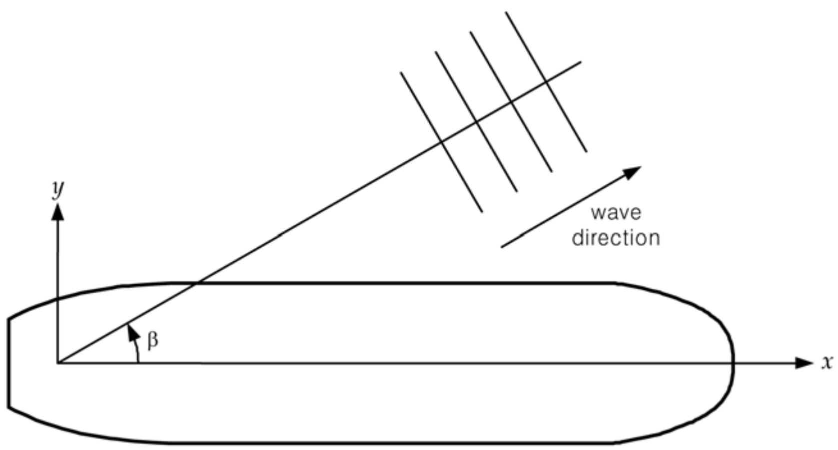
(a) head sea is waves propagating in the negative *x*-direction,

(b) beam sea is waves propagating in the positive or negative *y*-direction,

(c) oblique sea is waves propagating in a direction between head and beam sea (or following and beam sea), and

(d) following sea is waves propagating in positive *x*-direction.

Fig 7.1.1
Definition of Wave Heading



1.2.2 Sign conventions

1.2.2.1 Positive motions, as shown in **Fig 7.1.2**, are defined as:

(a) positive surge is translation along positive *x*-axis (forward)

(b) positive sway is translation along positive *y*-axis (towards port side of vessel)

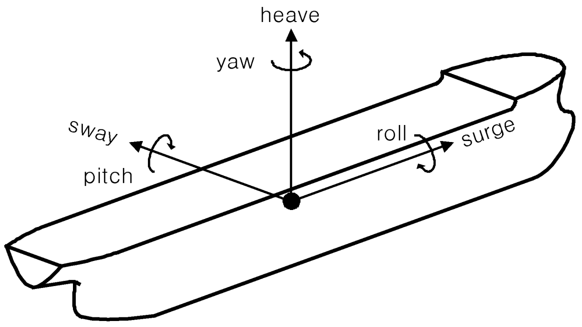
(c) positive heave is translation along positive *z*-axis (upwards)

(d) positive roll is starboard down and port side up

(e) positive pitch is bow down and stern up

(f) positive yaw is bow rotating towards portside of vessel and stern towards starboard side.

Fig 7.1.2
Definition of Positive Motions

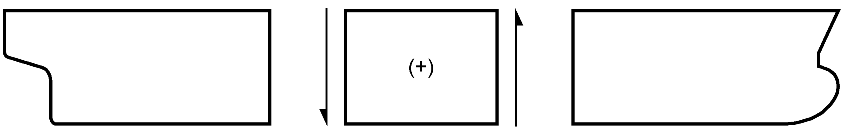


Note
1. This figure shows the rotation axis and not the coordinate system.

1.2.2.2 Positive accelerations are defined as:
(a) positive longitudinal acceleration is acceleration along positive *x*-axis (forward)
(b) positive transverse acceleration is acceleration along positive *y*-axis (towards portside of vessel)
(c) positive vertical acceleration is acceleration along positive *z*-axis (upwards).

1.2.2.3 The sign convention of positive vertical hull girder shear force is shown in **Fig 7.1.3.**

Fig 7.1.3
Positive Vertical Shear Force



1.2.2.4 The sign conventions of positive hull girder bending moments are shown in **Fig 7.1.4** and **7.1.5**, and are defined as:
(a) positive vertical bending moment is a hogging moment and negative vertical bending moment is a sagging moment
(b) positive horizontal bending moment is tension on the starboard side and compression on the port side.

Fig 7.1.4
Positive Vertical Bending Moment

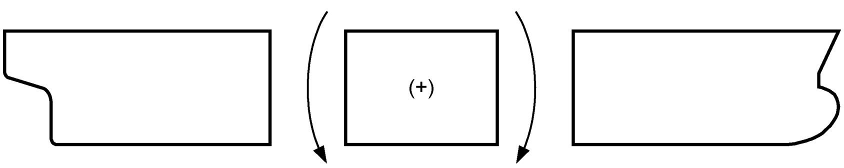
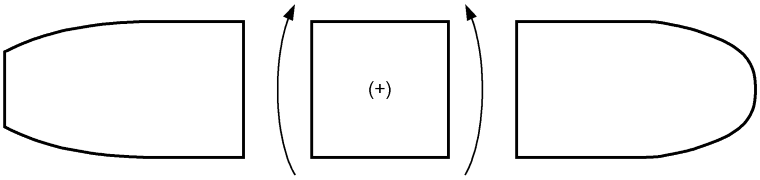


Fig 7.1.5
Positive Horizontal Bending Moment



2 Static Load Components

2.1 Static Hull Girder Loads

2.1.1 Permissible hull girder still water bending moment

2.1.1.1 The designer is to provide the permissible hull girder hogging and sagging still water bending moment limits for seagoing, $M_{sw\text{-}perm\text{-}sea}$, and harbour/sheltered water operations, $M_{sw\text{-}perm\text{-}harb}$.

2.1.1.2 The permissible hull girder hogging and sagging still water bending moment limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks, at the collision bulkhead, at the engine room forward bulkhead and at the midpoint between the fwd and aft engine room bulkhead.

2.1.1.3 The permissible hull girder hogging and sagging still water bending moment envelope is given by linear interpolation between values at the longitudinal positions given in **2.1.1.2.**

2.1.1.4 The permissible hull girder hogging and sagging still water bending moment envelopes are to be included in the loading manual as required in **Sec 8/1.1.2.**

2.1.1.5 The permissible hull girder hogging and sagging still water bending moment envelopes for seagoing operations, $M_{sw\text{-}perm\text{-}sea}$, are to envelop the minimum hull girder hogging and sagging still water bending moments given in **2.1.2.1** and **2.1.2.2** and the most severe hogging and sagging hull girder still water bending moments calculated for any seagoing loading condition given in the loading manual. The requirements for the loading conditions are given in **Sec 8/1.1.2.**

2.1.1.6 The permissible hull girder hogging and sagging still water bending moment envelopes for harbour/sheltered water operation, $M_{sw\text{-}perm\text{-}harb}$, are to envelop the minimum hull girder hogging and sagging still water bending moments given in **2.1.2.3** and the most severe hogging and sagging hull girder still water bending moments calculated for any harbour/sheltered water loading condition given in the loading manual and are not to be less than the permissible envelopes for seagoing operation, $M_{sw\text{-}perm\text{-}sea}$.

Guidance note:
It is recommended that, for initial design, the permissible hull girder hogging and sagging still water bending moment envelopes are at least 5% above the hull girder still water bending moment envelope from the loading conditions in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.2 Minimum hull girder still water bending moment

2.1.2.1 The minimum hull girder hogging and sagging still water bending moment for seagoing operations, $M_{sw\text{-}min\text{-}sea\text{-}mid}$, at amidships is to betaken as:
for hogging:

$$M_{sw-min-sea-mid} = f_{sea}\,(Z_{v-\min}\,\sigma_{perm-sea}\,10^3 - M_{wv-hog}) \quad \text{kNm}$$

which is identical to

$$M_{sw-min-sea-mid} = 0.01\,C_{wv}\,L^2\,B(11.97 - 1.9C_b) \quad \text{kNm}$$

for sagging:

$$M_{sw-min-sea-mid} = f_{sea}\,(Z_{v-\min}\,\sigma_{perm-sea}\,10^3 + M_{wv-sag}) \quad \text{kNm}$$

which is identical to

$$M_{sw-min-sea-mid} = -0.05185\,C_{wv}\,L^2\,B(C_b + 0.7) \quad \text{kNm}$$

Where:

f_{sea} -0.85 for sagging
1.0 for hogging

$Z_{v\text{-}min}$ rule minimum hull girder section modulus as given in **Sec 8/1.2.2.2**, in m^3

$\sigma_{perm\text{-}sea}$ allowable seagoing hull girder bending stress at midships, as defined in **Sec 8/1.2.3.2**, in N/mm^2

$M_{wv\text{-}hog}$ envelope values of hogging vertical wave bending moment at midships as defined in **3.4.1.1**, in kNm

$M_{wv\text{-}sag}$ envelope values of sagging vertical wave bending moment at midships as defined in **3.4.1.1**, in kNm

C_{wv} wave coefficient, as defined in **3.4.1.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**, in m

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

2.1.2.2 The minimum hull girder hogging and sagging still water bending moment for seagoing operations, $Ms_{w\text{-}min\text{-}sea}$, at any longitudinal position is to be taken as:

$$M_{sw-min-sea} = f_{sw} M_{sw-min-sea-mid} \quad \text{kNm}$$

Where:

f_{sw} 1.0 within $0.4L$ amidships

0.15 at $0.1L$ from A.P. or F.P.

0 at A.P. and F.P.

intermediate f_{sw} values are to be obtained by linear interpolation, see **Fig 7.2.1**

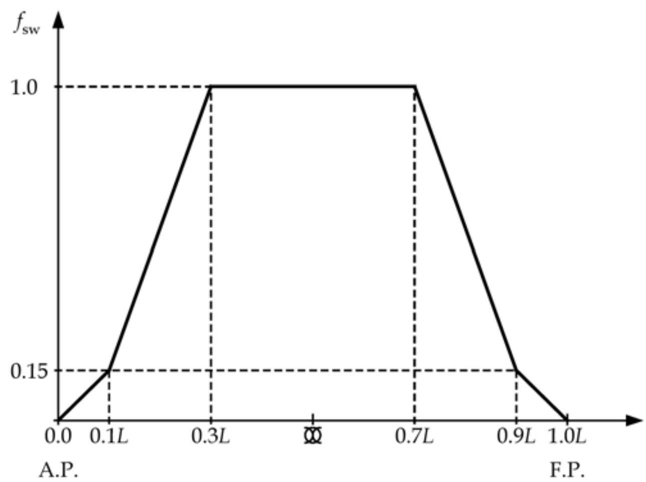
2.1.2.3 The minimum hull girder hogging and sagging still water bending moment for harbour/sheltered water operations, $M_{sw\text{-}min\text{-}harb}$, at any longitudinal position is to be taken as:

$$M_{sw-min-harb} = 1.25 M_{sw-min-sea} \quad \text{kNm}$$

Where:

$M_{sw\text{-}min\text{-}sea}$ corresponding minimum hull girder hogging and sagging still water bending moment for seagoing operation at the section under consideration, see **2.1.2.1** and **2.1.2.2**

Fig 7.2.1
Still Water Bending Moment Distribution



2.1.3 Still water shear force

2.1.3.1 The designer is to provide the permissible hull girder positive and negative still water shear force limits for seagoing, $Q_{sw\text{-}perm\text{-}sea}$, and harbour/sheltered water operations, $Q_{sw\text{-}perm\text{-}harb}$.

2.1.3.2 The permissible hull girder positive and negative still water shear force limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks, at the collision bulkhead and at the engine room forward bulkhead.

2.1.3.3 The permissible hull girder positive and negative still water shear force envelope is given by linear interpolation between values at the longitudinal positions given in **2.1.3.2.**

2.1.3.4 The permissible hull girder positive and negative still water shear force envelopes are to be included in the loading manual as required in **Sec 8/1.1.2.**

2.1.3.5 The permissible hull girder positive and negative still water shear force envelopes for seagoing operation, $Q_{sw\text{-}perm\text{-}sea}$, are to envelope the minimum hull girder positive and negative still water shear forces given in **2.1.4.1, 2.1.4.2** and the most severe positive and negative hull girder still water shear forces for any seagoing loading condition given in the loading manual. The requirements for the loading conditions are given in **Sec 8/1.1.2.**

2.1.3.6 The permissible hull girder positive and negative still water shear force envelopes for harbour operation, $Q_{sw\text{-}perm\text{-}harb}$, are to envelop the minimum hull girder positive and negative still water shear forces given in **2.1.4.3, 2.1.4.4** and the most severe positive and negative hull girder still water shear forces for any harbour/sheltered water loading condition given in the loading manual and are not to be less than the permissible envelopes for seagoing operation, $Q_{sw\text{-}perm\text{-}sea}$.

Guidance note:
It is recommended that, for initial design, the permissible hull girder still water shear force envelopes are at least 10 % above the hull girder shear force envelope from the loading conditions in the loading manual, to account for growth and design margins during the design and construction phase of the ship.

2.1.4 Minimum hull girder still water shear force

2.1.4.1 For ships with two longitudinal bulkheads, the minimum hull girder positive and negative still water shear force for seagoing operation, $Q_{sw\text{-}min\text{-}sea}$, in way of transverse bulkheads between centre cargo tanks, is to be taken as:

$$Q_{sw-min-sea} = \pm \max \begin{cases} 0.225 \rho g B_{local} l_{tk} T_{sc} \\ 0.5 \rho g \left[0.98 (V_{CT} + 2V_{ST}) - 0.7 B_{local} l_{tk} T_{sc} \right] \end{cases} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw\text{-}min\text{-}sea}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

B_{local} local breadth at T_{sc} at the middle length of the tank under consideration, in m

l_{tk} length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

V_{CT} volume of centre cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3

V_{ST} volume of side cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3

2.1.4.2 For ships with centreline longitudinal bulkhead, the minimum hull girder positive and negative still water shear force for seagoing operation, $Q_{sw\text{-}min\text{-}sea}$, in way of transverse bulkheads between cargo tanks is to be taken as:

$$Q_{sw-min-sea} = \pm 0.4 \rho g B_{local} l_{tk} T_{sc} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw\text{-}min\text{-}sea}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

B_{local} local breadth at T_{sc} at the middle length of the tank under consideration, in m

l_{tk} length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

2.1.4.3 For ships with two longitudinal bulkheads, the minimum hull girder positive and negative still water shear force for harbour/sheltered water operation, $Q_{sw\text{-}min\text{-}harb}$, in way of transverse bulkheads between centre cargo tanks, is to be taken as:

$$Q_{sw-min-harb} = \pm \max \begin{cases} 0.275\rho g B_{local} l_{tk} T_{sc} \\ 0.5\rho g \left[0.98(V_{CT} + 2V_{ST}) - 0.6 B_{local} l_{tk} T_{sc}\right] \end{cases} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw\text{-}min\text{-}harb}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

B_{local} local breadth at T_{sc} at the middle length of the tank under consideration, in m

l_{tk} length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

V_{CT} volume of centre cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3

V_{ST} volume of side cargo tank, taken for the cargo tank on the forward or aft side of the transverse bulkhead under consideration, in m^3

2.1.4.4 For ships with centreline longitudinal bulkhead, the minimum hull girder positive and negative still water shear force for harbour/sheltered water operation, $Q_{sw\text{-}min\text{-}harb}$, in way of transverse bulkheads between cargo tanks, is to be taken as:

$$Q_{sw-min-harb} = \pm\, 0.45\rho g B_{local} l_{tk} T_{sc} \quad \text{kN}$$

and taken as the maximum value of $Q_{sw\text{-}min\text{-}harb}$ calculated for cargo/ballast tanks forward and aft of the transverse bulkhead

Where:

ρ density of cargo/sea water, not to be taken less than 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

B_{local} local breadth at T_{sc} at the middle length of the tank under consideration, in m

l_{tk} length of cargo tank under consideration, taken at the forward or aft side of the transverse bulkhead under consideration, in m

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

2.2 Local Static Loads

2.2.1 General

2.2.1.1 The following static loads are considered:

(a) static sea pressure
(b) static tank pressure
(c) tank overpressure
(d) static deck load

2.2.2 Static sea pressure

2.2.2.1 The static sea pressure, P_{hys}, is to be taken as:

$$P_{hys} = \rho_{sw} g (T_{LC} - z) \quad \text{kN/m}^2$$

Where:

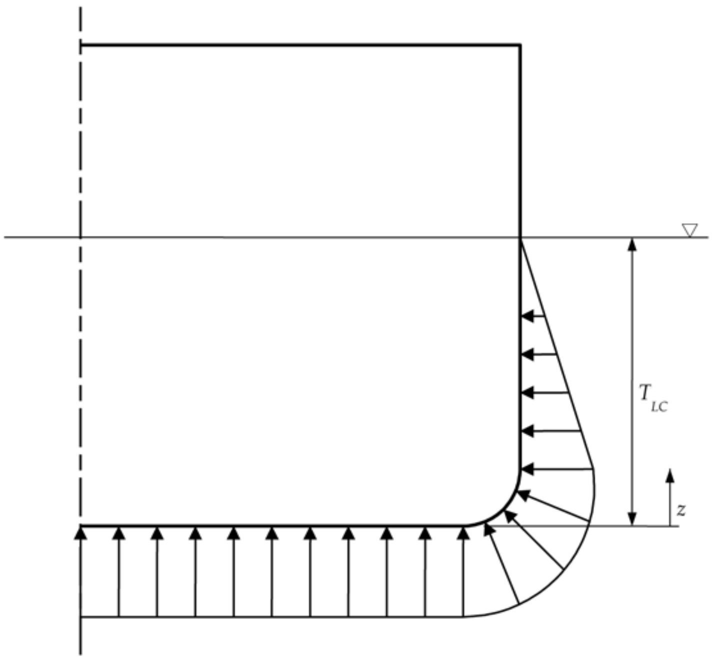
z vertical coordinate of load point, in m, and is not to be greater than T_{LC}, see **Fig 7.2.2**

ρ_{sw} density of sea water, 1.025 tonnes/m^3

T_{LC} draught in the loading condition being considered, in m

g acceleration due to gravity, 9.81 m/s^2

Fig 7.2.2
Static Sea Pressure



2.2.3 Static tank pressure

2.2.3.1 The static tank pressure, P_{in-tk}, is to be taken as:

$$P_{in-tk} = \rho g z_{tk} \quad \text{kN/m}^2$$

Where:

z_{tk} vertical distance from highest point of tank, excluding small hatchways, to the load point, see **Fig 7.2.3**, in m

ρ density of liquid in the tank, is not to be taken as less than
0.9 for liquid cargo for fatigue strength
1.025 otherwise
see **Sec 2/3.1.8**, in tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

2.2.3.2 The static tank pressure, $P_{in\text{-}air}$, in the case of overfilling or filling during flow through ballast water exchange, is to be taken as:

$$P_{in-air} = \rho_{sw} g z_{air} \quad kN/m^2$$

Where:

z_{air} vertical distance from top of air pipe or overflow pipe to the load point, whichever is the lesser, see **Fig 7.2.3**, in m

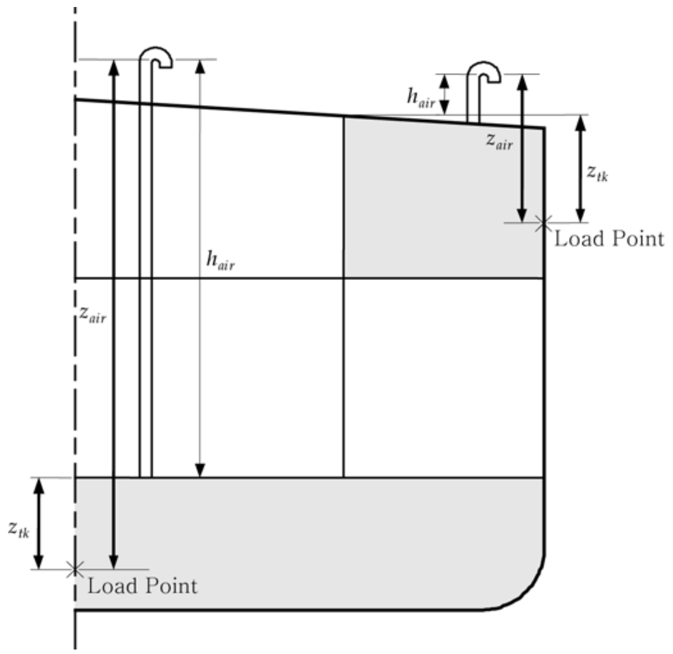
$= z_{tk} + h_{air}$

ρ_{sw} density of sea water, 1.025 $tonnes/m^3$

g acceleration due to gravity, 9.81 m/s^2

h_{air} height of air pipe or overflow pipe, in m, is not to be taken less than 0.76 m above highest point of tank, excluding small hatchways. For tanks with tank top below the weather deck the height of air-pipe or overflow pipe is not to be taken less than 0.76 m above deck at side unless a lesser height is approved by the flag Administration. See also **Fig 7.2.3.**

Fig 7.2.3
Pressure-Heads and Distances used for Calculation of Static Tank Pressure



2.2.3.3 The added overpressure due to sustained liquid flow through air pipe or overflow pipe in the case of overfilling or filling during flow through ballast water exchange, P_{drop}, is to be taken as 25 kN/m^2. Additional calculations may be required where piping arrangements may lead to a higher pressure drop, for example long pipes or arrangements such as bends and valves.

2.2.3.4 The pressure, $P_{in\text{-}flood}$, in compartments and tanks in a flooded or damaged condition is to be taken as:

$$P_{in-flood} = \rho_{sw} g z_{flood} \quad kN/m^2$$

Where:

z_{flood} vertical distance from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations or to freeboard deck if the damage waterline is not given, in m

ρ_{sw} density of sea water, 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

2.2.3.5 The tank testing pressure, $P_{in\text{-}test}$, is to be taken as the greater of the following, see also the testing requirements in **Table 11.5.1**:

$$P_{in-test} = \rho_{sw} g z_{test} \quad \text{kN/m}^2$$

$$P_{in-test} = \rho_{sw} g z_{tk} + P_{valve} \quad \text{kN/m}^2$$

Where:

z_{test} vertical distance to the load point, is to be taken as the greater of the following, in m:

(a) top of overflow

(b) 2.4 m above top of tank

z_{tk} vertical distance from highest point of tank, excluding small hatchways, to the load point, see **Fig 7.2.3**, in m

ρ_{sw} density of sea water, 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

P_{valve} setting of pressure relief valve, if fitted, is not to be taken less than 25 kN/m^2

2.2.4 Static deck pressure from distributed loading

2.2.4.1 The pressure on decks and inner bottom, P_{stat}, is to be taken as:

$$P_{stat} = P_{deck} \quad \text{kN/m}^2$$

Where:

P_{deck} uniformly distributed pressure on lower decks and decks within superstructures, including platform decks in the main engine room and for other spaces with heavy machinery components, in kN/m^2. P_{deck} is not to be taken less than 16 kN/m^2. Design pressures for decks of deck houses are provided in **Sec 11/1.4.**

2.2.5 Static deck loads from heavy units

2.2.5.1 The scantlings of structure in way of heavy units of cargo and equipment are to consider gravity forces acting where the mass is 20 tonnes or greater. The load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, F_{stat}, is to be taken as:

$$F_{stat} = m_{un} g \quad \text{kN}$$

Where:

m_{un} mass of unit, in tonnes

g acceleration due to gravity, 9.81 m/s^2

3 Dynamic Load Components

3.1 General

3.1.1 Basic components

3.1.1.1 Formulas for ship motions and accelerations are given in this sub-section.

3.1.1.2 Formulas for the envelope value of the basic dynamic load components are also given. The basic load components are:

(a) vertical wave bending moment and shear force

(b) horizontal wave bending moment

(c) dynamic wave pressure

(d) dynamic tank pressures.

3.1.2 Envelope load values

3.1.2.1 The envelope loads for scantling requirements and strength assessment are given at a 10^{-8} probability level, while the envelope loads for fatigue strength are given at a 10^{-4} probability level.

3.1.2.2 For scantling requirements and strength assessments, correction factors to account for non-linear effects and operational considerations in heavy weather are given.

3.1.2.3 For fatigue strength a factor adjusts the envelope load from a 10^{-8} probability level to a 10^{-4} probability level. A speed correction factor is applicable where appropriate.

3.1.2.4 The envelope value is the long term value, at a given probability level, taking into consideration the effect of all wave headings.

3.1.3 Metacentric height and roll radius of gyration

3.1.3.1 The metacentric height, GM, and roll radius of gyration, $r_{roll\text{-}gyr}$, associated with the rule loading conditions or specified draughts are specified in **Table 7.3.1.**

Table 7.3.1
GM and $r_{roll\text{-}gyr}$

	T_{LC}	GM	$r_{roll\text{-}gyr}$
Loaded at deep draught	between 0.9 T_{sc} and T_{sc}	0.12 B	0.35 B
Loaded on reduced draught	0.6 T_{sc}	0.24 B	0.40 B
In ballast	T_{bal}, $T_{bal\text{-}n}$	0.33 B	0.45 B

Where:
B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**
T_{LC} draught in the loading condition being considered, in m
T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**
T_{bal} minimum design ballast draught, in m, as defined in **Sec 4/1.1.5.2**
$T_{bal\text{-}n}$ normal ballast draught, in m, as defined in **Sec 4/1.1.5.3**

3.1.3.2 For the optional loading conditions, GM is to be taken as the corrected metacentric height given in the loading manual. Where GM for optional loaded or gale/emergency ballast conditions is not specified, GM is to be taken as 0.12 B for mean draught greater or equal to 0.9 T_{sc}, and 0.24 B for mean draught equal or less than 0.6 T_{sc}. For optional loading conditions with a mean draught other than the values defined, GM is to be obtained by linear interpolation based on values for 0.6 T_{sc} and 0.9 T_{sc}.

3.1.3.3 $r_{roll\text{-}gyr}$ for optional loaded or gale/emergency ballast conditions is, unless provided based on the loading manual, to be taken as $0.35\,B$ for mean draught greater or equal to $0.9\,T_{sc}$, and $0.4\,B$ for mean draught equal or less than $0.6\,T_{sc}$. For optional loading conditions with a mean draught other than the values defined above, $r_{roll\text{-}gyr}$ may be obtained by linear interpolation based on values for $0.6\,T_{sc}$ and $0.9\,T_{sc}$.

3.1.3.4 For the loading conditions used for fatigue strength, GM is to be taken as the corrected metacentric height given in the loading manual. If not available, GM is to be taken as specified in **Table 7.3.1** for ballast condition and according to the procedure described in **3.1.3.2** for full load condition. $r_{roll\text{-}gyr}$ is, unless based on the loading condition, to be taken as specified in **Table 7.3.1** for ballast condition and according to the procedure described in **3.1.3.3** for full load condition.

3.2 Motions

3.2.1 General

3.2.1.1 The envelope values for ship motions are given at a 10^{-8} probability level.

3.2.2 Roll motion

3.2.2.1 The natural roll period, U_{roll}, is to be taken as:

$$U_{roll} = \frac{2.30 r_{roll-gyr}}{\sqrt{GM}} \quad \text{secs}$$

Where:

GM metacentric height, in m, as defined in **3.1.3**

$r_{roll\text{-}gyr}$ roll radius of gyration, in m, as defined in **3.1.3**

3.2.2.2 The roll angle, θ, is to be taken as:

$$\theta = \frac{50}{B+75}(1.25 - 0.025 U_{roll}) f_{bk} \quad \text{rads}$$

Where:

f_{bk} 1.2 for ships without bilge keels

1.0 for ships with bilge keels

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

U_{roll} roll period, in secs, as defined in **3.2.2.1**

3.2.3 Pitch motion

3.2.3.1 The characteristic pitch period, U_{pitch}, is to be taken as:

$$U_{pitch} = f_V \sqrt{0.6 \frac{2\pi}{g}(1 + f_T) L} \quad \text{s}$$

Where:

$$f_V = 1.0 + \frac{V_0}{V}\left(\frac{L}{525} - 0.67\right)$$

$$f_T = \frac{T_{LC}}{T_{sc}}$$

V_0 vessel speed, in knots, is to be taken as:

0 for scantling requirements and strength assessment

$0.75V$ for fatigue strength

V maximum service speed, in knots, as defined in **Sec 4/1.1.8.1**

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

T_{LC} draught in the loading condition being considered, in m

L rule length, in m, as defined in **Sec 4/1.1.1.1**

3.2.3.2 The pitch angle, φ, is to be taken as:

$$\varphi = 960\left(\frac{V_1}{C_b}\right)^{0.25}\frac{1}{L}\frac{\pi}{180} \qquad \text{radians}$$

Where:

V_1 vessel speed, in knots. Is to be taken as V, but not to be taken as less than 10

V maximum service speed, in knots, as defined in **Sec 4/1.1.8.1**

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

3.3 Ship Accelerations

3.3.1 General

3.3.1.1 The envelope values for combined translatory accelerations due to motion in six degrees of freedom are given. The transverse and longitudinal components of acceleration include the component of gravity due to roll and pitch.

3.3.2 Common acceleration parameter

3.3.2.1 The common acceleration parameter, a_0, is to be taken as:

$$a_0 = (1.58 - 0.47C_b)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

Where:

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

3.3.3 Vertical acceleration

3.3.3.1 The envelope vertical acceleration, a_v, at any position, is to be taken as:

$$a_v = f_{prob}\sqrt{a_{heave}^2 + a_{pitch-z}^2 + a_{roll-z}^2} \qquad \mathrm{m/s^2}$$

Where:

a_{heave} vertical acceleration due to heave, is to be taken as:

$$= f_V a_0 g \qquad \mathrm{m/s^2}$$

$a_{pitch-z}$ vertical acceleration due to pitch, is to be taken as:

$$= \left(0.3 + \frac{L}{325}\right)\varphi\left(\frac{2\pi}{U_{pitch}}\right)^2 |x - 0.45L| \qquad \mathrm{m/s^2}$$

a_{roll-z} vertical acceleration due to roll, is to be taken as:

$$= 1.2\theta\left(\frac{2\pi}{U_{roll}}\right)^2 |y| \qquad \mathrm{m/s^2}$$

a_0 common acceleration parameter, as defined in **3.3.2.1**

g acceleration due to gravity, 9.81 $\mathrm{m/s^2}$

φ pitch angle, in rads, as defined in **3.2.3.2**

U_{pitch} pitch period, in secs, as defined in **3.2.3.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

θ roll angle, in rads, as defined in **3.2.2.2**

U_{roll} roll period, in secs, as defined in **3.2.2.1**

x longitudinal coordinate, in m

y transverse coordinate, in m

f_{prob} as defined in **3.3.3.2** and **3.3.3.3** as appropriate

f_V as defined in **3.3.3.2** and **3.3.3.3** as appropriate

3.3.3.2 For scantling requirements and strength assessment:

f_{prob} is to be taken as 1.0

f_V is to be taken as 1.0

3.3.3.3 For fatigue strength:

f_{prob} is to be taken as 0.45

f_V $= \left(\frac{C_{b-LC}}{C_b}\right)^2 \left(1.2 - \frac{L}{1000}\right)$

Where:

$C_{b\text{-}LC}$ block coefficient for considered loading condition, as defined in **Sec 4/1.1.9.2**

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

3.3.4 Transverse acceleration

3.3.4.1 The envelope transverse acceleration, a_t, at any position, is to be taken as:

$$a_t = f_{prob}\sqrt{a_{sway}^2 + (g\sin\theta + a_{roll-y})^2} \quad \text{m/s}^2$$

Where:

a_{sway} transverse acceleration due to sway and yaw, is to be taken as:

$$= 0.3 g a_0 \quad \text{m/s}^2$$

$a_{roll\text{-}y}$ transverse acceleration due to roll, is to be taken as:

$$= \theta\left(\frac{2\pi}{U_{roll}}\right)^2 R_{roll} \quad \text{m/s}^2$$

θ roll angle, in rads, as defined in **3.2.2.2**

U_{roll} roll period, in secs, as defined in **3.2.2.1**

R_{roll} $= z - \left(\frac{D}{4} + \frac{T_{LC}}{2}\right)$ or $z - \left(\frac{D}{2}\right)$, whichever is the greater, in m

g acceleration due to gravity, 9.81 m/s^2

a_0 common acceleration parameter, as defined in **3.3.2.1**

T_{LC} draught in the loading condition being considered, in m

D moulded depth, as defined in **Sec 4/1.1.4.1**

z vertical coordinate, in m

f_{prob} as defined in **3.3.4.2** or **3.3.4.3** as appropriate

3.3.4.2 For scantling requirements and strength assessment:

f_{prob} is to be taken as 1.0

3.3.4.3 For fatigue strength:

f_{prob} is to be taken as 0.5

3.3.5 Longitudinal acceleration

3.3.5.1 The envelope longitudinal acceleration, a_{lng}, at any position, is to be taken as:

$$a_{lng} = 0.7 f_{prob} \sqrt{a_{surge}^2 + \left(\frac{L}{325}\left(g\ sin\varphi + a_{pitch-x}\right)\right)^2}$$

Where:

a_{surge} longitudinal acceleration due to surge, is to be taken as:

$= 0.2 g a_0$ m/s²

$a_{pitch-x}$ longitudinal acceleration due to pitch, is to be taken as:

$= f_V \varphi (2\pi / U_{pitch})^2 R_{pitch}$ m/s²

φ pitch angle, in rads, as defined in **3.2.3.2**

U_{pitch} pitch period, in secs, as defined in **3.2.3.1**

R_{pitch} pitch radius and is to be taken as the greater of $z - \left(\frac{D}{4} + \frac{T_{LC}}{2}\right)$ or $z - \left(\frac{D}{2}\right)$, in m

g acceleration due to gravity, 9.81 m/s²

a_0 common acceleration parameter, as defined in **3.3.2.1**

T_{LC} draught in the loading condition being considered, in m

D moulded depth, in m, as defined in **Sec 4/1.1.4.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

z vertical coordinate, in m

f_{prob} as defined in **3.3.5.2** and **3.3.5.3** as appropriate

f_V as defined in **3.3.5.2** and **3.3.5.3** as appropriate

3.3.5.2 For scantling requirements and strength assessment:

f_{prob} is to be taken as 1.0

f_V is to be taken as 1.0

3.3.5.3 For fatigue strength:

f_{prob} is to be taken as 0.5

f_V is to be taken as 1.7

3.4 Dynamic Hull Girder Loads

3.4.1 Vertical wave bending moment

3.4.1.1 The envelope hogging and sagging vertical wave bending moments, M_{wv-hog} and M_{wv-sag}, are to be taken as:

$$M_{wv-hog} = f_{prob} 0.19 f_{wv-v} C_{wv} L^2 B C_b$$

$$M_{wv-sag} = -f_{prob} 0.11 f_{wv-v} C_{wv} L^2 B (C_b + 0.7) \quad \text{kNm}$$

Where:

f_{wv-v} distribution factor for vertical wave bending moment along the vessel length, see **3.4.1.2** or **3.4.1.3** as appropriate

C_{wv} wave coefficient to be taken as:

$= 10.75 - \left(\frac{300 - L}{100}\right)^{\frac{3}{2}}$ for $150 \le L \le 300$

$= 10.75$ for $300 < L \le 350$

$= 10.75 - \left(\frac{L-350}{150}\right)^{\frac{3}{2}}$ for $350 < L \leq 500$

L	rule length, in m, as defined in **Sec 4/1.1.1.1**
B	moulded breadth, in m, as defined in **Sec 4/1.1.3.1**
C_b	block coefficient, as defined in **Sec 4/1.1.9.1**

3.4.1.2 For scantling requirements and strength assessment:

$f_{wv\text{-}v}$ distribution factor for vertical wave bending moment along the vessel length, is to be taken as:

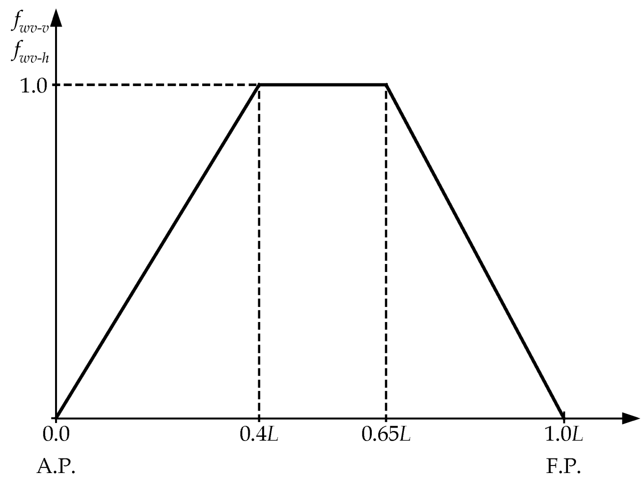
0.0 at A.P.
1.0 for 0.4 L to 0.65 L from A.P.
0.0 at F.P.

intermediate values to be obtained by linear interpolation, see **Fig 7.3.1**

f_{prob} is to be taken as 1.0

L rule length, in m, as defined in **Sec 4/1.1.1.1**

Fig 7.3.1
Vertical and Horizontal Wave Bending Moment Distribution for Scantling Requirements and Strength Assessment



3.4.1.3 For fatigue strength:

$f_{wv\text{-}v}$ distribution factor for vertical wave bending moment along the vessel length, is to be taken as:

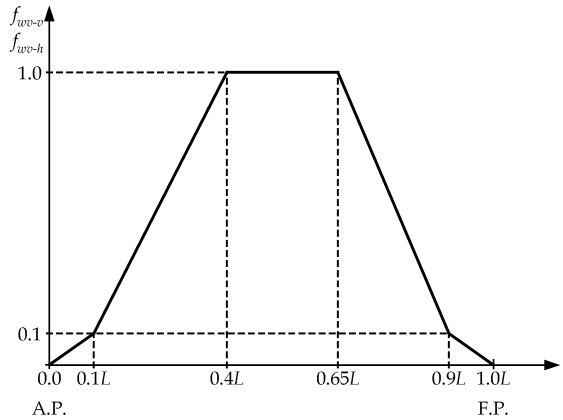
0.0 at A.P.
0.1 at 0.1 L from A.P.
1.0 for 0.4 L to 0.65 L from A.P.
0.1 at 0.9 L from A.P.
0.0 at F.P.

intermediate values to be obtained by linear interpolation, see **Fig 7.3.2**

f_{prob} is to be taken as 0.5

L rule length, in m, as defined in **Sec 4/1.1.1.1**

Fig 7.3.2
Vertical and Horizontal Wave Bending Moment Distribution for Fatigue Strength



3.4.2 Horizontal wave bending moment

3.4.2.1 The envelope horizontal wave bending moment, $M_{wv\text{-}h}$, is to be taken as:

$$M_{wv-h} = f_{prob}\left(0.3 + \frac{L}{2000}\right) f_{wv-h} C_{wv} L^2 T_{LC} C_b \quad \text{kNm}$$

Where:

$f_{wv\text{-}h}$ distribution factor for wave horizontal bending moment along the vessel length, see **3.4.2.2** or **3.4.2.3** as appropriate

C_{wv} wave coefficient, as defined in **3.4.1.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

T_{LC} draught in the loading condition being considered, in m

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

3.4.2.2 For scantling requirements and strength assessment:

$f_{wv\text{-}h}$ distribution factor for wave horizontal bending moment along the vessel length, is to be taken as:

0.0 at A.P.

1.0 for 0.4 L to 0.65 L from A.P.

0.0 at F.P.

intermediate values to be obtained by linear interpolation, see **Fig 7.3.1**

f_{prob} is to be taken as 1.0

L rule length, in m, as defined in **Sec 4/1.1.1.1**

3.4.2.3 For fatigue strength:

$f_{wv\text{-}h}$ distribution factor for wave horizontal bending moment along the vessel length, is to be taken as:

0.0 at A.P.

0.1 at 0.1 L from A.P.

1.0 for 0.4 L to 0.65 L from A.P.

0.1 at 0.9 L from A.P.

0.0 at F.P.

intermediate values to be obtained by linear interpolation, see **Fig 7.3.2**

f_{prob} is to be taken as 0.5

L rule length, in m, as defined in **Sec 4/1.1.1.1**

3.4.3 Vertical wave shear force

3.4.3.1 The envelope positive and negative vertical wave shear forces, Q_{wv-pos} and Q_{wv-neg}, are to be taken as:

$$Q_{wv-pos} = 0.3 f_{qwv-pos} C_{wv} LB(C_b + 0.7)$$

$$Q_{wv-neg} = -0.3 f_{qwv-neg} C_{wv} LB(C_b + 0.7) \quad \text{kN}$$

Where:

$f_{qwv-pos}$ distribution factor for positive vertical wave shear force along the vessel length and is to be taken as:

0.0	at A.P.
$1.59\dfrac{C_b}{(C_b+0.7)}$	for 0.2 L to 0.3 L from A.P.
0.7	for 0.4 L to 0.6 L from A.P.
1.0	for 0.7 L to 0.85 L from A.P.
0.0	at F.P.

$f_{qwv-neg}$ distribution factor for negative vertical wave shear force along the vessel length and is to be taken as:

0.0	at A.P.
0.92	for 0.2 L to 0.3 L from A.P.
0.7	for 0.4 L to 0.6 L from A.P.
$1.73\dfrac{C_b}{(C_b+0.7)}$	for 0.7 L to 0.85 L from A.P.
0.0	at F.P.

intermediate values of $f_{qwv-pos}$ and $f_{qwv-neg}$ are to be obtained by linear interpolation, see **Fig 7.3.3** and **Fig 7.3.4** respectively.

C_{wv} wave coefficient, as defined in **3.4.1.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

Fig 7.3.3
Positive Vertical Wave Shear Force Distribution

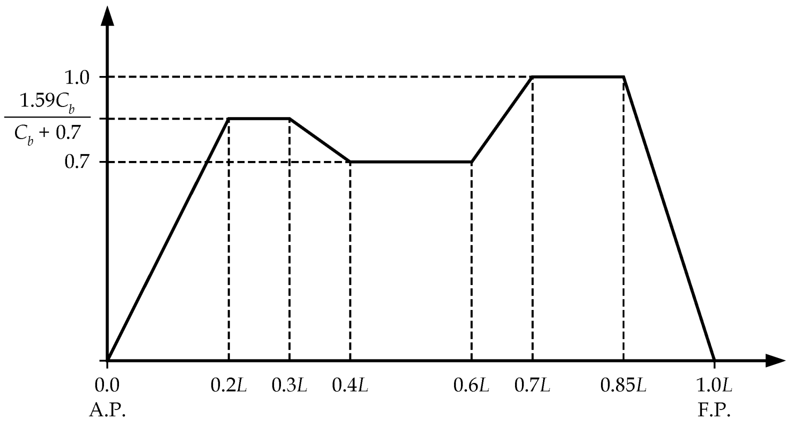
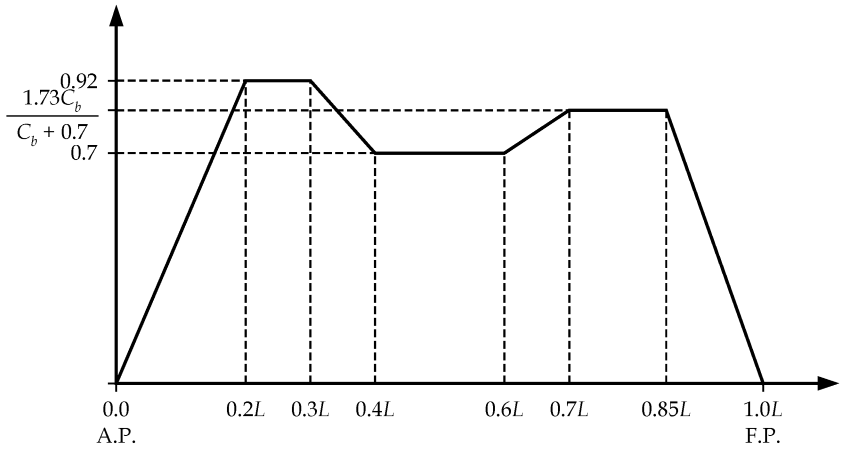


Fig 7.3.4
Negative Vertical Wave Shear Force Distribution



3.5 Dynamic Local Loads

3.5.1 General

3.5.1.1 This section provides the envelope values for dynamic wave pressure, dynamic tank pressure, green sea load and dynamic deck loads.

3.5.1.2 The envelope dynamic wave pressures are given in **3.5.2**

3.5.1.3 The envelope green sea load given in **3.5.3** only applies to scantling requirements and strength assessment. The green sea load for fatigue strength is to be taken as 0.

3.5.1.4 The envelope dynamic tank pressure is a combination of the inertial components due to vertical, transverse and longitudinal acceleration. The envelope dynamic tank pressure components are given in **3.5.4.**

3.5.1.5 The envelope dynamic deck loads are given in **3.5.5** and **3.5.6.**

3.5.2 Dynamic wave pressure

3.5.2.1 The envelope dynamic wave pressure, $P_{ex\text{-}dyn}$, is to be taken as the greater of the following:

$$P_1 = 2 f_{prob} f_{nl-P1}\left[\left(P_{11} + \frac{135B_{local}}{4(B+75)} - 1.2(T_{LC}-z)\right)f_1 + \frac{135B_{local}}{4(B+75)}f_2\right] \quad \text{kN/m}^2$$

$$P_2 = 26 f_{prob} f_{nl-P2}\left[\begin{array}{l}\left(\frac{B_{local}}{8}\theta + f_T C_b \frac{0.25B_{local}+0.8C_{wv}}{14}\left(0.7+\frac{2z}{T_{LC}}\right)\right)f_1 \\ +\left(\frac{B_{local}}{8}\theta + f_T C_b \frac{0.25B_{local}}{14}\left(0.7+\frac{2z}{T_{LC}}\right)\right)f_2\end{array}\right] \quad \text{kN/m}^2$$

Where:

B_{local} local breadth at the waterline, for considered draught, not to be taken less than $0.5B$, in m

θ roll angle, in rads, as defined in **3.2.2.2**

P_{11} = $(3f_s + 0.8)C_{wv}$

C_{wv} wave coefficient, as defined in **3.4.1.1**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

T_{LC} draught in the loading condition being considered, in m

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

f_1 $= f_{lng} - \frac{f_{lng}}{f_V} f_2 + f_2$

f_2 $= 0.25 f_V \left(\frac{4|y|}{B_{local}} - 1 \right)$ for $|y| < 0.25 B_{local}$

$= f_V \left(\frac{4|y|}{B_{local}} - 1 \right)$ for $|y| \geq 0.25 B_{local}$

f_T $= \frac{T_{LC}}{T_{sc}}$

f_s $= C_b + \frac{1.33}{\sqrt{C_b}}$ at, and aft of A.P.

$= C_b$ between $0.2L$ and $0.7L$ from A.P.

$= C_b + \frac{1.33}{C_b}$ at, and forward of F.P.

intermediate values to be obtained by linear interpolation

f_{lng} = 1.0 at, and aft of A.P.

= 0.7 for $0.2L$ to $0.7L$ from A.P.

= 1.0 at, and forward of F.P.

intermediate values to be obtained by linear interpolation

y transverse coordinate, in m

z vertical coordinate, in m

$f_{nl\text{-}P1}$, $f_{nl\text{-}P2}$, f_{prob}, and f_V are given in **3.5.2.2** for scantling requirements and strength assessment application and in **3.5.2.3** for fatigue strength.

3.5.2.2 For scantling requirements and strength assessment, the envelope maximum dynamic wave pressure, $P_{ex\text{-}max}$, see **Fig 7.3.5**, and minimum dynamic wave pressure, $P_{ex\text{-}min}$, see **Fig 7.3.6**, are to be taken as:

$P_{ex\text{-}max}$ $= P_{ex\text{-}dyn}$ kN/m² below still waterline

$= P_{WL} - 10(z - T_{LC})$ kN/m² for $T_{LC} < z \leq T_{LC} + \frac{P_{WL}}{10}$

$= 0$ kN/m² for $z > T_{LC} + \frac{P_{WL}}{10}$

$P_{ex\text{-}min}$ $= -P_{ex\text{-}dyn}$ kN/m² below still waterline

$= 0$ kN/m² above still waterline

$P_{ex\text{-}min}$ is not to be taken as less than $-\rho_{sw} g (T_{LC} - z)$

Where:

$P_{ex\text{-}dyn}$ envelope dynamic wave pressure, in kN/m², as defined in **3.5.2.1** with:

$f_{prob} = 1.0$

$f_{nl\text{-}P1} = 0.9$

$f_{nl\text{-}P2} = 0.65$

$f_V = 1.0$

P_{WL} pressure at waterline, to be taken as $P_{ex\text{-}dyn}$ at still waterline, in kN/m²

T_{LC} draught in the loading condition being considered, in m

ρ_{sw} density of sea water, 1.025 tonnes/m³

z vertical coordinate, in m

Fig 7.3.5
Transverse Distribution of Maximum Dynamic Wave Pressure for Scantling Requirements and Strength Assessment

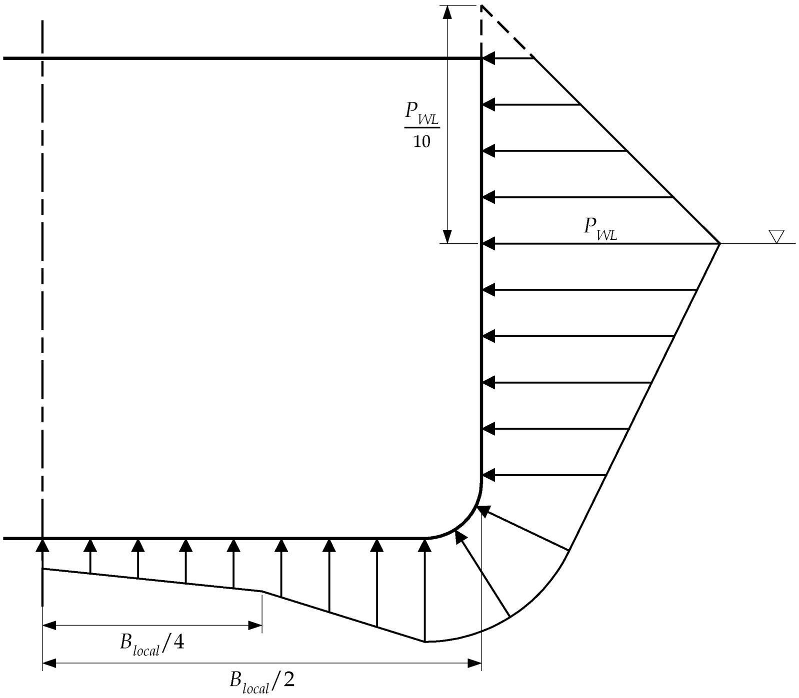
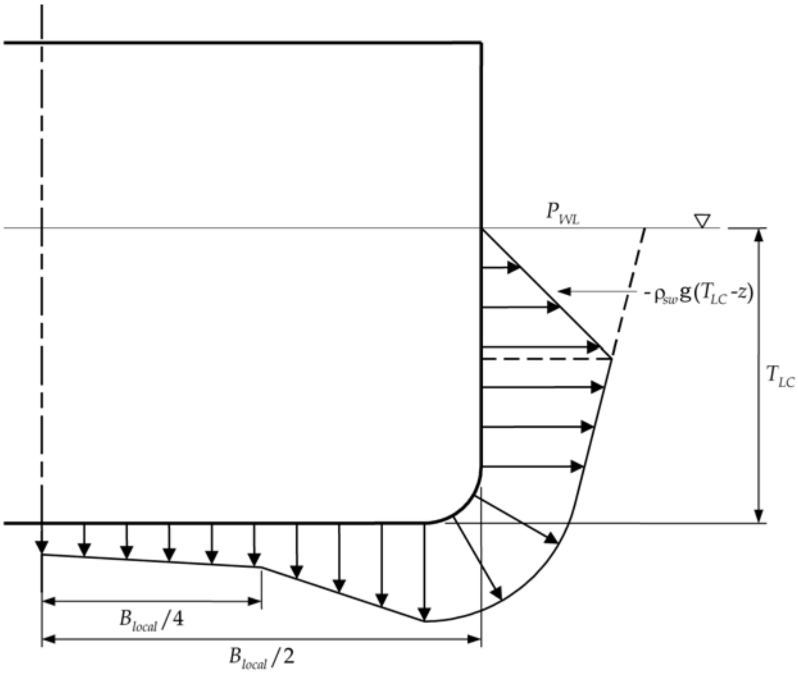


Fig 7.3.6
Transverse Distribution of Minimum Dynamic Wave Pressure for Scantling Requirements and Strength Assessment



3.5.2.3 The dynamic wave pressure pseudo-amplitude (half range), $P_{ex\text{-}amp}$, for fatigue strength, see **Fig 7.3.7**, is to be taken as:

$P_{ex\text{-}amp}$ = 0 kN/m^2 for $z \geq T_{LC} + h_{WL}$ or D, whichever is the lesser

= $0.5 P_{WL}$ kN/m^2 at still waterline

= $P_{ex\text{-}dyn}$ kN/m^2 for $z \leq T_{LC} - h_{WL}$ or 0, whichever is the greater

Intermediate values between the still waterline and $z = T_{LC} - h_{WL}$ to be obtained by linear interpolation

Where:

h_{WL} dynamic wave pressure head at the still waterline, is to be taken as:

= $P_{WL}/10$ m

P_{WL} pressure at waterline, and is to be taken as $P_{ex\text{-}max}$ at still waterline, in kN/m^2

$P_{ex\text{-}max}$ envelope maximum dynamic wave pressure is to be taken as the greater of P_1 and P_2, in kN/m^2

T_{LC} draught in the loading condition being considered, in m

D moulded depth, in m, as defined in Section4/1.1.4.1

P_1 as defined in **3.5.2**, in kN/m^2, with:

f_{prob} = 0.5

$f_{nl\text{-}P1}$ = 1.0

$$f_V = \begin{cases} 1.0 & \text{at, and aft of } 0.7L \\ 1.5 & \text{at, and forward of F.P.} \end{cases}$$

intermediate values of f_V to be obtained by linear interpolation

P_2 as defined in **3.5.2.1**, in kN/m^2, with:

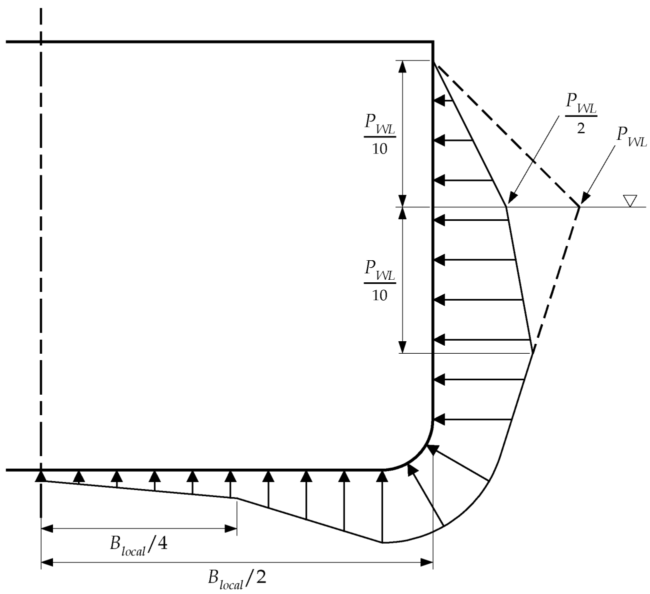
f_{prob} = 0.5

$f_{nl\text{-}P2}$ = 1.0

f_V = 1.0

z vertical coordinate, in m

Fig 7.3.7
Transverse Distribution of Dynamic Wave Pressure Amplitude for Fatigue Strength



3.5.3 Green sea load

3.5.3.1 The envelope green sea load on the weather deck, P_{wdk}, is to be taken as the greater of the following:

$P_{wdk} = f_{1-dk}\left(f_{op}P_{1-WL} - 10z_{dk-T}\right)$ kN/m²

$P_{wdk} = 0.8 f_{2-dk}\left(P_{2-WL} - 10z_{dk-T}\right)$ kN/m²

$P_{wdk} = 34.3$ kN/m²

Where:

$f_{1-dk} = 0.8 + \dfrac{L}{750}$

$f_{2-dk} = 0.5 + \dfrac{|y|}{B_{wdk}}$

f_{op} = 1.0 at and forward of 0.2 L from A.P.
= 0.8 at and aft of A.P.
intermediate values to be obtained by linear interpolation

P_{1-WL} P_1 pressure at still waterline for considered draught, in kN/m², see **3.5.2.1**

P_{2-WL} P_2 pressure at still waterline for considered draught, in kN/m², see **3.5.2.1**

z_{dk-T} distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in m

B_{wdk} local breadth at the weather deck, in m

L rule length, in m, as defined in **Sec 4/1.1.1.1**

y transverse coordinate of load point, in m

3.5.4 Dynamic tank pressure

3.5.4.1 The envelope dynamic tank pressure, P_{in-v}, due to vertical tank acceleration is to be taken as:

$P_{in-v} = \rho a_v (z_0 - z)$ kN/m² for strength assessment and scantling requirements

$P_{in-v} = \rho a_v |z_0 - z|$ kN/m² for fatigue strength

Where:

ρ density of liquid in the tank, in tonnes/m³, and is not to be taken as less than:
0.9 for cargo tanks for fatigue strength
1.025 otherwise,
see **Sec 2/3.1.8**

a_v envelope vertical acceleration, in m/s², as defined in **3.3.3.1**, and is to be taken at tank centre of gravity

z vertical coordinate of load point, in m

z_0 vertical coordinate of reference point, see **6.3.7** for scantling requirements and strength assessment, and **3.5.4.5** for fatigue strength, in m

3.5.4.2 The envelope dynamic tank pressure, P_{in-t}, due to transverse acceleration is to be taken as:

$P_{in-t} = f_{ull-t}\rho a_t (y_0 - y)$ kN/m² for strength assessment and scantling requirements

$P_{in-t} = \rho a_t |y_0 - y|$ kN/m² for fatigue strength

Where:

ρ density of liquid in the tank, in tonnes/m³, and is not to be taken as less than:
0.9 for cargo tanks for fatigue strength

1.025 otherwise,
see **Sec 2/3.1.8**

$f_{ull\text{-}t}$ factor to account for ullage in cargo tanks, and is to be taken as:
0.67 for cargo tanks, including cargo tanks designed for filling with water ballast
1.0 for ballast and other tanks

a_t envelope transverse acceleration, in m/s^2, as defined in **3.3.4.1**, and is to be taken at tank centre of gravity

y transverse coordinate of load point, in m

y_0 transverse coordinate of reference point, see **6.3.7** for scantling requirements and strength assessment, and **3.5.4.5** for fatigue strength, in m

3.5.4.3 The envelope dynamic tank pressure, $P_{in\text{-}lng}$, due to longitudinal acceleration is to be taken as:

$$P_{in-lng} = f_{ull-lng} \rho a_{lng} (x_0 - x) \quad kN/m^2$$ for strength assessment and scantling requirements

$$P_{in-lng} = \rho a_{lng} |x_0 - x| \quad kN/m^2$$ for fatigue strength

Where:

ρ density of tank liquid, in tonnes/m^3, and is not to be taken as less than:
0.9 for cargo tanks for fatigue strength
1.025 otherwise, see **Sec 2/3.1.8**

$f_{ull\text{-}lng}$ factor to account for ullage in cargo tanks, and is to be taken as:
0.62 for cargo tanks, including cargo tanks designed for filling with water ballast
1.0 for ballast and other tanks

a_{lng} envelope longitudinal acceleration, in m/s^2, as defined in **3.3.5.1**, and is to be taken at tank centre of gravity

x longitudinal coordinate of load point, in m

x_0 longitudinal coordinate of reference point, see **6.3.7** for scantling requirements and strength assessment, and **3.5.4.5** for fatigue strength, in m

3.5.4.4 For scantling requirements and strength assessment the simultaneous acting dynamic tank pressure, $P_{in\text{-}dyn}$, is to be taken as the summation of the components for the considered dynamic load case, see **6.3.7.**

3.5.4.5 For fatigue strength the dynamic tank pressure amplitude, $P_{in\text{-}amp}$, on a tank boundary with adjacent tank empty, is to be taken as:

$$P_{in-amp} = f_v P_{in-v} + f_{ull-t} f_t P_{in-t} + f_{ull-lng} f_{lng} P_{in-lng} \quad kN/m^2$$

Where:

$P_{in\text{-}v}$ envelope dynamic tank pressure due to vertical acceleration, in kN/m^2, as defined in **3.5.4.1**

$P_{in\text{-}t}$ envelope dynamic tank pressure due to transverse acceleration, in kN/m^2, as defined in **3.5.4.2**

$P_{in\text{-}lng}$ envelope dynamic tank pressure due to longitudinal acceleration, in kN/m^2, as defined in **3.5.4.3**

$f_{ull\text{-}t}$ factor to account for ullage in cargo tanks, not to be taken less than 0.0 nor greater than 1.0

$= \dfrac{|z_0 - z| + h_{roll}}{2h_{roll}}$ for cargo tanks

$= 1.0$ for ballast tanks

$f_{ull\text{-}lng}$ factor to account for ullage in cargo tanks, not to be taken less than 0.0 nor greater than 1.0

$= \dfrac{|z_0 - z| + h_{pitch}}{2h_{pitch}}$ for cargo tanks

$= 1.0$ for ballast tanks

h_{roll} roll height $= \dfrac{b_{fs} f_{prob} \theta}{2}$

h_{pitch} pitch height $= \dfrac{l_{fs} f_{prob} \varphi}{2}$

f_{prob} is to be taken as 0.5

θ roll angle, in rads, as defined in **3.2.2.2**

φ pitch angle, in secs, as defined in **3.2.3.2**

b_{fs} tank breadth at the top of the tank, see **Fig 7.3.8**, in m

l_{fs} tank length at the top of the tank, in m

x_0 longitudinal coordinate of reference point, and is to be taken as the middle of tank length at the top of the tank, in m

y_0 transverse coordinate of reference point, and is to be taken as the middle of tank breadth at the top of the tank, see **Fig 7.3.8**, in m

z_0 vertical coordinate of reference point, and is to be taken as the highest point of the tank, excluding small hatchways, see **Fig 7.3.8**, in m

f_v pressure combination factor, as given in **Table 7.3.2**

f_t pressure combination factor, as given in **Table 7.3.2**

f_{lng} pressure combination factor, as given in **Table 7.3.2**

3.5.4.6 For fatigue strength the dynamic tank pressure amplitude, $P_{in\text{-}amp}$, on a longitudinal tank boundary with adjacent tank full, is to be taken as:

$$P_{in-amp} = f_v \left| P_{in-v-tk1} - P_{in-v-tk2} \right| + f_t \left| f_{ull-t-tk1} P_{in-t-tk1} + f_{ull-t-tk2} P_{in-t-tk2} \right|$$
$$+ f_{lng} \left| f_{ull-lng-tk1} P_{in-lng-tk1} - f_{ull-lng-tk2} P_{in-lng-tk2} \right| \quad \text{kN/m}^2$$

Where:

$P_{in\text{-}v\text{-}tk1}$ dynamic tank pressure due to vertical acceleration in tank 1, in kN/m^2

$P_{in\text{-}v\text{-}tk2}$ dynamic tank pressure due to vertical acceleration in tank 2, in kN/m^2

$P_{in\text{-}t\text{-}tk1}$ dynamic tank pressure due to transverse acceleration in tank 1, in kN/m^2

$P_{in\text{-}t\text{-}tk2}$ dynamic tank pressure due to transverse acceleration in tank 2, in kN/m^2

$P_{in\text{-}lng\text{-}tk1}$ dynamic tank pressure due to longitudinal acceleration in tank 1, in kN/m^2

$P_{in\text{-}lng\text{-}tk2}$ dynamic tank pressure due to longitudinal acceleration in tank 2, in kN/m^2

$f_{ull\text{-}t\text{-}tk1}$ factor to account for ullage for tank 1, as defined in **3.5.4.5**

$f_{ull\text{-}t\text{-}tk2}$ factor to account for ullage for tank 2, as defined in **3.5.4.5**

$f_{ull\text{-}lng\text{-}tk1}$ factor to account for ullage for tank 1, as defined in **3.5.4.5**

$f_{ull\text{-}lng\text{-}tk2}$ factor to account for ullage for tank 2, as defined in **3.5.4.5**

f_v pressure combination factor, as given in **Table 7.3.2**

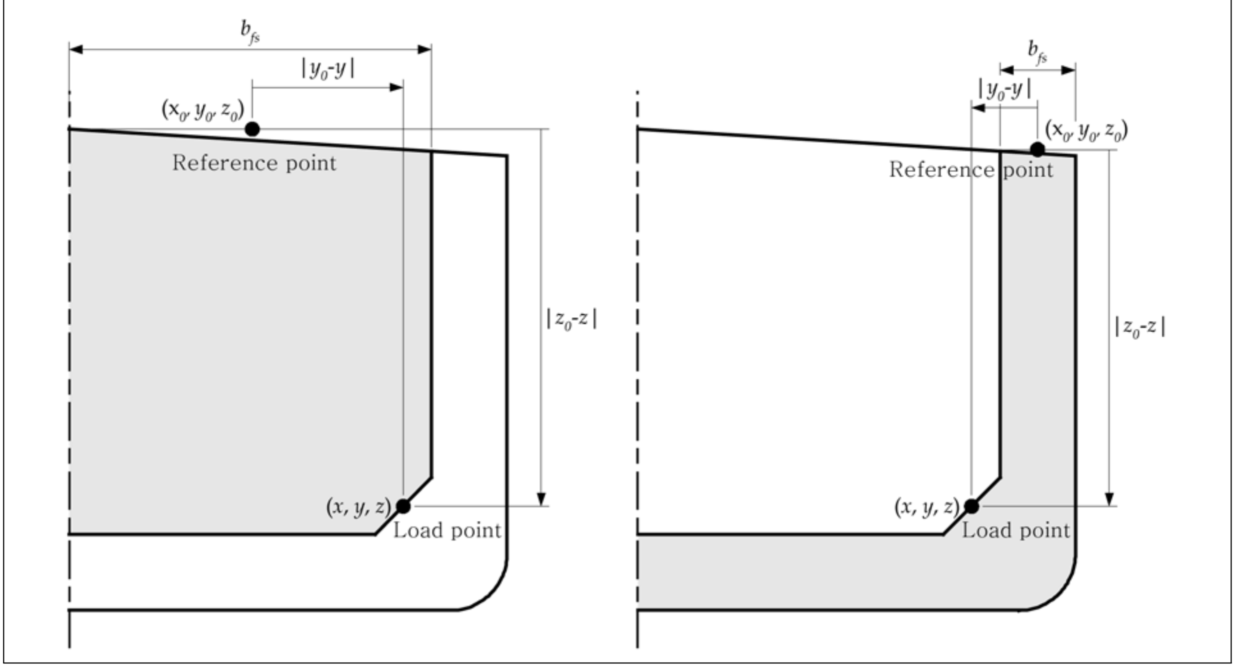
f_t pressure combination factor, as given in **Table 7.3.2**

f_{lng} pressure combination factor, as given in **Table 7.3.2**

Tank 1 and 2 are adjacent tanks with common longitudinal boundary

Table 7.3.2 Pressure Combination Factors for Fatigue Assessment		
	Cargo tanks	Ballast tanks
f_v	0.9	0.9
f_t	0.9	0.6
f_{lng}	0.4	0.4

Fig 7.3.8
Dynamic Tank Pressure Load and Reference Points for Fatigue Strength



3.5.4.7 For fatigue strength by hot spot stress (FE) approach, the dynamic tank pressure amplitudes due to vertical, transverse and longitudinal accelerations, illustrated in **Fig 7.3.9** are to be taken as:

$P_{in-v} = \rho a_v (z_0 - z)$ in kN/m^2

$P_{in-t} = f_{ull-t} \rho a_t (y_0 - y)$ in kN/m^2

$P_{in-lng} = f_{ull-lng} \rho a_{lng} (x_0 - x)$ in kN/m^2

Where:

ρ density of liquid in the tank, in tonnes/m^3, and is not to be taken as less than:
0.9 for cargo tanks
1.025 otherwise,
see **Sec 2/3.1.8**

f_{ull-t} factor to account for ullage in cargo tanks, as defined in **3.5.4.5**

$f_{ull-lng}$ factor to account for ullage in cargo tanks, as defined in **3.5.4.5**

x longitudinal coordinate of load point, in m

y transverse coordinate of load point, in m

z vertical coordinate of load point, in m

x_0 longitudinal coordinate of reference point, and is to be taken as the middle of the tank length at the top of the tank, in m

y_0 transverse coordinate of reference point, and is to be taken as the middle of the tank breadth at the top of the tank, in m

z_0 vertical coordinate of reference point, and is to be taken as the highest point in the tank, in m

a_v envelope vertical acceleration, in m/s^2, as defined in **3.3.3.1**, at tank centre of gravity

a_t envelope transverse acceleration, in m/s^2, as defined in **3.3.4.1**, at tank centre of gravity

a_{lng} envelope longitudinal acceleration, in m/s^2, as defined in **3.3.5.1**, at tank centre of gravity

Fig 7.3.9 (a)
Dynamic Tank Pressure due to Vertical Acceleration for Fatigue Strength

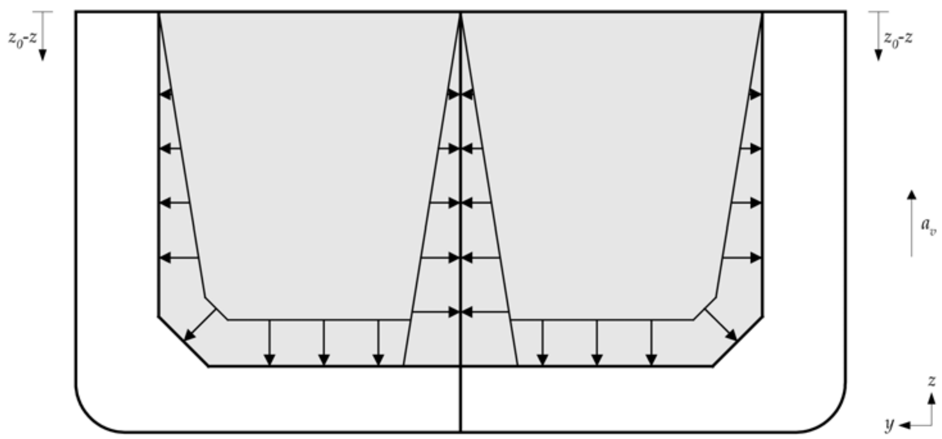


Fig 7.3.9 (b)
Dynamic Tank Pressure due to Transverse Acceleration for Fatigue Strength

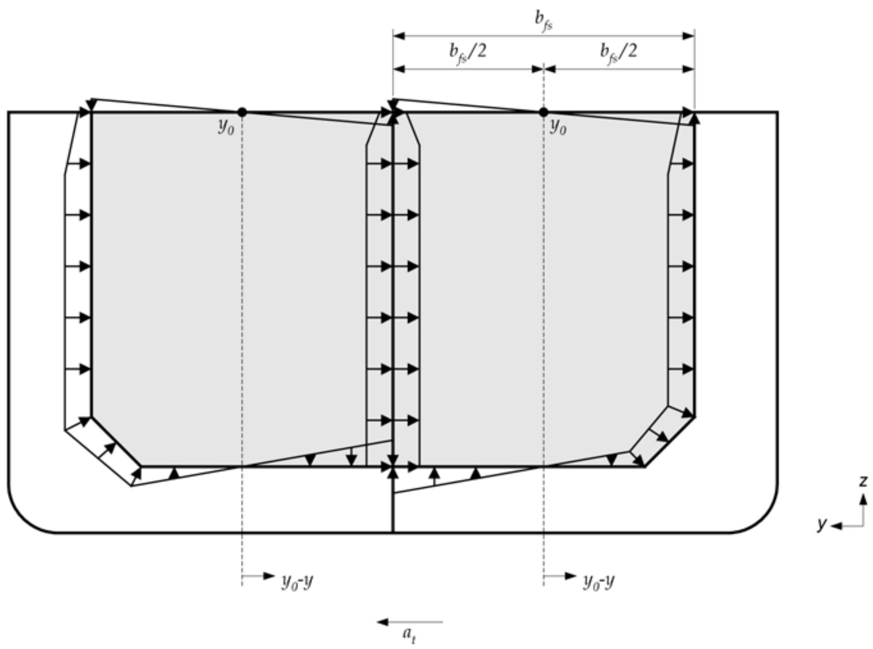
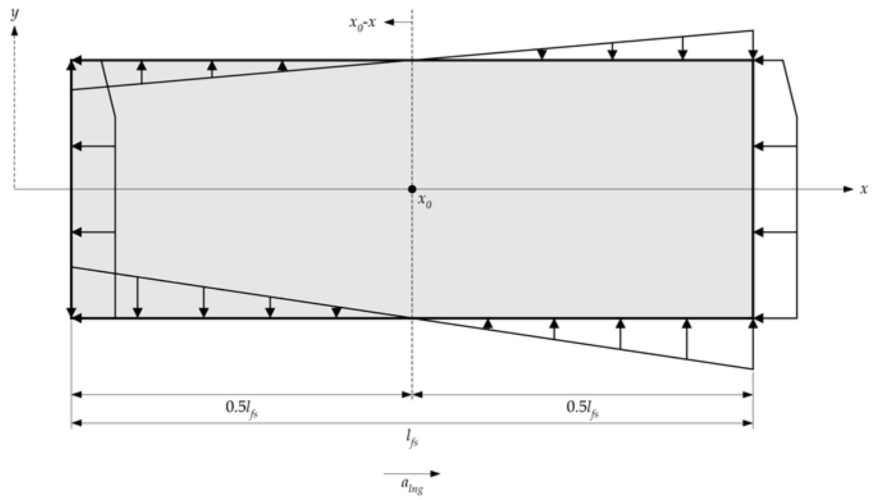


Fig 7.3.9 (c)
Dynamic Tank Pressure due to Longitudinal Acceleration for Fatigue Strength Illustrated for a Cargo Tank



3.5.5 Dynamic deck pressure from distributed loading

3.5.5.1 The envelope dynamic deck pressure, $P_{deck\text{-}dyn}$, on decks, inner bottom and hatch covers is to be taken as:

$$P_{deck-dyn} = P_{deck}\frac{a_v}{g} \quad \text{kN/m}^2$$

Where:

a_v envelope vertical acceleration, in m/s^2, as defined in **3.3.3.1**

P_{deck} uniformly distributed pressure on lower decks and decks within superstructure, in kN/m^2, as defined in **2.2.4.1**

g acceleration due to gravity, 9.81 m/s^2

3.5.6 Dynamic loads from heavy units

3.5.6.1 The envelope dynamic deck loads, F_v, F_t, F_{lng} acting vertically, transversely and longitudinally on supporting structures and securing systems for heavy units of cargo, equipment or structural components are to be taken as:

$$F_v = m_{un} a_v \quad \text{kN}$$

$$F_t = m_{un} a_t \quad \text{kN}$$

$$F_{lng} = m_{un} a_{lng} \quad \text{kN}$$

Where:

m_{un} mass of unit, in tonnes

a_v envelope vertical acceleration, in m/s^2, as defined in **3.3.3.1**, at centre of gravity of considered unit

a_t envelope transverse acceleration, in m/s^2, as defined in **3.3.4.1**, at centre of gravity of considered unit

a_{lng} envelope longitudinal acceleration, in m/s^2, as defined in **3.3.5.1**, at centre of gravity of considered unit

4 Sloshing and Impact Loads

4.1 General

4.1.1 Load Components

4.1.1.1 Sloshing pressures in tanks, and bow impact and bottom slamming pressures are given in this sub-section.

4.2 Sloshing Pressure in Tanks

4.2.1 Application and limitations

4.2.1.1 The sloshing pressures given in **4.2.2** to **4.2.4** are pressures induced by free movement of the tank liquids as a result of ship motions.

4.2.1.2 The given pressures do not include the effect of impact pressures due to high velocity impacts with tank boundaries or internal structures. For tanks with a maximum effective sloshing breadth, b_{slh}, greater than $0.56\,B$ or a maximum effective sloshing length, l_{slh}, greater than 0.13 L at any filling height from $0.05\,h_{max}$ to $0.95\,h_{max}$, an additional impact assessment is to be carried out in accordance with the individual Classification Society procedures. The effective sloshing lengths and breadths, l_{slh} and b_{slh}, are calculated using the equations in **4.2.2.1** and **4.2.3.1** respectively.

4.2.2 Sloshing pressure due to longitudinal liquid motion

4.2.2.1 The sloshing pressure in way of transverse tight and wash bulkheads due to longitudinal liquid motion, $P_{slh\text{-}lng}$, for a particular filling height, is to be taken as:

$$P_{slh-lng} = \rho g l_{slh} f_{slh}\left[0.4-\left(0.39-\frac{1.7 l_{slh}}{L}\right)\frac{L}{350}\right] \quad \text{kN/m}^2$$

Where:

ρ density of liquid in the tank, in tonnes/m^3, and is not to be taken as less than 1.025

l_{slh} effective sloshing length, at considered filling height as given in **4.2.2.3** and **4.2.2.4** for transverse tight bulkheads and transverse wash bulkheads respectively, in m

f_{slh} $= 1-2\left(0.7-\frac{h_{fill}}{h_{\max}}\right)^2$

L rule length, in m, as defined in **Sec 4/1.1.1.1**

h_{fill} filling height, measured from inner bottom, in m, see **Fig 7.4.1**

$h_{\max}$ maximum tank height excluding small hatchways, measured from inner bottom, in m, see **Fig 7.4.1**

g acceleration due to gravity, 9.81 m/s^2

4.2.2.2 The sloshing pressure due to longitudinal liquid motion, $P_{slh\text{-}lng}$, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling heights from $0.05\,h_{max}$ to $0.95\,h_{max}$, in $0.05\,h_{max}$ increments.

4.2.2.3 For calculation of sloshing pressures in way of transverse tight bulkheads, the effective sloshing length, l_{slh}, is to be taken as:

$$l_{slh} = \frac{(1+n_{wash-t}\alpha_{wash-t})(1+f_{wf}\alpha_{wf})l_{tk-h}}{(1+n_{wash-t})(1+f_{wf})} \quad \text{m}$$

Where:

n_{wash-t} number of transverse wash bulkheads in the tank

α_{wash-t} transverse wash bulkhead coefficient,

$= \dfrac{A_{opn-wash-t}}{A_{tk-t-h}}$

see **Fig 7.4.1**

α_{wf} transverse web frame coefficient,

$= \dfrac{A_{opn-wf-h}}{A_{tk-t-h}}$

see **Fig 7.4.2**

for tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, α_{wf}, may be taken as the weighted average of all web frame locations in the tank given as

$= \dfrac{\sum_{i=1}^{n} \dfrac{A_{opn\text{-}wf\text{-}h-i}}{A_{tk\text{-}t\text{-}h-i}}}{n_{wf}}$

$A_{opn-wash-t}$ total area of openings in the transverse section in way of the wash bulkhead below the considered filling height, in m^2

A_{tk-t-h} total transverse cross sectional area of the tank below the considered filling height, in m^2

$A_{opn-wf-h}$ the total area of openings in the transverse section in way of the web frame below the considered filling height, in m^2

f_{wf} factor to account for number of transverse web frames and transverse wash bulkheads in the tank:

$= n_{wf} / (1 + n_{wash-t})$

n_{wf} number of transverse web frames, excluding wash bulkheads, in the tank

l_{tk-h} length of cargo tank, at considered filling height, in m

Fig 7.4.1
Transverse Wash Bulkhead Coefficient

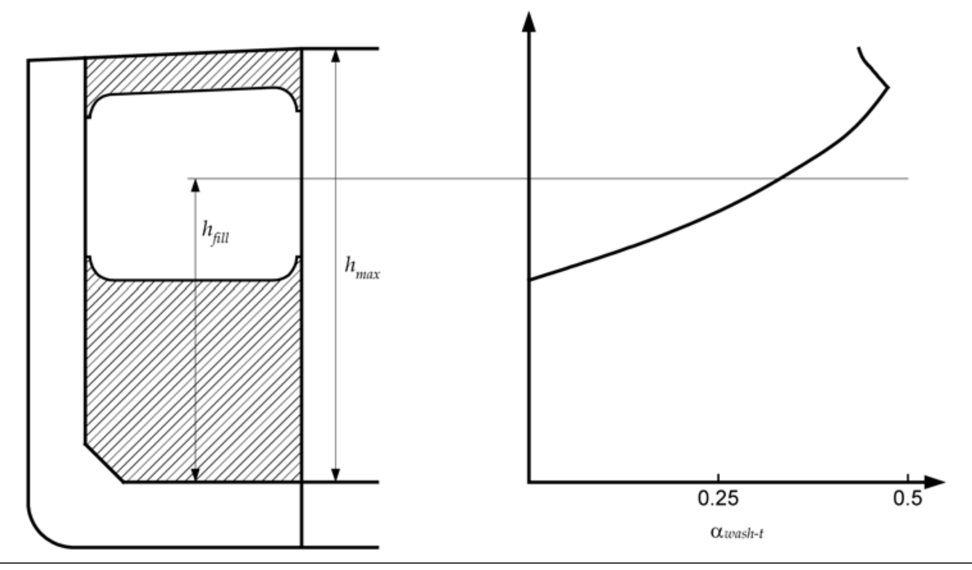
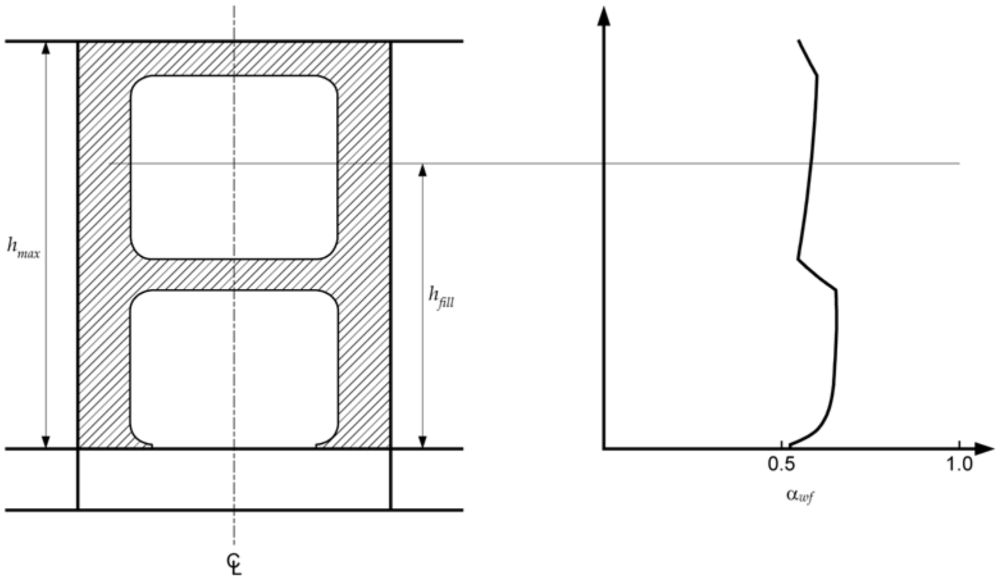


Fig 7.4.2
Transverse Web Frame Coefficient



4.2.2.4 For calculation of sloshing pressures in way of transverse wash bulkheads, the effective sloshing length, l_{slh}, is to be taken as:

$$l_{slh} = \frac{\left[1+\left(n_{wash-t}-1\right)\alpha_{wash-t}\right]\left(1+f_{wf}\alpha_{wf}\right)l_{tk-h}}{\left(1+n_{wash-t}\right)\left(1+f_{wf}\right)} \quad \text{m}$$

Where:

n_{wash-t} number of transverse wash bulkheads in the tank

α_{wash-t} transverse wash bulkhead coefficient,

$$= \frac{A_{opn\text{-}wash\text{-}t}}{A_{tk\text{-}t\text{-}h}}$$

see **Fig 7.4.1**

α_{wf} transverse web frame coefficient,

$$= \frac{A_{opn\text{-}wf\text{-}h}}{A_{tk\text{-}t\text{-}h}}$$

see **Fig 7.4.2**

for tanks with changing shape along the length and/or with web frames of different shape the transverse web frame coefficient, awf,may be taken as the weighted average of all web frame locations in the tank given as

$$= \frac{\sum_{i=1}^{n} \frac{A_{opn\text{-}wf\text{-}h-i}}{A_{tk\text{-}t\text{-}h-i}}}{n_{wf}}$$

$A_{opn-wash-t}$ the total area of openings in the transverse section in way of the wash bulkhead below the considered filling height, in m^2

A_{tk-t-h} total transverse cross sectional area of the tank below the considered filling height, in m^2

$A_{opn-wf-h}$ the total area of openings in the transverse section in way of the web frame below the considered filling height, in m^2

f_{wf} factor to account for number of transverse web frames and transverse wash bulkheads in the tank:

$= n_{wf} / (1 + n_{wash-t})$

n_{wf} number of transverse web frames, excluding wash bulkheads, in the tank

l_{tk-h} length of cargo tank, at considered filling height, in m

4.2.2.5 For tanks with internal web frames the sloshing pressure acting on a web frame adjacent to a transverse tight or wash bulkhead, P_{slh-wf}, provided it is located within $0.25\,l_{slh}$ from the bulkhead, is to be taken as:

$$P_{slh-wf} = P_{slh-lng}\left(1 - \frac{s_{wf}}{l_{slh}}\right)^2 \quad \text{kN/m}^2$$

Where:

$P_{slh-lng}$ sloshing pressure acting on bulkhead due to longitudinal liquid motion, as given in **4.2.2.1**

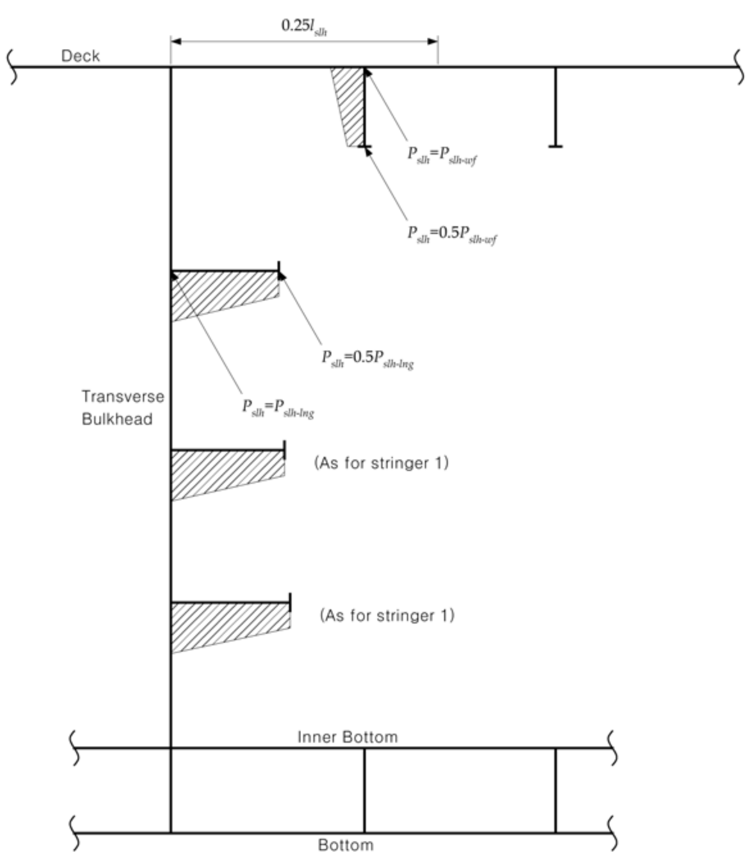
s_{wf} distance from bulkhead to web frame under consideration, in m

l_{slh} effective sloshing length, at considered filling height as defined in **4.2.2.3** and **4.2.2.4** for transverse tight and wash bulkheads respectively, in m

The distribution of pressure across the web frame is given in **Fig 7.4.3.**

4.2.2.6 For tanks with internal bulkhead stringers and/or web frames, the distribution of sloshing pressure, P_{slh}, across these members is shown in **Fig 7.4.3.**

Fig 7.4.3
Sloshing Pressure Distribution on Stringers and Web Frames



4.2.3 Sloshing pressure due to transverse liquid motion

4.2.3.1 The sloshing pressure in way of longitudinal tight and wash bulkheads due to transverse liquid motion, P_{slh-t}, for a particular filling height, is to be taken as:

$$P_{slh-t} = 7\rho g f_{slh}\left(\frac{b_{slh}}{B} - 0.3\right)GM^{0.75} \quad \text{kN/m}^2$$

Where:

ρ density of liquid in the tank, in tonnes/m^3, and is not to be taken as less than 1.025

b_{slh} effective sloshing breadth, see **4.2.3.3** and **4.2.3.4** for longitudinal tight bulkheads and longitudinal wash bulkheads respectively, not to be taken less than 0.3 B, in m.

GM metacentric height, is to be taken as 0.33 B for calculation of sloshing pressures in ballast tanks and 0.24 B for calculation of sloshing pressure in cargo tanks

f_{slh} $= 1-2\left(0.7-\frac{h_{fill}}{h_{max}}\right)^2$

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

h_{fill} filling height, measured from inner bottom, in m, see **Fig 7.4.1**

h_{max} maximum tank height excluding small hatchways, measured from inner bottom, in m, see **Fig 7.4.1**

g acceleration due to gravity, 9.81 m/s^2

4.2.3.2 The sloshing pressure due to transverse liquid motion, P_{slh-t}, is to be taken as a constant value over the full tank depth and is to be taken as the greater of the sloshing pressures calculated for filling heights from 0.05 h_{max} to 0.95 h_{max}, in 0.05 h_{max} increments.

4.2.3.3 For calculation of sloshing pressures in way of longitudinal tight bulkheads the effective sloshing breadth, b_{slh}, is to be taken as:

$$b_{slh} = \frac{(1+n_{wash-lng}\alpha_{wash-lng})(1+f_{grd}\alpha_{grd})b_{tk-h}}{(1+n_{wash-lng})(1+f_{grd})} \quad \text{m}$$

Where:

$n_{wash-lng}$ number of longitudinal wash bulkheads in the tank

$\alpha_{wash-lng}$ longitudinal wash bulkhead coefficient

$= \frac{A_{opn-wash-lng}}{A_{tk-lng-h}}$

α_{grd} girder coefficient

$= \frac{A_{opn-grd-h}}{A_{tk-lng-h}}$

$A_{opn-wash-lng}$ total area of openings in the longitudinal section in way of the wash bulkhead below the considered filling height, in m^2

$A_{tk-lng-h}$ total longitudinal cross sectional area of the tank below the considered filling height, in m^2

$A_{opn-grd-h}$ total area of openings in the longitudinal section below the considered filling height, in m^2

f_{grd} factor to account for longitudinal girders and longitudinal wash bulkheads in the tank:

$= n_{grd}/(1+n_{wash-lng})$

n_{grd} number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank

b_{tk-h} tank breadth at considered filling height, in m

4.2.3.4 For calculation of sloshing pressures in way of longitudinal wash bulkheads the effective sloshing breadth, b_{slh}, is to be taken as:

$$b_{slh} = \frac{\left[1+\left(n_{wash-lng}-1\right)\alpha_{wash-lng}\right]\left(1+f_{grd}\alpha_{grd}\right)b_{tk-h}}{\left(1+n_{wash-lng}\right)\left(1+f_{grd}\right)} \quad \text{m}$$

Where:

$n_{wash-lng}$ number of longitudinal wash bulkheads in the tank

$\alpha_{wash-lng}$ longitudinal wash bulkhead coefficient

$= \frac{A_{opn\text{-}wash\text{-}lng}}{A_{tk\text{-}lng\text{-}h}}$

α_{grd} girder coefficient

$= \frac{A_{opn\text{-}grd\text{-}h}}{A_{tk\text{-}lng\text{-}h}}$

$A_{opn-wash-lng}$ total area of openings in the longitudinal section in way of the wash bulkhead below the considered filling height, in m^2

$A_{tk-lng-h}$ total longitudinal cross sectional area of the tank below the considered filling height, in m^2

$A_{opn-grd-h}$ total area of openings in the longitudinal section below the considered filling height, in m^2

f_{grd} factor to account for longitudinal girders and longitudinal wash bulkheads in the tank:

$= n_{grd} / (1+n_{wash-lng})$

n_{grd} number of longitudinal girders, excluding longitudinal wash bulkheads, in the tank

b_{tk-h} tank breadth at considered filling height, in m

4.2.3.5 For tanks with internal longitudinal girders or web frames, the sloshing pressure on the girder/web frame adjacent to a longitudinal wash bulkhead, $P_{slh-grd}$, provided it is located within 0.25 b_{slh} from the bulkhead, is to be taken as:

$$P_{slh-grd} = P_{slh-t}\left(1-\frac{s_{grd}}{b_{slh}}\right)^2 \quad \text{kN/m}^2$$

Where:

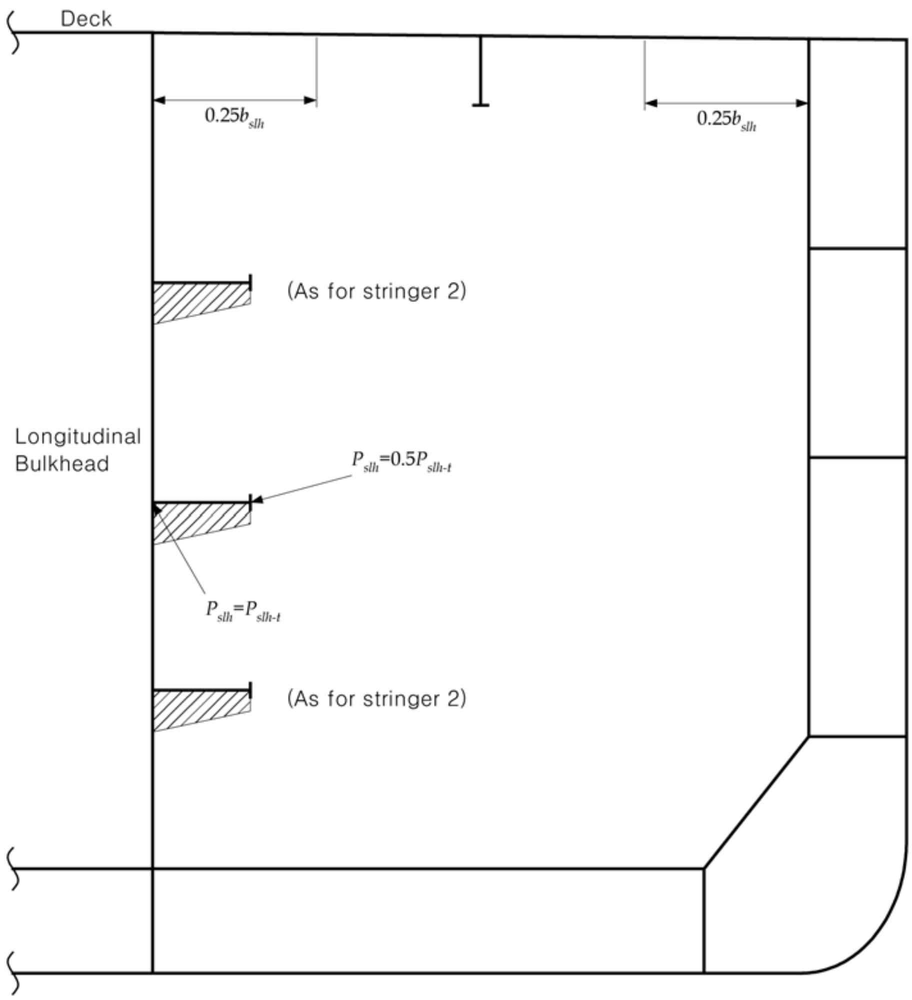
P_{slh-t} sloshing pressure acting on bulkhead due to transverse liquid motion, in kN/m^2, see **4.2.3.1**

s_{grd} distance from longitudinal bulkhead to longitudinal girder being considered, in m

b_{slh} effective sloshing breadth, see **4.2.3.3** and **4.2.3.4** for longitudinal tight bulkheads and longitudinal wash bulkheads respectively, in m

4.2.3.6 For tanks with internal longitudinal stringers and or girders/web frames, the distribution of sloshing pressure across these members is shown in **Fig 7.4.4.**

Fig 7.4.4
Pressure Distribution on Stringers and Longitudinal Girders



4.2.4 Minimum sloshing pressure

4.2.4.1 The minimum sloshing pressure, $P_{slh-min}$, in cargo and ballast tanks except tanks of cellular construction is to be taken as 20 kN/m^2.

4.2.4.2 The minimum sloshing pressure, $P_{slh-min}$, in cellular construction ballast tanks is to be taken as 12 kN/m^2.

4.3 Bottom Slamming Loads

4.3.1 Application and limitations

4.3.1.1 The slamming loads in this section apply to ships with $C_b \geq 0.7$ and bottom slamming draught $\geq 0.01\,L$ and $\leq 0.045\,L$.

4.3.2 Slamming pressure

4.3.2.1 The bottom slamming pressure, P_{slm}, is to be taken as the greater of:

$P_{slm-mt} = f_{slm} 130 g c_{slm-mt} e^{c_1}$ kN/m^2 for empty ballast tanks

$P_{slm-full} = f_{slm} 130 g c_{slm-full} e^{c_1} - c_{av} \rho g z_{ball}$ kN/m^2 for full ballast tanks

Where:

g acceleration due to gravity, 9.81 $\mathrm{m/s^2}$

f_{slm} longitudinal slamming distribution factor, see **Fig 7.4.5**, is to be taken as:

0 at $0.5L$

1 at $[0.175-0.5(C_{bl}-0.7)]L$ from F.P.

1 at $[0.1-0.5(C_{bl}-0.7)]L$ from F.P.

0.5 at, and forward of F.P.

intermediate values to be obtained by linear interpolation.

C_{bl} block coefficient, C_b, as defined in **Sec 4/1.1.9.1**, but not to be taken less than 0.7 or greater than 0.8

c_{slm-mt} slamming coefficient for empty ballast tanks

$$= 5.95 - 10.5\left(\frac{T_{FP-mt}}{L}\right)^{0.2}$$

$c_{slm-full}$ slamming coefficient for full ballast tanks

$$= 5.95 - 10.5\left(\frac{T_{FP-full}}{L}\right)^{0.2}$$

c_1 is to be taken as:

0 for $L \leq 180$ m

$= -0.0125(L-180)^{0.705}$ for $L > 180$ m

T_{FP-mt} design slamming ballast draught at F.P. with ballast tanks within the bottom slamming region empty as defined in **4.3.2.3**, in m

$T_{FP-full}$ design slamming ballast draught at F.P. with ballast tanks within the bottom slamming region full as defined in **4.3.2.4**, in m

c_{av} dynamic load coefficient, to be taken as 1.25

L rule length, in m, as defined in **Sec 4/1.1.1.1**

z_{ball} vertical distance from tank top to load point, in m

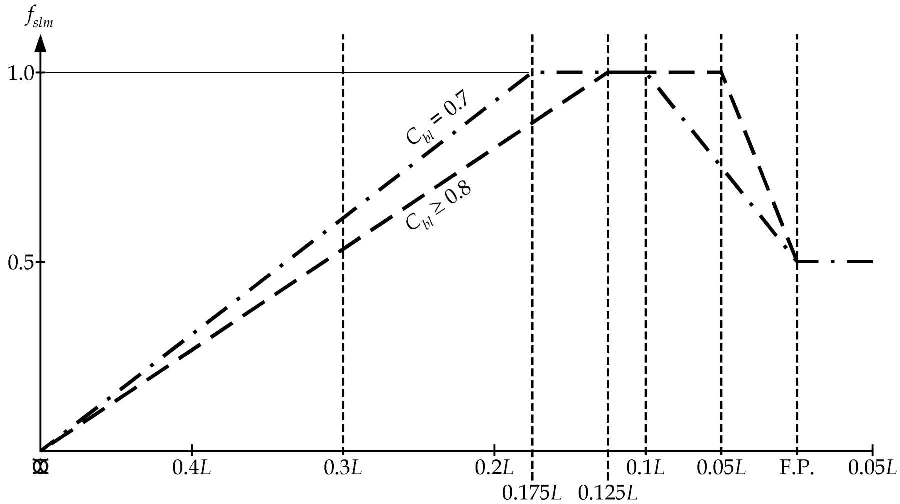
4.3.2.2 The designer is to provide the design slamming draughts T_{FP-mt} and $T_{FP-full}$.

4.3.2.3 The design slamming draught at the F.P., T_{FP-mt}, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for all seagoing conditions wherein the ballast tanks within the bottom slamming region are empty. This includes any loading conditions with tanks inside the bottom slamming region that use the "sequential" ballast water exchange method.

4.3.2.4 The design slamming draught at the F.P., $T_{FP-full}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for any seagoing conditions wherein the ballast tanks within the bottom slamming region are full. This includes any loading condition with tanks inside the bottom slamming region that use the "flow-through" ballast water exchange method.

4.3.2.5 The loading guidance information is to clearly indicate the design slamming draughts and the ballast water exchange method used for each ballast tank, see **Sec 8/1.1.**

Fig 7.4.5
Longitudinal Distribution of Slamming Pressure



4.4 Bow Impact Loads

4.4.1 Application and limitations

4.4.1.1 The bow impact pressure applies to the side structure in the area forward of $0.1L$ aft of F.P. and between the waterline at draught T_{bal} and the highest deck at side.

4.4.2 Bow impact pressure

4.4.2.1 The bow impact pressure, P_{im}, is to be taken as:

$$P_{im} = 1.025 f_{im} c_{im} V_{im}^2 \sin\gamma_{wl} \quad \text{kN/m}^2$$

Where:

f_{im} 0.55 at $0.1L$ aft of F.P.
0.9 at $0.0125L$ aft of F.P.
1.0 at and forward of F.P.
intermediate values to be obtained by linear interpolation

V_{im} impact speed, in m/s
$= 0.514 V_{fwd} \sin\alpha_{wl} + \sqrt{L}$

V_{fwd} forward speed, in knots
= 0.75 V but is not to be taken as less than 10

V service speed, in knots, as defined in **Sec 4/1.1.8.1**

α_{wl} local waterline angle at the position considered, but is not to be taken as less than 35 degrees, see **Fig 7.4.6.**

γ_{wl} local bow impact angle measured normal to the shell from the horizontal to the tangent line at the position considered but is not to be less than 50 degrees, see **Fig 7.4.6.**

C_{im} 1.0 for positions between draughts T_{bal} and T_{sc}
$= \sqrt{1 + \cos^2\left[90 \frac{(h_{fb} - 2h_0)}{h_{fb}}\right]}$ for positions above draught T_{sc}

h_{fb} vertical distance from the waterline at draught T_{sc} to the highest deck at side, see **Fig 7.4.6**, in m

h_0 vertical distance from the waterline at draught T_{sc}, to the position considered, see **Fig 7.4.6**, in m

L rule length, in m, as defined in **Sec 4/1.1.1.1**

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

T_{bal} minimum design ballast draught, in m, for the normal ballast condition as defined in **Sec 4/1.1.5.2**

WL_j waterline at the position considered, see **Fig 7.4.6**

Guidance Note

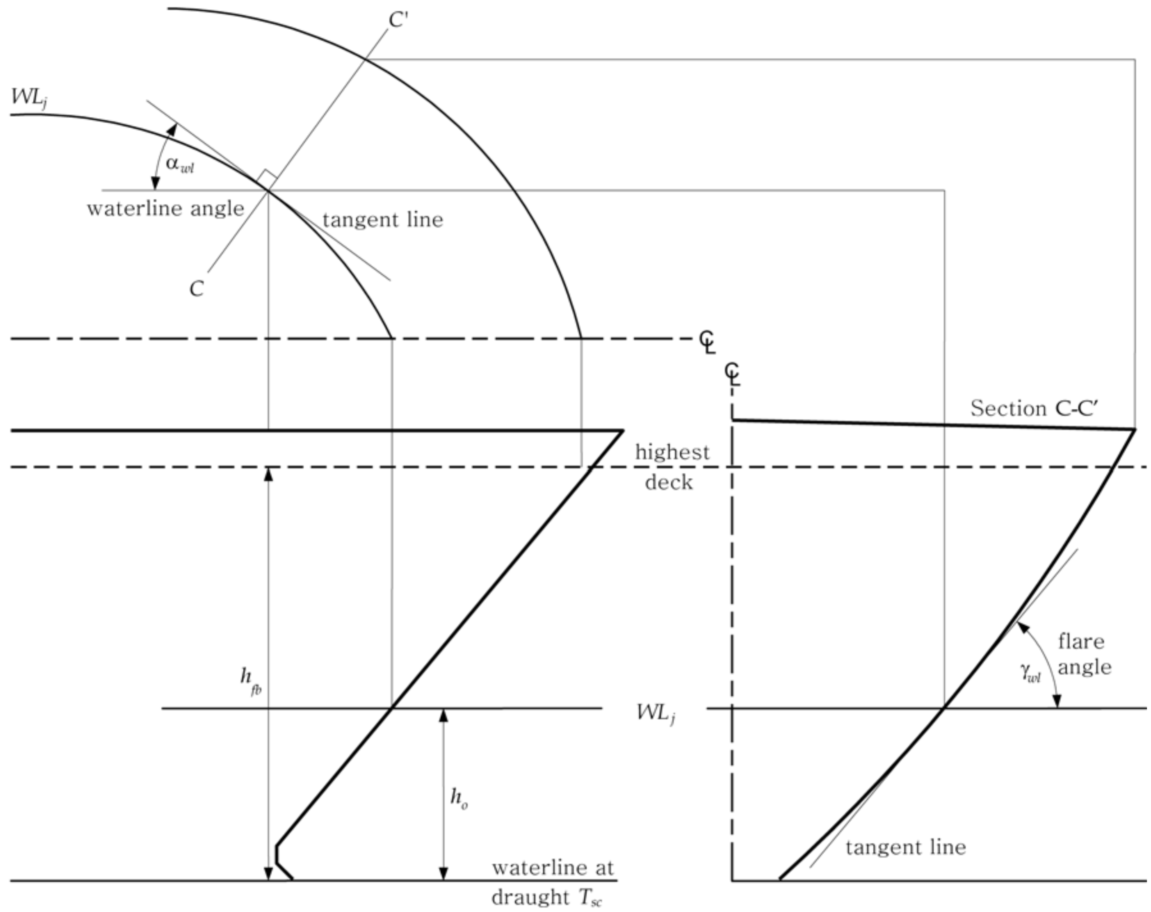
Where local bow impact angle measured normal to the shell, γ_{wl}, is not available, this angle may be taken as:

$$\gamma_{wl} = \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$$

Where

β_{pl} local body plan angle at the position considered from the horizontal to the tangent line, but is not to be less than 35 degrees

Fig 7.4.6
Definition of Bow Geometry



5 Accidental Loads

5.1.1 Local Pressure

5.1.1.1 The pressure in compartments and tanks in flooded condition or damaged condition is to be taken as $P_{in\text{-}flood}$, see **2.2.3.4.**

6 Combination of Loads

6.1 General

6.1.1 Application

6.1.1.1 The design load combinations S, $S+D$, and A are to be used for scantling calculations for the scantling requirements and strength assessment (by FEM). design load combinations are defined in **Sec 2/4.2.2** and the relevant loads and load combination are to be taken as given in **6.2.**

6.1.1.2 The dynamic loads, D, consist of several dynamic load cases. For each dynamic load case, the envelope load values as given in **Sub-Sec 3** are multiplied with dynamic load combination factors to give simultaneously acting dynamic loads. The procedures for calculating the simultaneously acting dynamic loads are given in **6.3.** The dynamic load combination factors are given in **6.4** for strength assessment (by FEM) and in **6.5** for scantling requirements.

6.2 Design Load Combination

6.2.1 General

6.2.1.1 The design load combinations are given in **Table 7.6.1.**

Table 7.6.1
Design Load Combinations

Load components		S	$S + D$	A
$M_{v-total}$		$M_{sw-harb}$	M_{sw-sea} + M_{wv}	-
$M_{h-total}$		-	M_h	-
Q		$Q_{sw-harb}$	Q_{sw-sea} + Q_{wv}	-
P_{ex}	Weather Deck	-	$P_{wdk-dyn}$	-
	Hull envelope	P_{hys}	P_{hys} + P_{wv-dyn}	-
P_{in}	Ballast tanks (BWE with sequential filling method)	the greater of a) $P_{in-test}$ b) P_{in-air} + P_{drop}	P_{in-tk} + P_{in-dyn}	$P_{in-flood}$
	Ballast tanks (BWE with flow-through method)	the greater of a) $P_{in-test}$ b) P_{in-air} + P_{drop}	P_{in-air} + P_{drop} + P_{in-dyn}	$P_{in-flood}$
	Cargo tanks including cargo tanks designed for filling with water ballast	the greater of a) $P_{in-test}$ b) P_{in-tk} + P_{valve}	P_{in-tk} + P_{in-dyn}	-
	Other tanks with liquid filling	the greater of a) $P_{in-test}$ b) P_{in-air}	P_{in-tk} + P_{in-dyn}	$P_{in-flood}$
	Watertight boundaries	-	-	$P_{in-flood}$
P_{dk}	Internal decks for dry spaces	P_{stat}	P_{stat} + P_{dk-dyn}	-
	Decks for heavy units	F_{stat}	F_{stat} + F_{dk-dyn}	-

(Header cell: Design Load Combination / Load components)

Table 7.6.1 (Continued)
Design Load Combinations

Note:
1. Separate load requirements may be specified in strength assessment (FEM) and scantling requirements.

Where:

$M_{v\text{-}total}$	design vertical bending moment, in kNm	
$M_{sw\text{-}perm\text{-}harb}$	permissible hull girder hogging and sagging still water bending moment envelopes for harbour/sheltered water operation, in kNm	see **2.1.1**
$M_{sw\text{-}perm\text{-}sea}$	permissible hull girder hogging and sagging still water bending moment envelopes for seagoing operation, in kNm	see **2.1.1**
M_{wv}	vertical wave bending moment for a considered dynamic load case, in kNm	see **6.3.2.1**
$M_{h\text{-}total}$	design horizontal bending moment, in kNm	
M_h	horizontal wave bending moment for a considered dynamic load case, in kNm	see **6.3.3.1**
Q	design vertical shear force, in kN	
$Q_{sw\text{-}perm\text{-}harb}$	permissible hull girder positive and negative still water shear force limits for harbour/sheltered water operation, in kN	see **2.1.3**
$Q_{sw\text{-}perm\text{-}sea}$	permissible hull girder positive and negative still water shear force limits for seagoing operation, in kN	see **2.1.3**
Q_{wv}	vertical wave shear force for a considered dynamic load case, in kN	see **6.3.4.1**
P_{ex}	design sea pressure, in kN/m^2	
P_{hys}	static sea pressure at considered draught, in kN/m^2	see **2.2.2.1**
$P_{wv\text{-}dyn}$	dynamic wave pressure for a considered dynamic load case, in kN/m^2	see **6.3.5**
$P_{wdk\text{-}dyn}$	green sea load for a considered dynamic load case, in kN/m^2	see **6.3.6**
P_{in}	design tank pressure, in kN/m^2	
$P_{in\text{-}test}$	tank testing pressure, in kN/m^2	see **2.2.3.5**
$P_{in\text{-}air}$	static tank pressure in the case of overfilling or filling during flow through ballast water exchange, in kN/m^2	see **2.2.3.2**
P_{drop}	added overpressure due to liquid flow through air pipe or overflow pipe, in kN/m^2	see **2.2.3.3**
P_{valve}	setting of pressure relief valve, in kN/m^2	see **2.2.3.5**
$P_{in\text{-}tk}$	static tank pressure, in kN/m^2	see **2.2.3.1**
$P_{in\text{-}dyn}$	dynamic tank pressure for a considered dynamic load case, in kN/m^2	see **6.3.7**
$P_{in\text{-}flood}$	pressure in compartments and tanks in flooded or damaged condition, in kN/m^2	see **2.2.3.4**
P_{stat}	static pressure on decks and inner bottom, in kN/m^2	see **2.2.4.1**
P_{dk}	design deck pressure, in kN/m^2	
$P_{dk\text{-}dyn}$	dynamic deck pressure on decks, inner bottom and hatch covers for a considered dynamic load case, in kN/m^2	see **6.3.8.1**
F_{stat}	load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN	see **2.2.5.1**
$F_{dk\text{-}dyn}$	dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN	see **6.3.8.2**

6.3 Application of Dynamic Loads

6.3.1 Heading correction factor and dynamic load combination factors

6.3.1.1 The heading correction factor, f_β, is to be taken as:

f_β = 0.8 for beam sea dynamic load cases

= 1.0 for all other dynamic load cases

6.3.1.2 The dynamic load combination factors used for the calculations of the simultaneously acting dynamic loads, are to be taken as given in **Table 7.6.2** for strength assessment by FEM, see **6.4.** Dynamic load factors are to be taken as given in **Table 7.6.4** to **Table 7.6.9** for scantling assessment, see **6.5.**

6.3.2 Vertical wave bending moment for a considered dynamic load case

6.3.2.1 The simultaneously acting vertical wave bending moment, M_{wv}, is to be taken as:

$M_{wv} = f_\beta f_{mv} M_{wv-hog}$ kNm for $f_{mv} \geq 0$

$M_{wv} = -f_\beta f_{mv} M_{wv-sag}$ kNm for $f_{mv} < 0$

Where:

M_{wv-hog} hogging vertical wave bending moment, in kNm, as defined in **3.4.1.1**

M_{wv-sag} sagging vertical wave bending moment, in kNm, as defined in **3.4.1.1**

f_{mv} dynamic load combination factor for vertical wave bending moment for considered dynamic load case, see **6.3.1.2**

f_β heading correction factor, as defined in **6.3.1.1**

6.3.3 Horizontal wave bending moment for a considered dynamic load case

6.3.3.1 The simultaneously acting horizontal wave bending moment, M_h, is to be taken as:

$M_h = f_\beta f_{mh} M_{wv-h}$ kNm

Where:

M_{wv-h} horizontal wave bending moment, in kNm, as defined in **3.4.2**

f_{mh} dynamic load combination factor for horizontal wave bending moment for considered dynamic load case, see **6.3.1.2**

f_β heading correction factor, as defined in **6.3.1.1**

6.3.4 Vertical wave shear force for a considered dynamic load case

6.3.4.1 The simultaneously acting vertical wave shear force, Q_{wv}, is to be taken as:

$Q_{wv} = f_\beta f_{qv} Q_{wv-pos}$ kN for $f_{qv} \geq 0$

$Q_{wv} = -f_\beta f_{qv} Q_{wv-neg}$ kN for $f_{qv} < 0$

Where:

Q_{wv-pos} envelope positive vertical wave shear force, in kN, as defined in **3.4.3**

Q_{wv-neg} envelope negative vertical wave shear force, in kN, as defined in **3.4.3**

f_{qv} dynamic load combination factor for vertical wave shear force for considered dynamic load case, see **6.3.1.2**

f_β heading correction factor, as defined in **6.3.1.1**

6.3.5 Dynamic wave pressure distribution for a considered dynamic load case

6.3.5.1 The simultaneously acting dynamic wave pressure, P_{wv-dyn}, for the port and starboard side within the cargo tank region for a considered dynamic load case is to be taken as follows, but not to be less than $-\rho_{sw} g (T_{LC} - z)$ below still waterline or less than 0 above still waterline:

$$P_{wv-dyn} = P_{ctr} + \frac{|y|}{0.5B_{local}}\left(P_{bilge} - P_{ctr}\right)$$ between centreline and start of bilge

$$P_{wv-dyn} = P_{bilge} + \frac{z}{T_{LC}}\left(P_{WL} - P_{bilge}\right)$$ between end of bilge and still waterline

$$P_{wv-dyn} = P_{WL} - 10(z - T_{LC})$$ for side-shell above still waterline

intermediate values of P_{wv-dyn} around the bilge are to be obtained by linear interpolation along the vertical distance

Where:

P_{ctr} dynamic wave pressure at bottom centreline, to be taken as:

$= f_{ctr} P_{ex-max}$ kN/m^2

P_{bilge} dynamic wave pressure at z = 0 and y = $B_{local}/2$, to be taken as:

$= f_{bilge} P_{ex-max}$ kN/m^2

P_{WL} dynamic wave pressure at waterline, to be taken as:

$= f_{WL} P_{ex-max}$ kN/m^2

P_{ex-max} envelope maximum dynamic wave pressure, in kN/m^2, as defined in **3.5.2.2**

f_{WL} dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see **6.3.1.2**

f_{bilge} dynamic load combination factor for dynamic wave pressure at bilge for considered dynamic load case, see **6.3.1.2**

f_{ctr} dynamic load combination factor for dynamic wave pressure at centreline for considered dynamic load case, see **6.3.1.2**

B_{local} local breadth at waterline for considered draught , in m

T_{LC} draught in the loading condition being considered, in m

y transverse coordinate, in m

z vertical coordinate, in m

ρ_{sw} density of sea water, 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

6.3.5.2 The simultaneously acting dynamic wave pressure for the port and starboard side outside the cargo region, P_{wv-dyn}, for a considered dynamic load case is to be obtained by linear interpolation between P_{ctr} and P_{WL}, but not to be taken less than $-\rho_{sw} g (T_{LC} - z)$ below still waterline or less than 0 above still waterline.

$$P_{wv-dyn} = P_{ctr} + \frac{z}{T_{LC}}(P_{WL} - P_{ctr})$$ between bottom centreline and still waterline

$$P_{wv-dyn} = P_{WL} - 10(z - T_{LC})$$ above still waterline

Where:

P_{ctr} dynamic wave pressure at bottom centreline, and is to be taken as:

$f_{ctr} P_{ex-\max}$ kN/m^2

P_{WL} dynamic wave pressure at still waterline, and is to be taken as:

$f_{WL} P_{ex-\max}$ kN/m^2

P_{ex-max} envelope maximum dynamic wave pressure, in kN/m^2, as defined in **3.5.2.2**

f_{WL} dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see **6.3.1.2**

f_{ctr} dynamic load combination factor for dynamic wave pressure at centreline for considered dynamic load case, see **6.3.1.2**

T_{LC} draught in the loading condition being considered, in m

z vertical coordinate, in m

ρ_{sw} density of sea water, 1.025 tonnes/m^3

g acceleration due to gravity, 9.81 m/s^2

6.3.5.3 **Fig 7.6.1** to **Fig 7.6.3** illustrates simultaneously acting dynamic wave pressures.

Fig 7.6.1
Dynamic Wave Pressure for Head Sea Dynamic Load Cases

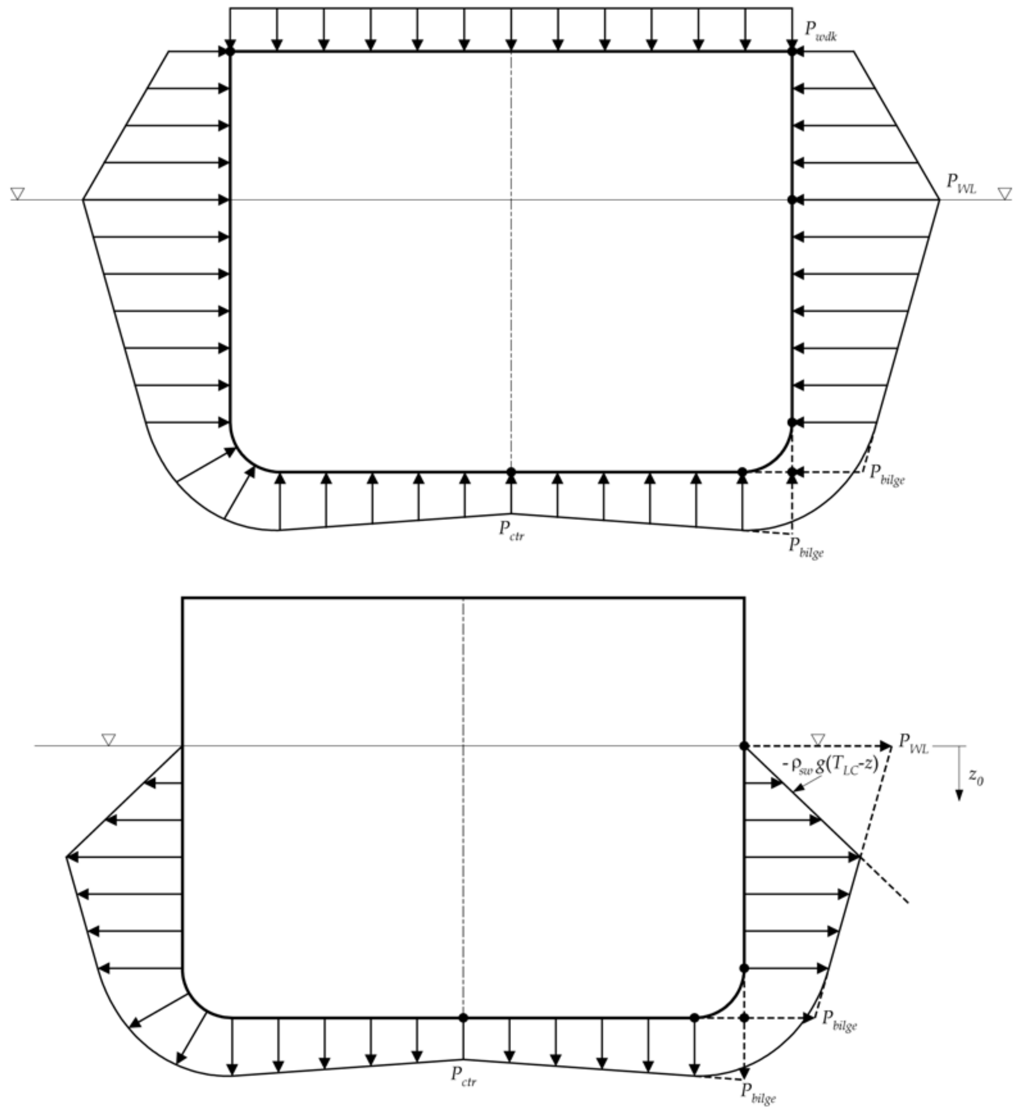


Fig 7.6.2
Dynamic Wave Pressure for Beam and Oblique Sea Dynamic Load Cases

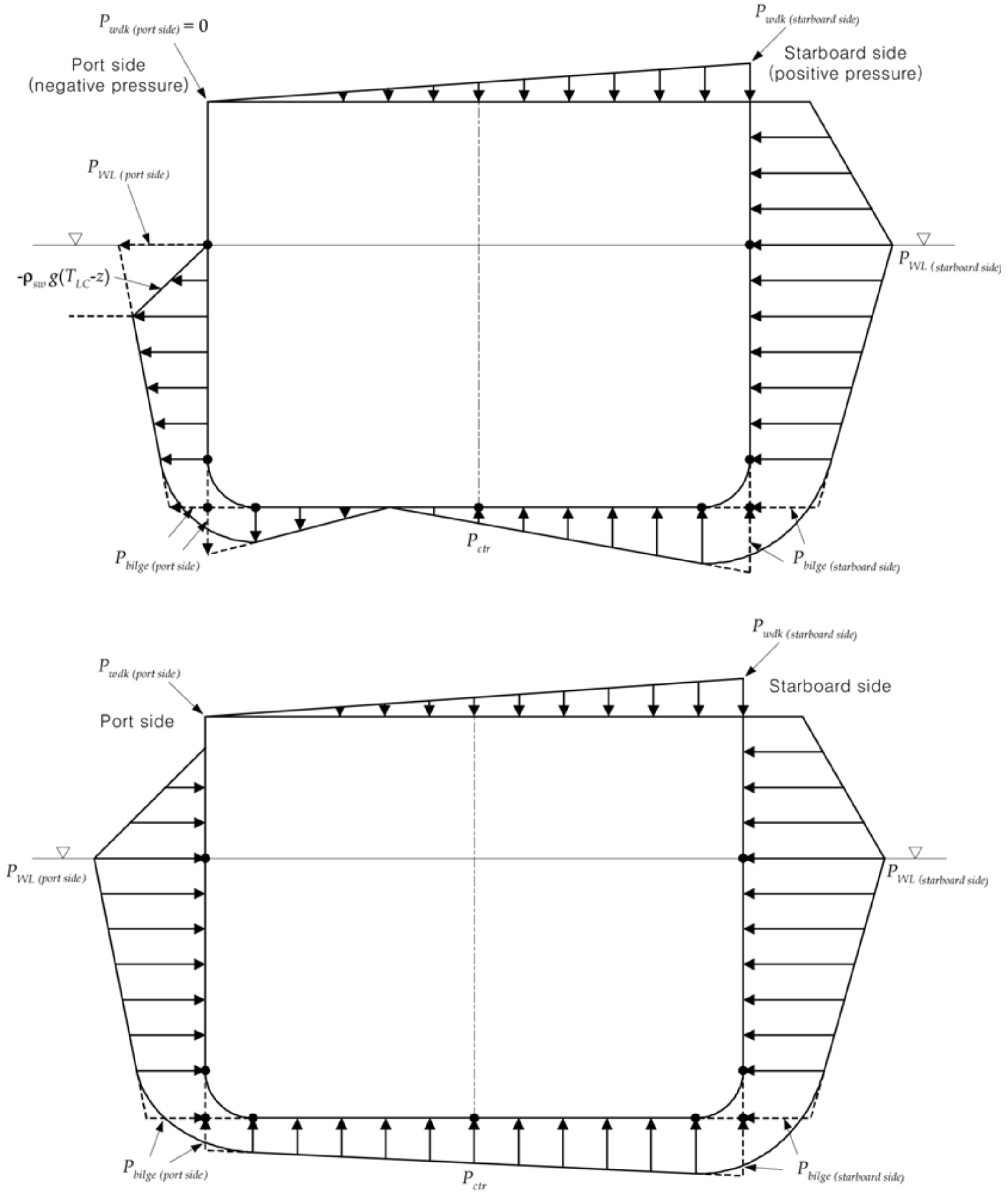
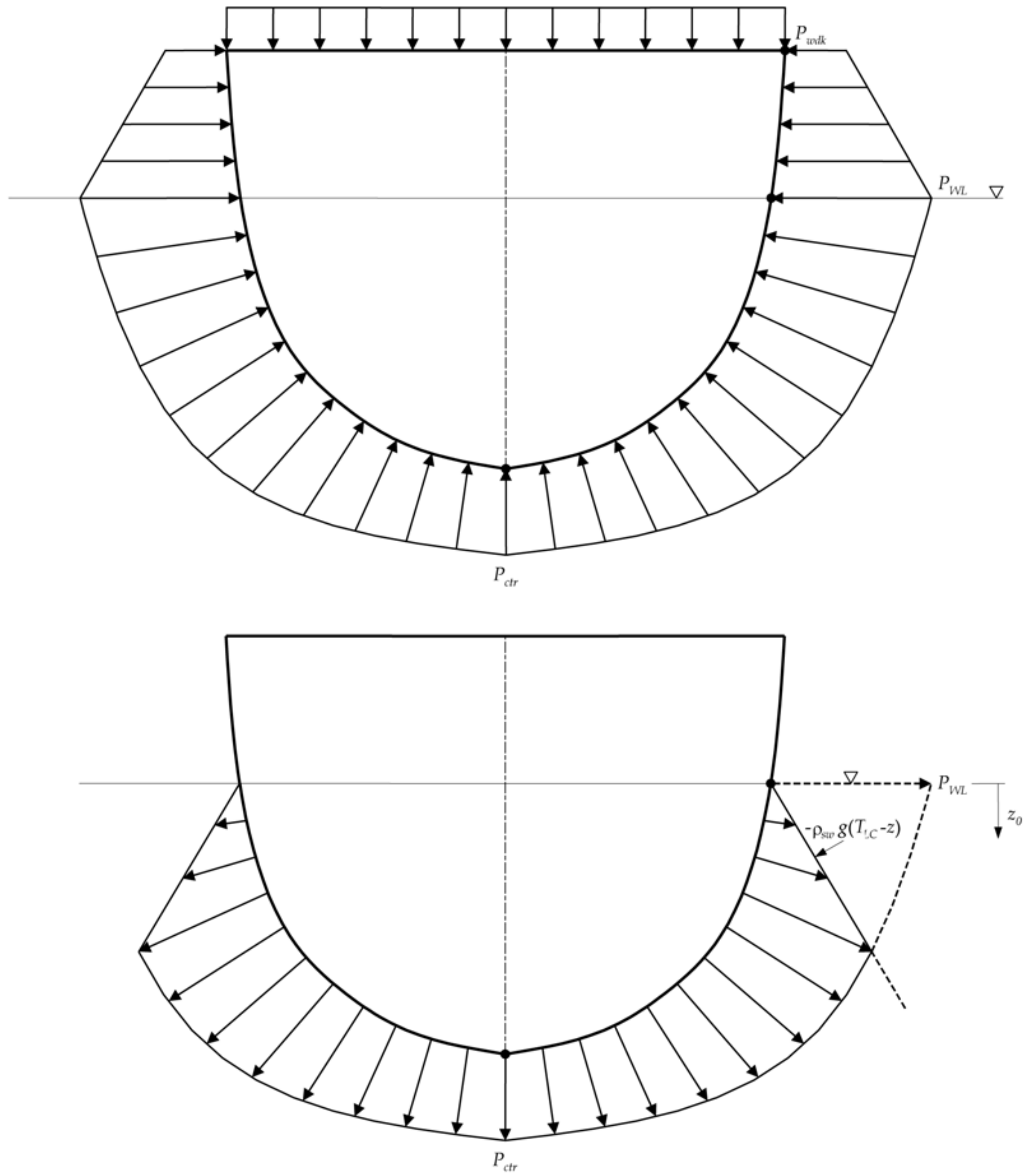


Fig 7.6.3
Pressure Distribution for Wave Crest and Wave Trough for Forward and Aft



6.3.6 Green sea load for a considered dynamic load case

6.3.6.1 The simultaneously acting green sea load on the weather deck, $P_{wdk-dyn}$, for strength assessment is obtained by linear interpolation between P_{wdk-pt} and $P_{wdk-stb}$:

The green sea load at the port side, P_{wdk-pt}, is to be taken as the greater of:

$$P_{wdk-pt} = f_{1-dk}\left(f_{WL} f_{op} P_{1-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

$$P_{wdk-pt} = 0.8\left(f_{WL} P_{2-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

P_{wdk-pt} is not to be taken as less than 34.3 kN/m^2 when $f_{WL} = 1.0$ and the ship's draught used in the design load case is greater or equal to 0.9 T_{sc}

The green sea load at the starboard side, $P_{wdk-stb}$, is to be taken as the greater of:

$$P_{wdk-stb} = f_{1-dk}\left(f_{WL} f_{op} P_{1-WL} - 10 z_{dk-T}\right) \quad \text{kN/m}^2$$

$P_{wdk-stb}$ = $0.8(f_{WL}P_{2-WL} - 10z_{dk-T})$ $\quad kN/m^2$

$P_{wdk-stb}$ is not to be taken as less than 34.3 kN/m^2 when $f_{WL} = 1.0$ and the ship's draught used in the design load case is greater or equal to 0.9 T_{sc}

P_{wdk-pt} and $P_{wdk-stb}$ are not to be taken as less than 0.

Where:

f_{1-dk} = $0.8 + \frac{L}{750}$

f_{op} = 1.0 at and forward of 0.2 L from A.P.
= 0.8 at and aft of A.P.
intermediate values to be obtained by linear interpolation

P_{1-WL} P_1 pressure at still waterline for considered draught, in kN/m^2, see **3.5.2.1**

P_{2-WL} P_2 pressure at still waterline for considered draught, in kN/m^2, see **3.5.2.1**

f_{WL} dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see **6.3.1.2**

z_{dk-T} distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in m

L rule length, in m, as defined in **Sec 4/1.1.1.1**

6.3.6.2 The simultaneously acting green sea load on the weather deck, $P_{wdk-dyn}$, for scantling requirements is to be taken as the greater of:

$P_{wdk-dyn}$ = $f_{1-dk}(f_{WL}f_{op}P_{1-WL} - 10z_{dk-T})$ $\quad kN/m^2$

but is not to be taken as less than 34.3 kN/m^2 when $f_{WL} = 1.0$ and the ship's draught used in the design load case is greater or equal to 0.9 T_{sc}

$P_{wdk-dyn}$ = $0.8f_{2-dk}(f_{WL}P_{2-WL} - 10z_{dk-T})$ $\quad kN/m^2$

but is not to be taken as less than 34.3 kN/m^2 when $f_{WL} = 1.0$ and $f_{2-dk} = 1.0$ and the ship's draught used in the design load case is greater or equal to 0.9 T_{sc}

$P_{wdk-dyn}$ = 0

Where:

f_{1-dk} = $0.8 + \frac{L}{750}$

f_{2-dk} = $0.5 + \frac{|y|}{B_{wdk}}$

f_{op} = 1.0 at and forward of 0.2 L from A.P.
= 0.8 at and aft of A.P.
intermediate values to be obtained by linear interpolation

P_{1-WL} P_1 pressure at still waterline for considered draught, in kN/m^2

P_{2-WL} P_2 pressure at still waterline for considered draught, in kN/m^2

f_{WL} dynamic load combination factor for dynamic wave pressure at still waterline for considered dynamic load case, see **6.3.1.2**

y transverse coordinate, in m

z_{dk-T} distance from the deck at side to the still waterline at the applicable draught for the loading condition being considered, in m

B_{wdk} local breadth at the weather deck, in m

L rule length, in m, as defined in **Sec 4/1.1.1.1**

6.3.7 Dynamic tank pressure for a considered dynamic load case

6.3.7.1 The simultaneously acting dynamic tank pressure, P_{in-dyn}, for tanks in the cargo region, is to be taken as:

$$P_{in-dyn} = f_\beta \left(f_v P_{in-v} + f_t P_{in-t} + f_{lng} P_{in-lng} \right) \quad \text{kN/m}^2$$

Where:

P_{in-v} envelope dynamic tank pressure due to vertical acceleration as defined in **3.5.4.1** with reference point z_0 taken as:
(a) top of tank
(b) top of air pipe/overflow for ballast tanks designed for BWE by flow-through method
see **Fig 7.6.4**, in kN/m^2

P_{in-t} envelope dynamic tank pressure due to transverse acceleration as defined in **3.5.4.2** with reference point y_0 taken as:
(a) tank top towards port side for $f_t > 0$
(b) tank top towards starboard side for $f_t < 0$
see **Fig 7.6.5**, in kN/m^2

P_{in-lng} envelope dynamic tank pressure due to longitudinal acceleration as defined in **3.5.4.3** with reference point x_0 taken as:
(a) forward bulkhead for $f_{lng} > 0$
(b) aft bulkhead of the tank for $f_{lng} < 0$
see **Fig 7.6.6**, in kN/m^2

f_v dynamic load combination factor for vertical acceleration for considered dynamic load case. f_v is to be taken as appropriate to the tank location, see **6.3.1.2**

f_t dynamic load combination factor for transverse acceleration for considered dynamic load case, see **6.3.1.2**

f_{lng} dynamic load combination factor for longitudinal acceleration for considered dynamic load case. f_{lng} is to be taken as most appropriate dependent on tank location, see **6.3.1.2**

f_β heading correction factor, as defined in **6.3.1.1**

x_0 longitudinal coordinate of reference point, in m

y_0 transverse coordinate of reference point, in m

z_0 vertical coordinate of reference point, in m

Note

1. For a non-parallel tank, y_0 should be selected from either forward or aft bulkhead corresponding to the reference point x_0. If the longitudinal load combination factor $f_{lng} = 0$, y_0 should be selected from the bulkhead with the greater breadth.
2. The vertical, transverse and longitudinal acceleration is to be taken at the centre of gravity of the tank under consideration.

6.3.7.2 The simultaneously acting dynamic tank pressure for tanks outside the cargo region, P_{in-dyn}, is to be taken as:

$$P_{in-dyn} = f_\beta \left(f_{v-mid} P_{in-v} + \left| f_t P_{in-t} \right| + \left| f_{lng} P_{in-lng} \right| \right) \quad \text{kN/m}^2$$

Where:

P_{in-v} envelope dynamic wave pressure due to vertical acceleration as given in **3.5.4.1** with

reference point z_0 taken as:
(a) top of tank
(b) top of air pipe for ballast tanks design for BWE by flow through
see **Fig 7.6.5**, in $\mathrm{kN/m^2}$

P_{in-t} envelope dynamic tank pressure due to transverse acceleration as given in **3.5.4.2** using $(y_0 - y)$ as extreme breadth of tank, in $\mathrm{kN/m^2}$

P_{in-lng} envelope dynamic tank pressure due to longitudinal acceleration as given in **3.5.4.3** using $(x_0 - x)$ as extreme length of tank, in $\mathrm{kN/m^2}$

f_{v-mid} dynamic load combination factor for vertical acceleration for considered dynamic load case, see **6.3.1.2**

f_t dynamic load combination factor for transverse acceleration for considered dynamic load case, see **6.3.1.2**

f_{lng} dynamic load combination factor for longitudinal acceleration for considered dynamic load case, see **6.3.1.2**

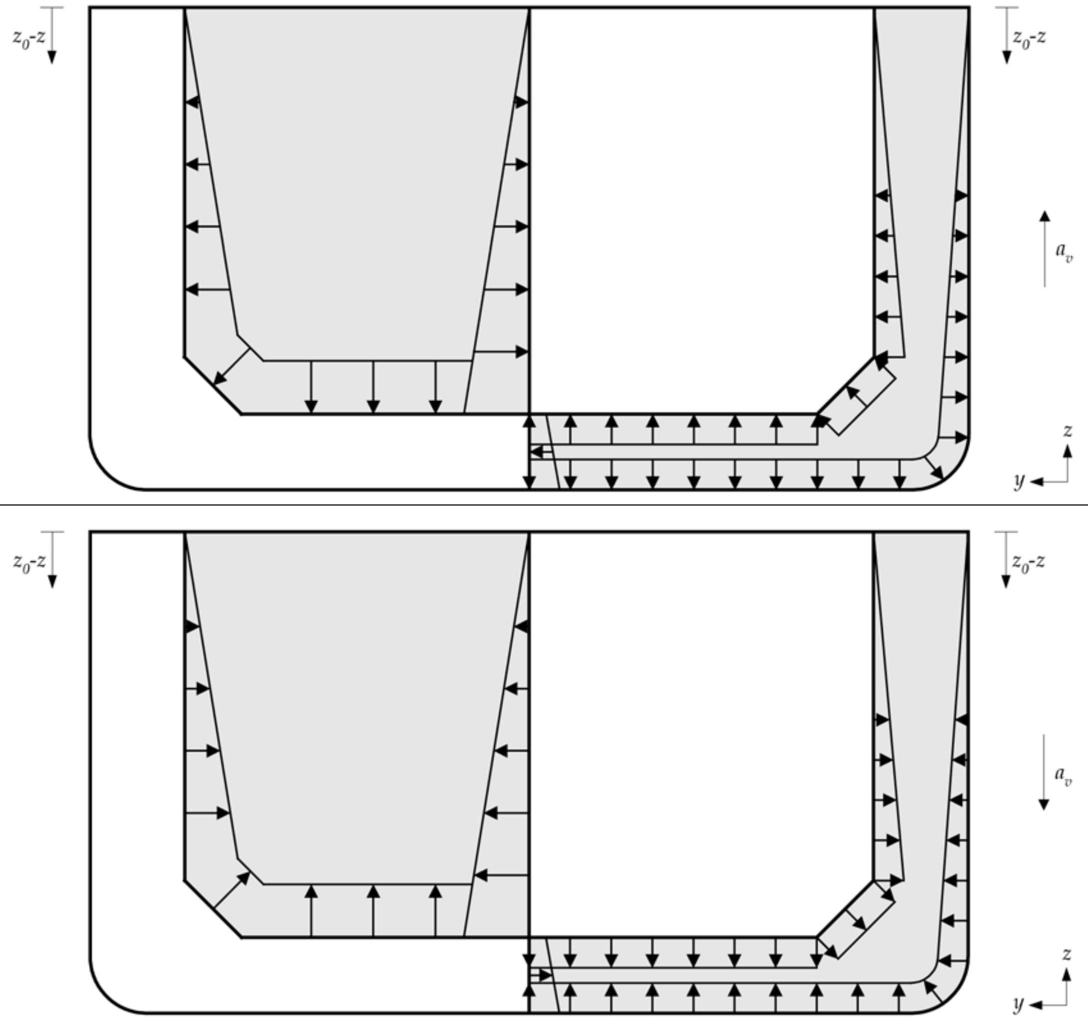
f_β heading correction factor, as defined in **6.3.1.1**

x_0 longitudinal coordinate of reference point, in m

y_0 transverse coordinate of reference point, in m

z_0 vertical coordinate of reference point, in m

Fig 7.6.4
Dynamic Tank Pressure in Cargo Tank (Left) and Ballast Tank (Right) due to Positive and Negative Vertical Tank Acceleration



Note
For ballast tank which is designed for ballast water exchange by flow-through method, reference point z_0 is to be taken as top of air pipe/overflow of the tank.

Fig 7.6.5
Dynamic Tank Pressure in Cargo Tank (Left) and Ballast Tank (Right) due to Negative and Positive Transverse Tank Acceleration

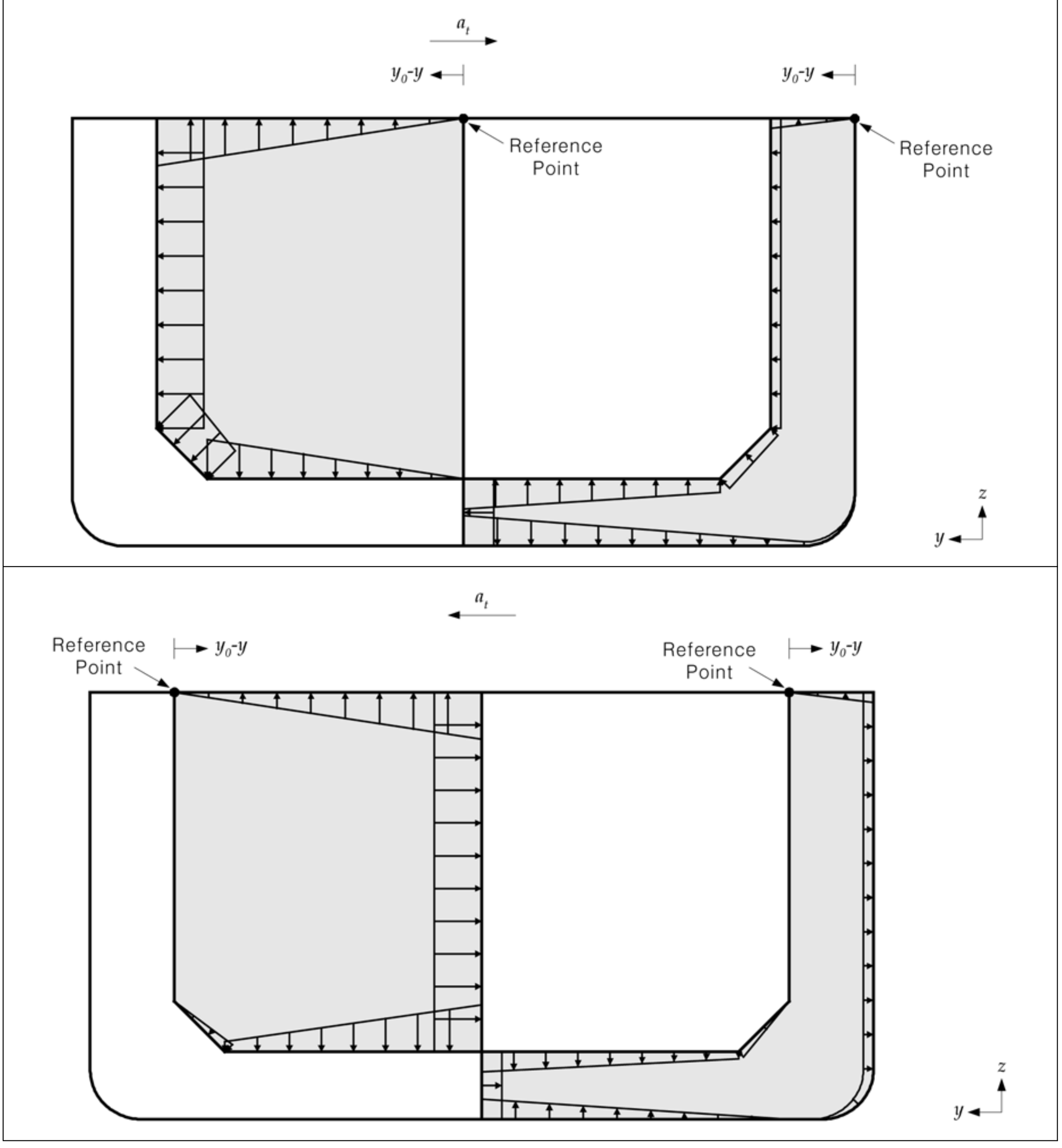
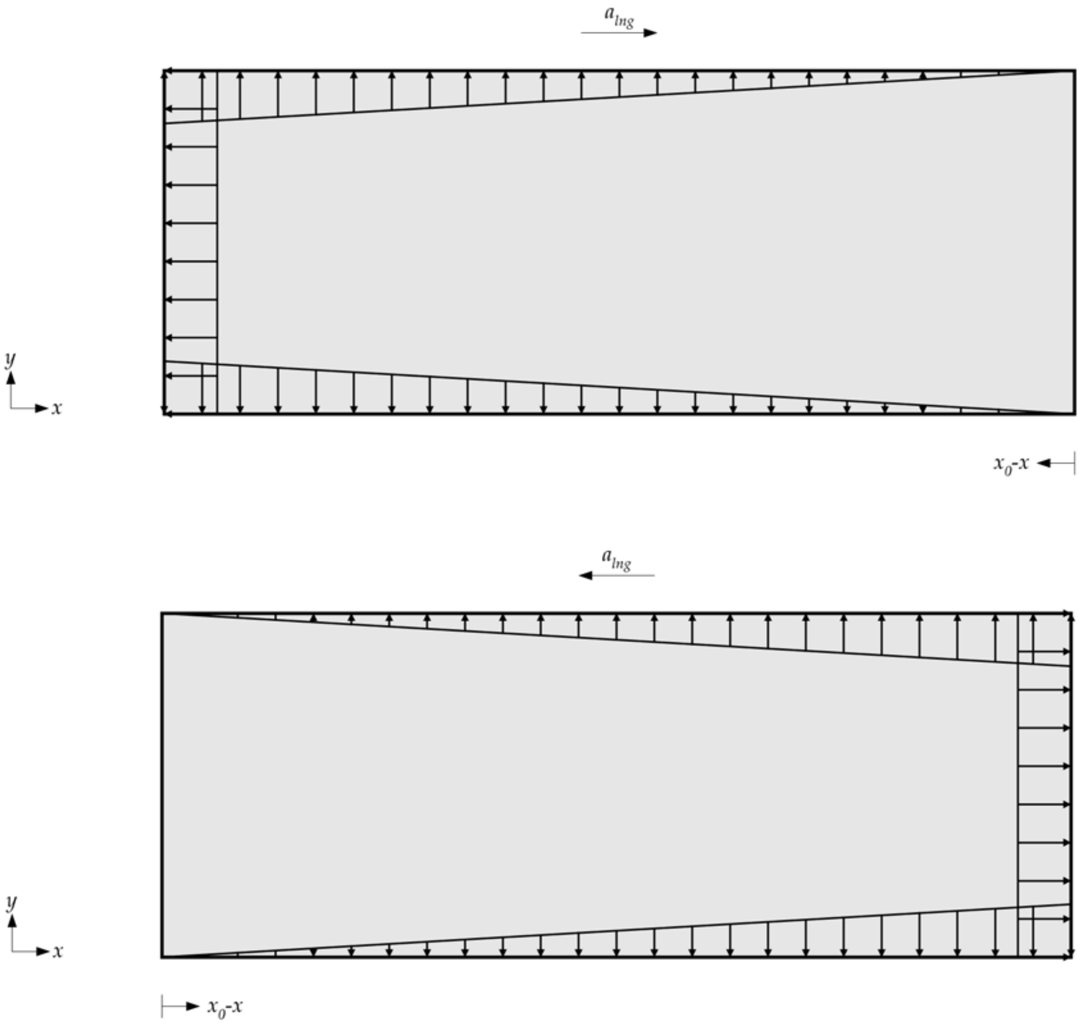


Fig 7.6.6
Dynamic Tank Pressure in Tanks due to Positive and Negative Longitudinal Acceleration



6.3.8 Dynamic deck loads for a considered dynamic load case

6.3.8.1 The simultaneously acting dynamic deck load for uniformly distributed load, P_{dk-dyn}, on the enclosed upper deck, where a forecastle or poop is fitted, and also on all lower decks, is to be taken as:

$$P_{dk-dyn} = f_\beta f_{v-mid} P_{deck-dyn} \quad \text{kN/m}^2$$

Where:

$P_{deck-dyn}$ envelope dynamic deck pressure on decks, inner bottom and hatch covers, in kN/m^2, as defined in **3.5.5.1**

f_{v-mid} dynamic load combination factor for vertical acceleration for considered dynamic load case, see **6.3.1.2**

f_β heading correction factor, as defined in **6.3.1.1**

6.3.8.2 The simultaneously acting dynamic vertical force for heavy units, F_{dk-dyn}, acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, is to be taken as:

$$F_{dk-dyn} = f_\beta f_{v-mid} F_v \quad \text{kN}$$

Where:

F_v envelope vertical dynamic load from heavy units, in kN, as defined in **3.5.6**

f_{v-mid} dynamic load combination factor for vertical acceleration for the considered dynamic load case, see **Table 7.6.2** and **Table 7.6.4** to **7.6.9**

f_β heading correction factor, as defined in **6.3.1.1**

6.4 Dynamic Load Cases and Dynamic Load Combination Factors for Strength Assessment

6.4.1 General

6.4.1.1 For strength assessment (FEM) the dynamic load cases given in **Table 7.6.2** are to be applied in accordance with the requirements of **Appendix B** for Design Load Combination $S+D$. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in **Table 7.6.2.**

Table 7.6.2
Dynamic Load Cases for Strength Assessment (by FEM)

Wave direction			Head sea				Beam sea		Oblique sea	
Max response			M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Sagging)	Q_{wv} (Hogging)	a_v		M_{wv-h} (Hogging)	
Dynamic Load Case			1	2	3	4	5a	5b	6a	6b
Global loads	M_{wv}	f_{mv}	-1.0	1.0	-1.0	1.0	0.0	0.0	0.4	0.4
	Q_{wv}	f_{qv}	1.0	-1.0	1.0	-1.0	0.0	0.0	0.0	0.0
	M_{wv-h}	f_{mh}	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-1.0
Accelerations	a_v	f_v	0.5	-0.5	0.3	-0.3	1.0	1.0	-0.1	-0.1
	a_t	f_t	0.0	0.0	0.0	0.0	-0.6	0.6	0.0	0.0
	a_{lng}	f_{lng}	-0.6	0.6	-0.6	0.6	-0.5	-0.5	0.5	0.5
Dynamic wave pressure for port side	P_{WL}	f_{WL}	-0.3	0.3	0.1	-0.1	1.0	0.4	0.6	0.0
	P_{bilge}	f_{bilge}	-0.3	0.3	0.1	-0.1	1.0	0.4	0.4	0.0
	P_{ctr}	f_{ctr}	-0.7	0.7	0.3	-0.3	0.9	0.9	0.5	0.5
Dynamic wave pressure for starboard side	P_{WL}	f_{WL}	-0.3	0.3	0.1	-0.1	0.4	1.0	0.0	0.6
	P_{bilge}	f_{bilge}	-0.3	0.3	0.1	-0.1	0.4	1.0	0.0	0.4
	P_{ctr}	f_{ctr}	-0.7	0.7	0.3	-0.3	0.9	0.9	0.5	0.5

Where:

Symbols are as defined in **3.3**, **6.3.5.1**, **Table 7.6.1** and below:

f_{v-mid} dynamic load combination factor associated with the vertical acceleration of a centre cargo and ballast tank

f_{v-pt} dynamic load combination factor associated with the vertical acceleration of a port cargo and side ballast tank

f_{v-stb} dynamic load combination factor associated with the vertical acceleration of a starboard cargo and side ballast tank

Note:

1. Load parameters and locations to be used for the calculations are to be taken as specified in **Appendix B/2.4.1**

6.5 Dynamic Load Cases and Dynamic Load Combination for Scantling Requirements

6.5.1 General

6.5.1.1 For the scantling requirements the dynamic load cases are to be applied in accordance with the design load sets given in **Table 8.2.7** through **Table 8.2.9** for the design load combination $S+D$. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in **Table 7.6.4** to **Table 7.6.9.**

6.5.1.2 The Dynamic Load Combination Factor (DLCF) table to be used depends on the longitudinal position being considered and is specified in **Fig 7.6.7** and **Table 7.6.3.**

6.5.1.3 Each dynamic load case in the DLCF tables maximises one or more dynamic load components. The minimised dynamic load components are to be calculated by multiplying all the dynamic load combination factors for a dynamic load case by -1.0. The scantling requirements are to be evaluated for all maximised and minimised dynamic load cases.

6.5.1.4 Load parameters to be used for the calculations are to be taken as specified in **Table 8.2.8** and **Table 8.2.9.**

Fig 7.6.7
Illustration of Structural Regions

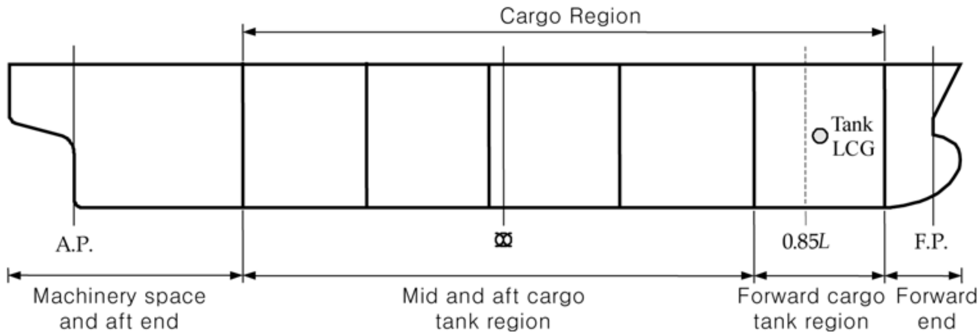


Table 7.6.3
Dynamic Load Combination Factor Tables used for Structural Region and Loading Condition

Structural region	Machinery Space and Aft End	Mid and aft cargo tank region	Forward cargo tank region	Forward end
Applicable for tanks and spaces	aft of aftmost cargo tank	where the tank LCG is aft of 0.85 L	where the tank LCG is at or forward of 0.85 L	forward of foremost bulkhead
Loaded DLCF	**Table 7.6.8**	**Table 7.6.4**	**Table 7.6.6**	**Table 7.6.8**
Ballast DLCF	**Table 7.6.9**	**Table 7.6.5**	**Table 7.6.7**	**Table 7.6.9**

Table 7.6.4
Dynamic Load Cases for Mid and Aft Cargo Tank Region for Loaded Condition

Wave direction			Head Sea			Oblique Sea		Beam Sea					
Max response			M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic Load Case			1	2	3	4a	4b	5a	5b	6a	6b	7a	7b
Global loads	M_{wv}	f_{mv}	1.0	-1.0	0.5	-0.2	-0.2	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3
	M_{wv-h}	f_{mh}	0.0	0.0	0.0	1.0	-1.0	-0.1	0.1	0.0	0.0	0.0	0.0
Accelerations	a_{v-mid}	f_{v-mid}	-0.2	0.5	-0.4	-0.1	-0.1	0.5	0.5	1.0	1.0	1.0	1.0
	a_{v-pt}	f_{v-pt}	-0.2	0.5	-0.4	-0.1	-0.1	0.2	0.6	0.8	1.0	0.8	1.0
	a_{v-stb}	f_{v-stb}	-0.2	0.5	-0.4	-0.1	-0.1	0.6	0.2	1.0	0.8	1.0	0.8
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	1.0	-1.0	0.5	-0.5	0.6	-0.6
	$a_{lng-mid}$	$f_{lng-mid}$	0.3	-0.6	1.0	-0.3	-0.3	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	a_{lng-pt}	f_{lng-pt}	0.3	-0.6	1.0	-0.4	-0.2	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	$a_{lng-stb}$	$f_{lng-stb}$	0.3	-0.6	1.0	-0.2	-0.4	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
	$a_{lng-ctr}$	$f_{lng-ctr}$	0.3	-0.6	1.0	-0.3	-0.3	-0.1	-0.1	-0.5	-0.5	-0.6	-0.6
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	0.7	-0.6	0.2	-0.3	-0.3	0.5	0.5	1.0	1.0	0.9	0.9
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.4	-0.1	0.8	-0.3	0.9	0.4	1.0	0.4
	P_{WL}	f_{WL}	0.3	-0.3	0.1	-0.6	-0.1	0.5	-0.2	0.8	0.4	1.0	0.4
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	0.7	-0.6	0.2	-0.3	-0.3	0.5	0.5	1.0	1.0	0.9	0.9
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.1	-0.4	-0.3	0.8	0.4	0.9	0.4	1.0
	P_{WL}	f_{WL}	0.3	-0.3	0.1	-0.1	-0.6	-0.2	0.5	0.4	0.8	0.4	1.0

Where: Symbols are as defined in **3.3, 3.4.2, 6.3.5.1** and **Table 7.6.1** and **Table 7.6.2** and below:

a_{v-pt} : vertical acceleration for port tank, in m/s^2
a_{v-stb} : vertical acceleration for starboard tank, in m/s^2
$a_{lng-mid}$: longitudinal acceleration for centre tank, in m/s^2
a_{lng-pt} : longitudinal acceleration for port tank, in m/s^2
$a_{lng-stb}$: longitudinal acceleration for starboard tank, in m/s^2
$a_{lng-ctr}$: longitudinal acceleration for centre double bottom ballast tank, in m/s^2
f_{lng-pt} : dynamic load combination factor associated with the longitudinal acceleration of a port side cargo or ballast tank
$f_{lng-stb}$: dynamic load combination factor associated with the longitudinal acceleration of a starboard side cargo or ballast tank
$f_{lng-ctr}$: dynamic load combination factor associated with the longitudinal acceleration of a centre double bottom ballast tank
$f_{lng-mid}$: dynamic load combination factor associated with the longitudinal acceleration of a centre tank

Table 7.6.5
Dynamic Load Cases for Mid and Aft Cargo Tank Region for Ballast Condition

Wave direction			Head Sea			Oblique Sea		Beam Sea					
Max response			M_{wv}	a_v	a_{lng}	M_{wv-h}		a_t		P_{ctr}		P_{WL}	
Dynamic Load Case			1	2	3	4a	4b	5a	5b	6a	6b	7a	7b
Global loads	M_{wv}	f_{mv}	1.0	-1.0	0.4	-0.4	-0.4	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2
	M_{wv-h}	f_{mh}	0.0	0.0	0.0	1.0	-1.0	0.1	-0.1	-0.1	0.1	-0.2	0.2
Accelerations	a_{v-mid}	f_{v-mid}	-0.1	0.4	-0.2	0.1	0.1	0.5	0.5	1.0	1.0	1.0	1.0
	a_{v-pt}	f_{v-pt}	-0.1	0.4	-0.2	0.1	0.1	0.1	0.8	0.7	1.0	0.6	1.0
	a_{v-stb}	f_{v-stb}	-0.1	0.4	-0.2	0.1	0.1	0.8	0.1	1.0	0.7	1.0	0.6
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	1.0	-1.0	0.8	-0.8	0.6	-0.6
	$a_{lng-mid}$	$f_{lng-mid}$	0.2	-0.1	1.0	-0.6	-0.6	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	a_{lng-pt}	f_{lng-pt}	0.2	-0.1	1.0	-0.6	-0.4	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	$a_{lng-stb}$	$f_{lng-stb}$	0.2	-0.1	1.0	-0.4	-0.6	0.0	0.0	-0.2	-0.2	-0.1	-0.1
	$a_{lng-ctr}$	$f_{lng-ctr}$	0.2	-0.1	1.0	-0.4	-0.4	0.0	0.0	-0.2	-0.2	-0.1	-0.1
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1.0	-0.8	0.3	-0.5	-0.5	0.3	0.3	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	-0.4	0.0	0.9	-0.4	0.9	0.3	0.9	0.2
	P_{WL}	f_{WL}	0.3	-0.2	0.1	-0.6	0.0	0.7	-0.4	0.9	0.2	1.0	0.2
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1.0	-0.8	0.3	-0.5	-0.5	0.3	0.3	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.3	-0.2	0.1	0.0	-0.4	-0.4	0.9	0.3	0.9	0.2	0.9
	P_{WL}	f_{WL}	0.3	-0.2	0.1	0.0	-0.6	-0.4	0.7	0.2	0.9	0.2	1.0

Where:
Symbols are as defined in **3.3, 3.4.2, 6.3.5.1** and **Table 7.6.1, Table 7.6.2** and **Table 7.6.4**

Table 7.6.6
Dynamic Load Cases for Forward Cargo Tank Region for Loaded Condition

Wave direction			Head Sea		Oblique Sea								Beam Sea			
Max response			a_v	a_{lng}	a_{lng}		P_{ctr}		P_{bilge}		P_{WL}		a_v		a_t	
Dynamic Load Case			1	2	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b
Global loads	M_{wv}	f_{mv}	-0.7	0.9	0.3	0.3	-0.6	-0.6	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.1	-0.1
	M_{wv-h}	f_{mh}	0.0	0.0	-0.2	0.2	0.2	-0.2	-0.1	0.1	0.2	-0.2	-0.1	0.1	-0.5	0.5
Accelerations	a_{v-mid}	f_{v-mid}	0.7	-0.6	-0.6	-0.6	0.7	0.7	0.9	0.9	0.7	0.7	1.0	1.0	0.4	0.4
	a_{v-pt}	f_{v-pt}	0.7	-0.6	-0.6	-0.6	0.7	0.7	0.9	1.0	0.7	0.7	0.9	1.0	0.3	0.6
	a_{v-stb}	f_{v-stb}	0.7	-0.6	-0.6	-0.6	0.7	0.7	1.0	0.9	0.7	0.7	1.0	0.9	0.6	0.3
	a_t	f_t	0.0	0.0	-0.4	0.4	0.1	-0.1	0.7	-0.7	0.5	-0.5	0.6	-0.6	1.0	-1.0
	$a_{lng-mid}$	$f_{lng-mid}$	-0.8	1.0	0.8	0.8	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5	-0.1	-0.1
	a_{lng-pt}	f_{lng-pt}	-0.8	1.0	1.0	0.6	-1.0	-0.9	-0.5	-0.5	-1.0	-0.7	-0.5	-0.5	-0.1	-0.1
	$a_{lng-stb}$	$f_{lng-stb}$	-0.8	1.0	0.6	1.0	-0.9	-1.0	-0.5	-0.5	-0.7	-1.0	-0.5	-0.5	-0.1	-0.1
	$a_{lng-ctr}$	$f_{lng-ctr}$	-0.8	1.0	0.8	0.8	-1.0	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5	-0.1	-0.1
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1.0	-0.9	-0.4	-0.4	1.0	1.0	0.8	0.8	0.5	0.5	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.6	-0.7	-0.6	-0.2	0.9	0.6	1.0	0.5	0.7	0.3	1.0	0.5	0.8	-0.1
	P_{WL}	f_{WL}	0.3	-0.5	-0.9	-0.2	0.8	0.4	0.9	0.4	1.0	0.2	0.9	0.4	0.6	-0.2
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1.0	-0.9	-0.4	-0.4	1.0	1.0	0.8	0.8	0.5	0.5	0.8	0.8	0.4	0.4
	P_{bilge}	f_{bilge}	0.6	-0.7	-0.2	-0.6	0.6	0.9	0.5	1.0	0.3	0.7	0.5	1.0	-0.1	0.8
	P_{WL}	f_{WL}	0.3	-0.5	-0.2	-0.9	0.4	0.8	0.4	0.9	0.2	1.0	0.4	0.9	-0.2	0.6

Where:
Symbols are as defined in **3.3, 3.4.2, 6.3.5.1** and **Table 7.6.1, Table 7.6.2** and **Table 7.6.4**

Table 7.6.7
Dynamic Load Cases for Forward Cargo Tank Region for Ballast Condition

Wave direction			Head Sea		Oblique Sea								Beam Sea			
Max response			a_v	a_{lng}	a_{lng}		P_{ctr}		P_{bilge}		P_{WL}		a_v		a_t	
Dynamic Load Case			1	2	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b
Global loads	M_{wv}	f_{mv}	-0.8	0.9	0.7	0.7	-1.0	-1.0	-0.2	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
	M_{wv-h}	f_{mh}	0.0	0.0	-0.4	0.4	0.0	0.0	-0.5	0.5	0.3	-0.3	-0.4	0.4	-0.4	0.4
Accelerations	a_{v-mid}	f_{v-mid}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.6	0.6	0.9	0.9	1.0	1.0	0.4	0.4
	a_{v-pt}	f_{v-pt}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.3	0.8	0.7	0.7	0.5	1.0	0.0	0.7
	a_{v-stb}	f_{v-stb}	0.7	-0.6	-0.7	-0.7	0.4	0.4	0.8	0.3	0.7	0.7	1.0	0.5	0.7	0.0
	a_t	f_t	0.0	0.0	0.0	0.0	0.0	0.0	0.9	-0.9	0.2	-0.2	0.7	-0.7	1.0	-1.0
	$a_{lng-mid}$	$f_{lng-mid}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.3	-0.3	-0.9	-0.9	0.0	0.0	0.0	0.0
	a_{lng-pt}	f_{lng-pt}	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.5	0.2	-0.9	-0.6	0.0	0.0	0.0	0.0
	$a_{lng-stb}$	$f_{lng-stb}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	0.2	-0.5	-0.6	-0.9	0.0	0.0	0.0	0.0
	$a_{lng-ctr}$	$f_{lng-ctr}$	-0.9	1.0	1.0	1.0	-0.6	-0.6	-0.3	-0.3	-0.9	-0.9	0.0	0.0	0.0	0.0
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1.0	-0.7	-0.9	-0.9	1.0	1.0	0.6	0.6	0.6	0.6	0.4	0.4	0.2	0.2
	P_{bilge}	f_{bilge}	0.5	-0.4	-0.7	-0.3	0.6	0.6	1.0	-0.3	0.9	0.2	0.8	0.2	0.7	-0.3
	P_{WL}	f_{WL}	0.3	-0.2	-0.6	-0.1	0.4	0.4	0.9	-0.3	1.0	0.1	0.8	0.2	0.7	-0.4
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1.0	-0.7	-0.9	-0.9	1.0	1.0	0.6	0.6	0.6	0.6	0.4	0.4	0.2	0.2
	P_{bilge}	f_{bilge}	0.5	-0.4	-0.3	-0.7	0.6	0.6	-0.3	1.0	0.2	0.9	0.2	0.8	-0.3	0.7
	P_{WL}	f_{WL}	0.3	-0.2	-0.1	-0.6	0.4	0.4	-0.3	0.9	0.1	1.0	0.2	0.8	-0.4	0.7

Where:
Symbols are as defined in **3.3, 3.4.2, 6.3.5.1** and **Table 7.6.1, Table 7.6.2** and **Table 7.6.4**

Table 7.6.8
Dynamic Load Cases for Spaces Outside the Cargo Tank Region for Loaded Condition

Ship location			Machinery Space and Aft End							Forward End			
Wave direction			Following Sea	Oblique Sea		Beam Sea				Beam Sea			
Max response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic Load Case			1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
Global loads	M_{wv}	f_{mv}	-1.0	-0.7	-0.7	-0.4	-0.4	-0.1	-0.1	-	-	-	-
Accelerations	a_{v-mid}	f_{v-mid}	0.6	0.9	0.9	1.0	1.0	0.3	0.3	1.0	1.0	0.3	0.3
	a_{v-pt}	f_{v-pt}	0.6	-	0.9	-	1.0	-	0.4	-	1.0	-	0.3
	a_{v-stb}	f_{v-stb}	0.6	0.9	-	1.0	-	0.4	-	1.0	-	0.3	-
	a_t	f_t	0.0	0.2	-0.2	0.5	-0.5	1.0	-1.0	0.7	-0.7	1.0	-1.0
	a_{lng}	f_{lng}	0.8	0.7	0.7	0.6	0.6	-0.1	-0.1	-0.7	-0.7	-0.1	-0.1
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1.0	0.8	0.8	0.7	0.7	0.2	0.2	1.0	1.0	0.2	0.2
	P_{WL}	f_{WL}	0.5	1.0	0.2	0.8	0.3	0.5	-0.3	1.0	0.8	0.2	0.0
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1.0	0.8	0.8	0.7	0.7	0.2	0.2	1.0	1.0	0.2	0.2
	P_{WL}	f_{WL}	0.5	0.2	1.0	0.3	0.8	-0.3	0.5	0.8	1.0	0.0	0.2

Where:

Symbols are as defined in **3.3, 6.3.5.1** and **Table 7.6.1, Table 7.6.2** and **Table 7.6.4**

Table 7.6.9
Dynamic Load Cases for Spaces Outside the Cargo Tank Region for Ballast Condition

Ship location			Machinery Space and Aft End							Forward End			
Wave direction			Following Sea	Oblique Sea		Beam Sea				Beam Sea			
Max response			P_{ctr}	P_{WL}		a_v		a_t		a_v		a_t	
Dynamic Load Case			1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
Global loads	M_{wv}	f_{mv}	-1.0	-0.3	-0.3	0.2	0.2	0.1	0.1	-	-	-	-
Accelerations	a_{v-mid}	f_{v-mid}	0.6	0.9	0.9	1.0	1.0	0.3	0.3	1.0	1.0	0.3	0.3
	a_{v-pt}	f_{v-pt}	0.6	-	0.9	-	1.0	-	0.5	-	1.0	-	0.5
	a_{v-stb}	f_{v-stb}	0.6	0.9	-	1.0	-	0.5	-	1.0	-	0.5	-
	a_t	f_t	0.0	0.1	-0.1	0.6	-0.6	1.0	-1.0	0.7	-0.7	1.0	-1.0
	a_{lng}	f_{lng}	0.7	0.8	0.8	0.2	0.2	0.0	0.0	-0.3	-0.3	0.0	0.0
Dynamic wave pressure for starboard side	P_{ctr}	f_{ctr}	1.0	0.7	0.7	0.5	0.5	0.1	0.1	0.6	0.6	0.1	0.1
	P_{WL}	f_{WL}	0.8	1.0	0.3	0.6	0.1	0.4	-0.3	0.7	0.3	0.3	-0.1
Dynamic wave pressure for port side	P_{ctr}	f_{ctr}	1.0	0.7	0.7	0.5	0.5	0.1	0.1	0.6	0.6	0.1	0.1
	P_{WL}	f_{WL}	0.8	0.3	1.0	0.1	0.6	-0.3	0.4	0.3	0.7	-0.1	0.3

Where:
Symbols are as defined in **3.3, 6.3.5.1** and **Table 7.6.1, Table 7.6.2** and **Table 7.6.4**

Section 8

Scantling Requirements

1 Longitudinal Strength

1.1 Loading Guidance

1.1.1 General

1.1.1.1 All ships are to be provided with loading guidance information containing sufficient information to enable the master of the ship to maintain the ship within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in **1.1.2** and **1.1.3** respectively.

1.1.1.2 The loading guidance information is to be based on the final data of the ship.

1.1.1.3 Modifications resulting in changes to the main data of the ship (lightship weight, buoyancy distribution, tank volumes or usage, etc), require the Loading Manual to be updated and re-approved, and subsequently the Loading Computer System to be updated and re-approved. However, new loading guidance need not be re-submitted provided that the resulting draughts, still water bending moments and shear forces do not differ from the originally approved data by more than 2 %.

1.1.1.4 The loading guidance is to be prepared in a language understood by the users. If this language is not English, a translation into English shall be included. When applicable a document translating the language of the input and output data for the Loading Computer System into English is to be provided.

1.1.1.5 The loading guidance information is to include the following statement, to ensure the crew are aware of the operational limitations for minimum draught forward:

The scantlings are approved for a minimum draught forward, at F.P. In sea conditions where slamming is likely to occur, the forward draught is not to be less than the following:

(a) ⋯*m* with double bottom ballast tanks *No(s)*⋯ filled, or

(b) ⋯*m* with double bottom ballast tanks *No(s)*⋯ empty

1.1.2 Loading Manual

1.1.2.1 The Loading Manual is a document that:

(a) describes the loading conditions on which the design and approval of the ship has been based for seagoing and harbour/sheltered water operation

(b) describes the results of the calculations of still water bending moments, shear forces and where applicable, limitations due to torsional and lateral loads

(c) describes relevant operational limitations as given in **1.1.2.7.**

1.1.2.2 The following loading conditions and design loading and ballast conditions upon which the approval of the hull scantlings is based are, as a minimum, to be included in the Loading Manual:

(a) Seagoing conditions including both departure and arrival conditions

- homogeneous loading conditions including a condition at the scantling draft (homogeneous loading conditions shall not include filling of dry and clean ballast tanks)
- a normal ballast condition where:
  - the ballast tanks may be full, partially full or empty. Where partially full options are exercised, the conditions in **1.1.2.5** are to be complied with
  - all cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea
  - the propeller is to be fully immersed, and
  - the trim is to be by the stern and is not to exceed $0.015L$, where L is as defined in **Sec 4/1.1.1**
- a heavy ballast condition where:

· the draught at the forward perpendicular is not to be less than that for the normal ballast condition

· ballast tanks in the cargo tank region or aft of the cargo tank region may be full, partially full or empty. Where the partially full options are exercised, the conditions in **1.1.2.5** are to be complied with

· the fore peak water ballast tank is to be full. If upper and lower fore peak water ballast tanks are fitted, the lower is required to be full. The upper fore peak tank may be full, partially full or empty.

If upper and lower fore peak tanks are fitted and only one of them is designated as water ballast tank, the other may be empty.

· all cargo tanks are to be empty including cargo tanks suitable for the carriage of water ballast at sea

· the propeller is to be fully immersed

· the trim is to be by the stern and is not to exceed $0.015\,L$, where L is as defined in **Sec 4/1.1.1**

- any specified non-uniform distribution of loading
- conditions with high density cargo including the maximum design cargo density, when applicable
- mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions
- conditions covering ballast water exchange procedures with the calculations of the intermediate conditions just before and just after ballasting and/or deballasting any ballast tank

(b) Harbour/sheltered water conditions

- conditions representing typical complete loading and unloading operations
- docking condition afloat
- propeller inspection afloat condition, in which the propeller shaft centre line is at least $D_{prop}/4$ above the waterline in way of the propeller, where D_{prop} is the propeller diameter

(c) Additional design conditions

- a design ballast condition in which all segregated ballast tanks in the cargo tank region are full and all other tanks are empty including fuel oil and fresh water tanks.

Guidance Note
The design condition specified in (c) is for assessment of hull strength and is not intended for ship operation. This condition will also be covered by the IMO73/78 SBT condition provided the corresponding condition in the Loading Manual only includes ballast in segregated ballast tanks in the cargo tank region.

1.1.2.3 The calculation for the departure conditions are to be based on full tanks according to the applicable stability regulations for filling of tanks; note bunker tanks are not to be taken less than 95 % full and other consumables are to be taken at 100 % capacity. Arrival conditions are to be based on 10 % of the maximum capacity of bunker, fresh water and stores.

1.1.2.4 Where the amount and disposition consumables at any intermediate stage of the voyage are considered more severe than of those described in **1.1.2.3**, calculations for such intermediate conditions are also to be submitted for approval.

1.1.2.5 Ballast loading conditions involving partially filled peak and/or other ballast tanks in any departure, arrival or intermediate condition are not permitted to be used as design loading conditions unless, for all filling levels between empty and full, the resulting stress levels are within the stress and buckling acceptance criteria. For design purposes this criteria will be satisfied if the stress levels are within the stress and buckling acceptance criteria for loading conditions with the appropriate tanks full, empty and partially filled at intended level in any departure, arrival or intermediate condition. The corresponding full, empty and partially filled tank conditions are to be considered as design conditions for calculation of the still water bending moment and shear force, but these do not need to comply with propeller immersion and trim requirements as specified in **1.1.2.2(a)**. Where multiple ballast tanks are intended to be partially filled, all combinations of full, empty or partially filled at intended levels for those tanks are to be investigated. These requirements are not applicable to ballast water exchange using the sequential method.

1.1.2.6 In cargo loading conditions, the requirements for partially filled ballast tanks as specified in **1.1.2.5** are applicable to the peak ballast tanks only.

1.1.2.7 The Loading Manual is to include the design basis and operational limitations upon which the approval of the hull scantlings are based. The information listed in **Table 8.1.1** is to be included in the Loading Manual.

1.1.2.8 The approval of the hull scantlings is based on the rule defined loading patterns and the loading conditions given in the Loading Manual.

Table 8.1.1
Design Parameters

Parameter
Permissible limits of still water bending moments (seagoing operation and harbour/sheltered water operation)
Permissible limits of still water shear forces (seagoing operation and harbour/sheltered water operation)
Scantling draught, T_{sc}
Design minimum ballast draught at midships, T_{bal}
Design slamming draught forward with forward double bottom ballast tanks filled, $T_{FP-full}$
Design slamming draught forward with forward double bottom ballast tanks empty, T_{FP-mt}
Maximum allowable cargo density
Maximum cargo density in any loading condition in Loading Manual
Description of the ballast exchange operations including any limitations
Design speed

1.1.2.9 The following additional loading conditions are to be included in the Loading Manual if the ship is specifically approved and intended to be operated in such conditions:

(a) sea-going ballast conditions including water ballast carried in one or more cargo tanks which are intended for use in emergency situations as allowed by MARPOL Regulation 13. (Ship approved for loading pattern A8 of Table B.2.3 or B7 of Table B.2.4)

(b) seagoing loading conditions where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of 0.9 T_{sc}

(c) seagoing loading conditions with cargo tanks less than 25 % full with the combination of mean ship's draught greater than 0.9 T_{sc}

(d) seagoing loading conditions where the net static downward load on the double bottom exceeds that given with the combination of a full cargo tank at a cargo density of 1.025 tonnes/m^3 and a mean ship's draught of 0.6 T_{sc}

(e) for ships arranged with cross ties in the centre cargo tank, seagoing loading conditions showing a non-symmetric loading pattern where the difference in filling level between corresponding port and starboard wing cargo tanks exceeds 25 % of the filling height in the wing cargo tank (Ship approved for loading pattern A7 of Table B.2.3)

1.1.2.10 This sub-section is not intended to prevent any other loading conditions to be included in the Loading Manual, nor is it intended to replace in any way the required Loading Manual/ Instrument.

1.1.2.11 A tanker may in actual operation be loaded differently from the design loading conditions specified in the Loading Manual, provided limitations for longitudinal and local strength as defined in the Loading Manual and Loading Instrument onboard and applicable stability requirements are not exceeded.

1.1.3 Loading computer system

1.1.3.1 The loading computer system, is to be a system, which unless stated otherwise is digital and that can easily and quickly ascertain whether operational limitations are exceeded for any loading condition.

1.1.3.2 The loading computer system is to be approved based on the Rules of the individual Classification Society.

1.1.3.3 The loading computer system is to be capable of producing any specific loading condition and verify that these comply with all the operational limitations given in **1.1.2.2**, and provide plots including input and output.

1.1.3.4 If any of the operational limitations are not checked, the user is to be properly informed when using the system, and by the plots provided, so that each such item is verified by other means. The loading computer system is as a minimum to verify that the following are satisfied:

(a) draught limitations

(b) still water bending moments and shear forces are reported at the specified locations/read-out points.

1.1.3.5 The final test conditions for the loading computer are to be based on conditions given in the final Loading Manual. The test conditions are subject to approval and the shear forces and bending moments calculated by the loading computer system, at each read out point, are to be within $0.02\,Q_{sw\text{-}perm}$ or $0.02\,M_{sw\text{-}perm}$ of the results given in the loading manual, where $Q_{sw\text{-}perm}$ and $M_{sw\text{-}perm}$ are the assigned permissible shear force and bending moment at each read out point respectively.

1.1.3.6 Before a loading computer system is accepted, all relevant aspects of the computer, including but not limited to the following, are to be demonstrated to the Surveyor:

(a) verification that the final data of the ship has been used

(b) verification that the relevant limits for all read-out points are correct

(c) that the operation of the system after installation onboard, is in accordance with the approved test conditions

(d) that the approved test conditions are available onboard

(e) that an operational manual is available onboard.

1.2 Hull Girder Bending Strength

1.2.1 General

1.2.1.1 The net vertical hull girder section modulus, $Z_{v\text{-}net50}$, is to be equal to or greater than the requirements given by **1.2.2.2** and **1.2.3.2**. The net vertical hull girder moment of inertia, $I_{v\text{-}net50}$, as defined in **Sec 4/2.6.1.1** is to be equal to or greater than the requirement given by **1.2.2.1.**

1.2.1.2 Scantlings of all continuous longitudinal members of the hull girder based on moment of inertia and section modulus requirement in **1.2.2.1** and **1.2.2.2** are to be maintained within $0.4\,L$ midships.

1.2.1.3 The hull girder section modulus requirements in **1.2.3** apply along the full length of the hull girder, from A.P. to F.P.

1.2.1.4 Structural members included in the hull girder section modulus are to satisfy the buckling criteria given in **1.4.**

1.2.2 Minimum requirements

1.2.2.1 At the midship cross section the net vertical hull girder moment of inertia about the horizontal neutral axis, $I_{v\text{-}net50}$, is not to be less than the rule minimum vertical hull girder moment of inertia, $I_{v\text{-}min}$, defined as:

$$I_{v-min} = 2.7 C_{wv} L^3 B (C_b + 0.7) \cdot 10^{-8} \quad \text{m}^4$$

Where:

C_{wv} wave coefficient as defined in **Table 8.1.2**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

C_b block coefficient, as defined in **Sec 4/1.1.9.1** but is not to be taken as less than 0.70

Table 8.1.2
Wave Coefficient C_{wv}

rule length	C_{wv}
$150 \leq L \leq 300$	$10.75 - [(300 - L) / 100]^{3/2}$
$300 < L < 350$	10.75
$350 \leq L \leq 500$	$10.75 - [(L - 350) / 150]^{3/2}$

1.2.2.2 At the midship cross section the net vertical hull girder section modulus, $Z_{v\text{-}min}$, at the deck and keel is not to be less than the rule minimum hull girder section modulus, $Z_{v\text{-}min}$, defined as:

$$Z_{v-min} = 0.9 k C_{wv} L^2 B (C_b + 0.7) \cdot 10^{-6} \quad \text{m}^3$$

Where:

k higher strength steel factor, as defined in **Sec 6/1.1.4**

C_{wv} wave coefficient as defined in **Table 8.1.2**

L rule length, in m, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

C_b block coefficient, as defined in **Sec 4/1.1.11.1** but is not to be taken as less than 0.70

1.2.2.3 The net hull girder section modulus at keel, $Z_{v\text{-}net50\text{-}kl}$, is to be calculated in accordance with **Sec 4/2.6.1.2** and taking z at the keel.

1.2.2.4 The net hull girder section modulus at deck, $Z_{v\text{-}net50\text{-}dk}$, is to be calculated in accordance with **Sec 4/2.6.1.2** and taking z at the effective deck height, see **1.2.2.5.**

1.2.2.5 The effective deck height from the horizontal neutral axis for the hull girder section modulus, $z_{dk\text{-}eff}$, is to be taken as:

$$z_{dk-eff} = z_{dk-side} - z_{NA-net50} \quad \text{m}$$

When no effective longitudinal strength members are positioned above a line extending from moulded deck line at side to a position $(z_{dk\text{-}side} - z_{NA\text{-}net50})/0.9$ from the neutral axis at the centreline

$$z_{dk-eff} = (z_y - z_{NA-net50}) \left(0.9 + 0.2 \frac{y_{cl}}{B} \right) \quad \text{m}$$

When any effective longitudinal strength members are positioned above a line extending from moulded deck line at side to a position $(z_{dk\text{-}side} - z_{NA\text{-}net50})/0.9$ from the neutral axis at the centreline

Where:

z_y distance from the baseline to top of the continuous strength member at a distance y

from the centreline, in m, giving the largest value of z_{dk-eff}, see **Fig 8.1.1**

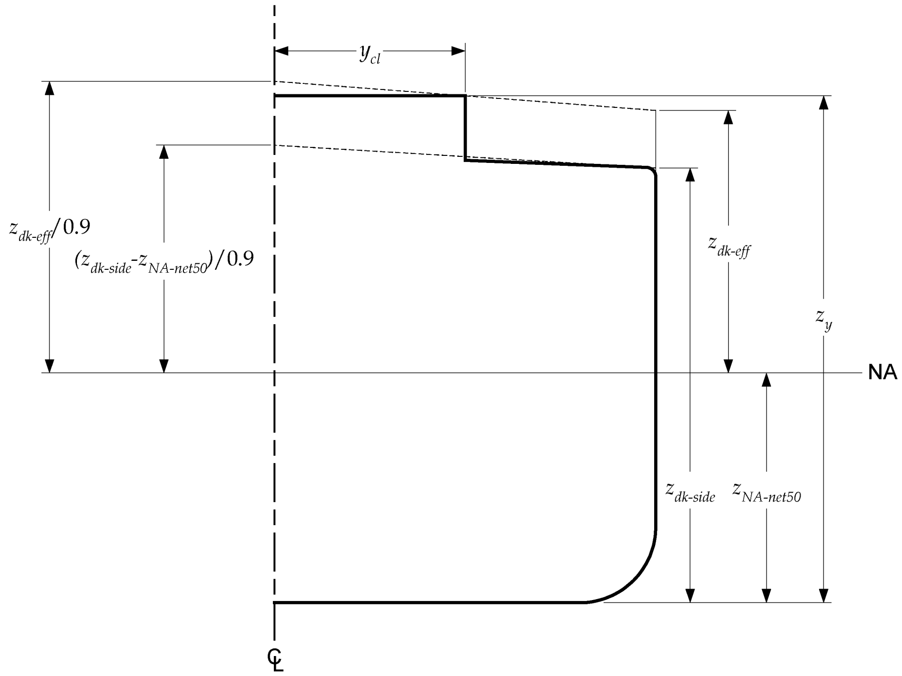
$z_{NA-net50}$ distance from baseline to horizontal neutral axis, in m, see **Fig 8.1.1**

y_{cl} distance from the top of the continuous strength member to the centreline of the ship, in m, giving the largest value of z_{dk-eff}, see **Fig 8.1.1**

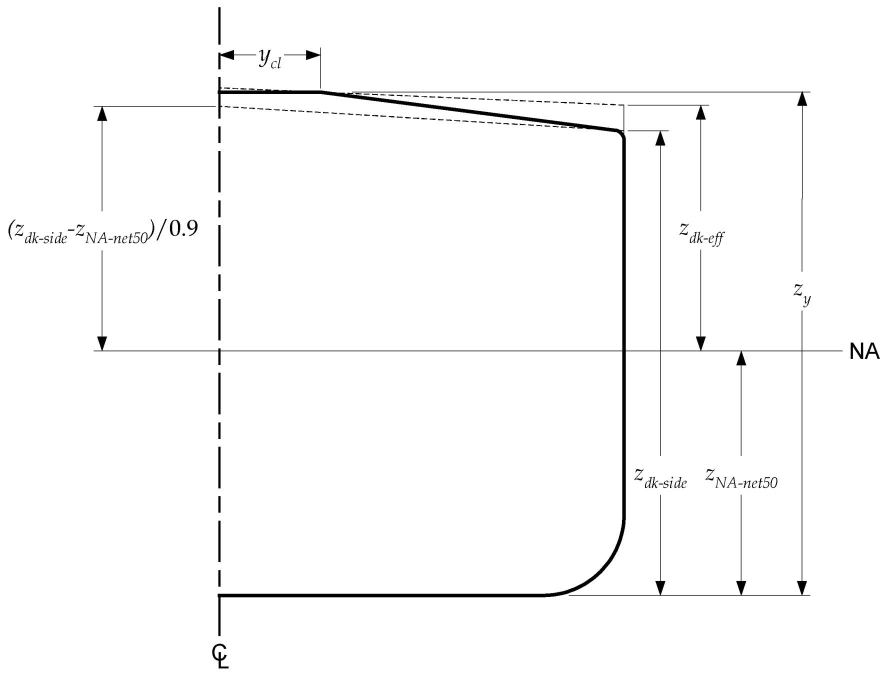
B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

$z_{dk-side}$ distance from the baseline to the moulded deck line at side, in m, see **Fig 8.1.1**

Fig 8.1.1
Position for Calculation of Section Modulus Deck



(a) Trunk deck or continuous hatch coaming



(b) Ship with large camber

1.2.3 Hull girder requirement on total design bending moment

1.2.3.1 The net vertical hull girder section modulus requirement as defined in **1.2.3.2** is to be assessed for both hogging and sagging conditions.

1.2.3.2 The net hull girder section modulus about the horizontal neutral axis, $Z_{v\text{-}net50}$, is not to be less than the rule required hull girder section modulus, $Z_{v\text{-}req}$, based on the permissible still-water bending moment and design wave bending moment defined as:

$$Z_{v-req} = \frac{|M_{sw-perm} + M_{wv-v}|}{\sigma_{perm}} 10^{-3} \quad m^3$$

Where:

$M_{sw\text{-}perm}$ permissible hull girder hogging or sagging still water bending moment as given in **Table 8.1.3**, in kNm

$M_{wv\text{-}v}$ hogging or sagging vertical wave bending moment, in kNm as given in **Table 8.1.3**

σ_{perm} permissible hull girder bending stress as given in **Table 8.1.3**, in N/mm^2

Table 8.1.3
Loads and Corresponding Acceptance Criteria for Hull Girder Bending Assessment

Design load combination	Still water bending moment, $M_{sw\text{-}perm}$	Wave bending moment, $M_{wv\text{-}v}$	Permissible hull girder bending stress, σ_{perm} (1)	
(S)	$M_{sw\text{-}perm\text{-}harb}$	0	$143/k$	within 0.4 L amidships
			$105/k$	at and forward of 0.9 L from A.P. and at and aft of 0.1 L from A.P.
(S + D)	$M_{sw\text{-}perm\text{-}sea}$	$M_{wv\text{-}v}$	$190/k$	within 0.4 L amidships
			$140/k$	at and forward of 0.9 L from A.P. and at and aft of 0.1 L from A.P

Where:

$Ms_{w\text{-}perm\text{-}harb}$ permissible hull girder hogging and sagging still water bending moment for harbour/sheltered water operation, in kNm, as defined in **Sec 7/2.1.1**

$M_{sw\text{-}perm\text{-}sea}$ permissible hull girder hogging and sagging still water bending moment for seagoing operation, in kNm, as defined in **Sec 7/2.1.1**

$M_{wv\text{-}v}$ hogging and sagging vertical wave bending moments, in kNm, as defined in **Sec 7/3.4.1**
$M_{wv\text{-}vis}$ to be taken as:
$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment
$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

k higher strength steel factor, as defined in **Sec 6/1.1.4**

Note
1. σ_{perm} is to be linearly interpolated between values given.

1.3 Hull Girder Shear Strength

1.3.1 General

1.3.1.1 The hull girder shear strength requirements apply along the full length of the hull girder, from A.P to F.P.

1.3.2 Assessment of hull girder shear strength

1.3.2.1 The net hull girder shear strength capacity, $Q_{v\text{-}net50}$, as defined in **1.3.2.2** is not to be less than the required vertical shear force, $Q_{v\text{-}req}$, as indicated in the following:

$$Q_{v-req} = Q_{sw-perm} + Q_{wv} \quad kN$$

Where:

$Q_{sw\text{-}perm}$ permissible hull girder positive or negative still water shear force as given in **Sec 7/2.1.3**, in kN

Q_{wv} vertical wave positive or negative shear force as defined in **Sec 7/3.4.3**, in kN

1.3.2.2 The permissible positive and negative still water shear forces for seagoing and harbour/sheltered water operations, $Q_{sw\text{-}perm\text{-}sea}$ and $Q_{sw\text{-}perm\text{-}harb}$ are to satisfy:

$$Q_{sw-perm} \le Q_{v-net50} - Q_{wv-pos} \quad \text{kN}$$

for maximum permissible positive shear force

$$Q_{sw-perm} \ge -Q_{v-net50} - Q_{wv-neg} \quad \text{kN}$$

for minimum permissible negative shear force

Where:

$Q_{sw\text{-}perm}$ permissible hull girder still water shear force as given in **Table 8.1.4**, in kN

$Q_{v\text{-}net50}$ net hull girder vertical shear strength to be taken as the minimum for all plate elements that contribute to the hull girder shear capacity

$$= \frac{\tau_{ij-perm} t_{ij-net50}}{1000 q_v} \quad \text{kN}$$

$\tau_{ij\text{-}perm}$ permissible hull girder shear stress, τ_{perm}, as given in **Table 8.1.4**, in N/mm^2, for plate ij

$Q_{wv\text{-}pos}$ positive vertical wave shear force, in kN, as defined in **Table 8.1.4**

$Q_{wv\text{-}neg}$ negative vertical wave shear force, in kN, as defined in **Table 8.1.4**

$t_{ij\text{-}net50}$ equivalent net thickness, t_{net50}, for plate ij, in mm. For longitudinal bulkheads between cargo tanks, t_{net50} is to be taken as $t_{sfc\text{-}net50}$ and $t_{str\text{-}k}$ as appropriate, see **1.3.3.1** and **1.3.4.1**

t_{net50} net thickness of plate, in mm

$$= t_{grs} - 0.5 t_{corr}$$

t_{grs} gross plate thickness, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm

$t_{w\text{-}grs}$ gross thickness of the corrugation web, in mm

$t_{f\text{-}grs}$ gross thickness of the corrugation flange, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

q_v unit shear flow per mm for the plate being considered and based on the net scantlings. Where direct calculation of the unit shear flow is not available, the unit shear flow may be taken equal to:

$$= f_i \left(\frac{q_{1-net50}}{I_{v-net50}} \right) \cdot 10^{-9} \quad \text{mm}^{-1}$$

f_i shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in **Fig 8.1.2**

$q_{1\text{-}net50}$ first moment of area, in cm^2, about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. The first moment of area is to be based on the net thickness, t_{net50}

$I_{v\text{-}net50}$ net vertical hull girder section moment of inertia, in m^4, as defined in **Sec 4/2.6.1.1**

Table 8.1.4
Loads and Corresponding Acceptance Criteria for Hull Girder Shear Assessment

Design load combination	Still water shear force, $Q_{sw\text{-}perm}$	Vertical wave shear force, Q_{wv}	Permissible shear stress, τ_{perm}
Harbour/sheltered water operations (S)	$Q_{sw\text{-}perm\text{-}harb}$	0	$105/k$ for plate ij
Seagoing operations (S + D)	$Q_{sw\text{-}perm\text{-}sea}$	Q_{wv}	$120/k$ for plate ij

Where:

$Q_{sw\text{-}perm\text{-}harb}$ permissible positive or negative hull girder still water shear force for harbour operation, in kN, as defined in **Sec 7/2.1.3**

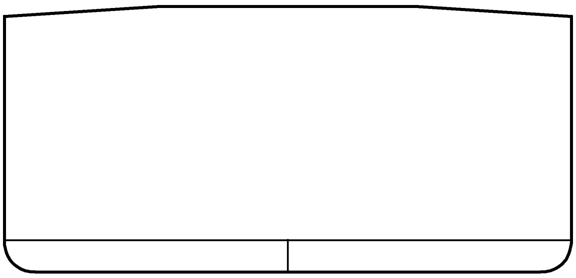
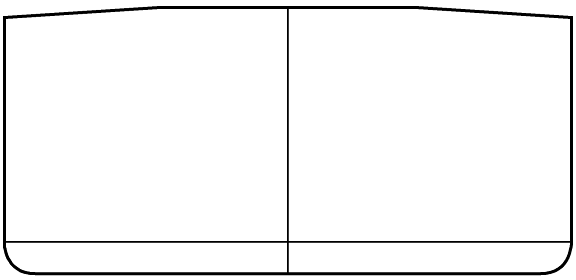
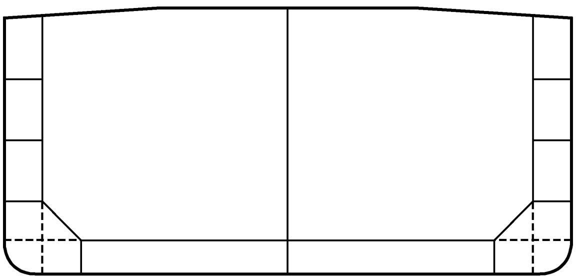
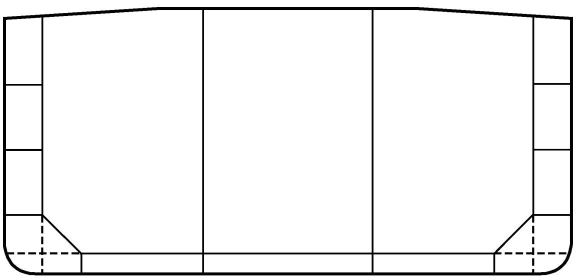
$Qs_{w\text{-}perm\text{-}sea}$ permissible positive or negative hull girder still water shear force for seagoing operation, in kN, as defined in **Sec 7/2.1.3**

Q_{wv} positive or negative vertical wave shear, in kN, as defined in **Sec 7/3.4.3**. Q_{vw} is to be taken as:
$Q_{wv\text{-}pos}$ for assessment with respect to maximum positive permissible still water shear force
$Q_{wv\text{-}neg}$ for assessment with respect to minimum negative permissible still water shear force

plate ij for each plate j, index i denotes the structural member of which the plate orms a component

k higher strength steel factor, as defined in **Sec 6/1.1.4**

Fig 8.1.2
Shear Force Distribution Factors

Hull configuration	f_i factors
Outside cargo region (no longitudinal bulkhead) 	Side shell $f_1 = 0.5$
Outside cargo region (centreline bulkhead) 	Side shell $f_1 = 0.231 + 0.076 \frac{A_{1-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.538 - 0.152 \frac{A_{1-net50}}{A_{3-net50}}$
One centreline bulkhead 	Side shell $f_1 = 0.055 + 0.097 \frac{A_{1-net50}}{A_{2-net50}} + 0.020 \frac{A_{2-net50}}{A_{3-net50}}$ Inner hull $f_2 = 0.193 - 0.059 \frac{A_{1-net50}}{A_{2-net50}} + 0.058 \frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.504 - 0.076 \frac{A_{1-net50}}{A_{2-net50}} - 0.156 \frac{A_{2-net50}}{A_{3-net50}}$
Two longitudinal bulkheads 	Side shell $f_1 = 0.028 + 0.087 \frac{A_{1-net50}}{A_{2-net50}} + 0.023 \frac{A_{2-net50}}{A_{3-net50}}$ Inner hull $f_2 = 0.119 - 0.038 \frac{A_{1-net50}}{A_{2-net50}} + 0.072 \frac{A_{2-net50}}{A_{3-net50}}$ Longitudinal bulkhead $f_3 = 0.353 - 0.049 \frac{A_{1-net50}}{A_{2-net50}} - 0.095 \frac{A_{2-net50}}{A_{3-net50}}$

Where:

i index for the structural member under consideration:
1, for the side shell
2, for the inner hull
3, for the longitudinal bulkhead

$A_{i-net50}$ net area as defined in **Sec 4/2.6.4** and based on deduction of $0.5\, t_{corr}$, of the structural member, i, at one side of the section under consideration. The area $A_{3-net50}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline.

1.3.3 Shear force correction for longitudinal bulkheads between cargo tanks

1.3.3.1 For longitudinal bulkheads between cargo tanks the effective net plating thickness of the plating above the inner bottom, $t_{sfc\text{-}net50}$ for plate *ij,* used for calculation of hull girder shear strength, $Q_{v\text{-}.net50}$, is to be corrected for local shear distribution and is given by:

$$t_{sfc-net50} = t_{grs} - 0.5t_{corr} - t_{\Delta} \quad \text{mm}$$

Where:

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

t_{Δ} thickness deduction for plate *ij*, in mm, as defined in **1.3.3.2**

1.3.3.2 The vertical distribution of thickness reduction for shear force correction is assumed to be triangular as indicated in **Fig 8.1.3**. The thickness deduction, t_{Δ}, to account for shear force correction is to be taken as:

$$t_{\Delta} = \frac{\delta Q_3}{h_{blk}\tau_{ij-perm}}\left(1 - \frac{x_{blk}}{0.5l_{tk}}\right)\left(2 - \frac{2(z_p - h_{db})}{h_{blk}}\right) \quad \text{mm}$$

Where:

δQ_3 shear force correction for longitudinal bulkhead as defined in **1.3.3.3** and **1.3.3.5** for ships with one or two longitudinal bulkheads respectively, in kN.

l_{tk} length of cargo tank, in m

h_{blk} height of longitudinal bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in **Fig 8.1.3**

x_{blk} the minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in m. To be taken positive and not greater than $0.5\,l_{tk}$

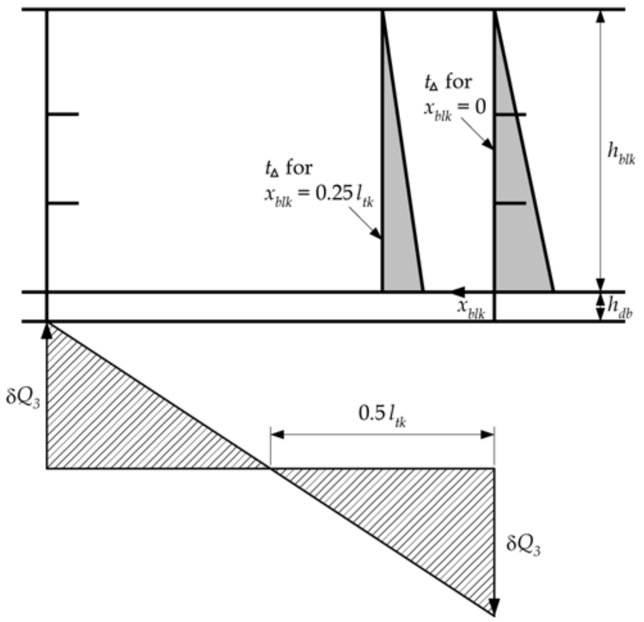
z_p the vertical distance from the lower edge of plate *ij* to the base line, in m. Not to be taken as less than h_{db}

h_{db} height of double bottom, in m, as shown in **Fig 8.1.3**

$\tau_{ij-perm}$ permissible hull girder shear stress, τ_{perm}, in $\mathrm{N/mm^2}$ for plate *ij*
= $120/k_{ij}$

k_{ij} higher strength steel factor, *k*, for plate *ij* as defined in **Sec 6/1.1.4**

Fig 8.1.3
Shear Force Correction for Longitudinal Bulkheads



1.3.3.3 For ships with a centreline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δQ_3, is to be taken as:

$\delta Q_3 = 0.5 K_3 F_{db}$ kN

Where:

K_3 correction factor, as defined in **1.3.3.4**

F_{db} maximum resulting force on the double bottom in a tank, in kN, as defined in **1.3.3.7**

1.3.3.4 For ships with a centreline bulkhead between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0.40\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

Where:

n number of floors between transverse bulkheads

f_3 shear force distribution factor, see **Fig 8.1.2**

1.3.3.5 For ships with two longitudinal bulkheads between the cargo tanks, the shear force correction, δQ_3, is to be taken as:

$\delta Q_3 = 0.5 K_3 F_{db}$ kN

Where:

K_3 correction factor, as defined in **1.3.3.6**

F_{db} maximum resulting force on the double bottom in a tank, in kN, as defined in **1.3.3.7**

1.3.3.6 For ships with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3, in way of transverse bulkhead is to be taken as:

$$K_3 = \left[0.5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3\right]$$

Where:

n number of floors between transverse bulkheads

r ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by:

$$r = \frac{1}{\left[\frac{A_{3-net50}}{A_{1-net50} + A_{2-net50}} + \frac{2\times10^4 b_{80}(n_s+1)A_{3-net50}}{l_{tk}(n_s A_{T-net50} + R)}\right]}$$

Note: for preliminary calculations, r may be taken as 0.5

l_{tk} length of cargo tank, between transverse bulkheads in the side cargo tank, in m

b_{80} 80 % of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in m, at tank mid length

$A_{T-net50}$ net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section. $A_{T-net50}$ is to be calculated with net thickness given by t_{grs} - 0.5 t_{corr}

$A_{1-net50}$ net area, as shown in **Fig 8.1.2**, in m^2

$A_{2-net50}$ net area, as shown in **Fig 8.1.2**, in m^2

$A_{3-net50}$ net area, as shown in **Fig 8.1.2**, in m^2

f_3 shear force distribution factor, as shown in Figure8.1.2

n_S number of wash bulkheads in the side cargo tank

R total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n-n_s}{2} - 1\right)\frac{A_{Q-net50}}{\gamma} \qquad \text{cm}^2$$

$$\gamma = 1 + \frac{300 b_{80}^2 A_{Q-net50}}{I_{psm-net50}}$$

$A_{Q-net50}$ net shear area, in cm^2, of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs. $A_{Q-net50}$ is to be calculated using the net thickness given by t_{grs} - 0.5 t_{corr}. The net shear area is to be calculated at the mid span of the members.

$I_{psm-net50}$ net moment of inertia for primary support members, in cm^4, of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by t_{grs} - 0.5 t_{corr}. The net moment of inertia is to be calculated at the mid span of the member including an attached plate width equal to the primary support member spacing

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

1.3.3.7 The maximum resulting force on the double bottom in a tank, F_{db}, is to be taken as:

$$F_{db} = g\left|W_{CT} + W_{CWBT} - \rho_{sw} b_2 l_{tk} T_{mean}\right| \qquad \text{kN}$$

Where:

W_{CT} weight of cargo, in tonnes, as defined in **Table 8.1.5**

W_{CWBT} weight of ballast, in tonnes, as defined in **Table 8.1.5**

b_2 breadth, in m, as defined in **Table 8.1.5**

l_{tk} length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in m

T_{mean} draught at the mid length of the tank for the loading condition considered, in m.

g acceleration due to gravity, 9.81 m/s^2

ρ_{sw} density of sea water, 1.025 tonnes/m^3

Table 8.1.5
Design Conditions for Double Bottoms

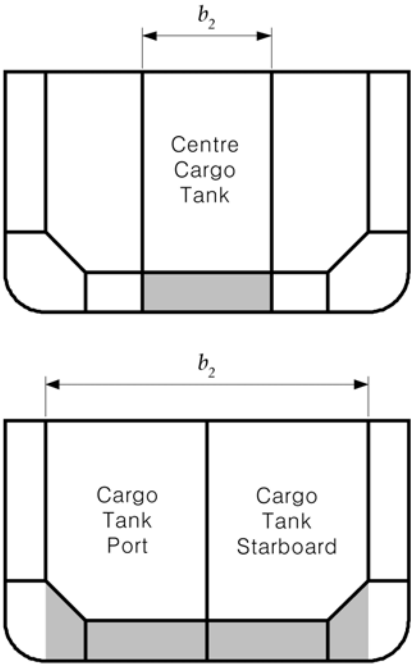
Structural Configuration	W_{CT}	W_{CWBT}	b_2
Ships with one longitudinal bulkhead	weight of cargo in cargo tanks, in tonnes, using a minimum specific gravity of 1.025 tonnes/m^3	weight of ballast between port and starboard inner sides, in tonnes	maximum breadth between port and starboard inner sides at mid length of tank, in m, as shown in **Fig 8.1.4**
Ships with two longitudinal bulkheads	weight of cargo in the centre tank, in tonnes, using a minimum specific gravity of 1.025 tonnes/m^3	weight of ballast below the centre cargo tank, in tonnes	maximum breadth of the centre cargo tank at mid length of tank, in m, as shown in **Fig 8.1.4**

1.3.3.8 The maximum resulting force on the double bottom in a tank, F_{db}, is in no case to be less than that given by the rule minimum conditions given in **Table 8.1.6.**

Table 8.1.6
Rule Minimum Conditions for Double Bottoms

Structural Configuration	Positive/negative force, F_{db}	Minimum condition
Ships with one longitudinal bulkhead	Max positive net vertical force, F_{db}+	0.9 T_{sc} and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	0.6 T_{sc} and full cargo tanks and empty ballast tanks
Ships with two longitudinal bulkheads	Max positive net vertical force, F_{db}+	0.9 T_{sc} and empty cargo and ballast tanks
	Max negative net vertical force, F_{db}-	0.6 T_{sc} and full centre cargo tank and empty ballast tanks

Fig 8.1.4
Tank Breadth to be Included for Different Tanker Types



1.3.4 Shear force correction due to loads from transverse bulkhead stringers

1.3.4.1 In way of transverse bulkhead stringer connections, within areas as specified in **Fig 8.1.6**, the equivalent net thickness of plate used for calculation of the hull girder shear strength, t_{str-k}, where the index k refers to the identification number of the stringer, is not to be taken greater than:

$$t_{str-k} = t_{sfc-net50}\left(1 - \frac{\tau_{str}}{\tau_{ij-perm}}\right) \quad \text{mm}$$

Where:

$t_{sfc-net50}$ effective net plating thickness, in mm, as defined in **1.3.3.1** and calculated at the transverse bulkhead for the height corresponding to the level of the stringer

$\tau_{ij-perm}$ permissible hull girder shear stress, τ_{perm}, for plate ij

$= 120/k_{ij}$ N/mm²

k_{ij} higher strength steel factor, k, for plate ij a defined in **Sec 6/1.1.4**

τ_{str} $= \dfrac{Q_{str-k}}{l_{str} t_{sfc-net50}}$ N/mm²

l_{str} connection length of stringer, in m, see **Fig 8.1.5**

Q_{str-k} shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full

$= 0.8 F_{str-k}\left(1 - \dfrac{z_{str} - h_{db}}{h_{bhd}}\right)$ kN

F_{str-k} total stringer supporting force, in kN, as defined in **1.3.4.2**

h_{db} the double bottom height, in m, as shown in **Fig 8.1.6**

h_{blk} height of bulkhead, in m, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in **Fig 8.1.6**

z_{str} the vertical distance from baseline to the considered stringer, in m.

1.3.4.2 The total stringer supporting force, F_{str-k}, in way of a longitudinal bulkhead is to be taken as:

$$F_{str-k} = \frac{P_{str} b_{str} (h_k + h_{k-1})}{2} \quad \text{kN}$$

Where:

P_{str} pressure on stringer, in kN/m^2, to be taken as: $10\,h_{tt}$

h_{tt} the height from the top of the tank to the midpoint of the load area between $h_k/2$ below the stringer and $h_{k-1}/2$ above the stringer, in m

h_k the vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 % of the average vertical distance to the inner bottom, in m

h_{k-1} the vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as 80 % of the average vertical distance to the upper deck, in m

b_{str} load breadth acting on the stringer, in m, see **Fig 8.1.7** and **8.1.8**

Fig 8.1.5
Effective Connection Length of Stringer

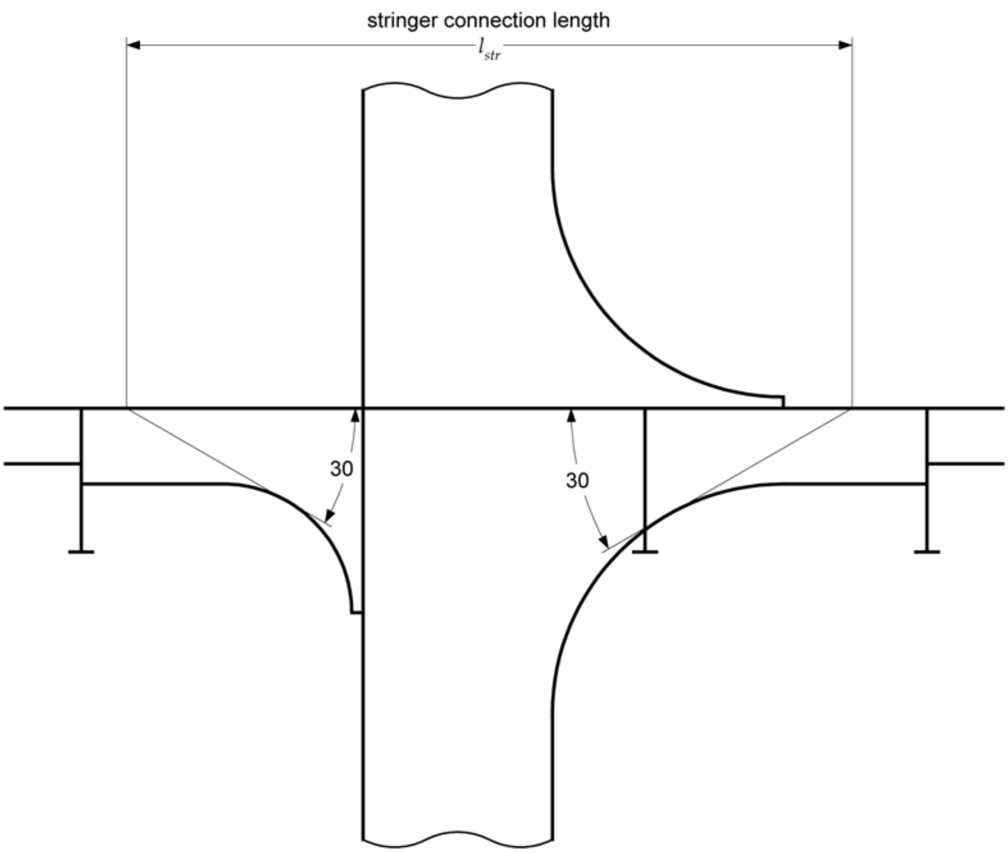


Fig 8.1.6
Region for Stringer Correction, t_{ij}, for a Tanker with Three Stringers

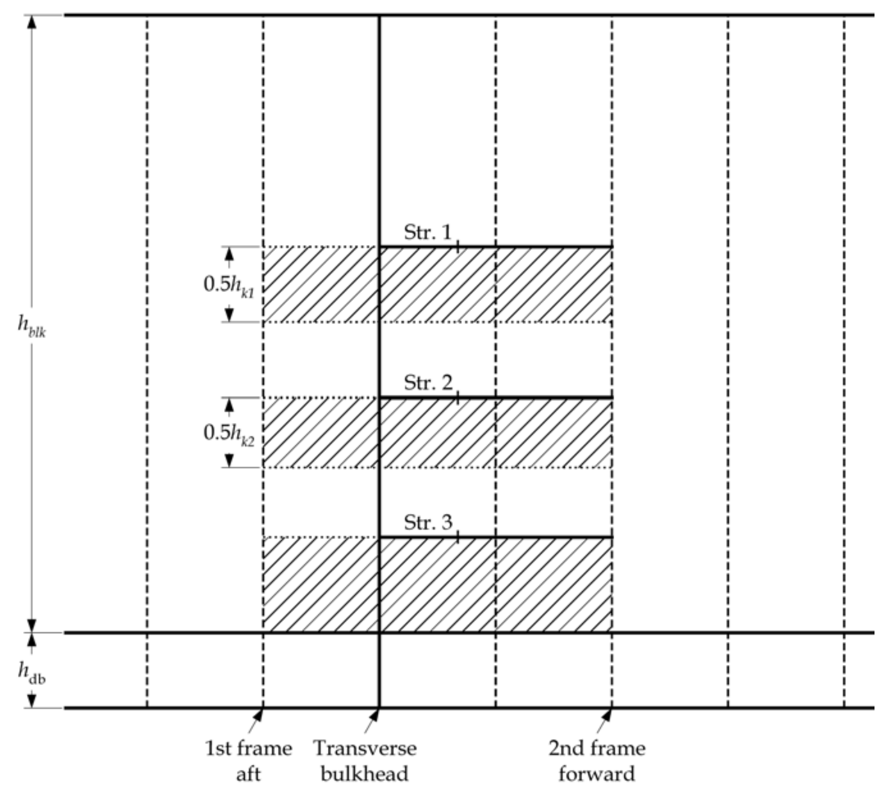
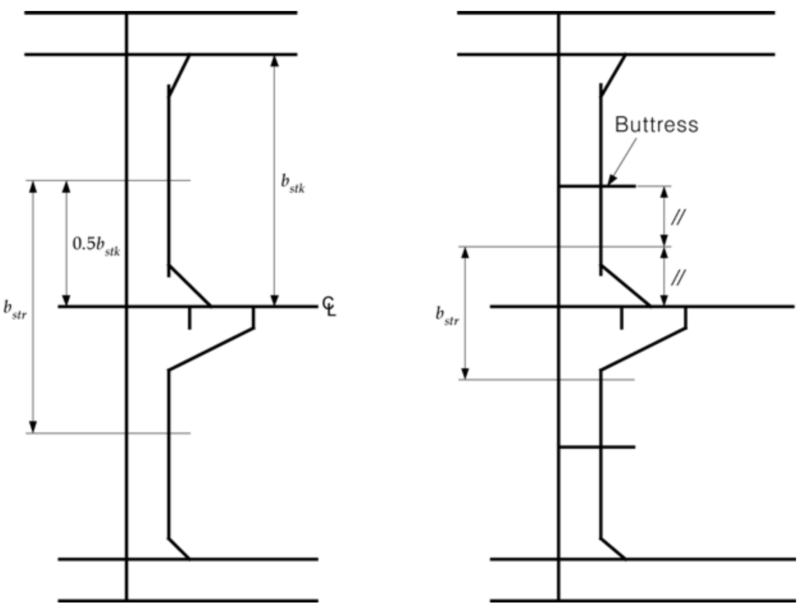
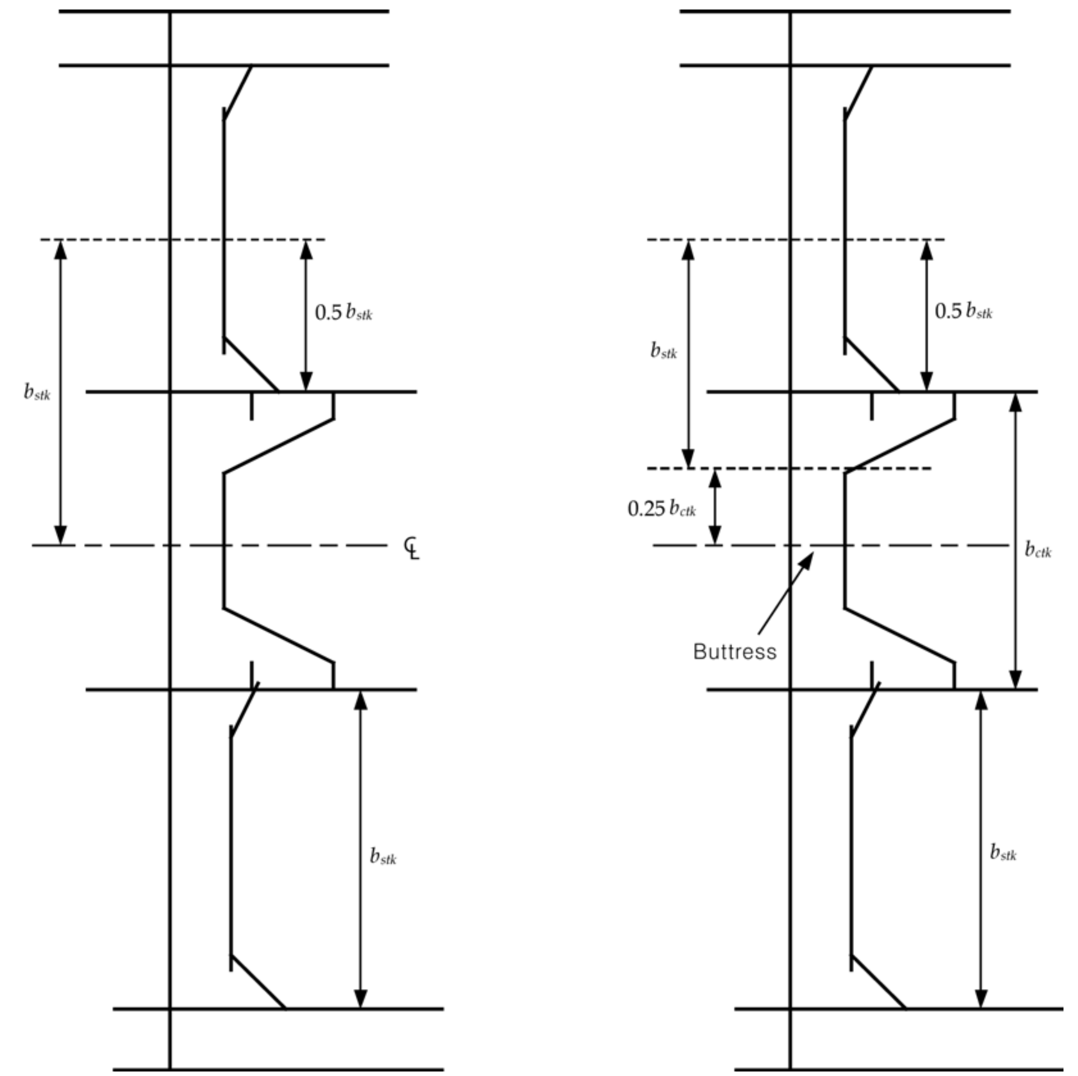


Fig 8.1.7
Load Breadth of Stringers for Ships with a Centreline Bulkhead



1.3.4.3 Where reinforcement is provided to meet the above requirement, the reinforced area based on t_{str-k} is to extend longitudinally for the full length of the stringer connection and aminimum of one frame spacing forward and aft of the bulkhead. The reinforced area shall extend vertically from above the stringer level and down to 0.5 h_k below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below is as defined in **1.3.4.2.** For the lowermost stringer the plate thickness requirement t_{str-k} is to extend down to the inner bottom, see **Fig 8.1.6.**

Fig 8.1.8
Load Breadth of Stringers for Ships with Two Inner Longitudinal Bulkheads



1.4 Hull Girder Buckling Strength

1.4.1 General

1.4.1.1 These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for still water bending and shear forces given in **Sec 7/2.1**, and wave bending moments and shear forces given in **Sec 7/3.4.**

1.4.1.2 The hull girder buckling strength requirements apply along the full length of the ship, from A.P to F.P.

1.4.1.3 For the purposes of assessing the hull girder buckling strength in this sub-section, the following are to be considered separately:

(a) axial hull girder compressive stress to satisfy requirements in **1.4.2.6** and **1.4.2.8**

(b) hull girder shear stress to satisfy requirements in **1.4.2.7.**

1.4.2 Buckling assessment

1.4.2.1 The buckling assessment of plate panels and longitudinals is to be determined according to **Sec 10/3.1** with hull girder stresses calculated on net hull girder sectional properties.

1.4.2.2 The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net}, as follows:

$$t_{net} = t_{grs} - 1.0 t_{corr} \quad \text{mm}$$

Where:

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

1.4.2.3 The hull girder compressive stress due to bending, $\sigma_{hg\text{-}net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg-net50} = \left| \frac{(z - z_{NA-net50})(M_{sw-perm-sea} + M_{wv-v})}{I_{v-net50}} \right| 10^{-3} \quad \text{N/mm}^2$$

$$\sigma_{hg-net50} = \frac{30}{k} \quad \text{N/mm}^2$$

Where:

$M_{sw\text{-}perm\text{-}sea}$ permissible still water bending moment for seagoing operation, in kNm, as defined in **Sec 7/2.1.1**, with signs as given in **1.4.2.4**

$M_{wv\text{-}v}$ hogging and sagging vertical wave bending moments, in kNm, as defined in **Sec 7/3.4.1**, with signs as given in **1.4.2.4**

$M_{wv\text{-}v}$ is to be taken as:

$M_{wv\text{-}hog}$ for assessment with the hogging still water bending moment

$M_{wv\text{-}sag}$ for assessment with the sagging still water bending moment

z distance from the structural member under consideration to the baseline, in m

$z_{NA\text{-}net50}$ distance from the baseline to the horizontal neutral, in m, see **Fig 8.1.1**

$I_{v\text{-}net50}$ net vertical hull girder section moment of inertia, in m^4, as defined in **Sec 4/2.6.1.1**

k higher strength steel factor, as defined in **Sec 6/1.1.4.1**

1.4.2.4 The sagging bending moment values of $M_{sw\text{-}perm\text{-}sea}$ and $M_{wv\text{-}v}$ are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

1.4.2.5 The design hull girder shear stress for the buckling assessment, $\tau_{hg\text{-}net50}$, is to be calculated based on net hull girder sectional properties and is to be taken as:

$$\tau_{hg-net50} = \left| (Q_{sw-perm-sea} + Q_{wv}) \left(\frac{1000 q_v}{t_{ij-net50}} \right) \right| \quad \text{N/mm}^2$$

Where:

$Q_{sw\text{-}perm\text{-}sea}$ positive and negative still water permissible shear force for seagoing operation, in kN, as defined in **Sec 7/2.1.3**

Q_{wv} positive or negative vertical wave shear, in kN, as defined in **Sec 7/3.4.3.**

Q_{vw} is to be taken as:

$Q_{wv\text{-}pos}$ for assessment with the positive permissible still water shear force

$Q_{wv\text{-}neg}$ for assessment with the negative permissible still water shear force

$t_{ij\text{-}net50}$ net thickness for the plate ij, in mm

$= t_{ij\text{-}grs} - 0.5\, t_{corr}$

$t_{ij\text{-}grs}$ gross plate thickness of plate *ij*, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm

$t_{w\text{-}grs}$ gross thickness of the corrugation web, in mm

$t_{f\text{-}grs}$ gross thickness of the corrugation flange, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

q_v unit shear per mm for the plate being considered as defined in **1.3.2.2**

Note

1. Maximum of the positive shear (still water + wave) and negative shear (still water + wave) is to be used as the basis for calculation of design shear stress
2. All plate elements *ij* that contribute to the hull girder shear capacity are to be assessed. See also **Table 8.1.4** and **Fig 8.1.2**
3. The gross rule required thicknesses is to be calculated considering shear force correction.
4. For longitudinal bulkheads between cargo tanks, $t_{ij\text{-}net50}$ is to be taken as $t_{sfc\text{-}net50}$ and $t_{str\text{-}k}$ as appropriate.

1.4.2.6 The compressive buckling strength, of plate panels, is to satisfy the following criteria:

$\eta \le \eta_{allow}$

Where:

η buckling utilisation factor

$$\frac{\sigma_{hg-net50}}{\sigma_{cr}}$$

$\sigma_{hg\text{-}net50}$ hull girder compressive stress based on net hull girder sectional properties, in N/mm^2 as defined in **1.4.2.3**

σ_{cr} critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate, in N/mm^2, as specified in **Sec 10/3.2.1.3**. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ as described in **Sec 6/3.3.2.2** is to be used for the calculation of σ_{cr}.

η_{allow} allowable buckling utilisation factor:

= 1.0 for plate panels at or above $0.5\,D$

= 0.90 for plate panels below $0.5\,D$

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

1.4.2.7 The shear buckling strength, of plate panels, is to satisfy the following criteria:

$\eta \le \eta_{allow}$

Where:

η buckling utilisation factor

$$\frac{\tau_{hg-net50}}{\tau_{cr}}$$

$\tau_{hg\text{-}net50}$ design hull girder shear stress, in N/mm^2, as defined in **1.4.2.5**

τ_{cr} critical shear buckling stress, in N/mm^2, as specified in **Sec 10/3.2.1.3.** The critical shear buckling stress is to be calculated for the effects of hull girder shear stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_{corr}$ as described in **Sec 6/3.3.2.2** is to be used for the calculation of τ_{cr}

η_{allow} allowable buckling utilisation factor

= 0.95

t_{grs} gross plate thickness, in mm

t_{corr} corrosion addition, in mm, as defined in **Sec 6/3.2**

1.4.2.8 The compressive buckling strength of longitudinal stiffeners is to satisfy the following criteria: $\eta \le \eta_{allow}$

Where:

η greater of the buckling utilisation factors given in **Sec 10/3.3.2.1** and **Sec 10/3.3.3.1**. The buckling utilisation factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored.

η_{allow} allowable buckling utilisation factor:

= 1.0 for stiffeners at or above $0.5D$

= 0.90 for stiffeners below $0.5D$

1.5 Hull Girder Fatigue Strength

1.5.1 General

1.5.1.1 The following provides a simplified fatigue control measure against the dynamic hull girder stresses in the longitudinal deck structure.

1.5.1.2 The requirements in **1.5.1.3** are not mandatory, but are recommended to be applied in the early design phase in order to give an indication of the required hull girder section modulus for compliance with the mandatory fatigue requirements specified in **Sec 9/3** and **Appendix C.**

1.5.1.3 The fatigue life for the deck structure as required by **Sec 9/3** and **Appendix C** is normally satisfied providing the net vertical hull girder section modulus at the moulded deck line at side, $Z_{v\text{-}net50}$, as defined in **Sec 4/2.6.1.1**, is not less than the required hullgirder section modulus, $Z_{v\text{-}fat}$, defined as:

$$Z_{v-fat} = \frac{M_{wv-hog} - M_{wv-sag}}{1000R_{al}} \quad \text{m}^3$$

Where:

$M_{wv\text{-}hog}$ hogging vertical wave bending moment for fatigue, in kNm, as defined in **Sec 7/3.4.1**

$M_{wv\text{-}sag}$ sagging vertical wave bending moment for fatigue, in kNm, as defined in **Sec 7/3.4.1**

R_{al} allowable stress range, in N/mm^2

= $0.17L + 86$ for class F-details

= $0.15L + 76$ for class F2-details

L rule length, in m, as defined in **Sec 4/1.1.1.1**

1.6 Tapering and Structural Continuity of Longitudinal Hull Girder Elements

1.6.1 Tapering based on minimum hull girder section property requirements

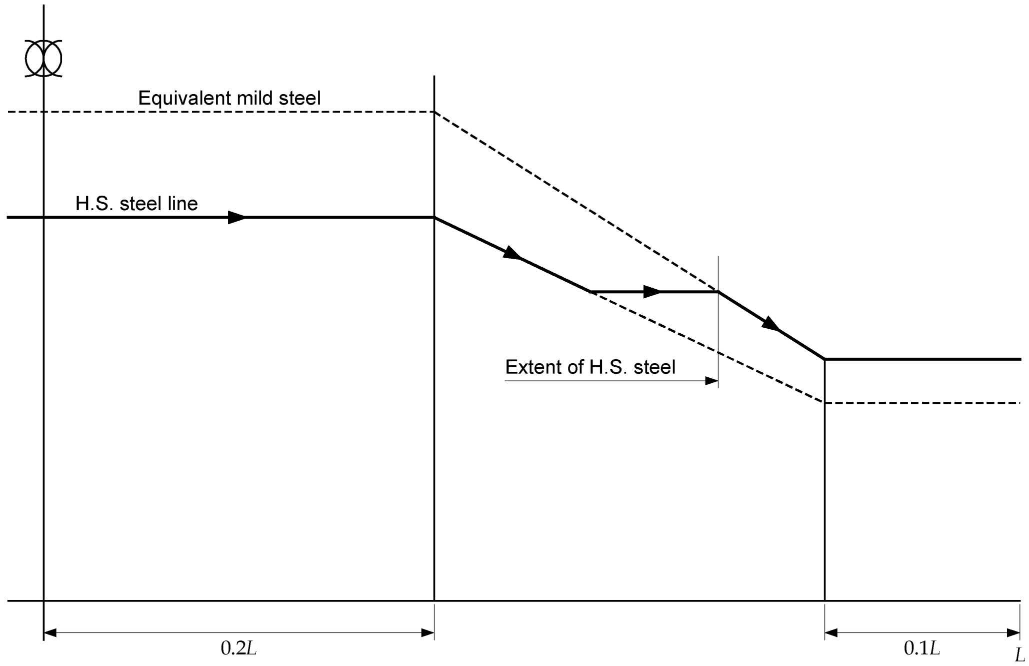
1.6.1.1 Scantlings of all continuous longitudinal members of the hull girder based on the moment of inertia and section modulus requirements given in **1.2.2** are to be maintained within $0.4L$ of amidships.

1.6.1.2 Scantlings outside of $0.4L$ amidships as required by the rule minimum moment of inertia and section modulus as given in **1.2.2** may be gradually reduced to the local requirements at the ends provided the hull girder bending and buckling requirements, along the full length of the ship, as given in **1.2.3** and **1.4** are complied with. For tapering of higher strength steel, see **1.6.2** and **1.6.3.**

1.6.2 Longitudinal extent of higher strength steel

1.6.2.1 Where used, the application of higher strength steel is to be continuous over the length of the ship up to locations where the longitudinal stress levels are within the allowable range for mild steel structure, see **Fig 8.1.9.**

Fig 8.1.9
Longitudinal Extent of Higher Strength Steel



1.6.3 Vertical extent of higher strength steel

1.6.3.1 The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, see also **Fig 8.1.10.**

$$z_{hts} = z_1\left(1 - \frac{190}{\sigma_1 k_i}\right) \quad \text{m}$$

Where:

z_1 distance from horizontal neutral axis to moulded deck line or keel respectively, in m

σ_1 to be taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively, in N/mm²

σ_{dk} hull girder bending stress at moulded deck line given by:

$$= \frac{|M_{sw-perm-sea} + M_{wv-v}|}{I_{v-net50}}(z_{dk-side} - z_{NA-net50}) \cdot 10^{-3} \quad \text{N/mm}^2$$

σ_{kl} hull girder bending stress at keel given by:

$$= \frac{|M_{sw-perm-sea} + M_{wv-v}|}{I_{v-net50}}(z_{NA-net50} - z_{kl}) \cdot 10^{-3} \quad \text{N/mm}^2$$

$M_{sw-perm-sea}$ permissible hull girder still water bending moment for seagoing operation, in kNm, as defined in **Sec 7/2.1.1**

$M_{wv\text{-}v}$ hogging and sagging vertical wave bending moments, in kNm, as defined in **Sec 7/3.4.1**

$M_{wv\text{-}v}$ is to be taken as:

$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment

$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

$I_{v\text{-}net50}$ net vertical hull girder moment of inertia, in m^4, as defined in **Sec 4/2.6.1.1**

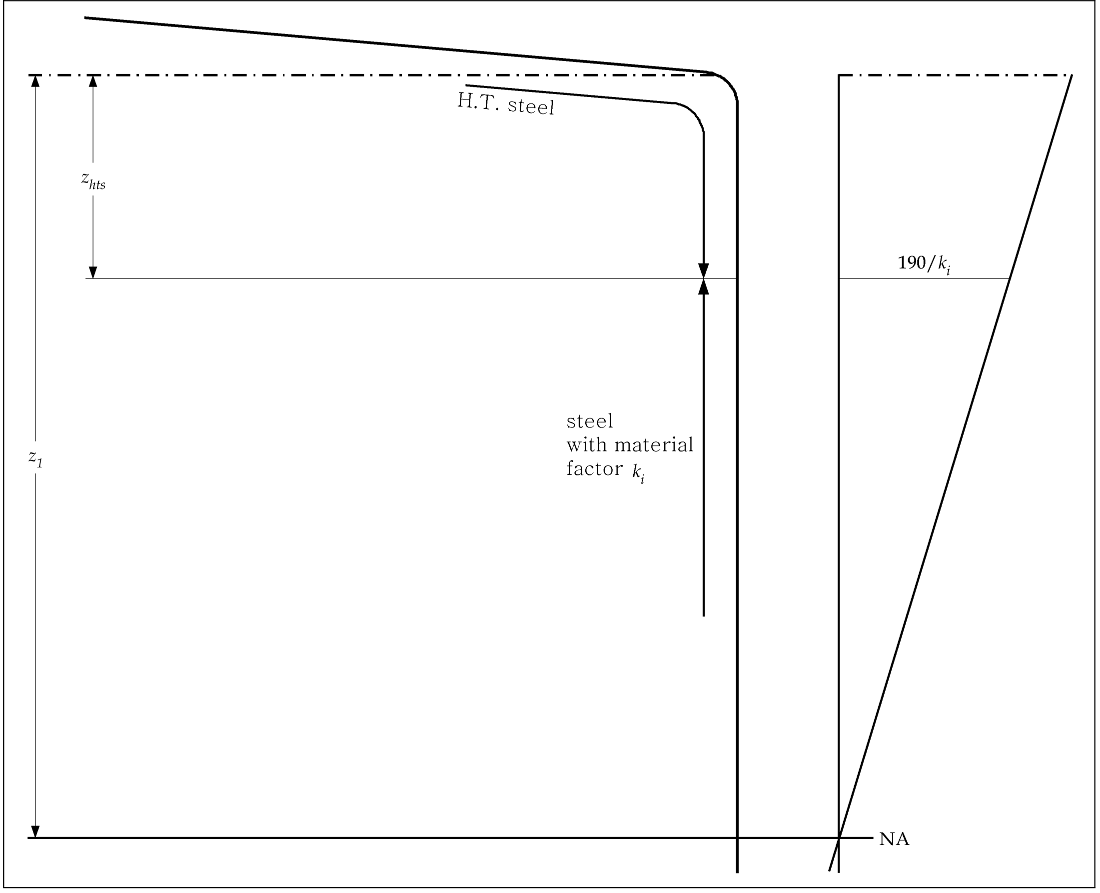
$z_{dk\text{-}side}$ distance from baseline to moulded deck line at side, in m

z_{kl} vertical distance from the baseline to the keel, in m

$z_{NA\text{-}net50}$ distance from baseline to horizontal neutral axis, in m

k_i higher strength steel factor for the area i defined in **Fig 8.1.10.** The factor, k, is defined in **Sec 6/1.1.4**

Fig 8.1.10
Vertical Extent of Higher Strength Steel



1.6.4 Tapering of plate thickness due to hull girder shear requirement

1.6.4.1 Longitudinal tapering of shear reinforcement is permitted, provided that for any longitudinal position the requirements given in **1.3.2** are complied with. Control of the shear strength at intermediate positions is to be carried out by linear interpolation of permissible shear limits at the bulkhead and in the middle of the tank.

1.6.5 Structural continuity of longitudinal bulkheads

1.6.5.1 Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets shall be fitted in line with the longitudinal bulkhead.

1.6.6 Structural continuity of longitudinal stiffeners

1.6.6.1 Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.6.6.2 Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft end of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel are to be considered.

2 Cargo Tank Region

2.1 General

2.1.1 Application

2.1.1.1 The requirements of this Sub-Section apply to the hull structure within the cargo tank region of the ship, for the shell, deck, inner bottom and bulkhead plating, stiffeners and primary support members.

2.1.2 Basis of scantlings

2.1.2.1 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements specified in **2.1.5** and **2.1.6**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

(c) for primary support members, the gross shear area, gross section modulus, and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion addition specified in **Sec 6/3**

(d) for application of the buckling requirements of **Sec 10/3**, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3.**

2.1.3 Evaluation of scantlings

2.1.3.1 The following scantling requirements are based on the assumption that all structural joints and welded details are designed and fabricated, such that they are to be compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements given in **Sec 4/3.**

2.1.3.2 The scantlings are to be assessed to ensure that the strength criteria are satisfied at all longitudinal positions, where applicable.

2.1.3.3 Local scantling increases are to be applied where applicable to cover local variations, such as increased spacing, increased stiffener spans and green sea pressure loads. Local scantling increases may also be required to cover fore end strengthening requirements, see **Sec 8/3.**

2.1.4 General scantling requirements

2.1.4.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Sec 8/1**

(b) strength against sloshing and impact loads, see **Sec 8/6**

(c) hull girder ultimate strength, see **Sec 9**

(d) strength assessment (FEM), see **Sec 9**

(e) fatigue strength, see **Sec 9/3**

(f) buckling and ultimate strength, see **Sec 10.**

2.1.4.2 The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with **Sec 4/2.**

2.1.4.3 The section modulus, shear areas and other sectional properties of the local and primary support members apply to the areas clear of the end brackets.

2.1.4.4 The spans of the local and primary support members are defined in **Sec 4/2.1.**

2.1.4.5 The moments of inertia for the primary support members are to be determined in association with the effective attached plating at the mid span as specified in **Sec 4/2.3.2.3.**

2.1.4.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and escape of air to the vents. See also **Sec 4/3.**

2.1.4.7 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in **Sec 4/3.2.4** and **4/3.2.5.**

2.1.4.8 Enlarged stiffeners (with or without web stiffening) used for Permanent Means of Access (PMA) are to comply with the following requirements:

(a) Buckling strength including proportion (slenderness ratio) requirements for primary support members as follows:

- For stiffener web, see **Sec 10/2.3.1.1(a), 10/3.2.**
- For stiffener flange, see **Sec 10/2.3.1.1(b), 10/2.3.3.1.**
- For web stiffeners, see **Sec 10/2.3.2.1, 10/2.3.2.2, 10/3.3.**

Note: Note 1 of table 10.2.1 is not applicable.

(b) Buckling strength of longitudinal PMA platforms without web stiffeners may also be ensured using the criteria for local support members in **Sec 10/2.2** and **Sec 10/3.3**, including Note 1 of **Table 10.2.1**, provided shear buckling strength of web is verified in line with **Sec 10/3.2.**

(c) All other requirements for local support members as follows:

- Corrosion additions: requirements for local support members
- Minimum thickness: requirements for local support members
- Fatigue: requirements for local support members

Note:
For primary support members (or part of it) used as a PMA platform the requirements for primary support members are to be applied.

2.1.5 Minimum thickness for plating and local support members

2.1.5.1 The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in **Table 8.2.1.**

Table 8.2.1
Minimum Net Thickness for Plating and Local Support Members in the Cargo Tank Region

Scantling Location			Net Thickness (mm)
Plating	Shell	Keel plating	$6.5 + 0.03\ L_2$
		Bottom shell/bilge/side shell	$4.5 + 0.03\ L_2$
	Upper Deck		$4.5 + 0.02\ L_2$
	Other structure	Hull internal tank boundaries	$4.5 + 0.02\ L_2$
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	$4.5 + 0.01\ L_2$
Local support members	Local support members on tight boundaries		$3.5 + 0.015\ L_2$
	Local support members on other structure		$2.5 + 0.015\ L_2$
Tripping brackets			$5.0 + 0.015\ L_2$

Where:
L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m

2.1.6 Minimum thickness for primary support members

2.1.6.1 The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirements given in **Table 8.2.2.**

Table 8.2.2
Minimum Net Thickness for Primary Support Members in Cargo Tank Region

Scantling Location	Net Thickness (mm)
Double bottom centreline girder	$5.5 + 0.025\ L_2$
Other double bottom girders	$5.5 + 0.02\ L_2$
Double bottom floors, web plates of side transverses and stringers in double hull	$5.0 + 0.015\ L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead, deck transverses (above and below upper deck) and cross ties.	$5.5 + 0.015\ L_2$
Where: L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m	

2.2 Hull Envelope Plating

2.2.1 Keel plating

2.2.1.1 Keel plating is to extend over the flat of bottom for the complete length of the ship. The breadth, b_{kl}, is not to be less than:

$$b_{kl} = 800 + 5L_2 \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but not to be taken greater than 300 m

2.2.1.2 The thickness of the keel plating is to comply with the requirements given in **2.2.2.**

2.2.2 Bottom shell plating

2.2.2.1 The thickness of the bottom shell plating is to comply with the requirements in **Table 8.2.4.**

2.2.3 Bilge plating

2.2.3.1 The thickness of bilge plating is not to be less than that required for the adjacent bottom shell, see **2.2.2.1**, or adjacent side shell plating, see **2.2.4.1**, whichever is the greater.

2.2.3.2 The net thickness of bilge plating, t_{net}, without longitudinal stiffening is not to be less than:

$$t_{net} = \frac{\sqrt[3]{r^2 S_t P_{ex}}}{100} \quad \text{mm}$$

Where:

P_{ex} design sea pressure for the design load set 1 calculated at the lower turn of bilge, in kN/m^2

r effective bilge radius

$= r_0 + 0.5(a + b)$ mm

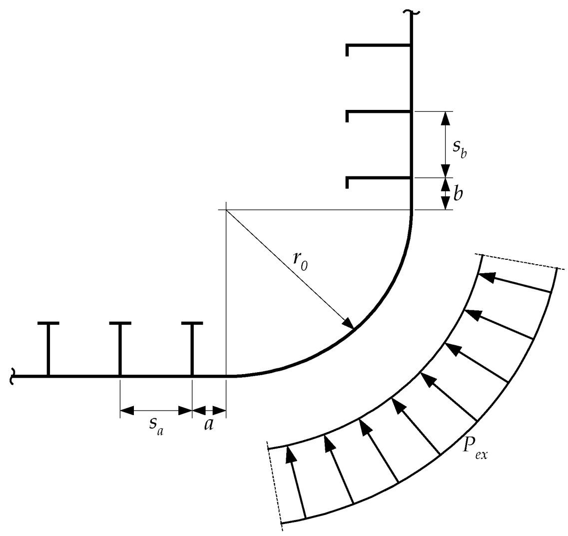
r_0 radius of curvature, in mm. See **Fig 8.2.1**

S_t distance between transverse stiffeners, webs or bilge brackets, in m *a* distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see **Fig 8.2.1** and **2.3.1.2.** Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero.

b distance between the upper turn of bilge and the lowest side longitudinal, in mm, see **Fig 8.2.1** and **2.3.1.2.** Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero.

Where plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to extend to the adjacent plate above the bilge provided that the plate seam is not more than $S_b/4$ below the lowest side longitudinal. Similarly for flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be applied provided that the plate seam is not more than $S_a/4$ beyond the outboard bottom longitudinal. Regularly longitudinally stiffened bilge plating is to be assessed as a stiffened plate. The bilge keel is not considered as "longitudinal stiffening" for the application of this requirement.

Fig 8.2.1
Unstiffened Bilge Plating



2.2.3.3 Where bilge longitudinals are omitted, the bilge plate thickness outside 0.4 L amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside of 0.4 L amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

2.2.4 Side shell plating

2.2.4.1 The thickness of the side shell plating is to comply with the requirements in **Table 8.2.4.**

2.2.4.2 The net thickness, t_{net}, of the side plating within the range as specified in **2.2.4.3** is not to be less than:

$$t_{net} = 26\left(\frac{s}{1000} + 0.7\right)\left(\frac{BT_{sc}}{\sigma_{yd}^{\ 2}}\right)^{0.25} \quad \text{mm}$$

Where:

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

B moulded breadth, in m as defined in **Sec 4/1.1.3.1**

T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.2.4.3 The thickness in **2.2.4.2** is to be applied to the following extent of the side shell plating, see **Fig 8.2.2**:

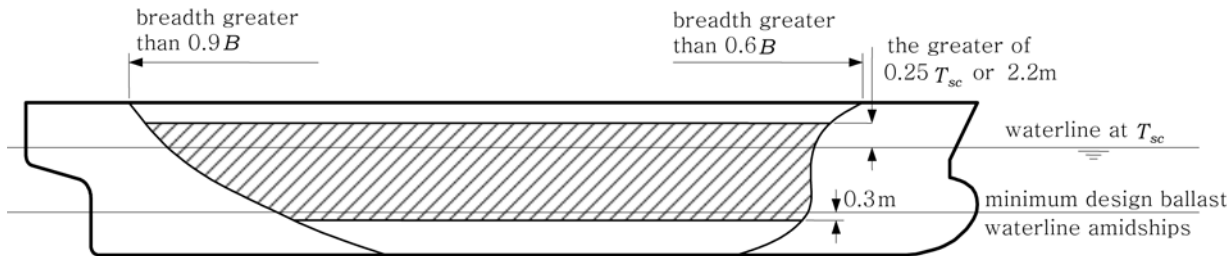
(a) longitudinal extent:

- between a section aft of amidships where the breadth at the waterline exceeds 0.9 B, and a section forward of amidships where the breadth at the waterline exceeds 0.6 B

(b) vertical extent:

- between 300 mm below the minimum design ballast waterline, T_{bal}, amidships to 0.25 T_{sc} or 2.2 m, whichever is greater, above the draught T_{sc}.

Fig 8.2.2
Extent of Side Shell Plating



2.2.5 Sheer strake

2.2.5.1 The sheer strake is to comply with the requirements in **2.2.4.**

2.2.5.2 The welding of deck fittings to rounded sheer strakes is to be avoided within 0.6L of amidships.

2.2.5.3 Where the sheer strake extends above the deck stringer plate, the top edge of the sheer strake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges Grinding may be required if the cutting surface is not smooth. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

2.2.6 Deck plating

2.2.6.1 The thickness of the deck plating is to comply with the requirements given in **Table 8.2.4.**

2.3 Hull Envelope Framing

2.3.1 General

2.3.1.1 The bottom shell, inner bottom and deck are to be longitudinally framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Where the side shell is longitudinally framed, the inner hull bulkheads are to be similarly constructed. Suitable alternatives which take account of resistance to buckling will be specially considered.

2.3.1.2 the spacing between the two outermost bottom longitudinals, s_a. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, b, is generally not to be greater than one-third of the spacing between the two lowest side longitudinals, s_b. See **Fig 8.2.1.**

2.3.1.3 The longitudinals are to comply with the requirements of continuity given in **Sec 4/3.2.**

2.3.2 Scantling criteria

2.3.2.1 The section modulus, and thickness, of the hull envelope framing is to comply with the requirements given in **Tables 8.2.5** and **8.2.6.**

2.3.2.2 Where the side shell longitudinal or the vertical stiffener is inclined to the longitudinal or vertical axis, respectively, the span is to be taken in accordance with **Sec 4/2.1.3.**

2.3.2.3 For curved stiffeners, the span is to be taken in accordance with **Sec 4/2.1.3.**

2.4 Inner Bottom

2.4.1 Inner bottom plating

2.4.1.1 The thickness of the inner bottom plating is to comply with the requirements given in **Table 8.2.4.**

2.4.1.2 In way of a welded hopper knuckle, the inner bottom is to be scarfed to ensure adequate load transmission to surrounding structure and reduce stress concentrations.

2.4.1.3 In way of corrugated bulkhead stools, where fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see **Sec 6/1.1.5.**

2.4.2 Inner bottom longitudinals

2.4.2.1 The section modulus and web plate thickness of the inner bottom longitudinals are to comply with the requirements given in **Tables 8.2.5** and **8.2.6.**

2.5 Bulkheads

2.5.1 General

2.5.1.1 The inner hull and longitudinal bulkheads are generally to be longitudinally framed, and plane. Corrugated bulkheads are to comply with the requirements given in **2.5.6.**

2.5.1.2 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

2.5.2 Longitudinal tank boundary bulkhead plating

2.5.2.1 The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in **Table 8.2.4.**

2.5.2.2 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarfed into the adjoining structure.

2.5.3 Hopper side structure

2.5.3.1 Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

2.5.4 Transverse tank boundary bulkhead plating

2.5.4.1 The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in **Table 8.2.4.**

2.5.5 Tank boundary bulkhead stiffeners

2.5.5.1 The section modulus and web thickness of stiffeners, on longitudinal or transverse tank boundary bulkheads, are to comply with the requirements given in **Tables 8.2.5** and **8.2.6.**

2.5.6 Corrugated bulkheads

2.5.6.1 The scantling requirements relating to corrugated bulkheads defined in **2.5.6** and **2.5.7** are net requirements. The gross scantling requirements are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3.**

2.5.6.2 In general, corrugated bulkheads are to be designed with the corrugation angles, ϕ, between 55 and 90 degrees, see **Fig 8.2.3.**

2.5.6.3 The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model in the midship region, see **Sec 9/2**. The global strength of corrugated bulkheads outside of midship region are to be considered based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the midship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

2.5.6.4 The net thicknesses, t_{net}, of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$t_{net} = 0.0158 b_p \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

P design pressure for the design load set being considered, calculated at the load point defined in **Sec 3/5.1**, in kN/m^2

b_p breadth of plate:

= b_f for flange plating, in mm. See **Fig 8.2.3**

= b_w for web plating, in mm. See **Fig 8.2.3**

C_a permissible bending stress coefficient:

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.5.6.5 Where the corrugated bulkhead is built with flange and web plate of different thickness, then the thicker net plating thickness, $t_{m\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$t_{m-net} = \sqrt{\frac{0.0005 b_p^2 |P|}{C_a \sigma_{yd}} - t_{n-net}^2} \quad \text{mm}$$

Where:

$t_{n\text{-}net}$ net thickness of the thinner plating, either flange or web, in mm

b_p breadth of thicker plate, either flange or web, in mm

P design pressure for the design load set being considered, calculated at the load point defined in **Sec 3/5.1**, in kN/m^2

C_a permissible bending stress coefficient:

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.5.7 Vertically corrugated bulkheads

2.5.7.1 In addition to the requirements of **2.5.6**, vertically corrugated bulkheads are also to comply with the requirements of **2.5.7.**

2.5.7.2 The net plate thicknesses as required by **2.5.7.5** and **2.5.7.6** are to be maintained for two thirds of the corrugation length, l_{cg}, from the lower end, where l_{cg} is as defined in **2.5.7.3.** Above that, the net plate thickness may be reduced by 20 %.

2.5.7.3 The net web plating thickness of the lower 15 % of the corrugation, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see **2.5.7.9.**

$$t_{w-net} = \frac{1000|Q_{cg}|}{d_{cg}\, C_{t-cg}\, \tau_{yd}} \quad \text{mm}$$

Where:

Q_{cg} design shear force imposed on the web plating at the lower end of the corrugation

$$= \frac{s_{cg}\, l_{cg}\, |3P_l + P_u|}{8000} \quad \text{kN}$$

P_l design pressure for the design load set being considered, calculated at the lower end of the corrugation, in kN/m^2

P_u design pressures for the design load set being considered, calculated at the upper end of the corrugation, in kN/m^2

s_{cg} spacing of corrugation, in mm. See **Fig 8.2.3**

l_{cg} length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in m, see **Fig 8.2.3**

d_{cg} depth of corrugation, in mm. See **2.5.7.4** and **Fig 8.2.3**

C_{t-cg} permissible shear stress coefficient

= 0.75 for acceptance criteria set AC1

= 0.90 for acceptance criteria set AC2

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.5.7.4 The depth of the corrugation, d_{cg}, is not to be less than:

$$d_{cg} = \frac{1000\, l_{cg}}{15} \quad \text{mm}$$

Where:

l_{cg} length of corrugation, which is defined as the distance between the lower stool or the inner bottom if no lower stool is fitted and the upper stool or the upper end where no upper stool is fitted, in m, see **Fig 8.2.3**

2.5.7.5 The net thicknesses of the flanges of corrugated bulkheads, $t_{f\text{-}net}$, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool, see **2.5.7.9.**

$$t_{f-net} = \frac{0.00657\, b_f \sqrt{\sigma_{bdg-max}}}{C_f} \quad \text{mm}$$

Where:

$\sigma_{bdg-max}$ maximum value of the vertical bending stresses in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length

$= \frac{1000 M_{cg}}{Z_{cg-act-net}}$ N/mm^2

M_{cg} as defined in **2.5.7.6**

$Z_{cg-act-net}$ actual net section modulus at the lower end and at the mid length of the corrugation, in cm^3

b_f breadth of flange plating, in mm. See **Fig 8.2.3**

b_w breadth of web plating, in mm. See **Fig 8.2.3**

C_f coefficient

$= 7.65 - 0.26\left(\frac{b_w}{b_f}\right)^2$

2.5.7.6 The net section modulus at the lower and upper ends and at the mid length of the corrugation ($l_{cg}/2$) of a unit corrugation, Z_{cg-net}, are to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by the following.

$$Z_{cg-net} = \frac{1000 M_{cg}}{C_{s-cg}\,\sigma_{yd}} \quad \text{cm}^3$$

Where:

M_{cg} $= \frac{C_i |P| s_{cg} l_o^2}{12000}$ kNm

P $= \frac{P_u + P_l}{2}$ kN/m^2

P_l, P_u design pressure for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m^2:

(a) for transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk}/2$ from the longitudinal bulkheads of each tank

(b) for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e., the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead

b_{tk} maximum breadth of tank under consideration measured at the bulkhead, in m

s_{cg} spacing of corrugation, in mm. See **Fig 8.2.3**

l_o effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in m, see **Fig 8.2.3**

l_{cg} length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in m, see **Fig 8.2.3**

C_i the relevant bending moment coefficients as given in **Table 8.2.3**

C_{s-cg} permissible bending stress coefficient

at the mid length of the corrugation length, lcg:

= c_e, but not to be taken as greater than 0.75 for acceptance criteria set AC1

= c_e, but not to be taken as greater than 0.90 for acceptance criteria set AC2

at the lower and upper ends of corrugation length, l_{cg}:
= 0.75 for acceptance criteria set AC1
= 0.90 for acceptance criteria set AC2

c_e $= \dfrac{2.25}{\beta} - \dfrac{1.25}{\beta^2}$ for $\beta \geq 1.25$

= 1.0 for $\beta < 1.25$

β $= \dfrac{b_f}{t_{f-net}}\sqrt{\dfrac{\sigma_{yd}}{E}}$

b_f breadth of flange plating, in mm, see **Fig 8.2.3**

t_{f-net} net thickness of the corrugation flange, in mm

E modulus of elasticity, in N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.2.3
Values of C_i

Bulkhead	At lower end of l_{cg}	At mid length of l_{cg}	At upper end of l_{cg}
Transverse Bulkhead	C_1	C_{m1}	0.80 C_{m1}
Longitudinal Bulkhead	C_3	C_{m3}	0.65 C_{m3}

Where:

C_1 $= a_1 + b_1\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.60

$= a_1 - b_1\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but is not to be taken as less than 0.55

a_1 $= 0.95 - \dfrac{0.41}{R_{bt}}$

$= 0.6$ for transverse bulkhead with no lower stool

b_1 $= -0.20 + \dfrac{0.078}{R_{bt}}$

$= 0.13$ for transverse bulkhead with no lower stool

C_{m1} $= a_{m1} + b_{m1}\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.55

$= a_{m1} - b_{m1}\sqrt{\dfrac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but is not to be taken as less than 0.60

a_{m1} $= 0.63 + \dfrac{0.25}{R_{bt}}$

$= 0.96$ for transverse bulkhead with no lower stool

b_{m1} $= -0.25 - \dfrac{0.11}{R_{bt}}$

$= 0.34$ for transverse bulkhead with no lower stool

Table 8.2.3 (Continued)
Values of C_i

C_3	$= a_3 + b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$	but is not to be taken as less than 0.60
	$= a_3 - b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.55
a_3	$= 0.86 - \frac{0.35}{R_{bl}}$	
	$= 0.6$	for longitudinal bulkhead with no lower stool
b_3	$= -0.17 + \frac{0.10}{R_{bl}}$	
	$= 0.13$	for longitudinal bulkhead with no lower stool
C_{m3}	$= a_{m3} + b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$	but is not to be taken as less than 0.55
	$= a_{m3} - b_{m3}\sqrt{\frac{A_{dl}}{l_{dk}}}$	for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.60
a_{m3}	$= 0.32 + \frac{0.24}{R_{bl}}$	
	$= 0.9$	for longitudinal bulkhead with no lower stool
b_{m3}	$= -0.12 - \frac{0.10}{R_{bl}}$	
	$= 0.19$	for longitudinal bulkhead with no lower stool
R_{bt}	$= \frac{A_{bt}}{b_{ib}}\left(1+\frac{l_{ib}}{b_{ib}}\right)\left(1+\frac{b_{av-t}}{h_{st}}\right)$	for transverse bulkheads
R_{bl}	$= \frac{A_{bl}}{l_{ib}}\left(1+\frac{l_{ib}}{b_{ib}}\right)\left(1+\frac{b_{av-l}}{h_{sl}}\right)$	for longitudinal bulkheads
A_{dt}	cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2 = 0 if no upper stool is fitted	
A_{dl}	cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2 = 0 if no upper stool is fitted	
A_{bt}	cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2	
A_{bl}	cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2	
b_{av-t}	average width of transverse bulkhead lower stool, in m. See **Fig 8.2.3**	
b_{av-l}	average width of longitudinal bulkhead lower stool, in m. See **Fig 8.2.3**	
h_{st}	height of transverse bulkhead lower stool, in m. See **Fig 8.2.3**	
h_{sl}	height of longitudinal bulkhead lower stool, in m. See **Fig 8.2.3**	
b_{ib}	breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See **Fig 8.2.3**	
b_{dk}	breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See **Fig 8.2.3**	
l_{ib}	length of cargo tank at the inner bottom level between transverse lower stools, in m. See **Fig 8.2.3**	
l_{dk}	length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See **Fig 8.2.3**	

2.5.7.7 For tanks with effective sloshing breadth, b_{slh}, greater than 0.56 B or effective sloshing length l_{slh}, greater than 0.13 L, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation in accordance with the requirements of the individual Classification Society.

2.5.7.8 For ships with a moulded depth, see **Sec 4/1.1.4**, equal to or greater than 16 m, alower stool is to be fitted in compliance with the following requirements:

(a) general:

- the height and depth are not to be less than the depth of the corrugation
- the lower stool is to be fitted in line with the double bottom floors or girders
- the side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom.

(b) stool top plating:

- the net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation
- the extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:

- within the region of the corrugation depth from the stool top plate the net thickness of the stool side plate is not to be less than 90 % of that required by **2.5.7.2** for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by **2.5.2**, **2.5.4** and **2.5.5** for transverse or longitudinal bulkhead plating and stiffeners
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80 % of the required thickness of the corrugation webs and is to be of at least the same material yield strength
- scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

2.5.7.9 For ships with a moulded depth, see **Sec 4/1.1.4**, less than 16 m, the lower stool may be eliminated provided the following requirements, in addition to the requirements of **2.5.7.6**, are complied with:

(a) general:

- double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively
- brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable gusset plates with shedder plates are to be fitted, see item (c) below and **Fig 8.2.3**
- the corrugated bulkhead and its supporting structure is to be assessed by Finite Element (FE) analysis in accordance with **Sec 9/2**. In addition the local scantlings requirements of **2.5.6.4** and **2.5.6.5** and the minimum corrugation depth requirement of **2.5.7.4** are to be applied.

(b) inner bottom and hopper tank plating:

- the inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation

(c) supporting structure:

- within the region of the corrugation depth below the inner bottom the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength

- the upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure
- brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80 % of the net thickness of the corrugation webs and are to be of at least the same material yield strength
- cut outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates
- where support is provided by gussets with shedder plates, the height of the gusset plate, see h_g in **Fig 8.2.3**, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates are not to be less than 100 % and 80 %, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material yield strength. Also see **2.5.7.11.**
- scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

2.5.7.10 In general, an upper stool is to be fitted in compliance with the following requirements:

(a) general:

- where no upper stool is fitted, finite element analysis is to be carried out to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure
- side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission
- brackets are to be arranged in the intersections between the upper stool and the structure on deck

(b) stool bottom plating:

- the net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation
- the extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:

- within the region of the corrugation depth above the stool bottom plate the net thickness of the stool side plate is to be not less than 80 % of that required by 2.5.7.2 for the corrugated bulkhead flange at the upper end where the same material is used. If material of different yield strength is used the required thickness is to be adjusted by the ratio of the two material factors(k). k is defined in **Sec 6/1.1.4.1**
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by **2.5.2**, **2.5.4** and **2.5.5** for the transverse or longitudinal bulkhead plating and stiffeners
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool
- scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

2.5.7.11 Where gussets with shedder plates or shedder plates (slanting plates) are fitted at the end connection of the corrugation to the lower stool or to the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

2.5.7.12 Welding for all connections and joints is to comply with **Sec 6/5.**

2.5.8 Non-tight bulkheads

2.5.8.1 Non-tight bulkheads (wash bulkheads), where fitted, are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and are to comply with the sloshing requirements given in **6.2**. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10 % of the area of the bulkhead.

Fig 8.2.3
Definition of Parameters for Corrugated Bulkhead
(Tankers with Longitudinal Bulkhead at Centreline)

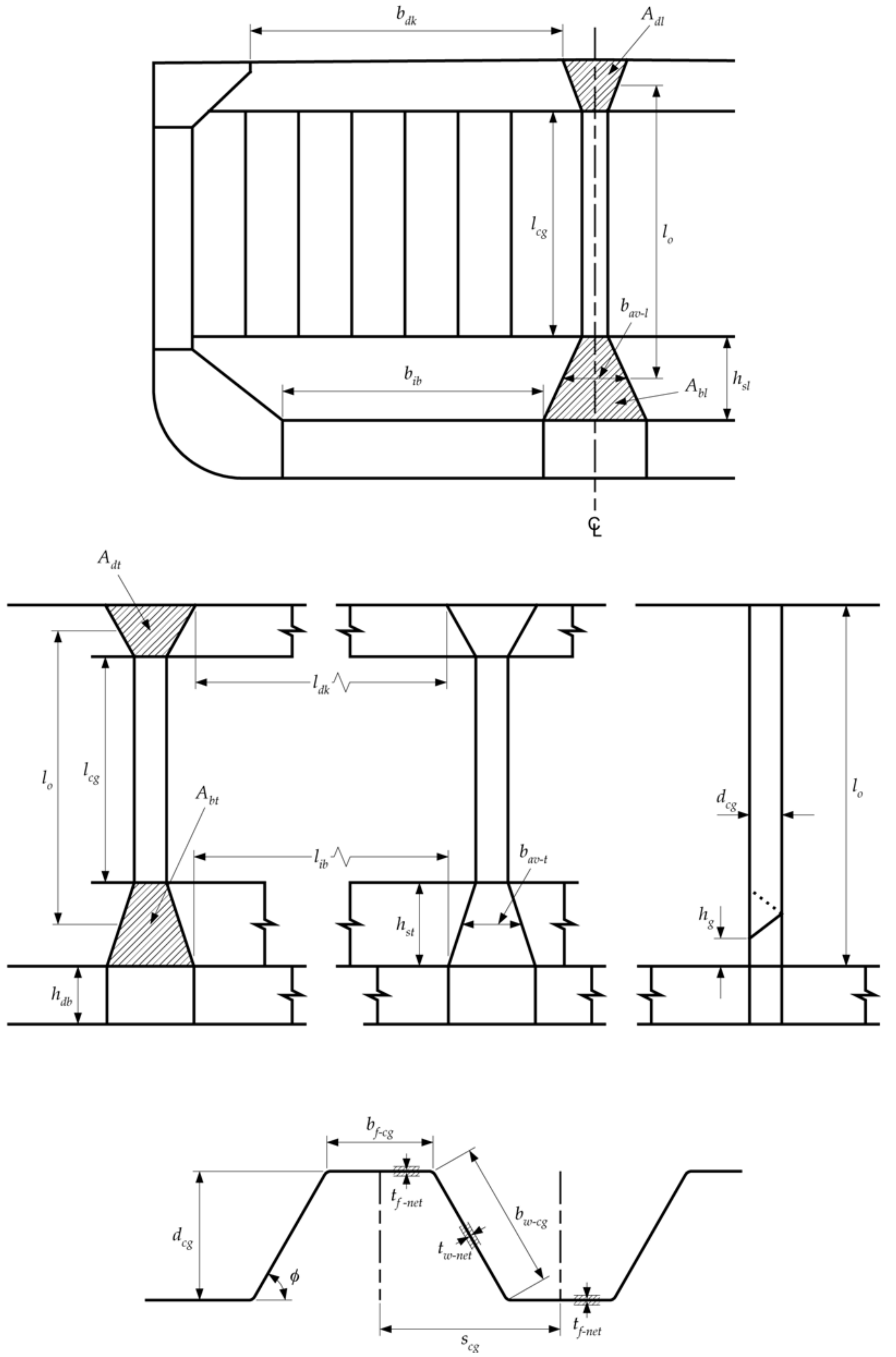


Table 8.2.4
Thickness Requirements for Plating

The minimum net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, as given in **Table 8.2.7**, and given by:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{|P|}{C_a\sigma_{yd}}} \quad \text{mm}$$

Where:

P design pressure for the design load set being considered and calculated at the load calculation point defined in **Sec 3/5.1**, in kN/m^2

α_p correction factor for the panel aspect ratio

$= 1.2 - \frac{s}{2100 l_p}$ but is not to be taken as greater than 1.0

s as defined in **Sec 4/2.2**, in mm

l_p length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

C_a permissible bending stress coefficient for the design load set being considered

$= \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

Acceptance Criteria Set	Structural Member		β_a	α_a	C_{a-max}
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC2	Longitudinal Strength Members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.0

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in **Sec 3/5.1.2**

$$= \left(\frac{(z - z_{NA-net50})\,M_{v-total}}{I_{v-net50}} - \frac{y\,M_{h-total}}{I_{h-net50}}\right)10^{-3} \quad N/mm^2$$

$M_{v-total}$ design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see **Table 7.6.1**

$M_{h-total}$ design horizontal bending moment at the longitudinal position under consideration for the design load set being considered, in kNm

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.1**, in m^4

$I_{h-net50}$ net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.2**, in m^4

y transverse coordinate of load calculation point, in m

z vertical coordinate of the load calculation point under consideration, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in **Sec 4/2.6.1**, in m

Table 8.2.5
Section Modulus Requirements for Stiffeners

The minimum net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design loadsets, as given in **Table 8.2.7**, and given by:

$$Z_{net} = \frac{|P| s\, l_{bdg}^{2}}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

P design pressure for the design load set being considered and calculated at the load calculation point defined in **Sec 3/5.2**, in kN/m^2

f_{bdg} bending moment factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for stiffeners with reduced end fixity see **Sec 7**.

l_{bdg} effective bending span, in m, as defined in **Sec 4/2.1.1**

s as defined in **Sec 4/2.2**, in mm

σ_{yd} specified minimum yield stress of the material, see also **Sec 3/5.2.6.5**, in N/mm^2

C_s permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of Hull Girder Bending Stress, σ_{hg}	Side Pressure Acting On	Acceptance Criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - a_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener side	

Acceptance Criteria Set	Structural Member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical member	0.75	0	0.75
AC2	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical member	0.9	0	0.9
	Watertight boundary Stiffeners	0.9	0	0.9

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the reference point defined in **Sec 3/5.2.2.5**

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} - \frac{y\, M_{h-total}}{I_{h-net50}} \right) 10^{-3} \quad \text{N/mm}^2$$

$M_{v\text{-}total}$ design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm.
$M_{v\text{-}total}$ is to be calculated in accordance with **Table 7.6.1** using the permissible hogging or sagging still water bending moment, $M_{sw\text{-}perm}$, to be taken as:

Stiffener Location	$M_{sw\text{-}perm}$	
	Pressure acting on Plate Side	Pressure acting on Stiffener Side
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$M_{h\text{-}total}$ design horizontal bending moment at longitudinal position under consideration for the design load set being considered, see T**able 7.6.1**, in kNm

$I_{v\text{-}net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.1**, in m^4

$I_{h\text{-}net50}$ net horizontal hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.2**, in m^4

y transverse coordinate of the reference point defined in **Sec 3/5.2.2.5**, in m

z vertical coordinate of the reference point defined in **Sec 3/5.2.2.5**, in m

$z_{NA\text{-}net50}$ distance from the baseline to the horizontal neutral axis, as defined in **Sec 4/2.6.1**, in m

Table 8.2.6 **Web Thickness Requirements for Stiffeners**	
The minimum net web thickness, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.2.7**, and given by: $t_{w-net} = \dfrac{f_{shr} \lvert P \rvert s\, l_{shr}}{d_{shr}\, C_t\, \tau_{yd}}$ mm	
Where:	
P	design pressure for the design load set being considered and calculated at the load calculation point defined in **Sec 3/5.1**, in kN/m^2
f_{shr}	shear force distribution factor: for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends: = 0.5 for horizontal stiffeners = 0.7 for vertical stiffeners for stiffeners with reduced end fixity, see **sec 7**
d_{shr}	as defined in **Sec 4/2.4.2.2**, in mm
C_t	permissible shear stress coefficient for the design load set being considered, to be taken as: = 0.75 for acceptance criteria set AC1 = 0.90 for acceptance criteria set AC2
s	as defined in **Sec 4/2.2**, in mm
l_{shr}	effective shear span, in m, see **Sec 4/2.1.2**
τ_{yd}	$= \dfrac{\sigma_{yd}}{\sqrt{3}}$ (N/mm^2)
σ_{yd}	specified minimum yield stress of the material, in N/mm^2

Table 8.2.7
Design Load Sets for Plating and Local Support Members

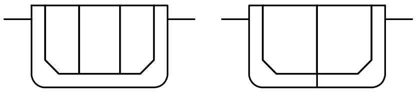
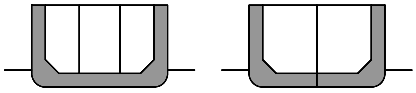
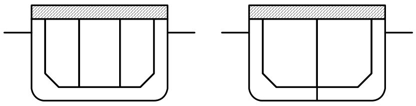
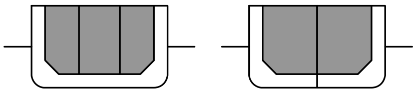
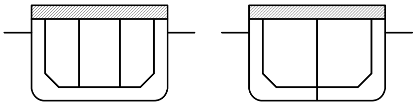
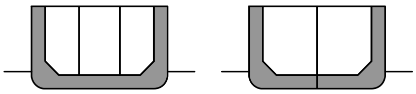
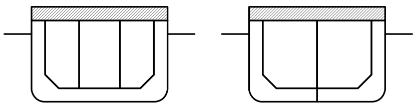
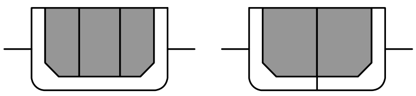
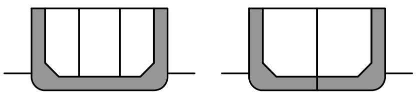
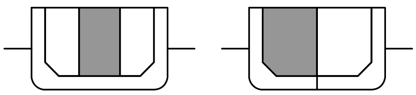
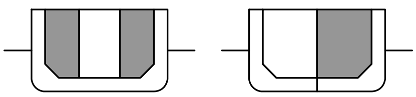
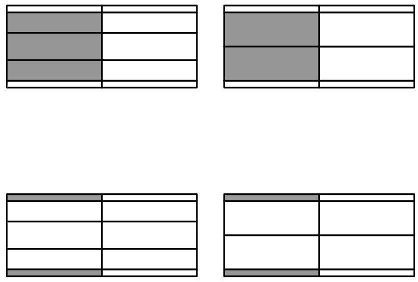
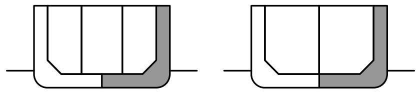
Structural Member		Design Load Set (1,2,3)	Load Component	Draught	Comment	Diagrammatic Representation
Keel, Bottom Shell, Bilge, Side Shell, Sheer strake		1	P_{ex}	T_{sc}	Sea pressure only	
		2	P_{ex}	T_{sc}		
		7	$P_{in}-P_{ex}$	T_{bal}	Net pressure difference between water ballast pressure and sea pressure	
		8	$P_{in}-P_{ex}$	$0.25\,T_{sc}$		
Deck	In way of cargo tanks	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
		3	P_{in}	$0.6\,T_{sc}$	Cargo pressure only	
		4	P_{in}	-		
		11	$P_{in-flood}$	-		
	In way of other tanks	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only	
		6	P_{in}	$0.25\,T_{sc}$		
		11	$P_{in-flood}$	-		
	Any location	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Simultaneously occurring green sea pressure may be ignored	
		10	P_{dk}	-		
Inner Bottom, Inner hull, Hopper side		3	P_{in}	$0.6\,T_{sc}$	Cargo pressure only	
		4	P_{in}	-		
		5	P_{in}	T_{bal}	Water ballast or other liquid pressure only	
		6	P_{in}	$0.25\,T_{sc}$		
		11	$P_{in-flood}$	-		
Longitudinal Bulkhead, Centreline Bulkhead		3	P_{in}	$0.6\,T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty. Two cases are to be evaluated: 1. Inner empty, outer full 2. Inner full, outer empty	
		4	P_{in}	-		
		11	$P_{in-flood}$	-		

Table 8.2.7 (Continued)
Design Load Sets for Plating and Local Support Members

Structural Member		Design Load Set (1,2,3)	Load Component	Draught	Comment	Diagrammatic Representation
Transverse Bulkhead	In way of cargo tanks	3	P_{in}	$0.6\,T_{sc}$	Pressure from one side only. Full cargo tank with adjacent fwd or aft cargo tank empty. Need to evaluate 2 cases 1) Fwd empty, aft full 2) Fwd full, aft empty	
		4	P_{in}	-		
		11	$P_{in-flood}$	-		
	In way of other tanks	5	P_{in}	T_{bal}		
		6	P_{in}	$0.25\,T_{sc}$		
		11	$P_{in-flood}$	-		
Other tank boundaries, e.g. Girders, Floors, Stringers		5	P_{in}	T_{bal}	Pressure from one side only. Full tank with adjacent tank empty. Need to evaluate 2 cases, see above	
		6	P_{in}	$0.25\,T_{sc}$		
		11	$P_{in-flood}$	-		

Where:
T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**
T_{bal} minimum design ballast draught, in m, as defined in **Sec 4/1.1.5.2**

Notes
1. Specification of design load combination, load component, acceptance criteria and other load parameters for each design load set are given in **Table 8.2.8**
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See Note 4 and **Table 8.2.8.**
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See Note 2.
4. Design load sets (DLS) for some structural members not covered by the above:
   For the boundaries of a stool water ballast tank with the cargo tank:
   - DLSs 5, 6 and 11 are to be applied for pressure from the WB tank side
   - DLSs 3, 4 and 11 for pressure from the cargo tank side

   For a double bottom girder separating two water ballast tanks or separating a water ballast and fuel oil tank:
   - DLSs 5, 6 and 11 are to be applied for pressure from each side in turn

   For the boundary of a stool void space to the cargo tank:
   - DLSs 3, 4 and 11 for pressure from the cargo tank side
   - DLS 11 for pressure from the void space side

Table 8.2.8
Specification of Design Load Combination, Acceptance Criteria and other Load Parameters for each Design Load Set

Design Load Set	Load Component(1)	Design Load Combination(2)	Acceptance Criteria Set	Parameters for Calculating Load Components		
				DLCF(3)	*GM*	$r_{roll\text{-}gyr}$
Hull envelope (*PSM* and *LSM*)						
1	Sea pressures P_{ex}	*S+D*	AC2	Loaded *DLCF*	0.12 *B*	0.35 *B*
2		*S*	AC1			
Cargo tank boundaries (*PSM* and *LSM*)						
3	Cargo pressures P_{in}	*S+D*	AC2	Loaded *DLCF*	0.24 *B*	0.40 *B*
4		*S*	AC1			
Boundaries of water ballast and other tanks (*PSM* and *LSM*)						
5	Water ballast or other liquid tank pressures P_{in}	*S+D*	AC2	Ballast *DLCF*	0.33 *B*	0.45 *B*
6		*S*	AC1			
7	Net water ballast minus sea pressures $P_{in} - P_{ex}$	*S+D*	AC2	Ballast *DLCF*	0.33 *B*	0.45 *B*
8		*S*	AC1			
Decks (*LSM* and *PSM*)						
9	Distributed and concentrated loads on deck P_{dk}	*S+D*	AC2	Ballast *DLCF*	0.33 *B*	0.45 *B*
10		*S*	AC1			
Watertight boundaries (*LSM* and *PSM*)						
11	Accidental flooding $P_{in-flood}$	*A*	AC2			
Hull envelope (*PSM*)						
12	Net cargo pressure minus sea pressure $P_{in} - P_{ex}$	*S+D*	AC2	Loaded *DLCF*	0.24 *B*	0.40 *B*
13		*S*	AC1			
14	Average cargo and sea pressure $(P_{in} + P_{ex})/2$	*S+D*	AC2	Loaded *DLCF*	0.12 *B*	0.35 *B*
15		*S+D*	AC2	Loaded *DLCF*	0.24 *B*	0.40 *B*
16		*S*	AC1			

Where:

PSM	Primary Support Members
LSM	Local Support Members
DLCF	Dynamic Load Combination Factors
P_{in} P_{ex} P_{dk} $P_{in-flood}$	as given in **Table 7.6.1** and as shown in **Table 8.2.7** or **Table 8.2.9**
B	moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

Note

1. Structural members are to be designed using all design load sets which are applicable. This table gives the pressure load component of the design load set. The hull girder bending moments are given in **Tables 8.2.4** and **8.2.5** for local support members.
2. This column specifies which column in the design load combination table is to be applied for each design load set, see **Table 7.6.1**. Where *S* denotes the static design load combination, *S+D* denotes the static plus dynamic design load combination and *A* denotes the accidental design load combination.
3. This column specifies which dynamic load combination factor table is to be used for the deviation of the pressure components and global load components, see **Table 7.6.1**

2.6 Primary Support Members

2.6.1 General

2.6.1.1 The scantlings of the primary support members in the cargo tank region for the extents shown in **Fig 8.2.4** are to be in accordance with the requirements of **2.6.1.2** to **2.6.1.7.**

2.6.1.2 The section modulus and shear area criteria for primary support members contained in **2.6** apply to structural configurations shown in **Fig 2.3.1** and are applicable to the following structural elements:

(a) floors and girders within the double bottom;

(b) deck transverses fitted below the upper deck;

(c) side transverses within double side structure;

(d) vertical web frames on longitudinal bulkheads with or without cross ties;

(e) horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports; and

(f) cross ties in wing cargo and centre cargo tanks.

2.6.1.3 The scantlings of primary support members are to be verified by the Finite Element (FE) cargo tank structural analysis defined in **Sec 9/2.**

2.6.1.4 The section modulus and/or shear area of a primary support member and/or the cross sectional area of a primary support member cross tie may be reduced to 85 % of the prescriptive requirements provided that the reduced scantlings comply with the FE cargo tank structural analysis and with **2.1.6.**

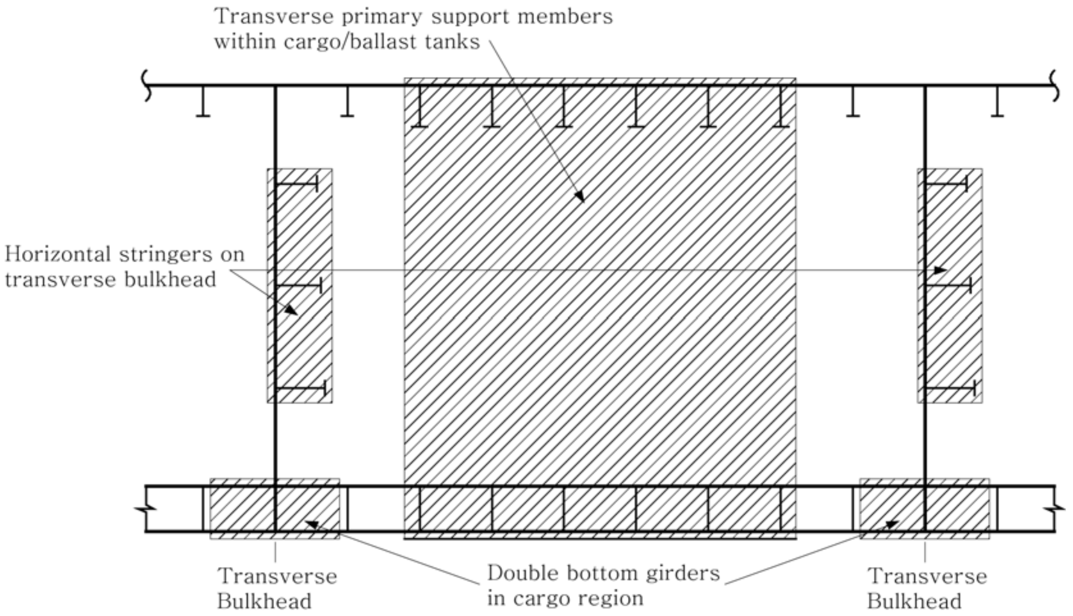
2.6.1.5 In general, primary support members are to be arranged in one plane to form continuous transverse rings. Brackets forming connections between primary support members of the ring are to be designed in accordance with **Sec 4/3.3.3.**

2.6.1.6 Webs of the primary support members are to be stiffened in accordance with **Sec 10/2.3.**

2.6.1.7 Webs of the primary support members are to have a depth of not less than given by the requirements of **2.6.4.1, 2.6.6.1** and **2.6.7.1**, as applicable. Lesser depths may be accepted where equivalent stiffness is demonstrated. See **3/5.3.3.4**. Primary support members that have open slots for stiffeners are to have a depth not less than 2.5 times the depth of the slots.

2.6.1.8 The scantlings of the first primary support members from the transverse bulkhead are to be in accordance with **Sec 8/7, 2.6.1.3, 2.6.1.4, 2.6.1.5, 2.6.1.6, 2.6.4.3** and **2.6.4.4**. In the application of **2.6.4.3** and **2.6.4.4** only the design green sea pressure is to be considered.

Fig 8.2.4
Depiction of Applicable Extents



2.6.2 Design load sets and permissible stress coefficients for primary support members

2.6.2.1 The design load sets for the evaluation of the primary support members are given in **Table 8.2.9.**

2.6.2.2 The permissible bending and shear stress coefficients for the evaluation of the primary support members are given in **Table 8.2.10.**

Table 8.2.9
Design Load Sets for Primary Support Members

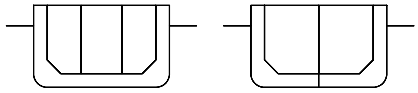
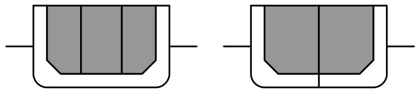
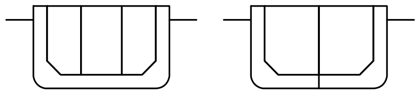
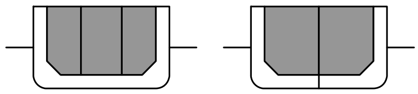
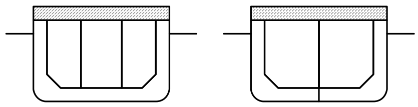
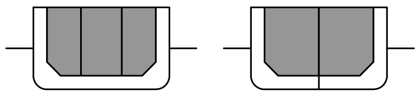
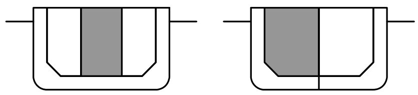
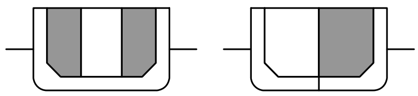
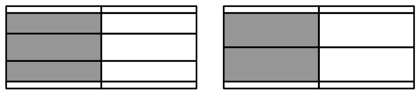
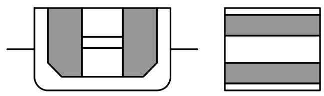
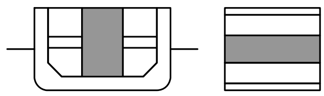
Structural Member	Design Load Set (1,5,6)	Load Component	Draught	Comment	Diagrammatic Representation
Double bottom floors and girders(3)	1	P_{ex}	$0.9T_{sc}$ (2)	Sea pressure only	
	2	P_{ex}	T_{sc}		
	12	$P_{in}-P_{ex}$	$0.6T_{sc}$	Net pressure difference between cargo pressure and sea pressure	
	13	$P_{in}-P_{ex}$	(4)		
Side transverses (3)	1	P_{ex}	$0.9T_{sc}$	Sea pressure only	
	2	P_{ex}	T_{sc}		
	3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
	4	P_{in}	-		
Deck transverses	1	P_{ex}	T_{sc}	Green sea pressure only or other loads on deck	
	3	P_{in}	$0.6T_{sc}$	Cargo pressure only	
	4	P_{in}	-		
Vertical web frames on longitudinal bulkheads	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty	
	4	P_{in}	-		
	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent cargo tank empty	
	4	P_{in}	-		
Horizontal stringers on transverse bulkhead	3	P_{in}	$0.6T_{sc}$	Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty. Two cases are to be evaluated: 1. forward empty/aft full 2. forward full/aft empty	
	4	P_{in}	-		
	11	$P_{in-flood}$	-		
Cross ties in centre tanks	3	$\frac{P_{in-pt}+P_{in-}}{2}$	$0.6T_{sc}$	Full wing cargo tanks, centre tank empty.	
	4	P_{in}	-		
Cross ties in wing tanks	14	$\frac{P_{in}+P_{ex}}{2}$	T_{sc}	Full centre tank, wing cargo tanks empty.	
	15	$\frac{P_{in}+P_{ex}}{2}$	$0.6T_{sc}$		
	16	$\frac{P_{in}+P_{ex}}{2}$	T_{sc}		

Table 8.2.9 (Continued)
Design Load Sets for Primary Support Members

Where:

P_{in-pt} design pressure from port side wing cargo tank, in kN/m^2
P_{in-stb} design pressure from starboard side wing cargo tank, in kN/m^2
T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**
T_{bal} minimum design ballast draught, in m, as defined in **Sec 4/1.1.5.2**

Notes

1. Specification of design load combination, load component, acceptance criteria set and other load parameters for each design load set are given in **Table 8.2.8.**
2. See **1.1.2.9(b)**
3. Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in **1.1.2.** Where the optional loading conditions exceed the minimum Rule required loading conditions the draughts will be subject to special consideration.
4. For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as $0.25T_{sc}$. For tankers with a centreline bulkhead, the draught is to be taken as $0.33T_{sc}$.
5. When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary support member are to be selected so as to specify all applicable cases from the following:
   - a full tank on one side of the member with the tank or space on the other side empty
   - a full tank on one side of the member with the external pressure minimised
   - external pressure maximised with the adjacent tank or space empty

   The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and $S+D$ design load combinations are to be selected. Design Load Set 11 may also need to be applied, depending on the particular structural configuration. See Note 4 on **Table 8.2.7** and **Table 8.2.8.**
6. For a void or dry space, the pressure component from the void side is to be ignored, except where Design Load Set 11 needs to be applied.

Table 8.2.10
Permissible Stress Coefficients, C_{s-pr} and C_{t-pr}, for Primary Support Members

Acceptance criteria set	Permissible bending stress coefficient, C_{s-pr}	Permissible shear stress coefficient, C_{t-pr}
AC1	0.70	0.70
AC2	0.85	0.85

2.6.3 Floors and girders in double bottom

2.6.3.1 Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools. Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

2.6.3.2 The net shear area, $A_{shr-net50}$, of the floors at any position in the floor is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= f_{shr} P S l_{shr}$ kN

f_{shr} shear force distribution factor

$= f_{shr-i}\left(1-\frac{2y_i}{l_{shr}}\right)$ but not to be taken as less than 0.2

f_{shr-i} shear force distribution factor at the end of the span, l_{shr}, as given in **Table 8.2.11**

l_{shr} effective shear span, of the double bottom floor, in m, as shown in **Fig 8.2.6**. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Sec 4/2.1.5.** Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig 8.2.6.**

y_i distance from the considered cross-section of the floor to the nearest end of the effective shear span, l_{shr}, in m

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

P design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2

C_{t-pr} permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.2.11
Shear Force Distribution Factors of Floors

Structural Configuration	Centre tank (f_{shr3} in **Fig 8.2.5**)	Wing Tank	
		At inboard end (f_{shr2} in **Fig 8.2.5**)	At hopper knuckle end (f_{shr1} in **Fig 8.2.5**)
Ships with centreline longitudinal bulkhead	-	0.4	0.6
Ships with two longitudinal bulkheads	0.5	0.50	0.65

Fig 8.2.5
Floor Shear Force Distribution Factors of Floors

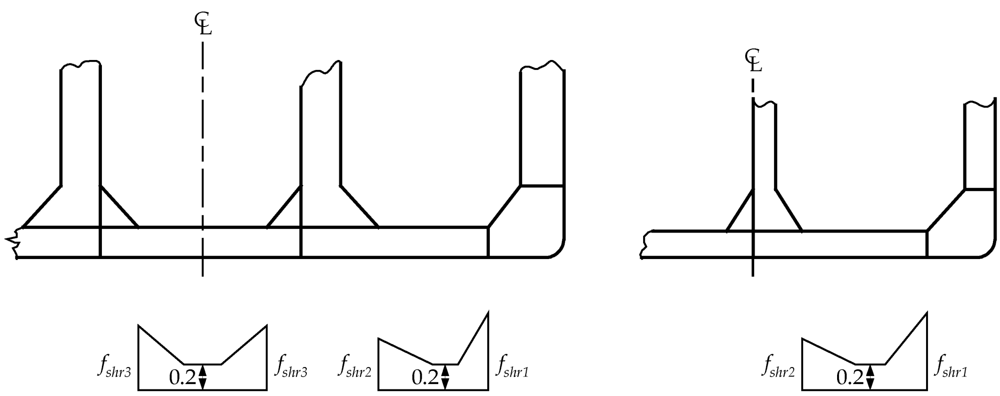
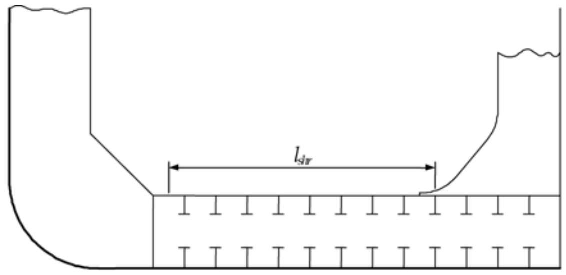
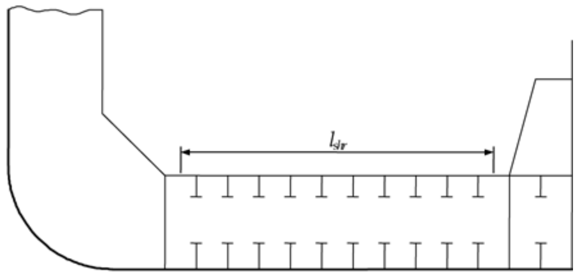


Fig 8.2.6
Effective Shear Span of Floors



Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

2.6.3.3 For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-net50}$, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= 0.21\, n_1\, n_2\, P\, l_{shr}^{\,2}$ kN

l_{shr} effective shear span, of the double bottom floor, in m, as shown in **Fig 8.2.6.** In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Sec 4/2.1.5.** Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig 8.2.6.**

P design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2

n_1 $= 0.00935\left(\frac{l_{shr}}{S}\right)^2 - 0.163\left(\frac{l_{shr}}{S}\right) + 1.289$

n_2 $= 1.3 - \left(\frac{S}{12}\right)$

S double bottom floor spacing, in m, as defined in **Sec 4/2.2.2**

$C_{t\text{-}pr}$ permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.6.3.4 For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, Ashr-net50, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad cm^2$$

Where:

Q design shear force

$= 0.14\, n_3\, n_4\, P\, l_{shr}{}^2$ kN

n_3 $= 1.072 - 0.0357\left(\dfrac{l_{shr}}{S}\right)$

n_4 $= 1.2 - \left(\dfrac{S}{18}\right)$

l_{shr} effective shear span, of the double bottom floor, in m, as shown in **Fig 8.2.6**. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Sec 4/2.1.5.** Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig 8.2.6.**

S double bottom floor spacing, in m, as defined in **Sec 4/2.2.2**

P design pressure for the design load set being considered, calculated at mid point of effective shear span, l_{shr}, of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m^2

$C_{t\text{-}pr}$ permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.6.4 Deck transverses

2.6.4.1 The web depth of deck transverses is not to be less than:

(a) $0.20\, l_{bdg\text{-}dt}$ for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads

(b) $0.13\, l_{bdg\text{-}dt}$ for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90 % of that of the deck transverses in the wing cargo tank

(c) $0.10\, l_{bdg\text{-}dt}$ for the deck transverses of ships with a centreline longitudinal bulkhead.

(d) See also **2.6.1.7**

Where:

$l_{bdg\text{-}dt}$ effective bending span of the deck transverse, in m, see **Sec 4/2.1.4** and **Fig 8.2.7**, but is not to be taken as less than 60 % of the breadth of the tank at the location being considered

2.6.4.2 The moment of inertia of the deck transverses, with associated deck plating, is to comply with **Sec 10/2.3.2.3** to control the overall deflection of the deck structure.

2.6.4.3 The net section modulus of deck transverses is not to be less than $Z_{in-net50}$ and $Z_{ex-net50}$ as given by the following. The net section modulus of the deck transverses in the wing cargo tanks is also not to be less than required for the deck transverses in the centre tanks.

$$Z_{in-net50} = \frac{1000 M_{in}}{C_{s-pr}\,\sigma_{yd}} \quad \text{cm}^3$$

$$Z_{ex-net50} = \frac{1000 M_{ex}}{C_{s-pr}\,\sigma_{yd}} \quad \text{cm}^3$$

Where:

M_{in} design bending moment due to cargo pressure, in kNm, to be taken as:

(a) for deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

$= 0.042\varphi_t P_{in-dt} S l_{bdg-dt}{}^2 + M_{st}$ but is not to be taken as less than M_0

(b) for deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

$= 0.042\varphi_t P_{in-dt} S l_{bdg-dt}{}^2 + M_{vw}$ but is not to be taken as less than M_0

M_{st} bending moment transferred from the side transverse

$= c_{st}\beta_{vw} P_{in-vw} S l_{bdg-vw}{}^2$ kNm

where a cross tie is fitted in a wing cargo tank and $l_{bdg-st-ct}$ is greater than 0.7 l_{bdg-st}, then l_{bdg-st} in the above formula may be taken as $l_{bdg-st-ct}$.

M_{vw} bending moment transferred from the vertical web frame on the longitudinal bulkhead

$= c_{vw}\beta_{vw} P_{in-vw} S l_{bdg-vw}{}^2$ kNm

where $l_{bdg-vw-ct}$ is greater than 0.7 l_{bdg-vw}, then l_{bdg-vw} in the above formula may be taken as $l_{bdg-vw-ct}$.

for vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses

M_0 minimum bending moment

$= 0.083 P_{in-dt} S l_{bdg-dt}{}^2$ kNm

M_{ex} design bending moment due to green sea pressure

$= 0.067 P_{ex-dt} S l_{bdg-dt}{}^2$ kNm

P_{in-dt} design cargo pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

P_{in-st} corresponding design cargo pressure in wing cargo tank for the design load set being considered, calculated at the mid point of effective bending span, l_{bdg-st}, of the side transverse located at mid tank, in kN/m^2

P_{in-vw} corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-vw}, of the vertical web frame on the longitudinal bulkhead located at mid tank, in kN/m^2

P_{ex-dt} design green sea pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

ϕ_t $= 1 - 5\left(\frac{y_{toe}}{l_{bdg-dt}}\right)$ but is not to be taken as less than 0.6

y_{toe} distance from the end of effective bending span, l_{bdg-dt}, to the toe of the end bracket of the deck transverse, in m

β_{st} $= 0.9\left(\frac{l_{bdg-st}}{l_{bdg-dt}}\right)\left(\frac{I_{dt}}{I_{st}}\right)$ but is not to be taken as less than 0.10 or greater than 0.65

β_{vw} $= 0.9\left(\frac{l_{bdg-vw}}{l_{bdg-dt}}\right)\left(\frac{I_{dt}}{I_{vw}}\right)$ but is not to be taken as less than 0.10 or greater than 0.50

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

l_{bdg-dt} effective bending span of the deck transverse, in m, see **Sec 4/2.1.4** and **Fig 8.2.7**, but is not to be taken as less than 60 % of the breadth of the tank at the location being considered

l_{bdg-st} effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see **Sec 4/2.1.4** and **Fig 8.2.7**

$l_{bdg-st-ct}$ effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see **Sec 4/2.1.4**

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see **Sec 4/2.1.4** and **Fig 8.2.7.**

$l_{bdg-vw-ct}$ effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see **Sec 4/2.1.4**

I_{dt} net moment of inertia of the deck transverse with an effective breadth of attached plating specified in **Sec 4/2.3.2.3**, in cm^4

I_{st} net moment of inertia of the side transverse with an effective breadth of attached plating specified in **Sec 4/2.3.2.3**, in cm^4

I_{vw} net moment of inertia of the longitudinal bulkhead vertical web frame with an effective breadth of attached plating specified in **Sec 4/2.3.2.3**, in cm^4

c_{st} as defined in **Table 8.2.12**

c_{vw} as defined in **Table 8.2.12**

C_{s-pr} permissible bending stress coefficient for primary support member as given in **Table 8.2.10**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.2.12
Values of c_{st} and c_{vw} for Deck Transverses

Structural Configuration			c_{st}	c_{vw}
Ships with centreline longitudinal bulkhead			0.056	-
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $l_{bdg-vw-ct}$	-	0.044
		M_{st} based on l_{bdg-st} or M_{vw} based on l_{bdg-vw}	0.044	0.016
	Cross ties in wing cargo tanks	M_{st} based on $l_{bdg-st-ct}$ or M_{vw} based on $l_{bdg-vw-ct}$	0.044	0.044
		M_{st} based on l_{bdg-st} or M_{vw} based on l_{bdg-vw}	0.041	0.015

2.6.4.4 The net shear area of deck transverses is not to be less than $A_{shr-in-net50}$ and $A_{shr-ex-net50}$ as given by:

$$A_{shr-in-net50} = \frac{10Q_{in}}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

$$A_{shr-ex-net50} = \frac{10Q_{ex}}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q_{in} design shear force due to cargo pressure

$= 0.65 P_{in-dt} S l_{shr} + c_1 D b_{ctr} S \rho g$ kN

Q_{ex} design shear force due to green sea pressure

$= 0.65 P_{ex-dt} S l_{shr}$ kN

P_{in-dt} design cargo pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

P_{ex-dt} design green sea pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-dt}, of the deck transverse located at mid tank, in kN/m^2

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

l_{shr} effective shear span, of the deck transverse, in m, see **Sec 4/2.1.5**

l_{bdg-dt} effective bending span of the deck transverse, in m, see **Sec 4/2.1.4** and **Fig 8.2.7**, but is not to be taken as less than 60 % of the breadth of the tank at the location being considered

c_1 = 0.04 in way of wing cargo tanks of ships with two longitudinal bulkheads
= 0.00 in way of centre tank of ships with two longitudinal bulkheads
= 0.00 for ships with a centreline longitudinal bulkhead

D moulded depth, in m, as defined in **Sec 4/1.1.4**

b_{ctr} breadth of the centre tank, in m

ρ density of liquid in the tank, in tonnes/m^3, not to be taken less than 1.025, see **Sec 2/3.1.8**

g acceleration due to gravity, 9.81 m/s^2

C_{t-pr} permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

$\tau_{yd} = \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Fig 8.2.7
Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads

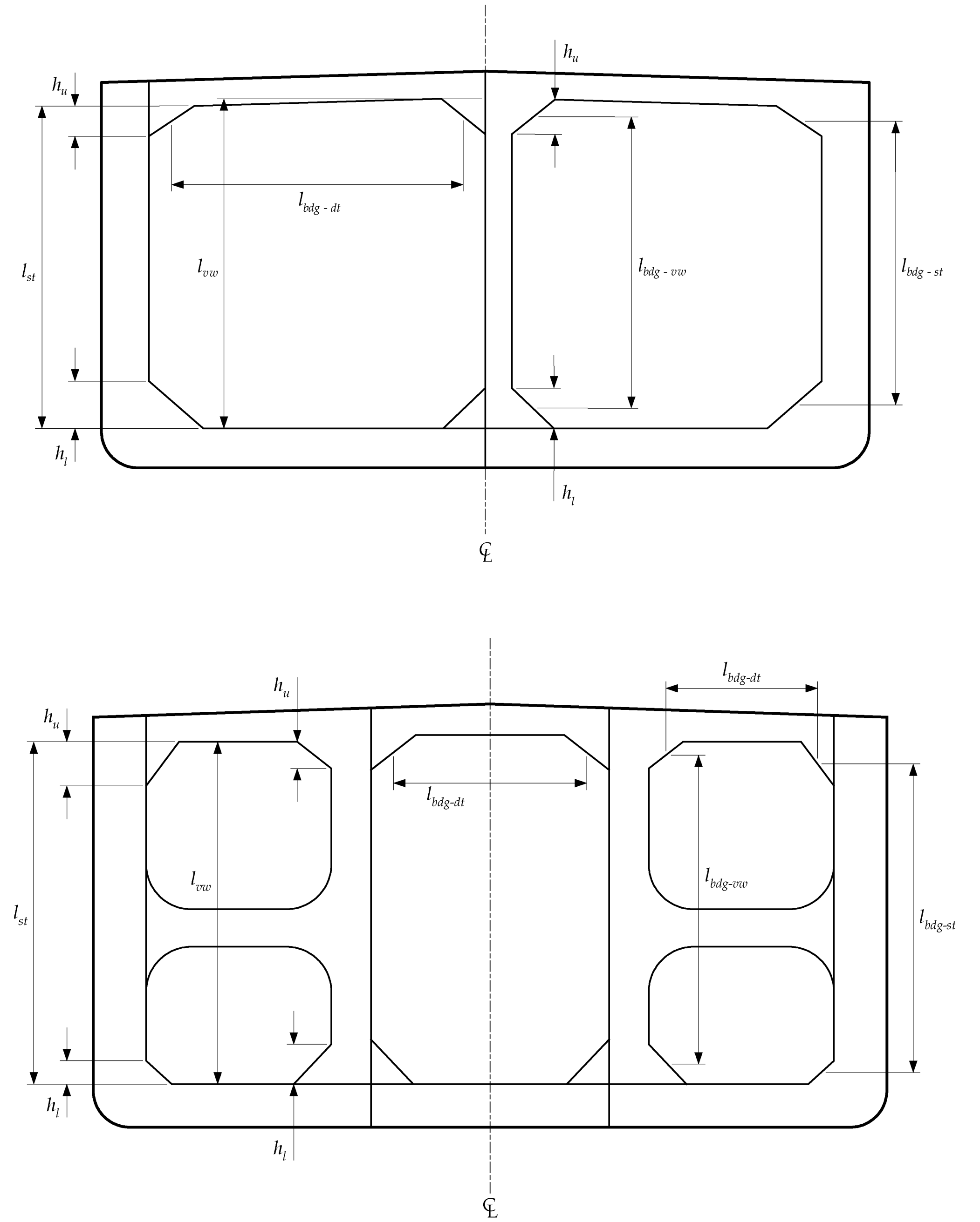
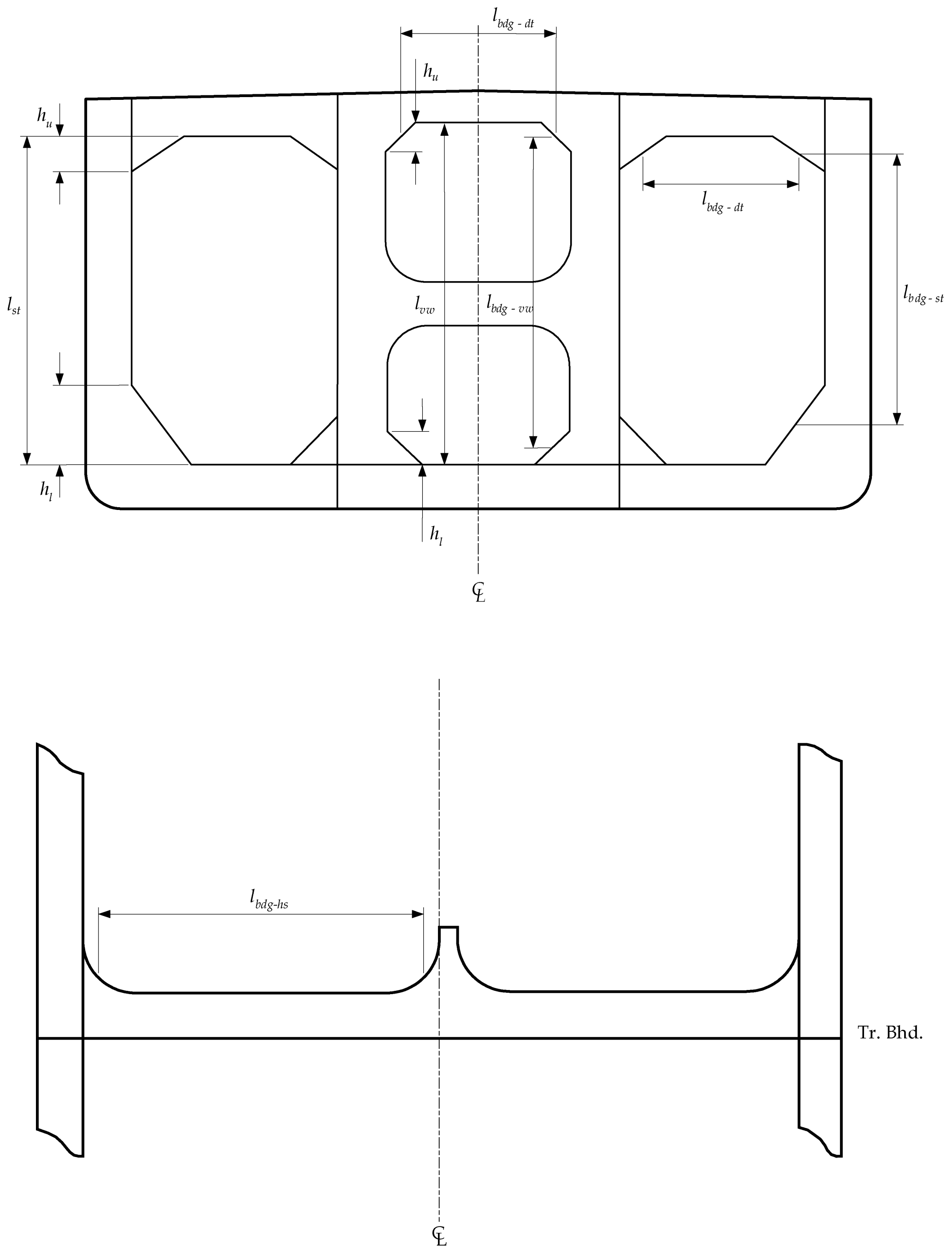


Fig 8.2.7 (Continued)
Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads



2.6.5 Side transverses

2.6.5.1 The net shear area, $A_{shr\text{-}net50}$, of side transverses is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force as follows, in kN:
= Q_u for upper part of the side transverse
= Q_l for lower part of the side transverse

Q_u = $S[c_u\, l_{st}\,(P_u + P_l) - h_u\, P_u]$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7\, l_{st}$, then l_{st} in the above formula is to be taken as $l_{st\text{-}ct}$.

Q_l to be taken as the greater of the following:

(a) $S[c_l\, l_{st}\,(P_u + P_l) - h_l\, P_l]$

(b) $0.35\, c_l\, S\, l_{st}\,(P_u + P_l)$

(c) $1.2\, Q_u$

where a cross tie is fitted in a wing cargo tank and $l_{st\text{-}ct}$ is greater than $0.7\, l_{st}$, then l_{st} in the above formula is to be taken as $l_{st\text{-}ct}$.

P_u design pressure for the design load set being considered, in kN/m^2, calculated at mid tank as follows:

(a) where deck transverses are fitted below deck, P_u is to be calculated at mid height of upper bracket of the side transverse, h_u

(b) where deck transverses are fitted above deck, P_u is to be calculated at the elevation of the deck at side, except in cases where item (c) applies

(c) where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows:

- the breadth at top of the wing structure is greater than 1.5 times the breadth of the double side and
- the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 degrees or more to vertical

P_u is to be calculated at mid depth of the top wing structure

P_l corresponding design pressure for the design load set being considered, calculated at mid height of bilge hopper, h_l, located at mid tank, in kN/m^2

l_{st} length of the side transverse, in m, and is to be taken as follows:

(a) where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and the inner bottom, see **Fig 8.2.7**

(b) where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and the inner bottom

$l_{st\text{-}ct}$ length of the side transverse, in m, and is to be taken as follows:

(a) where deck transverses are fitted below deck, l_{st} is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank

(b) where deck transverses are fitted above deck, l_{st} is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

h_u effective length of upper bracket of the side transverse, in m, and is to be taken as follows:

(a) where deck transverses are fitted below deck, h_u is as shown in **Fig 8.2.7** and as described in **Sec 4/2.1.5.**

(b) where deck transverses are fitted above deck, h_u is to be taken as 0.0, except in cases where item (c) applies.

(c) where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a top wing structure as follows:

- the breadth at top of the wing structure is greater than 1.5 times the breadth of the double side, and
- the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and the deck is 30 degrees or more to vertical

h_u is to be taken as the distance between the deck at side and the lower end of slope plate of the top wing structure.

h_l height of bilge hopper, in m, as shown in **Fig 8.2.7**

c_u and c_l as defined in **Table 8.2.13**

C_{t-pr} permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

Table 8.2.13
Values of c_u and c_l for Side Transverses

Structural Configuration			c_u		c_l	
Number of side stringers			Less than three	Equal to or greater than three	Less than three	Equal to or greater than three
Ships with a centreline longitudinal bulkhead			0.12	0.09	0.29	0.21
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank		0.12	0.09	0.29	0.21
Ships with two longitudinal bulkheads	Cross ties in wing cargo tanks	Q_u or Q_l based on l_{st-ct}	0.12	0.09	0.29	0.21
Ships with two longitudinal bulkheads	Cross ties in wing cargo tanks	Q_u or Q_l based on l_{st}	0.08		0.20	

2.6.5.2 The shear area over the length of the side transverse is to comply with the following:

(a) the required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}

(b) the required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}

(c) where Q_u and Q_l are determined based on l_{st-ct}, the required shear area for the lower part is also to be maintained below the cross tie

(d) for ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50 % of the required shear area for the lower part at mid span

(e) for ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Note
When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress

Where:

l_{shr} effective shear span of the side transverse, in m

$= l_{st} - h_u - h_l$ where Q_u and Q_l are determined based on l_{st}

$= l_{st-ct} - h_u$ where Q_u and Q_l are determined based on l_{st-ct}

l_{st}, l_{st-ct}, h_u, h_l, Q_u and Q_l as defined in **2.6.5.1**

2.6.6 Vertical web frames on longitudinal bulkhead

2.6.6.1 The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

(a) $0.14\, l_{bdg-vw}$ for ships with a centreline longitudinal bulkhead

(b) $0.09\, l_{bdg-vw}$ for ships with two longitudinal bulkheads

(c) see also **2.6.1.7**

Where:

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, see **2.6.6.2** and **Fig 8.2.7**

2.6.6.2 The net section modulus, Z_{net50}, of the vertical web frame is not to be less than:

$$Z_{net50} = \frac{1000\,M}{C_{s-pr}\,\sigma_{yd}} \quad \text{cm}^3$$

Where:

M design bending moment, in kNm, as follows:

$= c_u P S l_{bdg-vw}{}^2$ for upper part of the web frame

$= c_l P S l_{bdg-vw}{}^2$ for lower part of the web frame

where a cross tie is fitted and $l_{bdg-vw-ct}$ is greater than $0.7\, l_{bdg-vw}$, then l_{bdg-vw} in the above formula is to be taken as $l_{bdg-vw-ct}$.

P design pressure for the design load set being considered, calculated at mid point of the effective bending span, l_{bdg-vw}, of the vertical web frame located at mid tank, in kN/m^2

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see **Sec 4/2.1.4** and **Fig 8.2.7**

$l_{bdg-vw-ct}$ effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid depth of the cross tie on ships with two longitudinal bulkheads, in m, see **Sec 4/2.1.4**

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

C_{s-pr} permissible bending stress coefficient as given in **Table 8.2.10**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

c_u and c_l as defined in **Table 8.2.14**

Table 8.2.14
Values of c_u and c_l for Vertical Web Frame on Longitudinal Bulkheads

Structural Configuration			c_u	c_l
Ships with a centreline longitudinal bulkhead			0.057	0.071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.012	0.028
	Cross ties in wing cargo tanks	M based on $l_{bdg\text{-}vw\text{-}ct}$	0.057	0.071
		M based on $l_{bdg\text{-}vw}$	0.016	0.032

2.6.6.3 The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

(a) the required section modulus for the upper part is to be maintained over the upper 0.2 $l_{bdg\text{-}vw}$ or 0.2 $l_{bdg\text{-}vw\text{-}ct}$, as applicable

(b) the required section modulus for the lower part is to be maintained over the lower 0.2 $l_{bdg\text{-}vw}$ or 0.2 $l_{bdg\text{-}vw\text{-}ct}$, as applicable

(c) where the required section modulus is determined based on $l_{bdg\text{-}vw\text{-}ct}$, the required section modulus for the lower part is also to be maintained below the cross tie

(d) the required section modulus between the upper and lower parts is to be reduced linearly to 70 % of the required section modulus for the lower part at mid span

Note
When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

Where:

$l_{bdg\text{-}vw}$ and $l_{bdg\text{-}vw\text{-}ct}$ as defined in **2.6.6.2**

2.6.6.4 The net shear area, $A_{shr\text{-}net50}$, of the vertical web frame is not to be lesst han:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force as follows, in kN:
 = Q_u for upper part of the web frame
 = Q_l for lower part of the web frame

Q_u = $S\;[c_u\, l_{vw}\,(P_u + P_l) - h_u\, P_u]$

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than 0.7 l_{vw}, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

Q_l to be taken as the greater of the following:

(a) $S\,[c_l\, l_{vw}\,(P_u + P_l) - h_l\, P_l]$

(b) $c_w\, S\, c_l\, l_{vw}\,(P_u + P_l)$

(c) $1.2\, Q_u$

where a cross tie is fitted in a centre or wing cargo tank and $l_{vw\text{-}ct}$ is greater than 0.7 l_{vw}, then l_{vw} in the above formula is to be taken as $l_{vw\text{-}ct}$.

P_u design pressure for the design load set being considered, calculated at mid height of upper bracket of the vertical web frame, h_u, located at mid tank, in kN/m^2

P_l design pressure for the design load set being considered, calculated at mid height of lower bracket of the vertical web frame, h_l, located at mid tank, in kN/m^2

l_{vw} length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see **Fig 8.2.7**

$l_{vw\text{-}ct}$ length of the vertical web frame, in m, between the flange of the deck transverse and mid depth of the cross tie, where fitted

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

h_u effective length of upper bracket of the vertical web frame, in m, as shown in **Fig 8.2.7** and as described in **Sec 4/2.1.5**

h_l effective length of lower bracket of the vertical web frame, in m, as shown in **Fig 8.2.7** and as described in **Sec 4/2.1.5**

c_u and c_l as defined in **Table 8.2.15**

c_w 0.57 for ships with a centreline longitudinal bulkhead

0.50 for ships with two longitudinal bulkheads

$C_{t\text{-}pr}$ permissible shear stress coefficient for primary support member as given in **Table 8.2.10**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.2.15
Values of c_u and c_l for Vertical Web Frame on Longitudinal Bulkhead

Structural Configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0.17	0.28
Ships with two longitudinal bulkheads	Q_u or Q_l based on $l_{vw\text{-}ct}$		
	Q_u or Q_l based on l_{vw}	0.075	0.18

2.6.6.5 The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following:

(a) the required shear area for the upper part is to be maintained over the upper 0.2 l_{shr}

(b) the required shear area for the lower part is to be maintained over the lower 0.2 l_{shr}

(c) where Q_u and Q_l are determined based on $l_{vw\text{-}ct}$, the required shear area for the lower part is also to be maintained below the cross tie

(d) for ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50 % of the required shear area for the lower part at mid span

(e) for ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts

Note
When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

Where:

l_{shr} effective shear span of the side transverse

$= l_{vw} - h_u - h_l$ where Q_u and Q_l are determined based on l_{vw}

$= l_{vw-ct} - h_u$ where Q_u and Q_l are determined based on $l_{vw\text{-}ct}$

l_{vw}, $l_{vw\text{-}ct}$, h_u, h_l, Q_u and Q_l as defined in **2.6.6.4**

2.6.7 Horizontal stringers on transverse bulkheads

2.6.7.1 The web depth of horizontal stringers on transverse bulkhead is not to be less than:

(a) $0.28\, l_{bdg\text{-}hs}$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads

(b) $0.20\, l_{bdg\text{-}hs}$ for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks

(c) $0.20\, l_{bdg\text{-}hs}$ for horizontal stringers of ships with a centreline longitudinal bulkhead

(d) see also **2.6.1.7.**

Where:

$l_{bdg\text{-}hs}$ effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50 % of the breadth of the tank at the location being considered, see **Sec 4/2.1.4** and **Fig 8.2.7**

2.6.7.2 The net section modulus, Z_{net50}, of the horizontal stringer over the end $0.2\, l_{bdg\text{-}hs}$ is not to be less than:

$$Z_{net50} = \frac{1000\, M}{C_{s-pr}\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

M design bending moment:

$$= c\, P\, S\, l_{bdg-hs}^{\ 2} \quad \text{kNm}$$

P design pressure for the design load set being considered, calculated at mid point of effective bending span, $l_{bdg\text{-}hs}$, and at mid point of the spacing, S, of the horizontal stringer, in kN/m^2

S sum of the half spacing (distance between stringers) on each side of the horizontal stringer under consideration, in m

$l_{bdg\text{-}hs}$ effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50 % of the breadth of the tank at the location being considered, see **Sec 4/2.1.4** and **Fig 8.2.7**

c 0.073 for horizontal stringers in cargo tanks of ships with a centreline bulkhead

0.083 for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads

0.063 for horizontal stringers in the centre tank of ships with two longitudinal bulkheads

$C_{s\text{-}pr}$ permissible bending stress coefficient as given in **Table 8.2.10**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.6.7.3 The required section modulus at mid effective bending span is to be taken as 70 % of that required at the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

2.6.7.4 The net shear area, $A_{shr\text{-}net50}$, of the horizontal stringer over the end $0.2\, l_{shr}$ is not to be less than:

$$A_{shr-net50} = \frac{10Q}{C_{t-pr}\,\tau_{yd}} \quad \text{cm}^2$$

Where:

Q design shear force

$= 0.5\,P\,S\,l_{shr}$ kN

P design pressure for the design load set being considered, calculated at mid point of effective bending span, l_{bdg-hs}, and at mid point of the spacing, S, of the horizontal stringer, in kN/m^2

S sum of the half spacing (distance between stringers), on each side of the horizontal stringer under consideration, in m

l_{shr} effective shear span of the horizontal stringer, in m, see **Sec 4/2.1.5**

C_{t-pr} permissible shear stress coefficient as given in **Table 8.2.10**

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.6.7.5 The required shear area at mid effective shear span is to be taken as 50 % of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

2.6.8 Cross ties

2.6.8.1 The maximum applied design axial load on cross ties, W_{ct}, is to be less than or equal to the permissible load, $W_{ct-perm}$, as given by:

$$W_{ct} \le W_{ct-perm}$$

Where:

W_{ct} applied axial load

$= P\,b_{ct}\,S$ kN

$W_{ct-perm}$ permissible load

$= 0.1\,A_{ct-net50}\,\eta_{ct}\,\sigma_{cr}$ kN

P maximum design pressure for all the applicable design load sets being considered, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m^2

b_{ct} where cross tie is fitted in centre cargo tank:

$= 0.5\,l_{bdg-vw}$

where cross ties are fitted in wing cargo tanks:

$= 0.5\,l_{bdg-vw}$ for design cargo pressure from the centre cargo tank

$= 0.5\,l_{bdg-st}$ for design sea pressure

l_{bdg-vw} effective bending span of the vertical web frame on the longitudinal bulkhead, in m, see **Sec 4/2.1.4** and **Fig 8.2.7**.

l_{bdg-st} effective bending span of the side transverse, in m, see **Sec 4/2.1.4** and **Fig 8.2.7**.

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

η_{ct} utilisation factor, to be taken as:

$= 0.65$ for acceptance criteria set AC1

$= 0.75$ for acceptance criteria set AC2

σ_{cr} critical buckling stress in compression of the cross tie, in N/mm^2, as calculated using the net sectional properties in accordance with **Sec 10/3.5.1**, where the effective length of the cross tie is to be taken as follows, in m:

(a) for cross tie in centre tank:
distance between the flanges of longitudinal stiffeners on the starboard and port longitudinal bulkheads to which the cross tie's horizontal stiffeners are attached

(b) for cross tie in wing tank:
distance between the flanges of longitudinal stiffeners on the longitudinal bulkhead to which the cross tie's horizontal stiffeners are attached, and the inner hull plating

$A_{ct\text{-}net50}$ net cross sectional area of the cross tie, in cm^2

2.6.8.2 Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs. Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

2.6.8.3 Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

2.6.9 Primary support members located beyond 0.4*L* amidships

2.6.9.1 If a cargo tank FE analysis is not available for the region outside of 0.4*L* amidships, the requirements given in **2.6.9.2** and **2.6.9.3** may be used to obtain the scantlings of primary support members located beyond 0.4*L* of amidships. Scantlings used for the 0.4*L* amidships are to be those required by **Sec 8/2** and *Section9/2*, see *2.6.1.3* and *2.6.1.4*.

2.6.9.2 The net section modulus of primary support members, $Z_{end\text{-}net50}$, located beyond 0.4*L* of amidships is not to be less than:

$$Z_{end-net50} = \frac{Z_{mid-net50}\,\sigma_{yd-mid}\,M_{end}}{\sigma_{yd-end}\,M_{mid}} \quad cm^3$$

Where:

M_{end} bending moment, in kNm, for the structural member under consideration located beyond 0.4*L* amidships, calculated in accordance with corresponding requirements of **2.6.3** to **2.6.8** and using the design pressure specified for the given location

M_{mid} bending moment, in kNm, for the corresponding structural member and location of cross section, amidships, obtained from the corresponding requirements of **2.6.2** to **2.6.8**

$Z_{mid\text{-}net50}$ net section modulus at the flange of the corresponding structural member and location of cross section amidships, in cm^3

$\sigma_{yd\text{-}end}$ specified minimum yield stress of the flange of the structural member under consideration located beyond 0.4*L* amidships, in N/mm^2

$\sigma_{yd\text{-}mid}$ specified minimum yield stress of the flange of the structural member under consideration amidships, in N/mm^2

2.6.9.3 The net shear area for primary support members, $A_{shr\text{-}end\text{-}net50}$, located beyond 0.4*L* amidships is not to be less than:

$$A_{shr-end-net50} = \frac{A_{shr-mid-net50}\,\tau_{yd-mid}\,Q_{end}}{\tau_{yd-end}\,Q_{mid}} \quad cm^2$$

Where:

Q_{end} shear force, in kN, for the structural member under consideration located beyond 0.4*L* of amidships, calculated in accordance with the corresponding requirements of **2.6.3** to

2.6.8 and using the design pressure, specified for the given location

Q_{mid} shear force, in kN, for the corresponding structural member and corresponding location of cross section, amidships, obtained from the requirements of **2.6.2** to **2.6.8**

$A_{shr-mid-net50}$ shear area of corresponding structural member and location of cross section amidships, in cm^2

τ_{yd-end} $= \dfrac{\sigma_{yd-end}}{\sqrt{3}}$

τ_{yd-mid} $= \dfrac{\sigma_{yd-mid}}{\sqrt{3}}$

σ_{yd-end} specified minimum yield stress of the structural member under consideration located beyond 0.4L amidships, in N/mm^2

σ_{yd-mid} specified minimum yield stress of the structural member under consideration amidships, in N/mm^2

3 Forward of the Forward Cargo Tank

3.1 General

3.1.1 Application

3.1.1.1 The requirements of this Sub-Section apply to structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of 0.1*L* of the ship's length, measured from the F.P., special consideration will be given to the applicability of these requirements and the requirements of **Sec 8/2**.

3.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements of **3.1.4**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in **Sec 6/3**

(d) for application of buckling requirements of **Sec 10/2** the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

3.1.2 General scantling requirements

3.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Sec 8/1**

(b) strength against sloshing and impact loads, see **Sec 8/6**

(c) buckling/ultimate strength, see **Sec 10**

3.1.2.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass and other deck machinery, and in way of cranes, masts and derrick posts. See **Sec 11/3**.

3.1.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with **Sec 4/2**.

3.1.2.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to **Table 8.3.5**.

3.1.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structural design details are to comply with the requirements in **Sec 4/3**.

3.1.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also **Sec 4/3**.

3.1.2.7 Web stiffeners are to be fitted on primary support members at each longitudinal on the side and bottom shell. Alternative arrangements may be accepted where adequacy of stiffener end connections and strength of adjoining web and bulkhead plating is demonstrated.

3.1.3 Structural continuity

3.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. See also **1.6**.

3.1.3.2 In the transition zone aft of the fore peak into the forward cargo tank, due consideration is to be given to the arrangement of major longitudinal members in order to avoid abrupt changes in section. Structures within the fore peak, such as flats, decks, horizontal ring frames or side stringers, are to be scarphed effectively into the structure aft into the cargo tank. Where such structures are in line with longitudinal members aft of the forward cargo tank bulkhead fitting of tapered transition brackets may be used.

3.1.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward bulkhead of the forward cargo tank, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

3.1.3.4 Longitudinal framing of the strength deck is to be carried as far forward as practicable.

3.1.3.5 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends, except as permitted in **Sec 4/3.2.4** and **4/3.2.5**.

3.1.4 Minimum thickness

3.1.4.1 In addition to the thickness, section modulus and stiffener web shear area requirements as given in this Sub-Section, the thickness of plating and stiffeners in the forward region are to comply with the appropriate minimum thickness requirements given in **Table 8.3.1**.

3.2 Bottom Structure

3.2.1 Plate keel

3.2.1.1 A flat plate keel is to extend as far forward as practical and is to satisfy the scantling requirements given in **2.2.1**.

3.2.2 Bottom shell plating

3.2.2.1 The thickness of the bottom shell plating is to comply with the requirements in **3.9.2.1**.

3.2.3 Bottom longitudinals

3.2.3.1 Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.

3.2.3.2 The section modulus and thickness of the bottom longitudinals are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

Table 8.3.1
Minimum Net Thickness of Structure Forward of the Forward Cargo Tank

Scantling Location			Net Thickness (mm)
Plating	Shell	Keel plating	See **2.1.5.1**
		Bottom shell/bilge/side shell plating	See **2.1.5.1**
	Upper Deck		See **2.1.5.1**
	Other structure	Hull internal tank boundaries	See **2.1.5.1**
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	See **2.1.5.1**
		Pillar bulkheads	7.5
		Breasthooks	6.5
Floors and bottom girders			$5.5 + 0.02L_2$
Web plating of primary support members			$6.5 + 0.015L_2$
Local support members			See **2.1.5.1**
Tripping brackets			See **2.1.5.1**
Where: L_2 rule length, L, in m, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m			

3.2.4 Bottom floors

3.2.4.1 Bottom floors are to be fitted at each web frame location. The minimum depth of the floor at the centreline is to be not to be less than the required depth of the double bottom of the cargo tank region. See **Sec 5/3.2.1.1**.

3.2.5 Bottom girders

3.2.5.1 A supporting structure is to be provided at the centreline either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

3.2.5.2 Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that required for the depth of the double bottom in the cargo tank region, and the upper edge is to be stiffened. Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

3.2.5.3 Where a longitudinal wash bulkhead supports bottom transverses, the details and arrangements of openings in the bulkhead are to be configured to avoid areas of high stresses in way of the connection of the wash bulkhead with bottom transverses.

3.2.6 Plate stems

3.2.6.1 Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500 mm apart, measured along the stem. Where the stem radius is large, a centreline support structure is to be fitted.

3.2.6.2 Between the minimum design ballast draught, T_{bal} at the stem and the scantling draught, T_{sc}, the plate stem net thickness, $t_{stem-net}$, is not to be less than:

$$t_{stem-net} = \frac{L_2\sqrt{\frac{235}{\sigma_{yd}}}}{12} \quad \text{mm, but need not be taken as greater than 21 mm}$$

Where:

L_2 rule length, L, in m, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Above the scantling draught the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.

Below the minimum design ballast draught the thickness of the stem plate may be tapered to the requirements for the plate keel.

3.2.7 Floors and girders in spaces aft of the collision bulkhead

3.2.7.1 Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank, are to comply with the requirements in **3.2.4** and **3.2.5** and are to comply with the shear area requirements in **3.9.3.3**.

3.3 Side Structure

3.3.1 Side shell plating

3.3.1.1 The thickness of the side shell plating is to comply with the requirements in **3.9.2.1**. Where applicable, the thickness of the side shell plating is to comply with the requirements in **2.2.4.2**.

3.3.1.2 Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

3.3.2 Side shell local support members

3.3.2.1 Longitudinal framing of the side shell is to be carried as far forward as practicable.

3.3.2.2 The section modulus and thickness of the hull envelope framing is to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

3.3.2.3 End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and where not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

3.3.3 Side shell primary support structure

3.3.3.1 In general, the spacing of web frames, S as defined in **Sec 4/2.2.2**, is to be taken as:

$S = 2.6 + 0.005L_2$ m, but not to be taken greater than 3.5 m

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but is not to be taken greater than 300 m

3.3.3.2 In general, the transverse framing forward of the collision bulkhead stringers are to be spaced approximately 3.5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.

3.3.3.3 Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.

3.3.3.4 The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from **3.9.3**, with the following additional requirements:

(a) where no cross ties are fitted:

- the required section modulus of the web frame is to be maintained for 60 % of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20 %
- the required shear area of the lower part of the web frame is to be maintained for 60 %

of the shear span measured from the lower end.

(b) where one cross tie is fitted:

- the effective spans for bending and shear of a web frame or stringer are to be taken ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50 % of the values that are calculated ignoring the presence of the cross ties. For a web frame, the required section modulus and shear area of the lower part of the web frame is to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame is to be maintained for the section above the cross tie
- cross ties are to satisfy the requirements of **2.6.8** using the design loads specified in **Table 8.3.8**.

(c) configurations with multiple cross ties are to be specially considered, in accordance with **3.3.3.4(d)**

(d) where complex grillage structures are employed the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

3.3.3.5 The web depth of primary support members is not to be less than 14 % of the bending span and is to be at least 2.5 times as deep as the slots for stiffeners if the slots are not closed.

3.4 Deck Structure

3.4.1 Deck plating

3.4.1.1 The thickness of the deck plating is to comply with the requirements in **3.9.2.1** with the applicable lateral pressure, green sea and deck loads.

3.4.1.2 (void)

3.4.2 Deck stiffeners

3.4.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**, with the applicable lateral pressure, green sea and deck loads.

3.4.3 Deck primary support structure

3.4.3.1 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

3.4.3.2 The web depth of primary support members is not to be less than 10 % and 7 % of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in **Sec 4/2.1.4** or in case of a grillage structure, the distance between connections to other primary support members.

3.4.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also **Sec 11/3.**

3.4.4 Pillars

3.4.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.4.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

3.4.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45

% of the specified minimum yield stress of the material.

3.4.4.4 The scantlings of pillars are to comply with the requirements in **3.9.5**.

3.4.4.5 Where the loads from heavy equipment exceed the design load of **3.9.5**, the pillar scantlings are to be determined based on the actual loading.

3.5 Tank Bulkheads

3.5.1 General

3.5.1.1 Tanks may be required to have divisions or deep wash plates in order to minimise the dynamic stress on the structure.

3.5.2 Construction

3.5.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

3.5.3 Scantlings of tank boundary bulkheads

3.5.3.1 The thickness of tank boundary plating is to comply with the requirements in **3.9.2.1**.

3.5.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

3.5.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

3.5.3.4 Web plating of primary support members is to have a depth of not less than 14 % of the unsupported span in bending, and is not to be less than 2.5 times the depth of the slots if the slots are not closed.

3.5.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in **3.9.4**.

3.6 Watertight Boundaries

3.6.1 General

3.6.1.1 Watertight boundaries are to be fitted in accordance with **Sec 5/2**.

3.6.2 Collision bulkhead

3.6.2.1 The scantlings of structural components of the collision bulkheads are to comply with the requirements in **3.6.3**, as applicable. Additionally, the collision bulkhead is to comply with the requirements in **3.6.2.2** to **3.6.2.4**.

3.6.2.2 The position of the collision bulkhead is to be in accordance with **Sec 5/2.2**.

3.6.2.3 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the freeboard deck. Where the collision bulkhead is extended above the freeboard deck, the number of openings in the extension is to be kept to a minimum compatible with the design and proper working of the ship. The openings are to be fitted with weathertight closing appliances. The collision bulkhead may be pierced by pipes necessary for dealing with the contents of tanks forward of the bulkhead, provided the pipes are fitted with valves capable of being operated from above the freeboard deck. The valves are generally to be fitted on the collision bulkhead inside the fore peak and are not to be fitted inside the cargo tank.

3.6.2.4 Compartments forward of the collision bulkhead may not be arranged for the carriage of flammable liquids.

3.6.3 Scantlings of watertight boundaries

3.6.3.1 The thickness of boundary plating is to comply with the requirements in **3.9.2.1**.

3.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

3.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

3.6.3.4 Web plating of primary support members is to have a depth of not less than 10 % of the unsupported span in bending, and is not to be less than 2.5 times the depth of the slots if the slots are not closed.

3.6.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in **3.9.4**.

3.7 Superstructure

3.7.1 Forecastle structure

3.7.1.1 Forecastle structures are to be supported by girders with deep beams and web frames, and in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3.5 m. Pillars are to be provided as required by **3.4.4**. Main structural intersections are to be carefully developed with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

3.7.2 Forecastle end bulkhead

3.7.2.1 The details and scantlings of the forecastle end bulkhead are to meet the requirements of **Sec 11/1.4**.

3.8 Miscellaneous Structures

3.8.1 Pillar bulkheads

3.8.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section are to be determined using the requirements of **3.4.4**. The net moment of inertia of the stiffener is to be calculated with a width of 40 t_{net}, where t_{net} is the net thickness of plating, in mm.

3.8.1.2 Pillar bulkheads are to comply with the following requirements:

(a) the distance between bulkhead stiffeners is not to exceed 1500 mm

(b) where corrugated, the depth of the corrugation is not to be less than 100 mm.

3.8.2 Bulbous bow

3.8.2.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

3.8.2.2 At the forward end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced about 1m apart in conjunction with a deep centreline web.

3.8.2.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

3.8.2.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

3.8.2.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

3.8.2.6 The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling.

The increased plate thickness is to be the same as that required for plated stems given in **3.2.6**.

3.8.3 Chain lockers

3.8.3.1 Chain lockers are to meet the requirements of **Sec 11/4.2.9**.

3.8.4 Bow thruster tunnels

3.8.4.1 The net thickness of the tunnel plating, $t_{tun-net}$, is not to be less than as required for the shell plating in the vicinity of the bow thruster. In addition, $t_{tun-net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \quad \text{mm}$$

Where:

d_{tun} inside diameter of the tunnel, in mm, but not to be taken less than 970 mm

3.8.4.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured

3.9 Scantling Requirements

3.9.1 General

3.9.1.1 The design load sets are to be applied to the structural requirements for the local support and primary support members as given in **Table 8.3.8**. The static and dynamic load components are to be combined in accordance with **Table 7.6.1** and the procedure given in **Sec 7/6.3**.

3.9.2 Plating and local support members

3.9.2.1 For plating subjected to lateral pressure, the net plating thickness, t_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$t_{net} = 0.0158 \alpha_p s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \dfrac{s}{2100 l_p}$, but not to be greater than 1.0

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.1.2**, in kN/m^2

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_p length of plate panel, to be taken as the spacing of primary support members, unless carlings are fitted, in m

C_a permissible bending stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.2**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.3.2
Permissible Bending Stress Coefficient for Plating

Acceptance criteria set	Structural member	C_a
AC1	All plating	0.80
AC2	Hull envelope plating	0.95
	Internal boundary plating[(1)]	1.00

Note
1. Collision bulkhead plating is to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.2.2 For stiffeners subjected to lateral pressure, the net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$Z_{net} = \frac{|P| s \, l_{bdg}^{\ 2}}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m^2

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.1**, in m

f_{bdg} bending moment factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:
12 for horizontal stiffeners
10 for vertical stiffeners
for other configurations the bending moment factor may be taken as in **Table 8.3.5**.

C_s permissible bending stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.3**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.3.3
Permissible Bending Stress Coefficient for Stiffeners

Acceptance criteria set	Structural member	C_s
AC1	All stiffeners	0.75
AC2	All stiffeners[(1)]	0.90

Note
1. Collision bulkhead stiffeners are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.2.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$t_{w-net} = \frac{f_{shr} \left| P \right| s \, l_{shr}}{d_{shr} \, C_t \, \tau_{yd}} \quad \text{mm}$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m^2

f_{shr} shear force factor:

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:

0.5 for horizontal stiffeners

0.7 for vertical stiffeners

for other configurations the shear force factor may be taken as in **Table 8.3.5**.

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{shr} effective shear span, as defined in **Sec 4/2.1.2**, in m

d_{shr} effective web depth of stiffeners, in mm, as defined in **Sec 4/2.4.2.2**

C_t permissible shear stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.4**

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

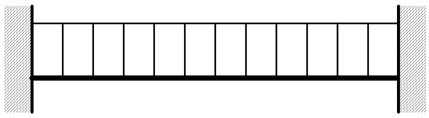
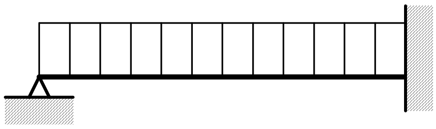
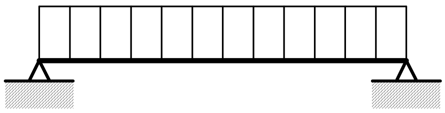
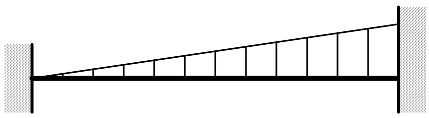
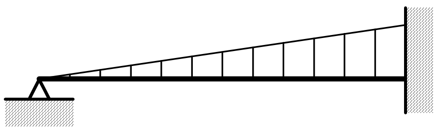
σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.3.4
Permissible Shear Stress Coefficient for Stiffeners

Acceptance criteria set	Structural member	C_t
AC1	All stiffeners	0.75
AC2	All stiffeners(1)	0.90

Note
1. Collision bulkhead stiffeners are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

Table 8.3.5
Bending Moment and Shear Force Factors, f_{bdg} and f_{shr}

Load and boundary condition				Bending moment and shear force factor (based on load at mid span, where load varies)		
	Position			1	2	3
Load model	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50
D				15.0 0.30	23.3 -	10.0 0.70
E				- 0.20	16.8 -	7.5 0.80

Note
1. The bending moment factor f_{bdg} for the support positions are applicable for a distance of 0.2 l_{bdg} from the end of the effective bending span for both local and primary support members.
2. The shear force factor f_{shr} for the support positions are applicable for a distance of 0.2 l_{shr} from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   (a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1}, f_{bdg2} and f_{bdg3}
   (b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   (a) the section modulus requirement within 0.2 l_{bdg} from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
   (b) the section modulus of mid span area is to be determined using $f_{bdg} = 24$, or f_{bdg2} from the table if lesser
   (c) the shear area requirement of end connections within 0.2 l_{shr} from the end of the effective span is to be determined using $f_{shr} = 0.5$ or the applicable f_{shr1} or f_{shr3}, whichever is greater
   (d) for models A through E the value of f_{shr} may be gradually reduced outside of 0.2 l_{shr} to wards 0.5 f_{shr} at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.
5. For other load models see **Table 8.7.1**.

3.9.3 Primary support members

3.9.3.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, see **3.3.3.4**.

3.9.3.2 For primary support members subjected to lateral pressure, the net section modulus, Z_{net50}, is to be taken as the greatest value for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$Z_{net50} = 1000 \frac{|P| S l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.3.3**, in kN/m^2

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.4**, in m

f_{bdg} bending moment factor, as given in **Table 8.3.5**

C_s permissible bending stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.6**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.3.6
Permissible Bending Stress Coefficient for Primary Support Members

Acceptance criteria set	Structure attached to primary support member	C_s
AC1	All boundaries, including decks and flats	0.70
AC2	All boundaries, including decks and flats(1)	0.85

Note
1. Collision bulkhead primary support members are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.3.3 For primary support members subjected to lateral pressure, the effective net shear area, $A_{shr\text{-}net50}$, is to be taken as the greatest value for all applicable design load sets, as given in **Table 8.3.8**, and given by:

$$A_{shr-net50} = 10 \frac{f_{shr} |P| S l_{shr}}{C_t \tau_{yd}} \quad \text{cm}^2$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.3.2**, in kN/m^2

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

l_{shr} effective shear span, as defined in **Sec 4/2.1.5**, in m

f_{shr} shear force factor, as given in **Table 8.3.5**

C_t permissible shear stress coefficient for the acceptance criteria set being considered, as given in **Table 8.3.7**

$\tau_{yd} = \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.3.7
Permissible Shear Stress Coefficient for Primary Support Members

Acceptance criteria set	Structure attached to primary support member	C_t
AC1	All boundaries, including decks and flats	0.70
AC2	All boundaries, including decks and flats[(1)]	0.85

Note
1. Collision bulkhead primary support members are to be evaluated for design load set 11 (accidental flooding) using acceptance criteria set AC1

3.9.3.4 Primary support members are to generally be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be necessary to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in **3.9.3.2** and **3.9.3.3** when subjected to the applicable design load sets.

3.9.4 Corrugated bulkheads

3.9.4.1 Special consideration will be given to the approval of corrugated bulkheads where fitted.

Guidance Note
Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see **2.5.6** and **2.5.7**.

3.9.5 Pillars

3.9.5.1 The maximum load on a pillar, W_{pill}, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Table 8.3.8**, and is to be less than or equal to the permissible pillar load as given by the following equation, where $W_{pill\text{-}perm}$ is based on the net properties of the pillar.

$$W_{pill} \le W_{pill-perm}$$

Where:

W_{pill} applied axial load on pillar

$= P b_{a-\sup} l_{a-\sup} + W_{pill-upr}$ kN

$W_{pill\text{-}perm}$ permissible load on a pillar

$= 0.1 A_{pill-net50}\, \eta_{pill}\, \sigma_{crb}$ kN

P design pressure for the design load set being considered, calculated at centre of the deck area supported by the pillar being considered, in kN/m^2

$b_{a\text{-}sup}$ mean breadth of area supported, in m

$l_{a\text{-}sup}$ mean length of area supported, in m

$W_{pill\text{-}upr}$ axial load from pillar or pillars above, in kN

$A_{pill\text{-}net50}$ net cross section area of the pillar, in cm^2

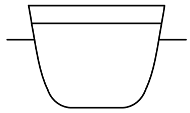
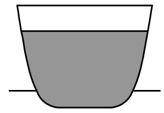
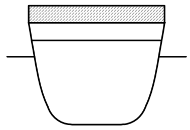
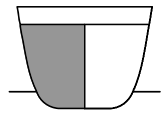
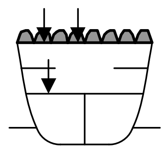
η_{pill} utilisation factor for the design load set being considered:

= 0.5 for acceptance criteria set AC1

= 0.6 for acceptance criteria set AC2

σ_{crb} critical buckling stress in compression of pillar based on the net sectional properties calculated in accordance with **Sec 10/3.5.1**, in N/mm^2

Table 8.3.8
Design Load Sets for Plating, Local Support Members and Primary Support Members

Type of Local Support and Primary Support Member	Design Load Set(1)	Load Component	External Draught	Comment	Diagrammatic Representation
Shell Envelope	1	P_{ex}	T_{sc}	Sea pressure only	
	2	P_{ex}	T_{sc}		
	5	P_{in}	T_{bal}	Tank pressure only. Sea pressure to be ignored	
	6	P_{in}	0.25 T_{sc}		
External Decks	1	P_{ex}	T_{sc}	Green sea pressure only	
Tank Boundaries and/or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	0.25 T_{sc}		
	11	$P_{in-flood}$	-		
Internal and External Decks or Flats	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Adjacent tanks empty. Green sea pressure may be ignored	
	10	P_{dk}	T_{bal}		

Where:
T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**
T_{bal} minimum design ballast draught, in m, as defined in **Sec 4/1.1.5.2**

Notes
1. The specification of design load combinations and other load parameters for the design load sets are given in **Table 8.2.8**
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See Note 4 on **Table 8.2.7** and **Table 8.2.8**.
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See Note 2.

4 Machinery Space

4.1 General

4.1.1 Application

4.1.1.1 The requirements of this Sub-Section apply to machinery spaces situated in the aft end region, aft of the aftermost cargo tank bulkhead and forward of, and including, the aft peak bulkhead.

4.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for application the minimum thickness requirements of **4.1.5**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions as specified in **Sec 6/3**.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions as specified in **Sec 6/3**.

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions as specified in **Sec 6/3**.

(d) for application of buckling requirements of **Sec 10/2** the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions as specified in **Sec 6/3**.

4.1.2 General scantling requirements

4.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Sec 8/1**

(b) strength against sloshing and impact loads, see **Sec 8/6**

(c) buckling/ultimate strength, see **Sec 10**.

4.1.2.2 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with **Sec 4/2**.

4.1.2.3 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to **Table 8.3.5**.

4.1.2.4 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structure design details are to comply with the requirements in **Sec 4/3**.

4.1.2.5 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above tanks. See also **Sec 4/3**.

4.1.3 Structural continuity

4.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be properly tapered towards the aft end. See also **1.6**.

4.1.3.2 Suitable arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities when structure that contributes to the main longitudinal strength of the ship is omitted in way of the machinery space.

4.1.3.3 Where inner hull or longitudinal bulkhead structures terminate at the forward engine room bulkhead, adequate backing structure is to be provided together with tapering brackets to ensure continuity of strength.

4.1.3.4 All shell frames and tank boundary stiffeners are to be continuous throughout, or are to be bracketed at their ends, except as permitted in **Sec 4/3.2.4** and **4/3.2.5**.

4.1.3.5 Longitudinal primary support members, lower decks, and bulkheads arranged in the engine room are to be aligned with similar structures in the cargo tank region, as far as practicable. Where direct alignment is not possible, suitable scarphing arrangements such as taper brackets are to be provided.

4.1.4 Arrangements

4.1.4.1 Where openings in decks/bulkheads are provided in the machinery space, the arrangements are to ensure support for deck, side, and bottom structure.

4.1.4.2 All parts of the machinery, shafting, etc., are to be supported to distribute the loads into the ship's structure. The adjacent structure is to be suitably stiffened.

4.1.4.3 Primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.

4.1.4.4 These requirements are formulated assuming conventional single screw, single engine propulsion arrangements. Twin-screw or multi-engine vessels, or vessels of higher power, may require additions to the scantlings of the structure and the area of attachments, which are proportional to the weight, power and proportions of the machinery especially where the engines are positioned relatively high in proportion to the width of the bed plate.

4.1.4.5 The foundations for main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. Consideration is to be given to the submittal of the following plans to the machinery manufacturer for review:

(d) foundations for main propulsion units

(e) foundations for reduction gears

(f) foundations for thrust bearings

(g) structure supporting (a), (b) and (c).

4.1.4.6 A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.

4.1.5 Minimum thickness

4.1.5.1 In addition to the requirements for thickness, section modulus and shear area, as given in **4.2** to **4.8**, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements given in **Table 8.4.1**.

Table 8.4.1
Minimum Net Thickness of Structure in the Machinery Space

Scantling Location			Net Thickness (mm)
Plating	Shell	Keel plating	See **2.1.5.1**
		Bottom shell/bilge/side shell plating	See **2.1.5.1**
	Upper deck		See **2.1.5.1**
	Other structure	Hull internal tank boundaries	See **2.1.5.1**
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	See **2.1.5.1**
		Lower decks and flats	$3.3 + 0.0067s$
		Inner bottom	$6.5 + 0.02L_2$
Bottom centreline girder			See **2.1.6.1**
Floors and bottom longitudinal girders off centreline			$5.5 + 0.02L_2$
Web plating of primary support members			$5.5 + 0.015L_2$
Local support members			See **2.1.5.1**
Tripping brackets			See **2.1.5.1**

Where:
L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m
s stiffener spacing, in mm, as defined in **Sec 4/2.2**

4.2 Bottom Structure

4.2.1 General

4.2.1.1 In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region, see **Sec 5/3.2.1**. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent. Lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

4.2.2 Bottom shell plating

4.2.2.1 The keel plate breadth is to comply with the requirements in **Sec 8/2.2.1.1**.

4.2.2.2 The thickness of the bottom shell plating (including keel plating) is to comply with the requirements in **4.8.1.1**.

4.2.3 Bottom shell stiffeners

4.2.3.1 The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.2.4 Girders and floors

4.2.4.1 The double bottom is to be arranged with a centreline girder.

4.2.4.2 Full depth bottom girders are to be arranged in way of the main machinery to effectively distribute its weight, and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.

4.2.4.3 Where fitted, side girders are to align with the bottom side girders in the adjacent space.

4.2.4.4 Where the double bottom is transversely framed, plate floors are to be fitted at every frame.

4.2.4.5 Where the double bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

4.2.4.6 Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

4.2.5 Inner bottom plating

4.2.5.1 Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer’s recommendations.

4.2.6 Sea chests

4.2.6.1 Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

4.3 Side Structure

4.3.1 General

4.3.1.1 The scantlings of the side shell plating and longitudinals are to be properly tapered from the midship region towards the aft end.

4.3.1.2 A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.

4.3.1.3 Stiffeners and primary support members are to be supported at their ends.

4.3.2 Side shell plating

4.3.2.1 The thickness of the side shell plating is to comply with the requirements in **4.8.1.1**. Where applicable, the thickness of the side shell plating is to comply with the requirements in **2.2.4.2**.

4.3.3 Side shell local support members

4.3.3.1 The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.3.3.2 (void)

4.3.3.3 End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and when not continuous are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

4.3.4 Side shell primary support members

4.3.4.1 Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

4.3.4.2 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.

4.3.4.3 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.3.4.4 The web depth is to be not less than 2.5 times the web depth of the adjacent frames if the slots are not closed.

4.3.4.5 Web plating of primary support members is to have a depth of not less than 14 % of the unsupported span in bending.

4.4 Deck Structure

4.4.1 General

4.4.1.1 All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.

4.4.1.2 The corners of the machinery space openings are to be of suitable shape and design to minimise stress concentrations.

4.4.1.3 In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

4.4.1.4 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

4.4.1.5 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

4.4.1.6 Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

4.4.1.7 The structural scantlings are to be not less than the requirement for tank boundaries if the deck forms the boundary of a tank.

4.4.1.8 The structural scantlings are to be not less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

4.4.2 Deck scantlings

4.4.2.1 The plate thickness of deck plating is to comply with the requirements in **4.8.1.1**.

4.4.2.2 The section modulus and thickness of deck stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.4.2.3 The web depth of deck stiffeners is to be not less than 60 mm.

4.4.2.4 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.4.2.5 The web depth of primary support members is not to be less than 10 % and 7 % of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in **Sec 4/2.1.4** or in case of a grillage structure the distance between connections to other primary support members.

4.4.2.6 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

4.4.3 Pillars

4.4.3.1 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

4.4.3.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets, or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

4.4.3.3 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

4.4.3.4 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45%of the specified minimum yield stress of the material.

4.4.3.5 The scantlings of pillars are to comply with the requirements in **4.8.4**.

4.4.3.6 Where the pillar loads from heavy equipment exceed the design load required by **4.8.4**, the pillar scantlings are to be determined based on the actual loading.

4.5 Machinery Foundations

4.5.1 General

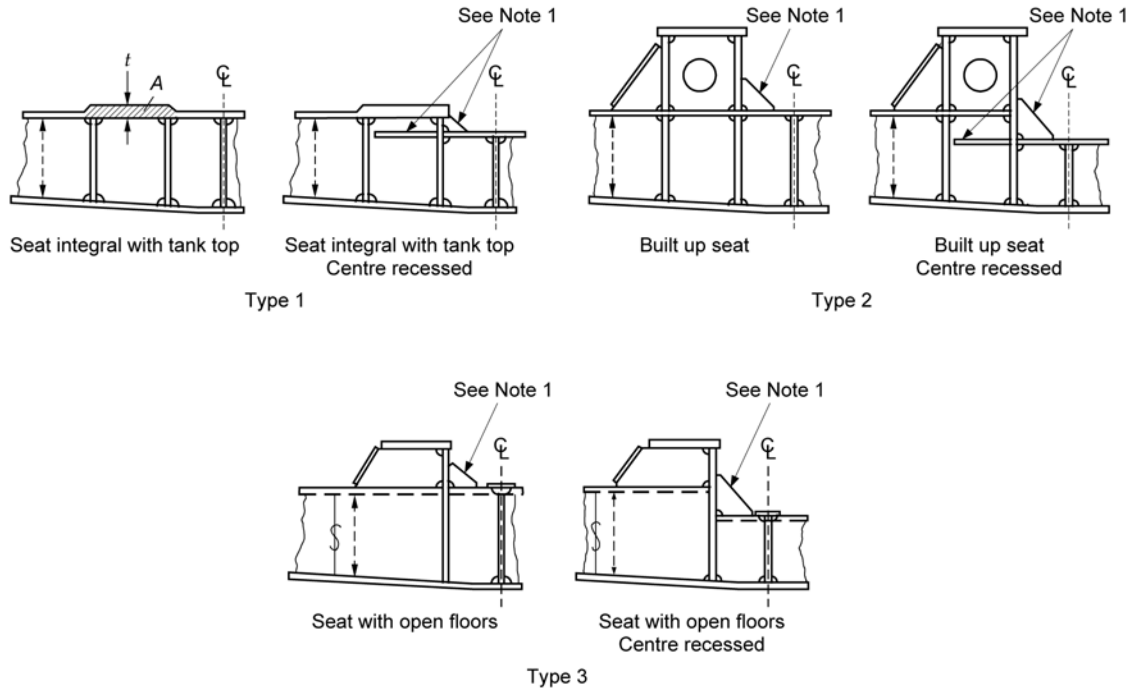
4.5.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of strength that is sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

4.5.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to substantially increase the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case, and the thrust bearing, see **Fig 8.4.1**, Type 1.

4.5.1.3 For main machinery supported on foundations of Type 2, as shown in **Fig 8.4.1**, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see **Fig 8.4.1**, Type 2.

4.5.1.4 For ships with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed, see **Fig 8.4.1**, Type 3.

Fig 8.4.1
Machinery Foundations



Note
1. Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with recommendations of the engine manufacturer.

4.5.2 Foundations for internal combustion engines and thrust bearings

4.5.2.1 In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

4.5.2.2 Generally two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

Guidance Note
In general, the gross thickness of foundation top plates is not to be less than 45mm, where the maximum continuous output of the propulsion machinery is 3500kw or greater.

4.5.3 Auxiliary foundations

4.5.3.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

4.6 Tank Bulkheads

4.6.1 General

4.6.1.1 Tanks may be required to have divisions or deep wash plates to minimise the dynamic stress on the structure.

4.6.2 Construction

4.6.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

4.6.3 Scantlings of tank boundary bulkheads

4.6.3.1 The thickness of tank boundary plating is to comply with the requirements in **4.8.1.1**.

4.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.6.3.4 Web plating of primary support members is to have a depth of not less than 14 % of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

4.7 Watertight Boundaries

4.7.1 General

4.7.1.1 Watertight boundaries within the machinery space are to be fitted in accordance with **Sec 5/2**.

4.7.2 Scantlings of watertight boundaries

4.7.2.1 The thickness of watertight boundary plating is to comply with the requirements in **4.8.1.1**.

4.7.2.2 The section modulus and thickness of stiffeners are to comply with the requirements in **4.8.1.2** and **4.8.1.3**.

4.7.2.3 The section modulus and shear area of primary support members are to comply with the requirements in **4.8.2**.

4.7.2.4 Web plating of primary support members is to have a depth of not less than 10 % of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

4.8 Scantling Requirements

4.8.1 Plating and local support members

4.8.1.1 For plating subjected to lateral pressure the net plating thickness is to comply with the requirements in **3.9.2.1**, but using the permissible bending stress coefficient, C_a, defined in **Table 8.4.2**.

4.8.1.2 For stiffeners subjected to lateral pressure the net section modulus requirement is to comply with the requirements in **3.9.2.2**, but using the permissible bending stress coefficient, C_s, defined in **Table 8.4.3**.

4.8.1.3 For stiffeners subjected to lateral pressure the net web thickness based on shear area requirements is to comply with the requirements in **3.9.2.3**.

Table 8.4.2
Permissible Bending Stress Coefficient for Plating

The permissible bending stress coefficient, C_a, for the design load set being considered is to be taken as:

$C_a = \beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

Where:

β_a, α_a, C_{a-max}

Acceptance Criteria Set	Structural Member		β_a	α_a	C_{a-max}
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC2	Longitudinal Strength Members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.0

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in **Sec 3/5.1.2**

$$= \frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} 10^{-3} \quad \text{N/mm}^2$$

$M_{v\text{-}total}$ design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-}perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, see **Table 7.6.1**

$I_{v\text{-}net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.1**, in m^4

z vertical coordinate of the load calculation point under consideration, in m

$z_{NA\text{-}net50}$ distance from the baseline to the horizontal neutral axis, as defined in **Sec 4/2.6.1**, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.4.3
Permissible Bending Stress Coefficient for Stiffeners

The permissible bending stress coefficient C_s is to be taken as:

Sign of Hull Girder Bending Stress, σ_{hg}	Side that Pressure is Acting On	Acceptance Criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than C_{s-max}
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s-max}$
Compression (-ve)	Stiffener side	

Where:

β_s, α_s, C_{s-max} permissible bending stress factors and are to be taken as:

Acceptance Criteria Set	Structural Member	β_s	α_s	C_{s-max}
AC1	Longitudinally effective stiffeners	0.85	1.0	0.75
	Other stiffeners	0.75	0	0.75
AC2	Longitudinally effective stiffeners	1.0	1.0	0.9
	Other stiffeners	0.9	0	0.9
	Watertight boundary stiffeners	0.9	0	0.9

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the reference point defined in **Sec 3/5.2.2.5**

$$= \left(\frac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} \right) 10^{-3} \quad \text{N/mm}^2$$

$M_{v-total}$ design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm
Mv-total is to be calculated in accordance with **Table 7.6.1** using the sagging or hogging still water bending moment

Stiffener Location	$M_{sw-perm}$	
	Pressure acting on Plate Side	Pressure acting on Stiffener Side
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.1**, in m^4

z vertical coordinate of the reference point defined in **Sec 3/5.2.2.5**, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in **Sec 4/2.6.1**, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

4.8.2 Primary support members

4.8.2.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.

4.8.2.2 For primary support members subjected to lateral pressure the net section modulus requirement is to comply with the requirements in **3.9.3.2**.

4.8.2.3 For primary support members subjected to lateral pressure the net cross sectional area of the web is to comply with the requirements in **3.9.3.3**.

4.8.2.4 Primary support members are to generally be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than permissible stresses and stress coefficients given in **3.9.3.2** and **3.9.3.3** when subjected to the applicable design load sets.

4.8.3 Corrugated bulkheads

4.8.3.1 Special consideration will be given to the approval of corrugated bulkheads where fitted.

Guidance Note
Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, see **2.5.6** and **2.5.7**.

4.8.4 Pillars

4.8.4.1 The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in **3.9.5**.

5 Aft End

5.1 General

5.1.1 Application

5.1.1.1 The requirements of this Sub-Section apply to structure located between the aft peak bulkhead and the aft end of the ship.

5.1.1.2 The requirements of this Sub-Section do not apply to the following:

(a) rudder horns

(b) structures which are not integral with the hull, such as rudders, steering nozzles and propellers

(c) other appendages permanently attached to the hull.

Where such items are fitted, the requirements of the individual Classification Society are to be complied with.

5.1.1.3 The net scantlings described in **5.1** to **5.7** are related to gross scantlings as follows:

(a) for application the minimum thickness requirements of **5.1.4**, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**.

(b) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

(c) for primary support members, the gross shear area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in **Sec 6/3**

(d) for application of buckling requirements of **Sec 10/2** the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**.

5.1.2 General scantling requirements

5.1.2.1 The hull structure is to comply with the applicable requirements of:

(a) hull girder longitudinal strength, see **Sec 8/1**

(b) strength against sloshing and impact loads, see **Sec 8/6**

(c) buckling/ultimate strength, see **Sec 10.**

5.1.2.2 The deck plating thickness and supporting structure are to be suitably reinforced for the steering gear, mooring windlasses, and other deck machinery. See **Sec 11/3.**

5.1.2.3 The net section modulus, shear area and other sectional properties of local and primary support members are to be determined in accordance with **Sec 4/2.**

5.1.2.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support members are to be applied as required in the notes to **Table8.3.5.**

5.1.2.5 The scantling criteria are based on assumptions that all structural joints and welded details are designed and fabricated such that they are compatible with the anticipated working stress levels at the locations considered. The loading patterns, stress concentrations and potential failure modes of structural joints and details during the design of highly stressed regions are to be considered. Structure design details are to comply with the requirements in **Sec 4/3.**

5.1.2.6 Limber, drain and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Arrangements are to be made for draining the spaces above deep tanks. See also **Sec 4/3.**

5.1.3 Structural continuity

5.1.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. See also **1.6.**

5.1.3.2 In transition zones forward of the aft peak into the machinery space, due consideration is to be given to the tapering of primary support members.

5.1.3.3 Longitudinal framing of the strength deck is to be carried aft to the stern.

5.1.3.4 All shell frames and tank boundary stiffeners are in general to be continuous, or are to be bracketed at their ends, except as permitted in **Sec 4/3.2.4** and **4/3.2.5.**

5.1.4 Minimum thickness

5.1.4.1 In addition to the thickness, section modulus and stiffener web shear area requirements as given in **5.2** to **5.7**, the thickness of plating and stiffeners in the aft end region is to comply with the appropriate minimum thickness requirements given in **Table8.5.1**.

Table 8.5.1
Minimum Net Thickness of Structure Aft of the Aft Peak Bulkhead

Scantling Location			Net Thickness (mm)
Plating	Shell	Keel plating	See **2.1.5.1**
		Bottom shell/bilge/side shell plating	See **2.1.5.1**
	Upper Deck		See **2.1.5.1**
	Other structure	Hull internal tank boundaries	See **2.1.5.1**
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	See **2.1.5.1**
		Pillar bulkheads	7.5
Bottom girders and aft peak floors			$5.5 + 0.02 L_2$
Web plating of primary support members			$6.5 + 0.015 L_2$
Local support members			See **2.1.5.1**
Tripping brackets			See **2.1.5.1**
Where: L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m			

5.2 Bottom Structure

5.2.1 General

5.2.1.1 Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube. Where floors do not extend to flats or decks they are to be stiffened by flanges at their upper end.

5.2.1.2 The centreline bottom girder is to extend as far aft as is practicable and is to be attached to the stern frame.

5.2.2 Aft peak floors and girders

5.2.2.1 The height of stiffeners, h_{stf}, on the floors and girders are to be not less than:

$h_{stf} = 80.0\ l_{stf}$ mm, for flat bar stiffeners

h_{stf} = 70.0 l_{stf} mm, for bulb profiles and flanged stiffeners

Where:

l_{stf} length of stiffener as shown in **Fig 8.5.1**, in m

5.2.2.2 In conjunction with the requirements of **5.2.2.1**, stiffeners are to be provided with end brackets as follows:

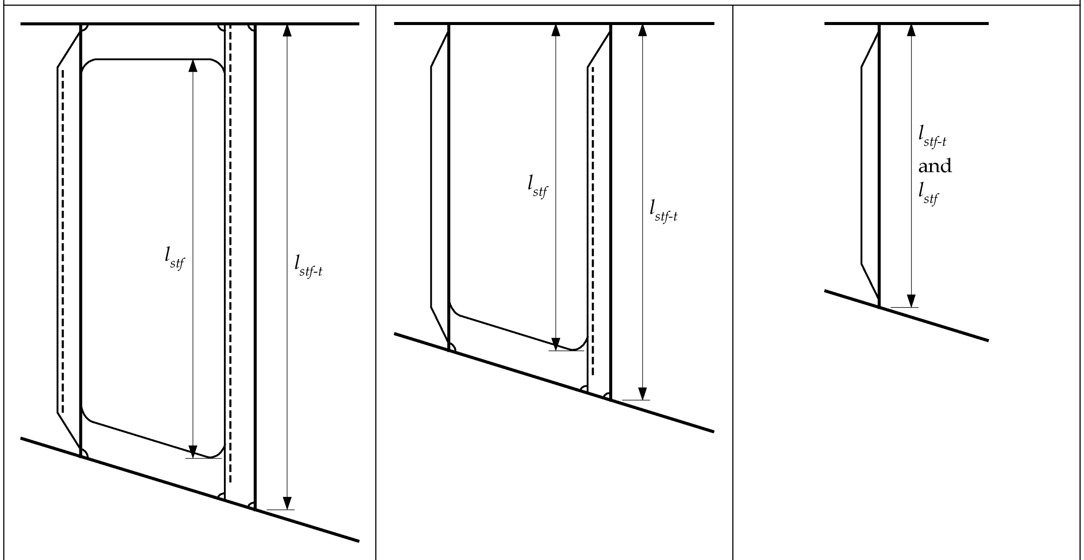
(a) brackets are to be fitted at the lower and upper ends when $l_{stf\text{-}t}$ exceeds 4 m

(b) brackets are to be fitted at the lower end when $l_{stf\text{-}t}$ exceeds 2.5 m.

Where:

$l_{stf\text{-}t}$ total length of stiffener as shown in **Fig 8.5.1**, in m

Figure 8.5.1
Stiffening of Floors and Girders in the Aft Peak



a) when $l_{stf\text{-}t} > 4$ b) when $l_{stf\text{-}t} > 2.5$ c) when $l_{stf\text{-}t} \leq 2.5$

5.2.2.3 Heavy plate floors are to be fitted in way of the aft face of the horn and in line with the webs in the rudder horn. They may be required to be carried up to the first deck or flat. In this area, cut outs, scallops or other openings are to be kept to a minimum.

5.2.3 Stern frames

5.2.3.1 Stern frames may be fabricated from steel plates or made of cast steel. For applicable material specifications and steel grades see **Table 6.1.3**. Stern frames of other material or construction will be specially considered.

5.2.3.2 Scantlings below the propeller boss on stern frames for single screw vessels are to comply with the requirements in **5.2.3.3** or **5.2.3.4**, as applicable.

5.2.3.3 Fabricated stern frames are to satisfy the following criteria:

(a) $t_{grs} \geq 2.25\sqrt{L}$ mm

(b) $w_{stn} \geq 450$ mm

(c) $$t_{grs} \geq \frac{C_f L^{1.5}}{w_{stn}^{\;2}\sqrt{1+\left(\frac{2l_{stn}}{w_{stn}}\right)^2}}$$ mm

Where:

t_{grs} gross thickness of side plating, in mm

w_{stn} width of stern frame, in mm, see **Fig 8.5.2a**

l_{stn} length of stern frame, in mm, see **Fig 8.5.2a**

L rule length, as defined in **Sec 4/1.1.1.1**

C_f = 9600

5.2.3.4 Cast stern frames are to satisfy the following criteria:

(a) $t_{1-grs} \geq 3.0\sqrt{L}$ mm, but not to be less than 25 mm

(b) $t_{2-grs} \geq 1.25 t_{1-grs}$ mm

(c) $$\frac{(t_{1-grs} + t_{2-grs})}{2} \geq \frac{C_f L^{1.5}}{w_{stn}{}^2 \sqrt{1 + \left(\frac{2 l_{stn}}{w_{stn}}\right)^2}}$$

Where:

t_{1-grs} gross thickness of casting at end, in mm, see **Fig 8.5.2b**

t_{2-grs} gross thickness of casting at mid length, in mm, see **Fig 8.5.2b**

w_{stn} width of stern frame, in mm, see **Fig 8.5.2b**

l_{stn} length of stern frame, in mm, see **Fig 8.5.2b**

L rule length, as defined in **Sec 4/1.1.1.1**

C_f = 8400

The thickness of butt welding to shell plating may be tapered below t_1 with a length of taper that is at least three times the offset. The castings are to be cored out to avoid large masses of thick material likely to contain defects and are to maintain a relatively uniform section throughout. Suitable radii are to be provided in way of changes in section.

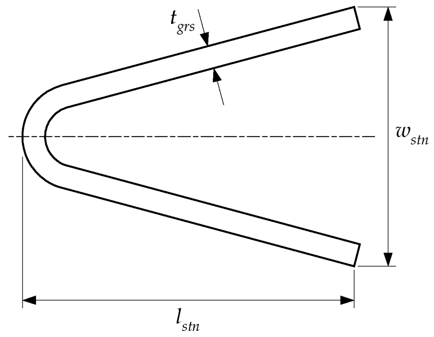
5.2.3.5 Above the propeller boss, the scantlings are to be in accordance with **5.2.3.2** to **5.2.3.4** except that in the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness may be reduced to 80 % of the applicable requirements in **5.2.3.2** to **5.2.3.4.**

5.2.3.5 Where round bars are used at the aft edge of stern frames, their scantlings and connection details are to facilitate welding.

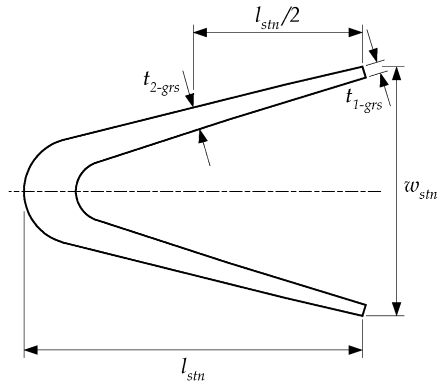
5.2.3.7 Ribs or horizontal brackets of thickness not less than 0.8 t_{grs} or 0.8 t_{1-grs} are to be provided at suitable intervals, where t_{grs} and t_{1-grs} are as defined in **5.2.3.3** and **5.2.3.4.** When t_{grs} or t_{1-grs} is reduced in accordance with **5.2.3.5**, a proportionate reduction in the thickness of ribs or horizontal brackets may be made.

5.2.3.8 Rudder gudgeons are to be an integral part of the stern frame and are to meet the requirements of the individual Classification Society.

Figure 8.5.2
Stern Frame



a Fabricated



b Cast

5.3 Shell Structure

5.3.1 Shell plating

5.3.1.1 The net thickness of the side shell and transom plating, t_{net}, is to comply with the requirements in **3.9.2.1** and is not to be less than:

$$t_{net} = 0.035(L_2 - 42) + 0.009s \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

5.3.1.2 The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in **3.9.2.1** and is not to be less than:

$$t_{net} = 0.094(L_2 - 43) + 0.009s \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greate than 300 m

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

5.3.1.3 In way of the boss and heel plate, the shell net plating thickness, t_{net}, is not to be less than:

$$t_{net} = 0.105(L_2 - 47) + 0.011s \quad \text{mm}$$

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

5.3.1.4 Within the extents specified in **2.2.4.3**, the thickness of the side shell plating is to comply with the requirements in **2.2.4.2**

5.3.1.5 Heavy shell plates are to be fitted locally in way of the heavy plate floors as required by **5.2.2.3**. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the horn plating is radiused into the shell plating, the radius at the shell connection, r, is not to be less than:

$r = 150 + 0.8L_2$ mm

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but need not be taken greater than 300 m

5.3.2 Shell local support members

5.3.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements in **3.9.2.2** and **3.9.2.3.**

5.3.3 Shell primary support members

5.3.3.1 The requirements of **5.3.3** apply to single side skin construction supported by system of vertical webs and/or horizontal stringers or flats.

5.3.3.2 Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

5.3.3.3 Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

5.3.3.4 The scantlings of web frames supporting; longitudinal framing, stringers and transverse framing are to be determined from **3.9.3.**

5.3.3.5 The web depth of primary support members is not to be less than 14 % of the bending span and is to be at least 2.5 times as deep as the slots for stiffeners if the slots are not closed.

5.4 Deck Structure

5.4.1 Deck plating

5.4.1.1 The thickness of the deck plating is to comply with the requirements in **3.9.2.1.**

5.4.1.2 (void)

5.4.2 Deck stiffeners

5.4.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3.**

5.4.3 Deck primary support members

5.4.3.1 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3.**

5.4.3.2 The web depth of primary support members is not to be less than 10 % and 7 % of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2.5 times the depth of the slots if the slots are not closed. Unsupported span in bending is bending span as defined in **Sec 4/2.1.4** or in case o a grillage structure the distance between connections to other primary support members.

5.4.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading. See also **Sec 11/3.**

5.4.4 Pillars

5.4.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

5.4.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets, or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

5.4.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45%of the specified minimum yield stress of the material.

5.4.4.4 The scantlings of pillars are to comply with the requirements in **3.9.5.**

5.4.4.5 Where the loads from heavy equipment exceed the design load of **3.9.5**, the pillar scantlings are to be determined based on the actual loading.

5.5 Tank Bulkheads

5.5.1 General

5.5.1.1 Tanks may be required to have divisions or deep wash structures to minimise the dynamic stress on the structure.

5.5.2 Construction

5.5.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

5.5.3 Scantlings of tank boundary bulkheads

5.5.3.1 The thickness of tank boundary plating is to comply with the requirements in **3.9.2.1.**

5.5.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3.**

5.5.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3.**

5.5.3.4 Web plating of primary support members is to have a depth of not less than 14 % of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

5.6 Watertight Boundaries

5.6.1 General

5.6.1.1 Watertight boundaries are to be fitted in accordance with **Sec 5/2.**

5.6.1.2 The number of openings in watertight bulkheads is to be kept to a minimum compatible with the design and operation of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

5.6.2 Aft peak bulkhead

5.6.2.1 An aft peak bulkhead complying with **Sec 5/2.3** is to be provided.

5.6.2.2 The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in **5.5** and **5.6.3**, as applicable.

5.6.3 Scantlings of watertight boundaries

5.6.3.1 The thickness of boundary plating is to comply with the requirements in **3.9.2.1.**

5.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in **3.9.2.2** and **3.9.2.3**.

5.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in **3.9.3**.

5.6.3.4 Web plating of primary support members is to have a depth of not less than 10 % of the unsupported span in bending and not less than 2.5 times the depth of the slots if the slots are not closed.

5.7 Miscellaneous Structures

5.7.1 Pillar bulkheads

5.7.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports not less effective than required for stanchions or pillars. The acting load and the required net cross sectional area of the pillar section is to be determined using the requirements of **5.4.4**. The net moment of inertia of the stiffener is to be calculated with a width of 40 t_{net} of the plating, where t_{net} is net plating thickness in mm.

5.7.1.2 Pillar bulkheads are to meet the following requirements:
(a) the distance between bulkhead stiffeners is not to exceed 1500 mm
(b) where corrugated, the depth of the corrugation is not to be less than 100 mm.

5.7.2 Rudder trunk

5.7.2.1 The scantlings of the rudder trunk are to be in accordance with the shell plating and framing in **5.3.1** and **5.3.2**. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

5.7.3 Stern thruster tunnels

5.7.3.1 The net thickness of the tunnel plating, $t_{tun-net}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{tun-net}$ is not to be taken less than:

$$t_{tun-net} = 0.008 d_{tun} + 1.8 \quad \text{mm}$$

Where:

d_{tun} inside diameter of the tunnel, in mm, but not to be taken less than 970 mm

5.7.3.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

6 Evaluation of Structure for Sloshing and Impact Loads

6.1 General

6.1.1 Application

6.1.1.1 The requirements of this Sub-Section cover the strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid and local impact loads that may occur in the forward structure. The sloshing and impact loads to be applied in **6.2** to **6.4** are described in **Sec 7/4**.

6.1.1.2 The net scantlings described in this Sub-Section are related to gross scantlings as follows:

(a) for plating and local support members, the gross thickness and gross cross sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in **Sec 6/3**

(b) for primary support members, the gross sectional area, gross section modulus and other gross cross sectional properties are obtained from the applicable requirements by adding one half of the full corrosion additions specified in **Sec 6/3.**

6.1.2 General scantling requirements

6.1.2.1 The requirements of **6.2** to **6.4** are to be applied in addition to the applicable requirements in **Sec 8**.

6.1.2.2 Local scantling increases due to impact or sloshing loads are to be made with due consideration given to details and avoidance of hard spots, notches and other harmful stress concentrations.

6.2 Sloshing in Tanks

6.2.1 Scope and limitations

6.2.1.1 The requirements of **6.2** specify the scantling requirements for boundary and internal structure of tanks subject to sloshing loads, as given in **Sec 7/4.2**, due to the free movement of liquid in tanks.

6.2.1.2 The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g. fuel oil bunkering tanks and main fresh water tanks, are to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressures.

6.2.1.3 All cargo and ballast tanks are to have scantlings suitable for unrestricted filling heights.

6.2.1.4 The following structural members are to be assessed:

(a) plates and stiffeners forming boundaries of tanks

(b) plates and stiffeners on wash bulkheads

(c) web plates and web stiffeners of primary support members located in tanks

(d) tripping brackets supporting primary support members in tanks.

6.2.1.5 For tanks with effective sloshing breadth, b_{slh}, greater than $0.56\,B$ or effective sloshing length, l_{slh}, greater than $0.13\,L$, an additional sloshing impact assessment is to be carried out in accordance with the individual Classification Society's procedures. The effective sloshing length, l_{slh}, and breadth, b_{slh}, are defined in **Sec 7/4.2.2** and **Sec 7/4.2.3** respectively.

6.2.2 Application of sloshing pressure

6.2.2.1 The following tanks are to be assessed for the design sloshing pressures $P_{slh-lng}$ and P_{slh-t} in accordance with **6.2.2.2** to **6.2.2.5**:

(a) cargo and slop tanks

(b) fore peak and aft peak ballast tanks

(c) other tanks which allow free movement of liquid, except as follows:

- where the effective sloshing length is less than $0.03\,L$, calculations involving $P_{slh-lng}$ are not required and

- where the effective sloshing breadth is less than 0.32 *B*, calculations involving P_{slh-t} are not required.

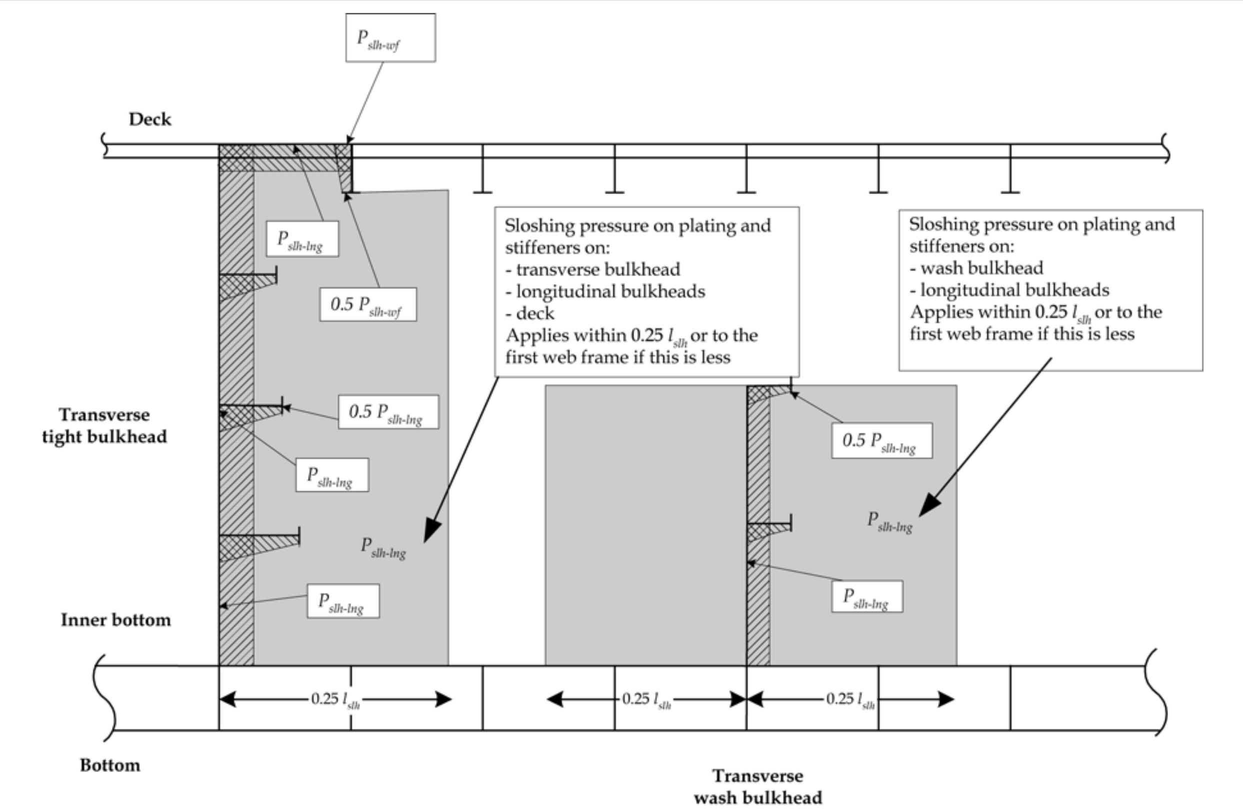
The design sloshing pressure for other tanks mentioned in **6.2.1.2** is to be taken as the minimum sloshing pressure, $P_{slh-min}$, as defined in **Sec 7/4.2.4**.

6.2.2.2 The design sloshing pressure due to longitudinal liquid motion, $P_{slh-lng}$, as defined in **Sec 7/4.2.2.1** is to be applied to the following members as shown in **Fig 8.6.1**:
(a) transverse tight bulkheads
(b) transverse wash bulkheads
(c) stringers on transverse tight and wash bulkheads
(d) plating and stiffeners on the longitudinal bulkheads, deck and inner hull which are between the transverse bulkhead and the first web frame from the bulkhead or the bulkhead and 0.25 l_{slh}, whichever is lesser.

6.2.2.3 In addition to **6.2.2.2**, the first web frame next to a transverse tight or wash bulkhead if the web frame is located within 0.25 l_{slh} from the bulkhead, as shown in **Fig 8.6.1**, is to be assessed for the web frame reflected sloshing pressure, P_{slh-wf}, as defined in **Sec 7/4.2.2.5**.

6.2.2.4 The minimum sloshing pressure, $P_{slh-min}$, as defined in **Sec 7/4.2.4** is to be applied to all other members.

Fig 8.6.1
Application of Sloshing Loads due to Longitudinal Liquid Motion

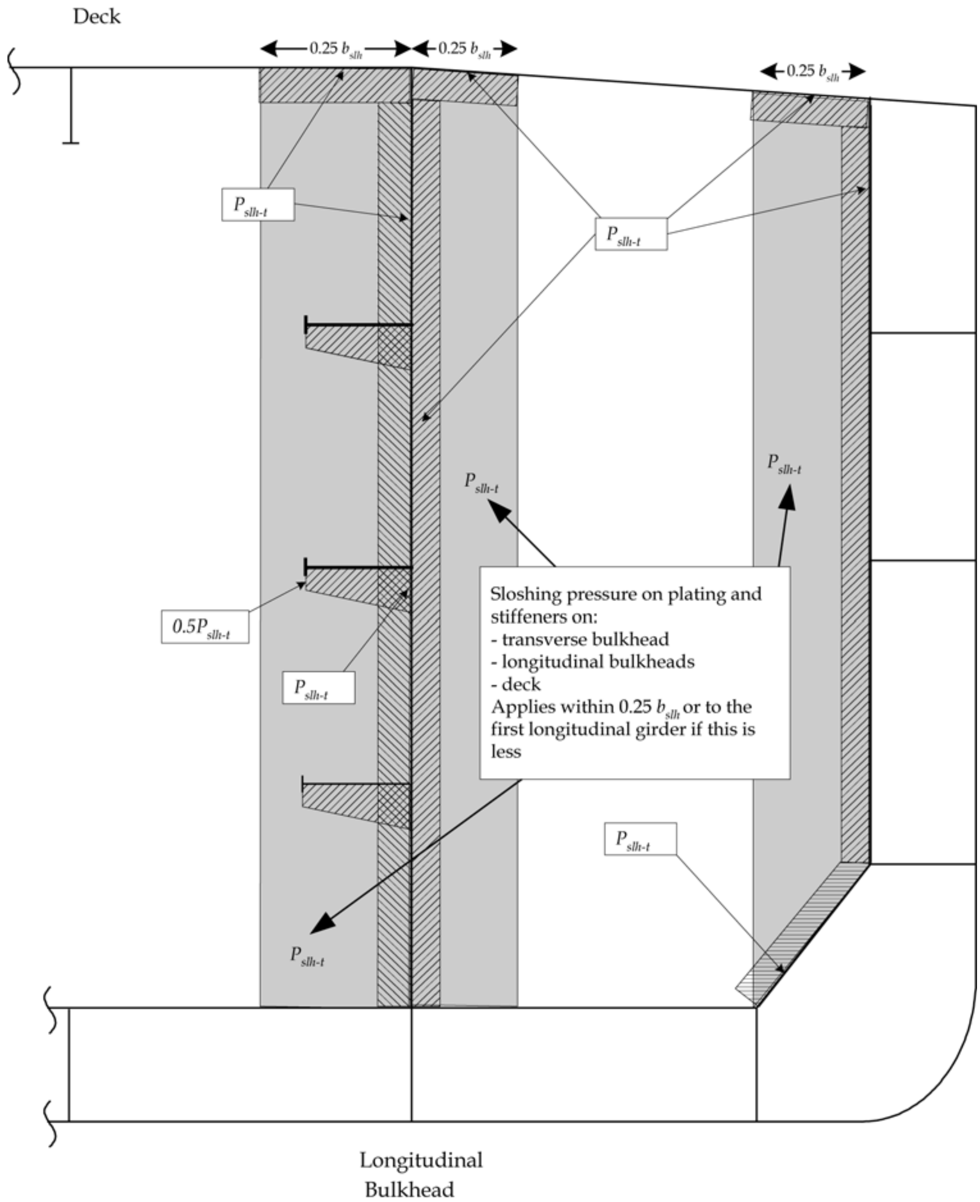


6.2.2.5 The design sloshing pressure due to transverse liquid motion, P_{shl-t}, as defined in **Sec 7/4.2.3.1**, is to be applied to the following members as shown in **Fig 8.6.2**:
(a) longitudinal tight bulkhead
(b) longitudinal wash bulkhead
(c) horizontal stringers on longitudinal tight and wash bulkheads

(d) plating and stiffeners on the transverse tight bulkheads including stringers and deck which are between the longitudinal bulkhead and the first girder from the bulkhead or the bulkhead and 0.25 b_{slh} whichever is lesser.

6.2.2.6 In addition to **6.2.2.5**, the first girder next to longitudinal tight or wash bulkhead if the girder is located within 0.25 b_{slh} from the longitudinal bulkhead, as shown in **Fig 8.6.2**, is to be assessed for the reflected sloshing pressure, $P_{slh-grd}$ as defined in **Sec 7/4.2.3.5**.

Fig 8.6.2
Application of Sloshing Loads due to Transverse Liquid Motion



6.2.2.7 The minimum sloshing pressure, $P_{slh-min}$, as defined in **Sec 7/4.2.4**, is to be applied to all other members.

6.2.2.8 The sloshing pressures due to transverse and longitudinal fluid motion are assumed to act independently. Structural members are therefore to be evaluated based on the greatest sloshing pressure due to longitudinal and transverse fluid motion.

6.2.3 Sloshing assessment of plating forming tank boundaries and wash bulkheads

6.2.3.1 The net thickness of plating forming tank boundaries and wash bulkheads, t_{net}, subjected to sloshing pressures is not to be less than:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{P_{slh}}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100 l_p}$$ but not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_p length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

P_{slh} the greater of $P_{slh-lng}$, P_{slh-t} or $P_{slh-min}$ as specified in **6.2.2**

C_a permissible plate bending stress coefficient as given in **Table 8.6.1**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.2.4 Sloshing assessment of stiffeners on tank boundaries and wash bulkheads

6.2.4.1 The net section modulus, Z_{net}, of stiffeners on tank boundaries and wash bulkheads subjected to sloshing pressures is not to be less than:

$$Z_{net} = \frac{P_{slh}\, s\, l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

l_{bdg} effective bending span, of stiffener, as defined in **Sec 4/2.1**, in m

C_s permissible bending stress coefficient as given in **Table 8.6.2**

P_{slh} the greater of $P_{slh-lng}$, P_{slh-t} or $P_{slh-min}$ as specified in **6.2.2**

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

f_{bdg} bending moment factor:

= 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners

= 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners

for other configurations the bending moment factor may be taken as given in **Table 8.3.5**

6.2.5 Sloshing assessment of primary support members

6.2.5.1 Web plating, web stiffeners and tripping brackets on stringers, girders and web frames in cargo and ballast tanks are to be assessed based on sloshing pressures as given in **6.2.2.**

6.2.5.2 The web plating net thickness of primary support members, t_{net}, is not to be less than:

$$t_{net} = 0.0158\alpha_p s\sqrt{\frac{P_{slh}}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \dfrac{s}{2100 l_p}$ but not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_p length of plate panel, mean spacing between local support members on the long edges of the panel, typically between tripping brackets, in m

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ or $P_{slh\text{-}min}$ as specified in **6.2.2**. The pressure is to be calculated at the load application point, defined in **Sec 3/5.1.2**, taking into account the distribution over the height of the member, as shown in **Fig 8.6.1**

C_a permissible plate bending stress coefficient as given in **Table 8.6.1**

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.2.5.3 The net section modulus, Z_{net}, of each individual stiffener on the web plating of primary support members subjected to sloshing pressures is not to be less than:

$$Z_{net} = \frac{P_{slh}\ s\ l_{bdg}^{\ 2}}{f_{bdg}\ C_s\ \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ or $P_{slh\text{-}min}$ as specified in **6.2.2**. The pressure is to be calculated at the load application point taking into account the distribution over the height of the member, as shown in **Fig 8.6.1** and **8.6.2.**

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{bdg} effective bending span, in m, of web stiffener as defined in **Sec 4/2.1**

C_s permissible bending stress coefficient as given in **Table 8.6.2**

f_{bdg} bending moment factor

= 12 for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners

= 8 for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners

for other configurations the bending moment factor may be taken as given in **Table 8.3.5**

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.2.5.4 The net section modulus, Z_{net}, in way of the base of tripping brackets supporting primary support members in cargo and ballast tanks is not to be less than:

$$Z_{net} = \frac{1000\,P_{slh}\ s_{trip}\ l_{trip}^2}{2\,C_s\ \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{slh} the greater of $P_{slh\text{-}lng}$, $P_{slh\text{-}t}$, $P_{slh\text{-}wf}$, $P_{slh\text{-}grd}$ and $P_{slh\text{-}min}$ as defined in **6.2.2**. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown in **Fig 8.6.1** and **8.6.2**

s_{trip} mean spacing, between tripping brackets or other primary support members or bulkheads, in m

l_{trip} length of tripping bracket, see **Fig 8.6.3**, in m

C_s permissible bending stress coefficient for tripping brackets

= 0.75

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.2.5.4bis The effective breadth of the attached plate to be used for calculating the section modulus of the tripping bracket supporting primary support members is to be taken as 1/3 the length of the tripping bracket, l_{trip}, as given in **8/6.2.5.4**.

6.2.5.5 The net shear area, $A_{shr-net}$, after deduction of cut-outs and slots, of tripping brackets supporting primary support members in cargo and ballast tanks is not to be less than:

$$A_{shr-net} = 10\frac{P_{slh}\ s_{trip}\ l_{trip}}{C_t \tau_{yd}} \quad cm^2$$

Where:

P_{slh} the greater of $P_{slh-lng}$, P_{slh-t}, P_{slh-wf}, $P_{slh-grd}$ and $P_{slh-min}$ as defined in **6.2.2**. The average pressure may be calculated at mid point of the tripping bracket taking into account the distribution as shown in **Fig 8.6.1** and **8.6.2**

s_{trip} mean spacing, between tripping brackets or other primary support members or bulkheads, in m

l_{trip} length of tripping bracket, see **Fig 8.6.3**, in m

C_t permissible shear stress coefficient, as given in **Table 8.6.3**

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Fig 8.6.3
Effective Length of Tripping Bracket

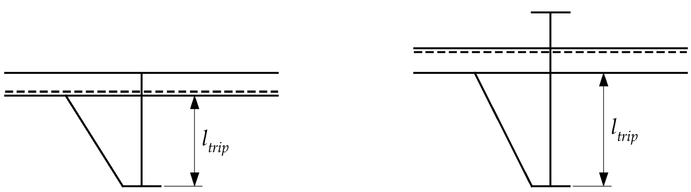


Table 8.6.1
Allowable Plate Bending Stress Coefficient, C_a, for Assessment of Sloshing on Plates

The permissible bending stress coefficient for the design load set being considered is to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than C_{a-max}

Where:

α_a, β_a, C_{a-max} permissible bending stress factors and are to be taken as follows

Acceptance Criteria Set	Structural Member		β_a	α_a	C_{a-max}
AC1	Longitudinal strength members in the cargo tank region including but not limited to : - deck - longitudinal plane bulkhead - horizontal corrugated longitudinal bulkhead - longitudinal girders and stringers within the cargo tank region	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other strength members including: - vertical corrugated longitudinal bulkhead - transverse plane bulkhead - transverse corrugated bulkhead - transverse stringers and web frames - plating of tank boundaries and primary support members outside the cargo tank region		0.8	0	0.8

σ_{hg} hull girder bending stress for the design load set being considered and calculated at the load calculation point defined in **Sec 3/5.1.2**

$$= \left(\frac{(z - z_{NA-net50})\, M_{sw-perm-sea}}{I_{v-net50}} \right) 10^{-3} \quad N/mm^2$$

z vertical coordinate of the load calculation point under consideration, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in **Sec 4/2.6.1**, in m

$M_{sw-perm-sea}$ permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm. The greatest of the sagging and hogging bending moment is to be used, see **Sec 7/2.1**.

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.1**, in m^4

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.6.2
Allowable Bending Stress Coefficient, C_s, for Assessment of Sloshing on Stiffeners

The permissible bending stress coefficient for the design load set being considered is to be taken as:

$$C_s = \beta_s - \alpha_s \frac{|\sigma_{hg}|}{\sigma_{yd}}$$ but not to be taken greater than C_{s-max}

Where:

α_s, β_s, C_{s-max} permissible bending stress factors and are to be taken as follows:

Acceptance Criteria Set	Structural Member		β_s	α_s	C_{s-max}
AC1	Longitudinal strength members in the cargo tank region including but not limited to: - deck stiffeners - stiffeners on longitudinal bulkheads - stiffeners on longitudinal girders and stringers within the cargo tank region	Longitudinal stiffeners	0.85	1.0	0.75
		Transverse or vertical stiffeners	0.7	0	0.7
	Other strength members including: - stiffeners on transverse bulkheads - stiffeners on transverse stringers and web frames - stiffeners on tank boundaries and primary support members outside the cargo tank region		0.75	0	0.75

σ_{hg} hull girder bending stress for the design load set being considered at the reference point defined in **Sec 3/5.2.2.5**

$$= \left(\frac{(z - z_{NA-net50})\, M_{sw-perm-sea}}{I_{v-net50}}\right) 10^{-3} \quad \text{N/mm}^2$$

z vertical coordinate of the reference point defined in **Sec 3/5.2.2.5**, in m

$z_{NA-net50}$ distance from the baseline to the horizontal neutral axis, as defined in **Sec 4/2.6.1**, in m

$M_{sw-perm-sea}$ permissible hull girder hogging and sagging still water bending moment for seagoing operation at the location being considered, in kNm.

Stiffener Location	$M_{sw-perm-sea}$	
	Pressure acting on Plate Side	Pressure acting on Stiffener Side
Above Neutral Axis	Sagging SWBM	Hogging SWBM
Below Neutral Axis	Hogging SWBM	Sagging SWBM

$I_{v-net50}$ net vertical hull girder moment of inertia, at the longitudinal position being considered, as defined in **Sec 4/2.6.1**, in m^4

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 8.6.3
Permissible Shear Stress Coefficient

Acceptance Criteria Set	Structural member	C_t
AC1	Tripping brackets	0.75

6.3 Bottom Slamming

6.3.1 Application

6.3.1.1 Where the minimum draughts forward, $T_{FP\text{-}mt}$ or $T_{FP\text{-}full}$, as specified in **Sec 7/4.3.2.1**, is less than 0.045 L, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

6.3.1.2 The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, see **1.1**.

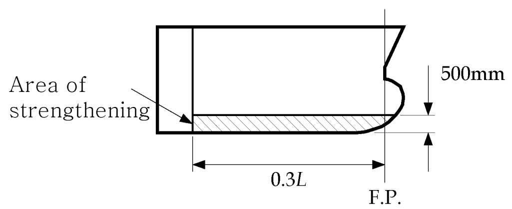
6.3.1.3 The scantlings described in **6.3** are net scantlings, which are related to gross scantlings as described in **6.1.1.2.** The section modulus and shear area of the primary support members is to be determined as specified in **Sec 4/2.5.**

6.3.1.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The cross sectional shear areas of primary support members are to be applied as required by **6.3.7.3** and **6.3.7.4.**

6.3.2 Extent of strengthening

6.3.2.1 The strengthening is to extend forward of 0.3 L from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see **Fig 8.6.4.**

Fig 8.6.4
Extent of strengthening against bottom slamming



6.3.2.2 Outside the region strengthened to resist bottom slamming the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.3.3 Design to resist bottom slamming loads

6.3.3.1 The design of end connections of stiffeners in the bottom slamming region is to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with **Sec 4/3.2.3.** Where it is not practical to comply with this requirement the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl-net}}{f_{bdg}} \quad \text{cm}^3$$

Where:

$Z_{pl\text{-}net}$ net plastic section modulus, in cm^3, as required by **6.3.5.1**

f_{bdg} bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 0 for both ends with low end fixity (simply supported)

= 1 for one end equivalent to built in and one end simply supported

6.3.3.2 Scantlings and arrangements at primary support members, including bulkheads, are to comply with **6.3.7.**

6.3.4 Hull envelope plating

$$t_{net} = \frac{0.0158\alpha_p s}{C_d}\sqrt{\frac{P_{slm}}{C_a\sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$= 1.2 - \frac{s}{2100 l_p}$ but not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_p length of plate panel, to be taken as the spacing between primary support members (see **Sec 4/2.2.2**) or panel breakers, in m

P_{slm} bottom slamming pressure as given in **Sec 7/4.3** and calculated at the load calculation point defined in **Sec 3/5.1.2**, in kN/m^2

C_d plate capacity correction coefficient

= 1.3

C_a permissible bending stress coefficient

= 1.0 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.5 Hull envelope stiffeners

6.3.5.1 The net plastic section modulus, Z_{pl-net}, of each individual stiffener, is not to be less than:

$$Z_{pl-net} = \frac{P_{slm}\, s l_{bdg}^{\,2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{slm} bottom slamming pressure as given in **Sec 7/4.3** and calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m^2

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.1**, in m

f_{bdg} bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 2.0 for continuous stiffeners or where stiffeners are bracketed at both ends

see **6.3.3.1** for alternative arrangements

C_s permissible bending stress coefficient

= 0.9 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.5.2 The net web thickness, t_{w-net}, of each longitudinal is not to be less than:

$$t_{w-net} = \frac{P_{slm}\, s l_{shr}}{2 d_{shr} C_t \tau_{yd}} \quad \text{mm}$$

Where:

l_{shr} effective shear span, as defined in **Sec 4/2.1.2**, in m

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

P_{slm} bottom slamming pressure as given in **Sec 7/4.3** and calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m^2

d_{shr} effective web depth of stiffener, in mm, as defined in **Sec 4/2.4.2.2**

C_t permissible shear stress coefficient

= 1.0 for acceptance criteria set AC3

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.5.3 The slenderness ratio of each longitudinal is to comply with **Sec 10/2.**

6.3.6 Definition of idealised bottom slamming load area for primary support members

6.3.6.1 The scantlings of items in **6.3.7** are based on the application of the slamming pressure defined in **Sec 7/4.3** to an idealised area of hull envelope plating, the slamming load area, A_{slm}, given by:

$$A_{slm} = \frac{1.1LBC_b}{1000} \quad \text{m}^2$$

Where:

L rule length, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

6.3.7 Primary support members

6.3.7.1 The size and number of openings in web plating of the floors and girders is to be minimised considering the required shear area as given in **6.3.7.2.**

6.3.7.2 The net shear area, $A_{shr\text{-}net50}$, of each primary support member web at any position along its span is not to be less than:

$$A_{shr-net50} = 10\frac{Q_{slm}}{C_t \tau_{yd}} \quad \text{cm}^2$$

Where:

Q_{slm} the greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, F_{slm} to the most onerous location, as determined in accordance with **6.3.7.3**

C_t permissible shear stress coefficient

= 0.9 for acceptance criteria set AC3

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.7.3 For simple arrangements of primary support members, where the grillage affect may be ignored, the shear force, Q_{slm}, is given by:

$$Q_{slm} = f_{pt} f_{dist} F_{slm} \quad \text{kN}$$

Where:

f_{pt} Correction factor for the proportion of patch load acting on a single primary support member

$= 0.5\left(f_{slm}{}^{3} - 2f_{slm}{}^{2} + 2\right)$

f_{slm} patch load modification factor

$= 0.5\dfrac{b_{slm}}{S}$, but not to be greater than 1.0

f_{dist} factor for the greatest shear force distribution along the span, see **Fig 8.6.5**

F_{slm} $= P_{slm} l_{slm} b_{slm}$

P_{slm} bottom slamming pressure as given in **Sec 7/4.3** and calculated at the load calculation point defined in Sec **3/5.3.2**, in kN/m^2

l_{slm} extent of slamming load area along the span

$= \sqrt{A_{slm}}$ m, but not to be greater than l_{shr}

l_{shr} effective shear span, as defined in **Sec 4/2.1.5**, in m

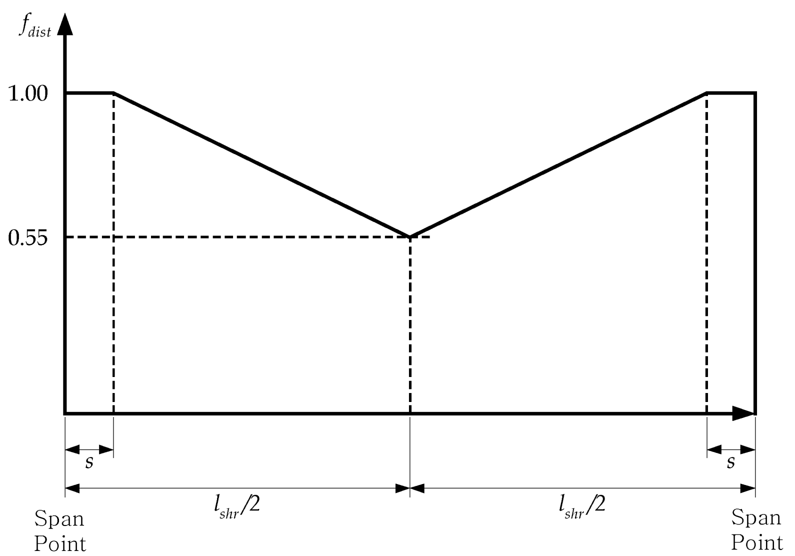
b_{slm} breadth of impact area supported by primary support member

$= \sqrt{A_{slm}}$ m, but not to be greater than S

A_{slm} as defined in **6.3.6.1**

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

Fig 8.6.5
Distribution of f_{dist} along the Span of Simple Primary Support Members



6.3.7.4 For complex arrangements of primary support members, the greatest shear force, Q_{slm}, at any location along the span of each primary support member is to be derived by direct calculation in accordance with **Table 8.6.4.**

Table 8.6.4
Direct Calculation Methods for Derivation of Q_{slm}

Type of analysis	Beam theory	Double bottom grillage
Model extent	Overall span of member between effective bending supports	Longitudinal extent to be one cargo tank length Transverse extent to be between inner hopper knuckle and centreline
Assumed end fixity of floors	Fixed at ends	Floors and girders to be fixed at boundaries of the model
Note 1. The envelope of greatest shear force along each primary support member is to be derived by applying the load patch to a number of locations along the span, see **6.3.7.2**.		

6.3.7.5 The net web thickness, $t_{w\text{-}net}$, of primary support members adjacent to the shell is not to be less than:

$$t_{w-net} = \frac{s_w}{70}\sqrt{\frac{\sigma_{yd}}{235}} \quad \text{mm}$$

Where:

s_w plate breadth, in mm, taken as the spacing between the web stiffening

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.3.8 Connection of longitudinals to primary support members

6.3.8.1 Longitudinals are, in general, to be continuous. Where this not practicable end brackets complying with **4/3.2.3** are to be provided.

6.3.8.2 The scantlings in way of the end connections of each longitudinal are to comply with the requirements of **Sec 4/3.4.**

6.4 Bow Impact

6.4.1 Application

6.4.1.1 The side structure in the area forward of $0.1\,L$ from the F.P. is to be strengthened against bow impact pressures.

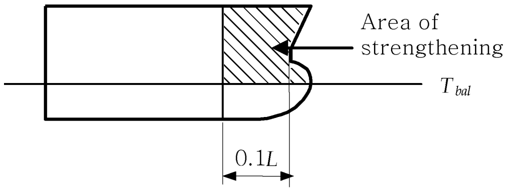
6.4.1.2 The scantlings described in **6.4** are net scantlings, which are related to gross scantlings as described in **6.1.1.2.**

6.4.1.3 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus of the primary support member is to apply along the bending span clear of end brackets and cross sectional areas of the primary support member is to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in **Fig 8.6.5.**

6.4.2 Extent of strengthening

6.4.2.1 The strengthening is to extend forward of $0.1\,L$ from the F.P. and vertically above the minimum design ballast draught, T_{bal}, defined in **Sec 4/1.1.5.2**. See **Fig 8.6.6.**

Fig 8.6.6
Extent of Strengthening Against Bow Impact



6.4.2.2 Outside the strengthening region as given in **6.4.2.1** the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.4.3 Design to resist bow impact loads

6.4.3.1 In the bow impact region, longitudinal framing is to be carried as far forward as practicable.

6.4.3.2 The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets complying with **Sec 4/3.2.3.** Where it is not practical to comply with this requirement the net plastic section modulus, $Z_{pl-alt-net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt-net} = \frac{16 Z_{pl-net}}{f_{bdg}} \quad \text{cm}^3$$

Where:

Z_{pl-net} effective net plastic section modulus, required by **6.4.5**, in cm^3

f_{bdg} bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 0 for both ends with low end fixity (simply supported)

= 1.0 for one end equivalent to built in and one end simply supported

6.4.3.3 Scantlings and arrangements at primary support members, including decks and bulkheads, are to comply with **6.4.7.** In areas of greatest bow impact load the adoption of web stiffeners arranged perpendicular to the hull envelope plating and the provision of double sided lug connections are, in general to be applied.

6.4.3.4 The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

6.4.4 Side shell plating

6.4.4.1 The net thickness of the side shell plating, t_{net}, is not to be less than:

$$t_{net} = 0.0158\, a_p\, s \sqrt{\frac{P_{im}}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100\, l_p}$$ but is not to be taken as greater than 1.0

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_p length of plate panel, to be taken as the spacing between the primary support members, see **Sec 4/2.2.2**, or panel breakers, in m

P_{im} bow impact pressure as given in **Sec 7/4.4** and calculated at the load calculation point defined in **Sec 3/5.1.2**, in kN/m²

C_a permissible bending stress coefficient

= 1.0 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.5 Side shell stiffeners

6.4.5.1 The effective net plastic section modulus, Z_{pl-net}, of each stiffener, in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl-net} = \frac{P_{im}\, s l_{bdg}^{\;2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

Where:

P_{im} bow impact pressure as given in **Sec 7/4.4** and calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m²

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.1**, in m

f_{bdg} bending moment factor

$$= 8\left(1 + \frac{n_s}{2}\right)$$

n_s = 2.0 for continuous stiffeners or where stiffeners are bracketed at both ends

see **6.3.3.1** for alternative arrangements

C_s permissible bending stress coefficient

= 0.9 for acceptance criteria set AC3

σ_{yd} specified minimum yield stress of the material, N/mm²

6.4.5.2 The net web thickness, t_{w-net}, of each stiffener is not to be less than:

$$t_{w-net} = \frac{P_{im}\, s l_{shr}}{2 d_{shr} C_t \tau_{yd}} \quad \text{mm}$$

Where:

l_{shr} effective shear span, as defined in **Sec 4/2.1.2**, in m

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

P_{im} bow impact pressure as given in **Sec 7/4.4** and calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m²

d_{shr} effective web depth of stiffener, in mm, as defined in **Sec 4/2.4.2.2**

C_t permissible shear stress coefficient

= 1.0 for acceptance criteria set AC3

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.5.3 The slenderness ratio of each longitudinal is to comply with **Sec 10/2.**

6.4.5.4 The minimum net thickness of breast hooks/diaphragm plates, t_{w-net}, is not to be less than:

$$t_{w-net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \quad \text{mm}$$

Where:

s spacing of stiffeners on the web, as defined in **Sec 4/2.2**, in mm. Where no stiffeners are fitted sistobetakenasthedepthoftheweb

σ_{yd} specified minimum yield stress of the material, in N/mm^2

6.4.6 Definition of idealised bow impact load area for primary support members

6.4.6.1 The scantlings of items in **6.4.7** are based on the application of the bow impact pressure, as defined in **Sec 7/4.4**, to an idealised area of hull envelope plating, where the bow impact load area, A_{slm}, is given by:

$$A_{slm} = \frac{1.1LBC_b}{1000} \quad \text{m}^2$$

Where:

L rule length, as defined in **Sec 4/1.1.1.1**

B moulded breadth, in m, as defined in **Sec 4/1.1.3.1**

C_b block coefficient, as defined in **Sec 4/1.1.9.1**

6.4.7 Primary support members

6.4.7.1 Primary support members in the bow impact region are to be configured to ensure effective continuity of strength and the avoidance of hard spots.

6.4.7.2 To limit the deflections under extreme bow impact loads and ensure boundary constraint for plate panels, the spacing, S, measured along the shell girth of web frames supporting longitudinal framing or stringers supporting transverse framing is not to be greater than:

$$S = 3 + 0.008L_2 \quad \text{m}$$

Where:

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but not to be taken greater than 300 m

6.4.7.3 End brackets of primary support members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

6.4.7.4 Tripping arrangements are to comply with **Sec 10/2.3.3.** In addition, tripping brackets are to be fitted at the toes of end brackets and at locations where the primary support member flange is knuckled or curved.

6.4.7.5 The net section modulus of each primary support member, Z_{net50}, is not to be less than:

$$Z_{net50} = 1000 \frac{f_{bdg-pt} P_{im}\, b_{slm} f_{slm} l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \quad \text{cm}^3$$

Where:

f_{bdg-pt} correction factor for the bending moment at the ends and considering the patch load

$$= 3f_{slm}^3 - 8f_{slm}^2 + 6f_{slm}$$

f_{slm} patch load modification factor

$$= \frac{l_{slm}}{l_{bdg}}$$

l_{slm} extent of bow impact load area along the span

$= \sqrt{A_{slm}}$ m, but not to be taken as greater than l_{bdg}

A_{slm} bow impact load area, in m^2, as defined in **6.4.6.1**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.4**, in m

P_{im} bow impact pressure as given in **Sec 7/4.4** and calculated at the load calculation point defined in **Sec 3/5.3.3**, in kN/m²

b_{slm} breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members as defined in **Sec 4/2.2.2**, but not to be taken as greater than l_{slm}, in m

f_{bdg} bending moment factor

= 12 for primary support members with end fixed continuous face plates, stiffeners or where stiffeners are bracketed in accordance with **Sec 4/3.3** at both ends

C_s permissible bending stress coefficient

= 0.8

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.7.6 The net shear area of the web, $A_{sh\text{-}net50}$, of each primary support member at the support/toe of end brackets is not to be less than:

$$A_{shr-net50} = \frac{5 f_{pt} P_{im} b_{slm} l_{shr}}{C_t \tau_{yd}} \quad \text{cm}^2$$

Where:

f_{pt} patch load modification factor

$$= \frac{l_{slm}}{l_{shr}}$$

l_{slm} extent of bow impact load area along the span

$= \sqrt{A_{slm}}$ m, but not to be taken as greater than l_{shr}

l_{shr} effective shear span, as defined in **Sec 4/2.1.5**, in m

P_{im} bow impact pressure as given in **Sec 7/4.4** and calculated at the load calculation point defined in **Sec 3/5.3.2**, in kN/m²

b_{slm} breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members as defined in **Sec 4/2.2.2**, but not to be taken as greater than l_{slm}, in m

C_t permissible shear stress coefficient

= 0.75 for acceptance criteria set AC3

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm²

σ_{yd} specified minimum yield stress of the material, in N/mm²

6.4.7.7 The net web thickness of each primary support member, $t_{w\text{-}net}$, including decks/bulkheads in way of the side shell is not to be less than:

$$t_{w-net} = \frac{P_{im} b_{slm}}{\sin \varphi_w \sigma_{crb}} \quad \text{mm}$$

Where:

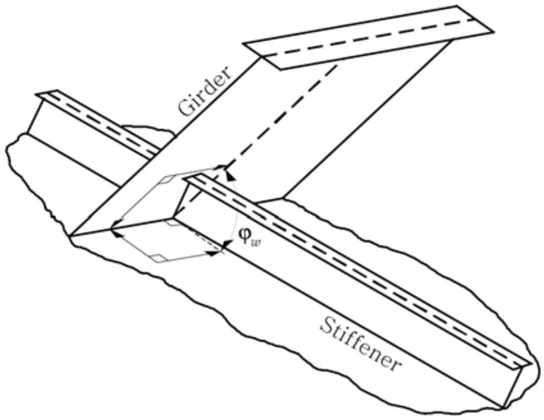
P_{im} bow impact pressure as given in **Sec 7/4.4** and calculated at the load calculation point defined in **Sec 3/5.3.2** or at the intersection of the side shell with the deck/bulkhead, in kN/m²

b_{slm} breadth of impact load area supported by the primary support member, to be taken as spacing between primary support members as defined in **Sec 4/2.2.2**, but not to be taken as greater than l_{slm}, in m

φ_w angle, in degrees, between the primary support member web and the shell plate, see **Fig 8.6.7**

σ_{crb} critical buckling stress in compression of the web of the primary support member or deck/bulkhead panel in way of the applied load given by **Sec 10/3.2.1**, in N/mm^2

Fig 8.6.7
Angle between Shell Primary Member and Shell Plate



6.4.8 Connection of stiffeners to primary support members

6.4.8.1 Stiffeners are, in general, to be continuous. Where this not practicable end brackets complying with **Sec 4/3.2.3** are to be provided.

6.4.8.2 The scantlings of the end connection of each stiffener are to comply with **Sec 4/3.4.**

7 Application of Scantling Requirements to Other Structure

7.1 General

7.1.1 Application

7.1.1.1 The requirements of this Sub-Section apply to plating, local and primary support members where the basic structural configurations or strength models assumed in **Sec 8/2** to **8/5** are not appropriate. These are general purpose strength requirements to cover various load assumptions and end support conditions. These requirements are not to be used as an alternative to the requirements of **Sec 8/2** to **8/5** where those sections can be applied.

7.1.1.2 The net scantlings described in **7.2** are related to gross scantlings as follows:

(a) for plating and local support members, the gross thickness and gross cross-sectional properties are obtained from the requirements of **7.2.2** by adding the full corrosion additions specified in **Sec 6/3**.

(b) for primary support members, the gross shear area, gross section modulus and other gross cross-sectional properties are obtained from the requirements of **7.2.3** by adding one half of the relevant full corrosion additions specified in **Sec 6/3**.

7.1.1.3 These requirements are to be applied in conjunction with all other appropriate requirements in **Sec 8, 9** and **10** for the particular structural member under consideration, including longitudinal strength, minimum thickness, proportions and structural stability, strength assessment(FEM), fatigue and hull girder ultimate strength.

7.1.1.4 The requirements for local and primary support members are to be specially considered when the member is:

(a) part of a grillage structure

(b) subject to large relative deflection between end supports

(c) where the load model or end support condition is not given in **Table 8.7.1.**

7.1.1.5 The application of alternative or more advanced calculation methods will be specially considered.

7.2 Scantling Requirements

7.2.1 General

7.2.1.1 The design load sets to be applied to the structural requirements for the local and primary support members are given in **Table 8.7.2**, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with **Table 7.6.1** and the requirements given in **Sec 7/6.3.**

7.2.2 Plating and local support members

7.2.2.1 For plating subjected to lateral pressure the net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$t_{net} = 0.0158\, \alpha_p s \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \quad \text{mm}$$

Where:

α_p correction factor for the panel aspect ratio

$$= 1.2 - \frac{s}{2100\, l_p}$$

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.1.2**, in kN/m^2

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_p length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in m

C_a permissible bending stress coefficient for the design load set being considered, as given in **Tables 8.2.4, 8.3.2** or **8.4.2**, as applicable for the individual member being considered

σ_{yd} specified minimum yield stress of the material, in N/mm^2

7.2.2.2 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net}, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$Z_{net} = \frac{|P| s l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \quad cm^3, \text{ for lateral pressure loads}$$

$$Z_{net} = \frac{1000 |F| l_{bdg}}{f_{bdg} C_s \sigma_{yd}} \quad cm^3, \text{ for point loads}$$

$$Z_{net} = \frac{\left| \sum \frac{P_i s l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j l_{bdg}}{f_{bdg-j}} \right|}{C_s \sigma_{yd}} \quad cm^3, \text{ for a combination of loads}$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m^2

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.1**

f_{bdg} bending moment factor

for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends:

= 12 for horizontal stiffeners

= 10 for vertical stiffeners

for other configurations the bending moment factor may be taken as in **Table 8.7.1**

C_s permissible bending stress coefficient for the design load set being considered as given in **Tables 8.2.5, 8.3.3** or **8.4.3**, as applicable for the individual member being considered

σ_{yd} specified minimum yield stress of the material, in N/mm^2

F point load for the design load set being considered, in kN

i indices for load component i

j indices for load component j

7.2.2.3 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, t_{w-net}, based on shear area requirements is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$t_{w-net} = \frac{f_{shr} |P| s l_{shr}}{d_{shr} C_t \tau_{yd}} \quad mm, \text{ for lateral pressure loads}$$

$$t_{w-net} = \frac{1000 f_{shr} |F|}{d_{shr} C_t \tau_{yd}} \quad mm, \text{ for point loads}$$

$$t_{w-net} = \frac{\left|\sum f_{shr-i} P_i \, s \, l_{shr} + \sum 1000 f_{shr-j} F_j\right|}{d_{shr} C_t \tau_{yd}}$$ mm, for a combination of loads

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.2.2**, in kN/m^2

f_{shr} shear force factor

for continuous stiffeners and where end connections are fitted consistent with idealization of the stiffener as having fixed ends:

= 0.5 for horizontal stiffeners

= 0.7 for vertical stiffeners

for other configurations the shear force factor may be taken as in **Table 8.7.1**.

s stiffener spacing, in mm, as defined in **Sec 4/2.2**

l_{shr} effective shear span, as defined in **Sec 4/2.1.2**

d_{shr} as defined in **Sec 4/2.4.2.2**

C_t permissible shear stress coefficient for the design load set being considered as given in **Tables 8.2.6** or **8.3.4**, as applicable for the individual member being considered

τ_{yd} $= \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

F point load for the design load set being considered, in kN

i indices for load component i

j indices for load component j

7.2.3 Primary support members

7.2.3.1 The requirements in **7.2.3** are applicable where the primary support member is idealised as a simple beam. More advanced calculation methods may be required to ensure that nominal stress level for all primary support members are less than the permissible stresses and stress coefficients given in **7.2.3.4** and **7.2.3.5** when subjected to the applicable design load sets. See also **7.1.1.4.**

7.2.3.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross sectional shear areas of the primary support member are to be applied as required in the notes of **Table 8.7.1.**

7.2.3.3 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

7.2.3.4 For primary support members the net section modulus requirement, Z_{net50}, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$Z_{net50} = \frac{1000\,|P|\,S\,l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}}$$ cm^3, for lateral pressure loads

$$Z_{net50} = \frac{1000\,|F|\,l_{bdg}}{f_{bdg} C_s \sigma_{yd}}$$ cm^3, for point loads

$$Z_{net50} = \frac{\left|\sum \frac{1000 P_i \, S \, l_{bdg}^2}{f_{bdg-i}} + \sum \frac{1000 F_j \, l_{bdg}}{f_{bdg-j}}\right|}{C_s \sigma_{yd}}$$ cm^3, for a combination of loads

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.3.3**, in kN/m^2

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

l_{bdg} effective bending span, as defined in **Sec 4/2.1.4**

f_{bdg} bending moment factor, as given in **Table 8.7.1**

C_s permissible bending stress coefficient for the design load set being considered as given in **Tables 8.2.10** or **8.3.6**, as applicable for the individual member being considered

σ_{yd} specified minimum yield stress of the material, in N/mm^2

F point load for the design load set being considered, in kN

i indices for load component i

j indices for load component j

7.2.3.5 For primary support members the net shear area of the web, $A_{shr-net50}$, is to be taken as the greatest value for all applicable design load sets given in **Table 8.7.2**, and given by:

$$A_{shr-net50} = \frac{10 f_{shr} |P| S l_{shr}}{C_t \tau_{yd}} \quad \text{cm}^2\text{, for lateral pressure loads}$$

$$A_{shr-net50} = \frac{10 f_{shr} |F|}{C_t \tau_{yd}} \quad \text{cm}^2\text{, for point loads}$$

$$A_{shr-net50} = \frac{\left| \sum 10 f_{shr-i} P_i l_{shr} + \sum 10 f_{shr-j} F_j \right|}{C_t \tau_{yd}} \quad \text{cm}^2\text{, for a combination of loads}$$

Where:

P design pressure for the design load set being considered, calculated at the load calculation point defined in **Sec 3/5.3.3**, in kN/m^2

S primary support member spacing, in m, as defined in **Sec 4/2.2.2**

l_{shr} effective shear span, as defined in **Sec 4/2.1.5**

f_{shr} bending moment factor, as given in **Table 8.7.1**

C_t permissible shear stress coefficient for the design load set being considered as given in **Tables 8.2.10** or **8.3.7**, as applicable for the individual member being considered

τ_{yd} $= \frac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

F point load for the design load set being considered, in kN

i indices for load component i

j indices for load component j

Table 8.7.1
Values of f_{bdg} and f_{shr}

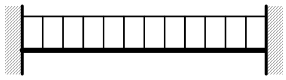
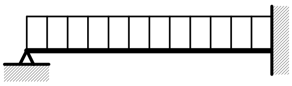
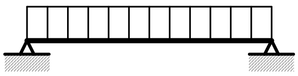
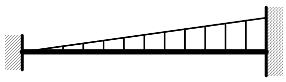
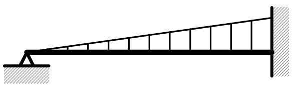
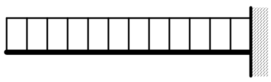
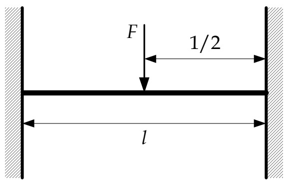
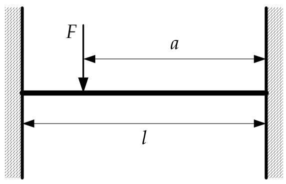
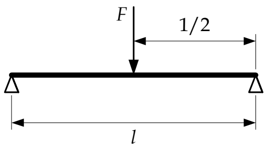
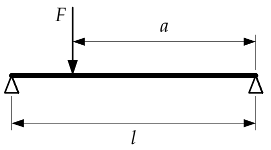
Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model	Position(1)			1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}	
A				12.0 0.50	24.0 -	12.0 0.50	Built in at both ends. Uniform pressure distribution
B				- 0.38	14.2 -	8.0 0.63	Built in one end plus simply supported one end. Uniform pressure distribution
C				- 0.50	8.0 -	- 0.50	Simply supported, (both ends are free to rotate). Uniform pressure distribution
D				15.0 0.30	23.3 -	10.0 0.70	Built in both ends. Linearly varying pressure distribution
E				- 0.20	16.8 -	7.5 0.80	Built in one end plus simply supported one end. Linearly varying pressure distribution
F				- -	- -	2.0 1.0	Cantilevered beam. Uniform pressure distribution
G				8.0 0.5	8.0 -	8.0 0.5	Built in at both ends. Single point load in the centre of the span
H				$\frac{l^3}{a^2(l-a)}$ $\frac{a^2(3l-2a)}{l^3}$	$\frac{l^4}{2a^2(l-a)^2}$ -	$\frac{l^3}{a(l-a)^2}$ $\frac{(l-a)^2(l+2a)}{l^3}$	Built in at both ends. Single point load, with load anywhere in the span

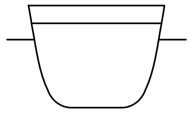
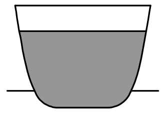
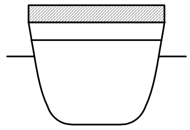
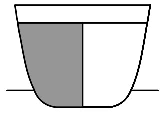
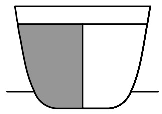
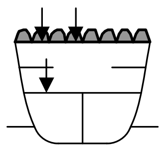
Table 8.7.1 (Continued)
Values of f_{bdg} and f_{shr}

Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model	Position(1)			1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}	
I	 			- 0.5	4 -	- 0.5	Simply supported. Single point load in the centre of the span
J	 			- $\frac{a}{l}$	$\frac{l^2}{a(l-a)}$ -	- $\frac{l-a}{l}$	Simply supported. Single point load, load anywhere along the span

Note
1. The bending moment factor f_{bdg} for the support positions are applicable for a distance of 0.2 l_{bdg} from the end of the effective bending span for both local and primary support members.
2. The shear force factor f_{shr} for the support positions are applicable for adistance of 0.2 l_{shr} from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   (a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1}, f_{bdg2} and f_{bdg3}
   (b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   (a) the section modulus requirement within 0.2 l_{bdg} from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}, however f_{bdg} is not to be taken greater than 12
   (b) the section modulus of mid span area is to be determined using $f_{bdg} = 24$, or f_{bdg2} from the table if lesser
   (c) the shear area requirement of end connections within 0.2 l_{shr} from the end of the effective span is to be determined using $f_{shr} = 0.5$ or the applicable f_{shr1} or f_{shr3}, whichever is greater
   (d) for models A through F the value of f_{shr} may be gradually reduced outside of 0.2 l_{shr} towards 0.5 f_{shr} at mid span where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

Where:
l effective span, l_{bdg} and l_{shr} as applicable
l_{bdg} as defined in **Sec 4/2.1.1** for local support members and **Sec 4/2.1.4** for primary support members
l_{shr} as defined in **Sec 4/2.1.2** for local support members and **Sec 4/2.1.5** for primary support members

Table 8.7.2
Design Load Sets for Plating, Local Support Members and Primary Support Members

Type of Local Support and Primary Support Member	Design Load Set (1)	Load Component	External Draught	Comment	Diagrammatic Representation
Shell Envelope	1	P_{ex}	T_{sc}	Sea pressure only	
	2	P_{ex}	T_{sc}		
	5	P_{in}	T_{bal}	Tank pressure only. Sea pressure to be ignored	
	6	P_{in}	$0.25\,T_{sc}$		
External Decks	1	P_{ex}	T_{sc}	Green sea pressure only	
Cargo Tank Boundaries	3	P_{in}	$0.6\,T_{sc}$	Pressure from one side only Full tank with adjacent tank empty	
	4	P_{in}	-		
	11	$P_{in-flood}$	-		
Other Tank Boundaries or Watertight Boundaries	5	P_{in}	T_{bal}	Pressure from one side only Full tank with adjacent tank empty	
	6	P_{in}	$0.25\,T_{sc}$		
	11	$P_{in-flood}$	-		
Internal and External Decks or Flats	9	P_{dk}	T_{bal}	Distributed or concentrated loads only. Adjacent tanks empty. Green sea pressure may be ignored	
	10	P_{dk}	T_{bal}		

Where:
T_{sc} scantling draught, in m, as defined in **Sec 4/1.1.5.5**
T_{bal} minimum design ballast draught, in m, as defined in **Sec 4/1.1.5.2**

Notes
1. The specification of design load combinations, and other load parameters for the design load sets are given in **Table 8.2.8**
2. When the ship's configuration cannot be described by the above, then the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the S and S+D design load combinations are to be selected. See Note 4 on **Table 8.2.7** and **Table 8.2.8.**
3. The boundaries of void and dry space not forming part of the hull envelope are to be evaluated using Design Load Set 11. See Note 2.

Section 9

Design Verification

1 Hull Girder Ultimate Strength

1.1 General

1.1.1 Application

1.1.1.1 The hull girder ultimate bending capacity in sagging is to be evaluated and checked to ensure it satisfies the following criteria. The criteria are applicable to intact ship structures, in extreme at sea conditions. They do not cover hogging, harbour or damaged conditions.

1.1.1.2 The scantling requirements in this Sub-Section are to be applied within 0.4 L amidships and are in addition to all other requirements within the rules.

1.1.1.3 Outside the 0.4 L region of amidships the plate and stiffeners may be gradually reduced towards the local requirements at the ends.

1.2 Rule Criteria

1.2.1 Vertical hull girder ultimate bending capacity

1.2.1.1 The vertical hull girder ultimate bending capacity is to satisfy the following criteria:

$$\gamma_S M_{sw} + \gamma_W M_{wv-sag} \leq \frac{M_U}{\gamma_R}$$

Where:

M_{sw} sagging still water bending moment, in kNm, to be taken as specified in **Table 9.1.1.**

$M_{wv\text{-}sag}$ sagging vertical wave bending moment, in kNm, to be taken as the midship sagging value defined in **Sec 7/3.4.1.1**

M_U sagging vertical hull girder ultimate bending capacity, in kNm, as defined in **Appendix A/1.1.1**

$\gamma_S, \gamma_W, \gamma_R$ are the partial safety factors for the design load combinations given in **1.4**

1.3 Hull Girder Bending Moment Capacity

1.3.1 Calculation of capacity

1.3.1.1 The hull girder ultimate bending capacity, M_U, in sagging is to be calculated according to **Appendix A/1.1.1.**

1.3.1.2 The effective area for the hull girder ultimate strength capacity assessment is specified in **Sec 8/1.2.1.**

1.3.1.3 The capacity is to be based on net scantlings using a corrosion addition, 0.5 t_{corr}, see **Sec 6/3.2**

1.4 Partial Safety Factors

1.4.1 General

1.4.1.1 The partial safety factors given in **Table 9.1.1** apply when M_U is calculated according to the single step method in **Appendix A/2.1** or the incremental method in **A/2.2**. The partial safety factors are given for two different design load combinations and both combinations are to be satisfied. Note that the definition of M_{sw} is different for each combination.

Table 9.1.1
Partial Safety Factors

Design load combination	Definition of Still Water Bending Moment, M_{sw}	γ_S	γ_W	γ_R
a)	Permissible sagging still water bending moment, $M_{sw\text{-}perm\text{-}sea}$, in kNm, see **Sec 7/2.1.1**	1.0	1.2	1.1
b)	Maximum sagging still water bending moment for operational seagoing homogeneous full load condition, $M_{sw\text{-}full}$, in kNm, see note1	1.0	1.3	1.1

Where:

γ_S partial safety factor for the sagging still water bending moment

γ_W partial safety factor for the sagging vertical wave bending moment covering environmental and wave load prediction uncertainties

γ_R partial safety factor for the sagging vertical hull girder bending capacity covering material, geometric and strength prediction uncertainties

Notes

1 The maximum sagging still water bending moment is to be taken from the departure condition with the ship homogeneously loaded at maximum draught and corresponding arrival and any mid-voyage conditions.

2 Strength Assessment (FEM)

2.1 General

2.1.1 Application

2.1.1.1 A strength assessment of the hull structure using finite element analysis is mandatory.

2.1.1.2 The finite element analysis consists of two parts:

(a) cargo tank analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads.

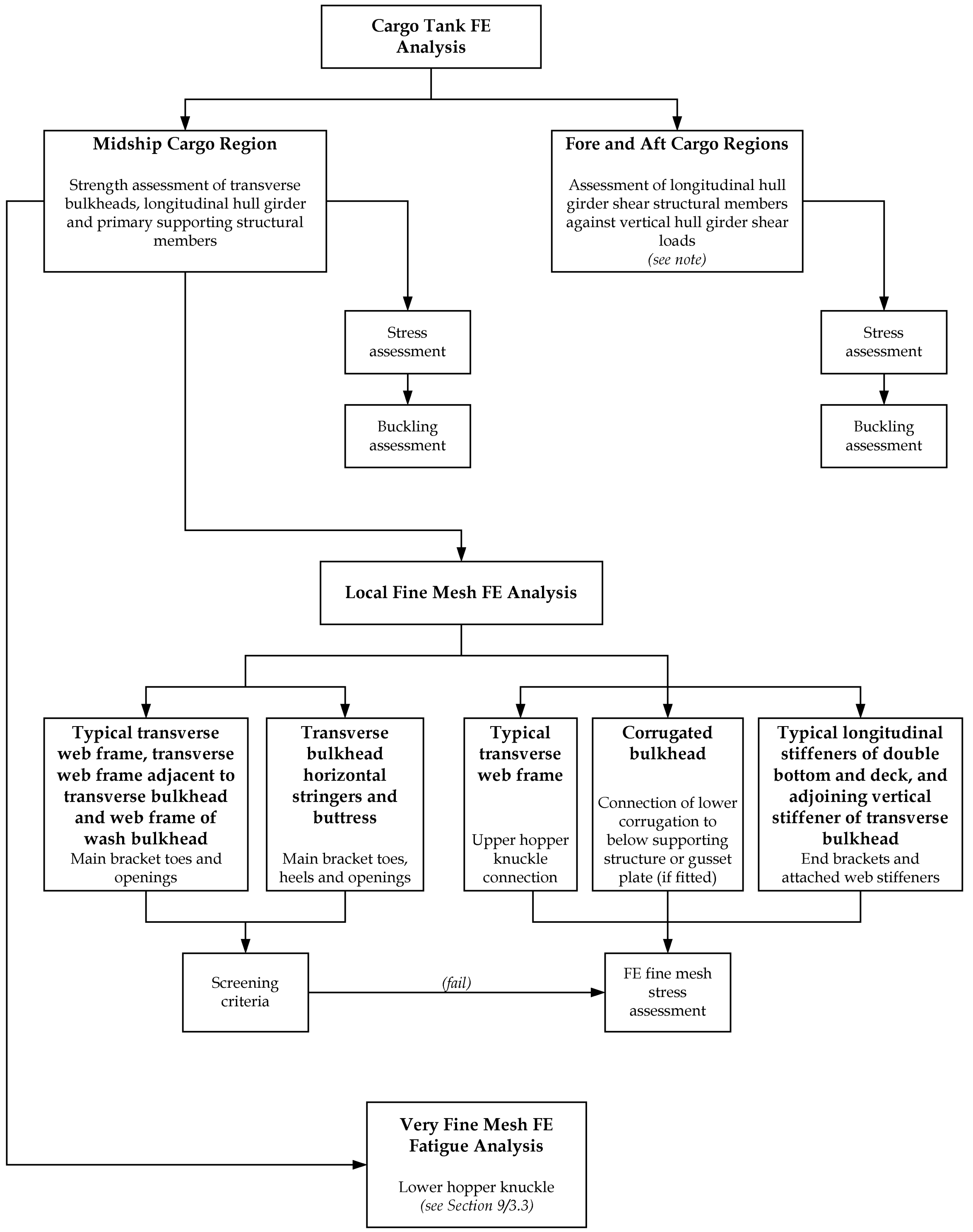
(b) fine mesh analysis to assess detailed stress levels in local structural details.

2.1.1.3 A flow diagram showing the minimum requirement of finite element analysis is shown in **Fig 9.2.1.**

2.1.1.4 The structural assessment is to be carried out in accordance with the requirements given in **Appendix B**. The structural assessment is to verify that the acceptance criteria specified in **2.2.5** and **2.3.5** are complied with.

2.1.1.5 The application of the scantlings verified by the structural assessment within the cargo tank region is to be in accordance with **2.4**.

Figure 9.2.1
Rule Minimum Requirement on Finite Element Analysis



Note

1. The strength assessment of longitudinal hull girder shear structural members, as defined in **2.2.1.1** and **Sec 4/Table 4.1.1**, against hull girder vertical shear loads in way of transverse bulkheads may be based on the midship cargo tank finite element model with modification of plate and stiffener properties where appropriate, see **Appendix B/1.1.1** and **Appendix B/2.2.1**

2.1.2 Submission of results

2.1.2.1 A detailed report of the structural analysis is to be submitted to demonstrate compliance with the specified structural design criteria. This report shall include the following information:

(a) list of plans used including dates and versions
(b) detailed description of structural modelling including all modelling assumptions and any deviations in geometry and arrangement of structure compared with plans
(c) plots to demonstrate correct structural modelling and assigned properties
(d) details of material properties, plate thickness, beam properties used in the model
(e) details of boundary conditions
(f) details of all loading conditions reviewed with calculated hull girder shear force and bending moment distributions
(g) details of applied loads and confirmation that individual and total applied loads are correct
(h) plots and results that demonstrate the correct behaviour of the structural model under the applied loads
(i) summaries and plots of global and local deflections
(j) summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member
(k) plate and stiffened panel buckling analysis and results
(l) tabulated results showing compliance, or otherwise, with the design criteria
(m) proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria.

2.1.3 Computer programs

2.1.3.1 In general, any finite element computation program recognised by the Classification Society may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

2.1.3.2 The computer program used for the assessment of panel buckling capability is to take account of the combined interaction of bi-axial compressive stresses, shear stress and lateral pressure loads, as required by **Sec 10/4.**

2.1.3.3 A computer program that has been demonstrated to produce reliable results to the satisfaction of the Classification Society is regarded as a recognised program. Where the computer programs employed are not supplied or recognised by the Classification Society, full particulars of the computer program, including calculation output, are to be submitted for approval. It is recommended that the designers consult the Classification Society on the suitability of the computer programs intended to be used prior to the commencement of any analysis work.

2.2 Cargo Tank Structural Strength Analysis

2.2.1 Objective and scope

2.2.1.1 The analysis is to cover at least the assessment of:

(a) longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in the midship cargo tank region, and
(b) longitudinal hull girder shear structural members in way of transverse bulkheads against hull girder vertical shear loads within the cargo area. These structural members include side shell, inner hull longitudinal bulkheads including upper sloped plate where fitted, hopper, longitudinal bulkheads and double bottom girders as defined in **Sec 4/Table 4.1.1.** The required strengthening in way of transverse bulkheads for hull girder shear loads in the forward, midship or aft cargo region may be based on the maximum hull girder shear force within the region considered. Alternatively assessment may be carried out to determine the strengthening requirement in way of individual transverse bulkhead position. The details are given in **Appendix B/1.1.1**.

2.2.1.2 The required strengthening in way of transverse bulkheads for hull girder shear loads in the forward, midship or aft cargo region may be based on the maximum hull girder shear force within the region considered. Alternatively assessment may be carried out to determine the strengthening requirement in way of individual transverse bulkhead position. The details are given in **Appendix B/1.1.1**

2.2.1.3 The analysis is to verify that the following are within the acceptance criteria under the applied static and dynamic loads:

(a) stress level in the plating of longitudinal hull girder structural members, primary support structural members and transverse bulkheads, face plate of primary support members modelled by plate or rod elements.

(b) buckling capability of plates and stiffened panels.

2.2.2 Structural modelling

2.2.2.1 The modelling scantlings of the cargo tank finite element model are to be based on net scantlings as described in **Sec 6/3.3.6.1** and **Appendix B/2.2.1.5.**

2.2.2.2 The length of the cargo tank finite element model is to cover three cargo tank lengths. Where the tanks in the midship cargo region are of different lengths, the middle tank of the finite element model is to represent the cargo tank of the greatest length. All main longitudinal and transverse structural elements are to be represented in the finite element model. These include inner and outer shell, double bottom floor and girder system, transverse and vertical web frames, stringers, transverse and longitudinal bulkhead structures. All plating and stiffeners, including web stiffeners, on these structural elements are to be modelled.

2.2.2.3 The mesh of the finite element model is to follow the stiffening system of the structure as far as practical, and is to represent the actual plate panels between stiffeners.

2.2.2.4 The structure modelling is to be in accordance with the requirements given in **Appendix B/2.2.**

2.2.3 Loads and loading conditions

2.2.3.1 The combinations of the ship static and dynamic loads which are likely to impose the most onerous load regimes on the hull structure are to be investigated in the structural analysis.

2.2.3.2 The standard load cases to be used in the structural analysis are given in **Appendix B/2.3.1.** These load cases cover seagoing conditions (design load combination S+D) and harbour/tank testing conditions (design load combination S).

2.2.3.3 Where the loading conditions specified by the designer are not covered by the standard load cases then these additional loading conditions are to be examined, see also **Appendix B/2.3.1.**

2.2.4 Load applications and boundary conditions

2.2.4.1 All simultaneously acting hull girder and local loads are to be applied to the model. The application of local and hull girder loads to the finite element model is to be in accordance with the requirement given in **Appendix B/2.4** and **B/2.5.**

2.2.4.2 The boundary conditions to be applied are given in **Appendix B/2.6.**

2.2.5 Acceptance criteria

2.2.5.1 Verification of results against the acceptance criteria is to be carried out in accordance with **Appendix B/2.7.**

2.2.5.2 Verification of results against the acceptance criteria is to be carried out for all structural members within the longitudinal extent of the middle tanks of the three tank FE model, and the regions forward and aft of the middle tanks up to the extent of the transverse bulkhead stringer and buttress structure. For the assessment of shear strength in way of transverse bulkheads against hull girder shear loads, stress level and buckling capability of inner hull longitudinal bulkheads including upper sloped plate where fitted, side shell, longitudinal bulkheads, hopper and bottom longitudinal girders are to be verified against the acceptance criteria. See also **Appendix B/2.7.1.**

2.2.5.3 The structural analysis is to demonstrate that the permissible von Mises stress criteria and utilisation factor against buckling for plate and stiffened panels specified in **Tables 9.2.1** and **9.2.2** are not exceeded.

2.2.5.4 Capacity models used for the assessment of local buckling capability of plate and stiffened panels are to be based on deduction of full corrosion addition thickness from the plate and stiffeners, as described in **Sec 6/3.3.6.2** and **Appendix B/2.7.3.**

2.2.5.5 Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible stresses and buckling utilisation factors given in **Tables 9.2.1** and **9.2.2** are to be reduced by 10 % for the corrugation and below supporting structure within the extent defined as follows:

(a) Full height of the corrugation

(b) Supporting structure for a transverse corrugated bulkhead - longitudinally within half a web frame space forward and aft of the bulkhead

(c) Supporting structure for a longitudinal corrugated bulkhead - transversely within three longitudinal stiffener spacings from each side of the bulkhead.

Table 9.2.1
Maximum Permissible Stresses

Structural component	Yield utilisation factor
Internal structure in tanks	
Plating of all non-tight structural members including transverse web frame structure, wash bulkheads, internal web, horizontal stringers, floors and girders. Face plate of primary support members modelled using plate or rod elements	$\lambda_y \leq 1.0$ (load combination S + D) $\lambda_y \leq 0.8$ (load combination S)
Structure on tank boundaries	
Plating of deck, sides, inner sides, hopper plate, bilge plate, plane and corrugated cargo tank longitudinal bulkheads. Tight floors, girders and webs	$\lambda_y \leq 0.9$ (load combination S + D) $\lambda_y \leq 0.72$ (load combination S)
Plating of inner bottom, bottom, plane transverse bulkheads and corrugated bulkheads.	$\lambda_y \leq 0.8$ (load combination S + D) $\lambda_y \leq 0.64$ (load combination S)

Where:

λ_y yield utilisation factor

$= \dfrac{\sigma_{vm}}{\sigma_{yd}}$ for plate elements in general

$= \dfrac{\sigma_{rod}}{\sigma_{yd}}$ for rod elements in general

σ_{vm} von Mises stress calculated based on membrane stresses at element's centroid, in N/mm^2

σ_{rod} axial stress in rod element, in N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2, but not to be taken as greater than 315 N/mm^2 for load combination S+D in areas of stress concentration[(2)]

Note

1. Structural items given in the table are for guidance only. Stresses for all parts of the FE model specified in **2.2.5.2** are to be verified against the permissible stress criteria. See also **Appendix B/2.7.1**
2. Areas of stress concentration are corners of openings, knuckle joints, toes and heels of primary supporting structural members and stiffeners
3. Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible stresses are to be reduced by 10 % in accordance with **2.2.5.5.**
4. The yield utilisation factor for plane and corrugated longitudinal bulkheads between cargo tanks may be taken as for non-tight structural members for FE load cases where either both sides of the bulkhead are empty or both sides are loaded. The water-tight bottom girder under the longitudinal bulkhead is to be treated as a tight structural member.

Table 9.2.2
Maximum Permissible Utilisation Factor Against Buckling

Structural component	Buckling utilisation factor
Plate and stiffened panels[(3)]	$\eta \leq 1.0$ (load combination S + D) $\eta \leq 0.8$ (load combination S)
Web plate in way of openings	$\eta \leq 1.0$ (load combination S + D) $\eta \leq 0.8$ (load combination S)
Pillar buckling of cross tie structure	$\eta \leq 0.75$ (load combination S + D) $\eta \leq 0.65$ (load combination S)
Corrugated bulkheads - flange buckling - column buckling	$\eta \leq 0.9$ (load combination S + D) $\eta \leq 0.72$ (load combination S)

Where:
η utilisation factor against buckling calculated in accordance with **Appendix D/5** and **Appendix B/2.7.3**. Also see **Sec 10/3.4.1** for web plate in way of openings and **Sec 10/3.5.1** for cross tie structure

Note
1. Buckling capability of curved panels (e.g. bilge plate), face plate and tripping bracket of primary supporting members are not assessed based on finite element stress result
2. Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible buckling utilisation factors are to be reduced by 10 % in accordance with **2.2.5.5**
3. Permissible buckling utilisation factors specified in this table are applicable for the reference advanced buckling method given in **Appendix D/1.1.2**. If alternative buckling procedures are used the permissible utilisation factors are to be assessed and if required adjusted to meet acceptance criteria for equivalence specified in **Appendix D/1.1.2**.

2.3 Local Fine Mesh Structural Strength Analysis

2.3.1 Objective and scope

2.3.1.1 For tankers of conventional arrangements, as a minimum requirement, the following areas in the midship cargo region are to be investigated:
(a) main bracket toes and openings at critical locations and upper hopper knuckle joint of a typical transverse web frame located in the midship tank. Where a wash bulkhead is fitted, main bracket toes and openings at critical locations of transverse and vertical webs
(b) main bracket toes and openings at critical locations on a typical transverse web frame adjacent to a transverse bulkhead in way of the transverse bulkhead horizontal stringers
(c) main bracket toes, heels and openings at critical locations of horizontal stringers, connection of transverse bulkhead to double bottom girder or buttress of a typical transverse bulkhead
(d) connections of transverse and longitudinal corrugated bulkheads to bottom stool or inner bottom and double bottom supporting structure if a lower stool is not fitted. If a gusset plate is fitted the connection between the corrugation and the upper corners of the gusset are to be assessed
(e) end brackets and attached web stiffeners of typical longitudinal stiffeners of double bottom and deck, and adjoining vertical stiffener of transverse bulkhead.

2.3.1.2 The selection of critical locations on the structural members described in **2.3.1.1** to perform fine mesh analysis is to be in accordance with **Appendix B/3.1.**

2.3.1.3 Where the stress level in areas of stress concentration on structural members not specified in **2.3.1.1** exceeds the acceptance criteria of the cargo tank analysis, a fine mesh analysis is to be carried out to demonstrate satisfactory scantlings.

2.3.1.4 Where the geometry can not be adequately represented in the cargo tank finite element model, a fine mesh analysis may be used to demonstrate satisfactory scantlings. In such cases the average stress within an area equivalent to that specified in the cargo tank analysis (typically s by s) is to comply with the requirement given in **Table 9.2.1.** See also Note 1 of **Table 9.2.3.**

2.3.2 Structural modelling

2.3.2.1 The fine mesh structural models are to be in accordance with the requirements given in **Appendix B/3.2.**

2.3.2.2 The fine mesh analysis may be carried out by means of a separate local finite element model with fine mesh zones, in conjunction with the boundary conditions obtained from the cargo tank model, or by incorporating fine mesh zones into the cargo tank model.

2.3.2.3 The extent of the local finite element models is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads. Detailed requirements on the extension of local finite element models are given in **Appendix B/3.2.**

2.3.2.4 The fine mesh zone is to represent the localised area of high stress. The finite element mesh size within the fine mesh zones is to be not greater than 50 mm × 50 mm. The extent of the fine mesh zone is to be in accordance with **Appendix B/3.2.**

2.3.2.5 The fine mesh models are to be based on the net scantlings in accordance with **Sec 6/3.3.6.3** and **Appendix B/3.2.**

2.3.3 Loads and loading conditions

2.3.3.1 Fine mesh detailed stress analysis is to be carried out for the standard load cases, and any other specifically specified load cases, required by **2.2.3.**

2.3.4 Load applications and boundary conditions

2.3.4.1 The application of loads and boundary conditions to the finite element model is to be in accordance with the requirements given in **Appendix B/3.4.**

2.3.5 Acceptance criteria

2.3.5.1 Verification of stress results against the acceptance criteria is to be carried out in accordance with **Appendix B/3.5.**

2.3.5.2 The structural assessment is to demonstrate that the von Mises stresses obtained from the fine mesh finite element analysis do not exceed the maximum permissible stress criteria specified in **Table 9.2.3.**

Table 9.2.3
Maximum Permissible Membrane Stresses for Fine Mesh Analysis

Element stress	Yield utilisation factor
Element not adjacent to weld	$\lambda_y \le 1.7$ (load combination S + D) $\lambda_y \le 1.36$ (load combination S)
Element adjacent to weld	$\lambda_y \le 1.5$ (load combination S + D) $\lambda_y \le 1.2$ (load combination S)

Where:

λ_y yield utilisation factor

$= \dfrac{k\,\sigma_{vm}}{235}$ for plate element

$= \dfrac{k\,\sigma_{rod}}{235}$ for rod or beam element

σ_{vm} von Mises stress calculated based on membrane stress at element's centroid, in N/mm^2

σ_{rod} axial stress in rod element, in N/mm^2

k higher strength steel factor, as defined in **Sec 6/1.1.4** but not to be taken as less than 0.78 for load combination S+D

Note

1. Where the von Mises stress of the elements in the cargo tank FE model in way of the area under investigation by fine mesh exceeds its permissible value specified in **Table 9.2.1**, average von Mises stress, obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the cargo tank finite element model is to be less than the permissible value specified in **Table 9.2.1**
2. The maximum permissible stresses are based on the mesh size of 50 mm × 50 mm. Where a smaller mesh size is used, an average von Mises stress calculated in accordance with **Appendix B/3.5.1** over an area equal to the specified mesh size may be used to compare with the permissible stresses.
3. Average von Mises stress is to be calculated based on weighted average against element areas:

$$\sigma_{vm-av} = \frac{\sum_{1}^{n} A_i \sigma_{vm-i}}{\sum_{1}^{n} A_i}$$

where

σ_{vm-av} is the average von Mises stress

σ_{vm-i} is the von Mises stress of the i^{th} plate element within the area considered

A_i is the area of the i^{th} plate element within the area considered

n is the number of elements within the area considered

4. Stress averaging is not to be carried across structural discontinuities and abutting structure
5. Where a lower stool is not fitted to a transverse or longitudinal corrugated bulkhead, the maximum permissible stresses are to be reduced by 10 % for the areas under investigation by fine mesh analysis.

2.4 Application of Scantlings in Cargo Tank Region

2.4.1 General

2.4.1.1 The application of the scantlings that comply with the requirements of the finite element strength assessment, to the structure within the cargo tank region, is to be in accordance with the requirements given in this sub-section.

2.4.1.2 The application given in this sub-section assumes that the same material yield strength of the structure is maintained throughout the cargo tank region. Where steel having a different yield strength is applied, the required scantlings are to be assessed.

2.4.1.3 The scaling procedure given in this sub-section is based on scantlings that satisfied the requirements given in **Sec 9/2** and **Appendix B.**

2.4.1.4 The net thickness and sectional properties for plating and local support members described in this sub-section are to be based on deduction of full corrosion addition, as specified in **Sec 6/Table 6.3.2**, from the gross scantlings. The gross thickness of plating, web and face plate of local support members are to be obtained by adding the full corrosion addition to the net thickness.

2.4.2 Application of scantlings to deck

2.4.2.1 The scantlings of deck plating and deck longitudinal stiffeners are to be maintained longitudinally within $0.4L$ amidships. The scantlings of deck plating and deck longitudinal stiffeners at a given transverse location within $0.4L$ amidships are not to be taken as less than the maximum of that required for the corresponding transverse location along the length of the middle tanks of the cargo tank finite element model required by **Appendix B/1.1.1.5.**

2.4.2.2 Outside $0.4L$ amidships, the scantlings of the deck plating and deck longitudinal stiffeners may be tapered to that required by **Sec 8** at the ends of the cargo tank region.

2.4.3 Application of scantlings to inner bottom

2.4.3.1 The thickness of inner bottom plating may vary along the length and breadth of a tank.

2.4.3.2 The scantlings of the inner bottom plating and longitudinal stiffeners of midship cargo tanks are not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by **Appendix B/1.1.1.5**. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-mos tcargo tanks.

2.4.3.3 For the fore-most and aft-most cargo tanks, the scantlings of the inner bottom longitudinal stiffeners are not to be less than the scantling requirements for the midship cargo tanks provided that the spacing of primary support members are not reduced in the forward and/or aft cargo tank. The minimum net thickness of the inner bottom plate, $t_{ib\text{-}net}$, is given by:

$$t_{ib-net} = t_{ib-net-mid}\left(\frac{l_{bdg}}{l_{bdg-mid}}\right)^{0.25} \frac{s_{ib}}{s_{ib-mid}} \quad \text{mm}$$

where:

$t_{ib\text{-}net\text{-}mid}$ required net thickness of the inner bottom plating for the corresponding location in the midship tank, in mm

l_{bdg} effective bending span, of floor at location under consideration, in accordance with **Fig 4.2.7**, in m

$l_{bdg\text{-}mid}$ effective bending span, of floor at corresponding location in midship tank, defined in accordance with **Fig 4.2.7**, in m

s_{ib} spacing between longitudinal stiffeners at location under consideration, in mm

$s_{ib\text{-}mid}$ spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.4 Application of scantlings to bottom

2.4.4.1 The scantlings of bottom longitudinal stiffeners are to be maintained longitudinally within $0.4L$ amidships. The scantlings of the bottom longitudinal stiffener at a given transverse location within $0.4L$ amidships are not to be less than the maximum of that required for the corresponding transverse location along the length of the middle tanks of the cargo tank finite element model required by **Appendix B/1.1.1.5.**

2.4.4.2 Outside $0.4L$ amidships, the scantlings of the bottom longitudinal stiffeners may be tapered to that required by **Sec 8** at the ends of the cargo region.

2.4.4.3 The thickness of the bottom plating may vary along the length and breadth of a tank. The bottom plate thicknesses of midship tanks are not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by **Appendix**

B/1.1.1.5. These thicknesses are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks.

2.4.4.4 For the fore-most and aft-most cargo tanks, the required minimum net thickness of the bottom plating, $t_{btm-net}$, is to be obtained as follows:

$$t_{btm-net} = t_{btm-net-mid}\left(\frac{l_{bdg}}{l_{bdg-mid}}\right)^{0.25}\frac{s_{btm}}{s_{btm-mid}} \quad \text{mm}$$

where:

$t_{btm-net-mid}$ required net thickness of the bottom plating for the corresponding location in the midship tank, in mm

l_{bdg} effective bending span, of floor at location under consideration, in accordance with **Fig 4.2.7**, in m

$l_{bdg-mid}$ effective bending span, of floor at corresponding location in midship tank, defined in accordance with **Fig 4.2.7**, in m

s_{btm} spacing between longitudinal stiffeners at location under consideration, in mm

$s_{btm-mid}$ spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.5 Application of scantlings to side shell, longitudinal bulkheads and inner hull longitudinal bulkheads

2.4.5.1 The scantlings of plating and longitudinal stiffeners of side shell, longitudinal bulkheads and inner longitudinal bulkheads within 0.15 D from the deck are to be maintained longitudinally within 0.4 L amidships. The scantlings of plating and longitudinal stiffener at a given height are not to be less than the maximum of that required for the corresponding vertical location along the length of the middle tanks of the cargo tank finite element model required by **Appendix B/1.1.1.5**. Outside 0.4 L amidships, the scantlings of the plating and stiffeners within 0.15 D from the deck may be tapered to that required by **Sec 8** at the ends of the cargo tank region.

2.4.5.2 The plate thickness of side shell, longitudinal bulkheads and inner hull longitudinal bulkheads, including hopper plating, outside 0.15 D from the deck may vary along the length and height of a tank. The plate thickness away from the transverse bulkheads is not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by **Appendix B/1.1.1.5**. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks. For the fore-most and aft-most cargo tanks, the minimum net thickness of the side shell, longitudinal bulkheads or inner hull longitudinal bulkheads (including hopper plating) plating outside 0.15 D from the deck is given by:

$$t_{net} = t_{net-mid}\frac{s}{s_{mid}} \quad \text{mm}$$

Where:

$t_{net-mid}$ required net thickness for corresponding location in the midship tank, in mm

s spacing between longitudinal stiffeners at location under consideration, in mm

s_{mid} spacing between longitudinal stiffeners at corresponding location in midship tank, in mm

2.4.5.3 The plate thickness of side shell, longitudinal bulkheads and inner hull longitudinal bulkheads, including hopper plating, in way of transverse bulkheads required for strengthening against hull girder shear loads is not to be less than that required by **Appendix B/1.1.1.6, B/1.1.1.7** and **B/1.1.1.8**. Within 0.15 D from the deck, the plate thicknesses in way of transverse bulkheads are not to be taken as less than that required by **2.4.5.1.** Outside 0.15 D from the deck, the plate thicknesses in way of transverse bulkheads are not to be taken as less than that required by **2.4.5.2.**

2.4.5.4 The scantlings of longitudinal stiffeners of side shell, longitudinal bulkheads, inner longitudinal bulkheads and hopper plate at a given height, outside 0.15 D from the deck, are not to be less than that required for the corresponding vertical location of the middle tanks of the cargo tank finite element model as required by **Appendix B/1.1.1.5**. These scantlings are to be maintained for all tanks within the cargo region.

2.4.6 Application of scantlings to transverse bulkheads

2.4.6.1 The scantlings of transverse bulkhead plating, stiffeners and horizontal stringers may vary along the height and breadth of the bulkhead. The scantlings at a given location are not to be less than the maximum required at the corresponding location of both middle tank end transverse bulkheads of the cargo tank finite element model as required by **Appendix B/1.1.1.5.**

2.4.7 Application of scantlings to primary structural support members

2.4.7.1 The web thickness of primary structural support members may vary along the length, breadth and height of a tank. The scantlings of the primary structural support members are not to be less than that required for the corresponding location of the middle tanks of the cargo tank finite element model required by **Appendix B/1.1.1.5**. These scantlings are to be maintained for all tanks within the cargo region, other than the fore-most and aft-most cargo tanks.

2.4.7.2 Scantling requirements for primary support members in the fore-most and aft-most cargo tanks are to be determined by scaling the scantlings of the corresponding structural members in the midship tanks in accordance with **Sec 8/2.6.9.**

2.4.8 Structural details and openings

2.4.8.1 Arrangement and scantlings of openings and structural details of primary structural members, complying with the requirements of **Appendix B/3**, are to be applied to the corresponding structural members in all tanks within the cargo tank region.

3 Fatigue Strength

3.1 Fatigue Evaluation

3.1.1 General

3.1.1.1 This Sub-Section, together with **Appendix C**, gives the minimum Rule requirements for design against fatigue failure for the structural details stipulated in these Rules. Structural details at other locations that are considered to be critical may require assessment using a procedure consistent with that contained in these Rules.

3.1.1.2 The fatigue criteria, applicable to a broad range of structural details and arrangements, are to be used for the assessment of fatigue strength utilising numerical techniques.

3.1.1.3 The fatigue analysis is to be carried out using either a '*nominal stress approach*' or a '*hot spot stress approach*' depending on the structural details, as specified in **3.4.** The procedure is illustrated in **Fig 9.3.1.**

3.1.1.4 In a *nominal stress approach,* stresses in a structural component are calculated by using either analytical methods (e.g. a beam model) or using numerical methods (e.g. a coarse finite elementmesh), based on the applied loads and the structural properties of the component.

3.1.1.5 In a *hot spot stress approach,* local stresses at a critical location (hotspot) where fatigue cracks may initiate are evaluated by numerical methods (e.g. a fine mesh finite element analysis). The analysis takes into account the influence of structural discontinuities due to the geometry of the connection but excludes the effects of welds.

3.2 Fatigue Criteria

3.2.1 Corrosion model

3.2.1.1 Net thicknesses in accordance with **Sec 6/3.3.7** are to be used in the fatigue assessment.

3.2.2 Loads

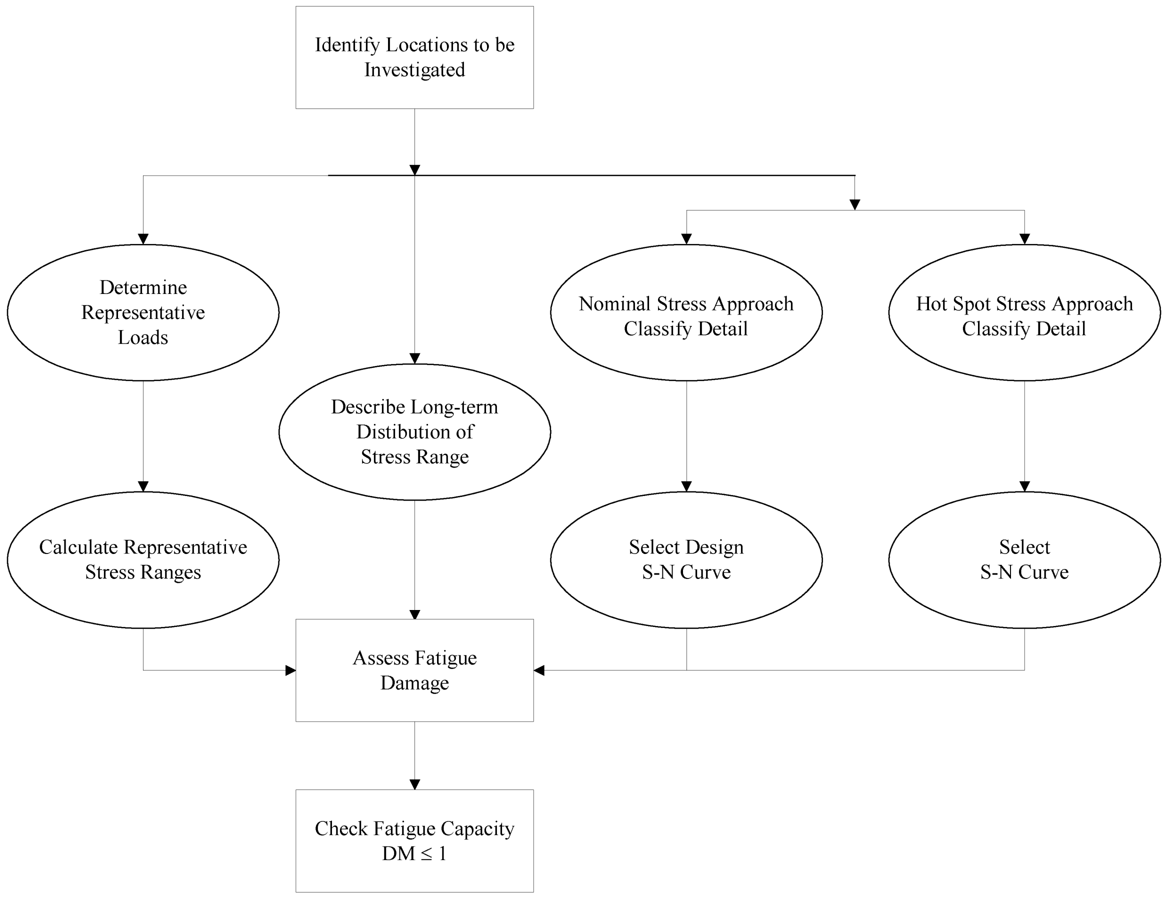
3.2.2.1 The loads specified in **Sec 7/3**, which are based on the North Atlantic wave environment, are to be used for the fatigue assessment. Other secondary cyclic loading, such as slamming, low cycle, or vibration induced fatigue, which may result in significant levels of stress range over the expected lifetime of the vessel, although not within the scope of these Rules, may need to be specially considered.

3.2.2.2 These Rules assume a 10^{-4} probability level of exceedance for the purposes of load application and fatigue strength assessment.

3.2.3 Acceptance criteria

3.2.3.1 The criteria stated in this sub-section and *Appendix C* are presented as a comparison of fatigue strength of the structure (capacity), and fatigue inducing loads (demands), in the form of a fatigue damage parameter, *DM*, see **Appendix C/1.4.1.1**. The calculated fatigue damage, *DM*, is to be less than or equal to 1 for the design life of the ship, which is not to be taken as less than 25 years.

Fig 9.3.1
Schematic of Fatigue Assessment Process
(For Each Location or Structural Detail)



3.3 Locations to Apply

3.3.1 Longitudinal structure

3.3.1.1 A fatigue strength assessment is to be carried out and submitted for the end connections of longitudinal stiffeners to transverse bulkheads, including wash bulkheads and web frames within the cargo tank region, located on the bottom shell, inner bottom, side shell, inner hull longitudinal bulkheads, longitudinal bulkheads and strength deck.

3.3.1.2 A fatigue strength assessment is to be carried out for scallops in way of block joints on the strength deck within the cargo tank region.

3.3.2 Transverse structure

3.3.2.1 A fatigue strength assessment is to be carried out and submitted for the knuckle between inner bottom and hopper plate for at least one transverse frame close to amidships. The total stress range for fatigue assessment is to be determined from a fine mesh finite element analysis.

3.4 Fatigue Assessment Methods

3.4.1 Nominal stress approach

3.4.1.1 The nominal stress approach, as described in **Appendix C/1**, is to be used for the fatigue evaluation of the following items:

(a) longitudinal stiffener end connections to the transverse bulkheads, including wash bulkheads, and web frames on the bottom, inner bottom, side shell, inner hull longitudinal bulkheads, longitudinal bulkheads and strength deck.

(b) scallops in way of block joints on the strength deck as described in **Appendix C/1.6.**

3.4.2 Hot spot stress approach

3.4.2.1 The hot spot stress approach, as described in **Appendix C/2**, is to be used for the fatigue evaluation of the following items:

(a) knuckle between inner bottom and hopper plate.

3.4.3 Alternative direct calculation approach

3.4.3.1 Where it is considered necessary to carry out a fatigue assessment using an alternative direct calculation approach, not applying the loads specified in **Sec 7/3**, it is to be based on the individual Classification Society's procedures. However, in no case are the scantlings to be lower than those which would be required by **3.4.1** and **3.4.2.**

Section 10

Buckling and Ultimate Strength

1 General

1.1 Strength Criteria

1.1.1 Scope

1.1.1.1 This Section contains the strength criteria for buckling and ultimate strength of local support members, primary support members and other structure such as pillars, corrugated bulkheads and brackets. These criteria are to be applied as specified in **Sec 8** for determining the initial structural scantlings and also **Sec 9** for the design verification.

1.1.1.2 All structural elements are to comply with the stiffness and proportions requirements specified in **Sub-Sec 2.**

1.1.1.3 For each structural member the characteristic buckling strength is to be taken as the most unfavourable/critical buckling mode.

1.1.1.4 The strength criteria are to be based on the following assumptions and limitations in respect to buckling and ultimate strength control in design:

(a) the buckling strength of stiffeners is to be greater than the plate panels they support

(b) the primary support members supporting stiffeners are to have sufficient inertia to prevent out of plane buckling of the primary member, see **2.3.2.3**

(c) all stiffeners with their associated effective plate are to have moments of inertia to provide adequate lateral stability, see **2.2.2**

(d) the proportions of local support members and primary support members are to be such that local instability is prevented

(e) tripping of primary support members (e.g. torsional instability) is to be prevented by fitment of tripping brackets or equivalents, see in **2.3.3**

(f) the web plate of primary support members is to be such that elastic buckling of the plate between web stiffeners is prevented

(g) for plates with openings, the buckling strength of the areas surrounding the opening or cut out and any edge reinforcements are adequate, see **3.4.2** and **2.4.3.**

2 Stiffness and Proportions

2.1 Structural Elements

2.1.1 General

2.1.1.1 All structural elements are to comply with the applicable slenderness or proportional ratio requirements in **2.2** to **2.3.**

2.1.1.2 The following requirements are based on net scantlings, see also **Sec 6/3.**

2.1.1.3 For structural idealisation and definitions see **Sec 4/2.**

2.2 Plates and Local Support Members

2.2.1 Proportions of plate panels and local support members

2.2.1.1 The net thickness of plate panels and stiffeners is to satisfy the following criteria:

(a) plate panels

$$t_{net} \geq \frac{s}{C}\sqrt{\frac{\sigma_{yd}}{235}}$$

(b) stiffener web plate

$$t_{w-net} \geq \frac{d_w}{C_w}\sqrt{\frac{\sigma_{yd}}{235}}$$

(c) flange/face plate

$$t_{f-net} \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{\sigma_{yd}}{235}}$$

Where:

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in **Sec 4/2.2.1**

t_{net} net thickness of plate, in mm

d_w depth of stiffener web, in mm, as given in **Table 10.2.1**

t_{w-net} net web thickness, in mm

b_{f-out} breadth of flange outstands, in mm, as given in **Table 10.2.1**

t_{f-net} net flange thickness, in mm

C, C_w, C_f slenderness coefficients, as given in **Table 10.2.1**

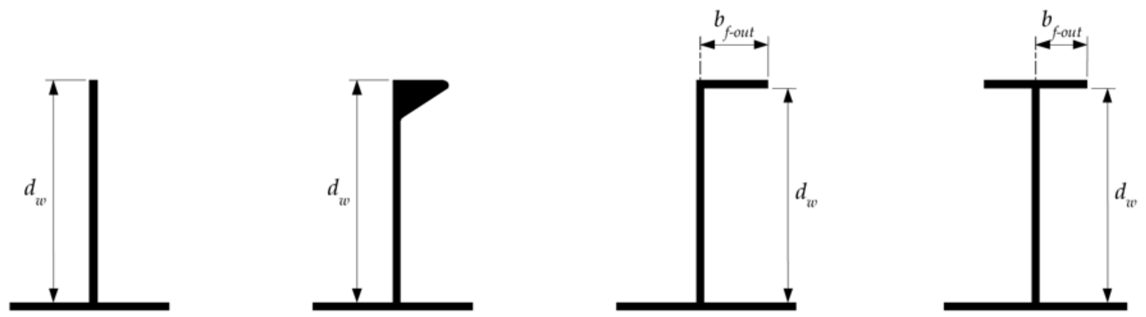
σ_{yd} specified minimum yield stress of the material, in N/mm^2

Table 10.2.1
Slenderness Coefficients

Item		Coefficient
plate panel, C	hull envelope and tank boundaries	100
	other structure	125
stiffener web plate, C_w	angle and T profiles	75
	bulb profiles	41
	flat bars	22
flange/face plate(1), C_f	angle and T profiles	12

Note
1. The total flange breadth, b_f, for angle and T profiles is not to be less than: $b_f = 0.25 d_w$
2. Measurements of breadth and depth are based on gross scantlings

Where:
t_{net} net thickness of plate, in mm
d_w depth of web plate, in mm
$t_{w\text{-}net}$ net web thickness, in mm
$b_{f\text{-}out}$ breadth of flange outstands, in mm
$t_{f\text{-}net}$ net flange thickness, in mm



Flat bars Bulb flats Angles T bars

2.2.2 Stiffness of stiffeners

2.2.2.1 The minimum net moment of inertia about the neutral axis parallel to the attached plate, I_{net}, of each stiffener with effective breadth of plate equalto 80 % of the stiffener spacing s, is given by:

$$I_{net} = C l_{stf}^2 A_{net} \frac{\sigma_{yd}}{235} \quad \text{cm}^4$$

Where:

l_{stf} length of stiffener between effective supports, in m

A_{net} net sectional area of stiffener including attached plate assuming effective breadth of 80 % of stiffener spacing s, in cm^2

s stiffener spacing, in mm, as defined in **Sec 4/2.2.1**

σ_{yd} specified minimum yield stress of the material of the attached plate, in N/mm^2

C slenderness coefficient:
= 1.43 for longitudinals subject to hull girder stresses
= 0.72 for other stiffeners

2.3 Primary Support Members

2.3.1 Proportions of web plate and flange/face plate

2.3.1.1 The net thicknesses of the web plates and face plates of primary support members are to satisfy the following criteria:

(a) web plate

$$t_{w-net} \geq \frac{s_w}{C_w}\sqrt{\frac{\sigma_{yd}}{235}}$$

(b) flange/face plate

$$t_{f-net} \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{\sigma_{yd}}{235}}$$

Where:

s_w plate breadth, in mm, taken as the spacing between the web stiffeners. For web plates with stiffening parallel to the attached plate the spacing may be corrected in accordance with **Appendix D/Fig 5.6.**

t_{w-net} net web thickness, in mm

b_{f-out} breadth of flange outstand, in mm

t_{f-net} net flange thickness, in mm

C_w slenderness coefficient for the web plate
= 100

C_f slenderness coefficient for the flange/face plate
= 12

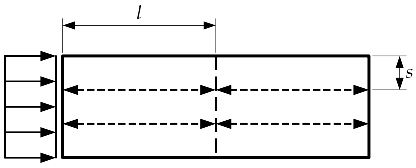
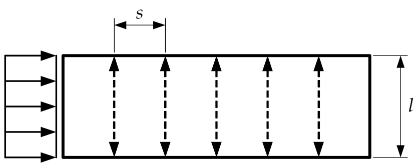
σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.3.2 Stiffness requirements

2.3.2.1 The web and flange net thicknesses of web stiffeners are not to be less than specified in **2.2.1.**

2.3.2.2 The net moment of inertia of each web stiffener, I_{net}, with effective breadth of plate equal to 80 % of stiffener spacing s, is not to be less than as defined in **Table 10.2.2.**

Table 10.2.2
Stiffness Criteria for Web Stiffening

Mode	Inertia requirements, cm^4
(a) web stiffeners parallel to the flanges of the primary support member 	$I_{net} = Cl^2 A_{net} \dfrac{\sigma_{yd}}{235}$
(b) web stiffeners normal to flanges of the primary support member 	$I_{net} = 1.14\text{x}10^{-5} l\ s^2 t_{w-net} \left(2.5\dfrac{1000l}{s} - 2\dfrac{s}{1000l}\right)\dfrac{\sigma_{yd}}{235}$

Where:

C = 1.43 for longitudinal stiffeners in cargo tank region
= 0.72 for other stiffeners

l length of web stiffener, in m.
For web stiffeners welded to local support members (LSM), the length is to be measured between the flanges of the local support members.
For sniped web stiffeners the length is to be measured between the lateral supports e.g. the total distance between the flanges of the primary support member as shown for Mode (b).

A_{net} net section area of web stiffener including attached plate assuming effective breadth of 80 % of stiffener spacing s, in cm^2

s spacing of stiffeners, in mm, as defined in **Sec 4/2.2.1**

$t_{w\text{-}net}$ net web thickness of the primary support member, in mm

σ_{yd} specified minimum yield stress of the material of the web plate of the primary support member, in N/mm^2

2.3.2.3 The net moment of inertia for primary support members, $I_{prm\text{-}net50}$, supporting stiffeners subject to axial compressive stresses, including effective plate width at mid span, is not to be less than:

$$I_{psm-net50} = 300 \frac{l_{bdg}^4}{S^3 s} I_{net} \qquad cm^4$$

Where:

l_{bdg} bending span of primary support member, in m

S distance between primary support members, in m

s spacing of stiffeners, in mm, as defined in **Sec 4/2.2.1**

I_{net} maximum required moment of inertia, as given in **2.2.2.1**, for stiffeners within the central half of the bending span, in cm^4

2.3.3 Spacing between flange supports or tripping brackets

2.3.3.1 The torsional buckling mode of primary support members is to be controlled by flange supports or tripping brackets. The unsupported length of the flange of the primary support member, i.e. the distance between tripping brackets, s_{bkt}, is not to be greater than:

$$s_{bkt} = b_f C \sqrt{\frac{A_{f-net50}}{\left(A_{f-net50} + \frac{A_{w-net50}}{3}\right)}\left(\frac{235}{\sigma_{yd}}\right)}$$ m, but need not be less than $s_{bkt-min}$

Where:

b_f breadth of flange, in mm

C slenderness coefficient:

= 0.022 for symmetrical flanges

= 0.033 for one sided flanges

$A_{f-net50}$ net cross-sectional area of flange, in cm^2

$A_{w-net50}$ net cross-sectional area of the web plate, in cm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

$s_{bkt-min}$ = 3.0 m for primary support members in the cargo tank region, on tank boundaries or on the hull envelope including external decks

= 4.0 m for primary support members in other areas

2.4 Other Structure

2.4.1 Proportions of pillars

2.4.1.1 For I-sections the thickness of the web plate and the flange thickness is to comply with **2.2.1.1.**

2.4.1.2 The thickness of thin walled box sections is to comply with **2.2.1.1(b)**. The radius of circular tube sections is to be less than 50 times the net thickness of the pillar.

2.4.2 Proportions of brackets

2.4.2.1 The net thickness of end brackets, $t_{bkt-net}$, is except as specified in **2.4.2.2** not to be less than:

$$t_{bkt-net} = \frac{d_{bkt}}{C}\sqrt{\frac{\sigma_{yd}}{235}}$$ mm

Where:

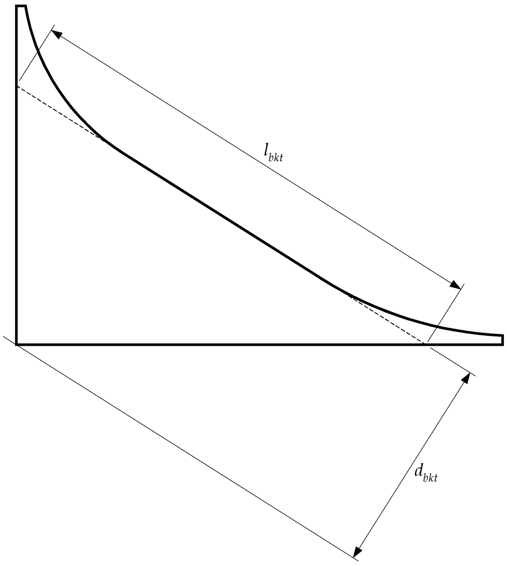
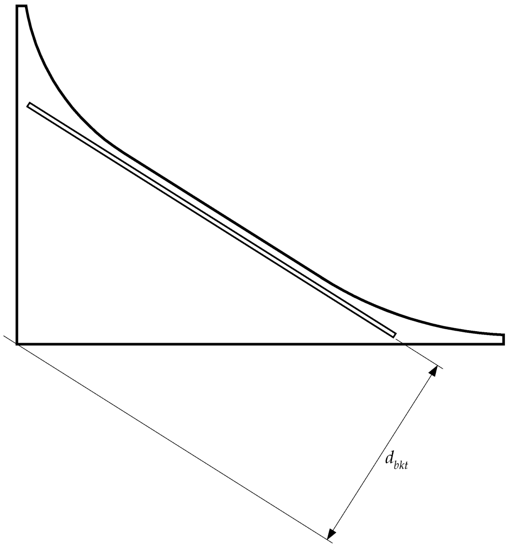
d_{bkt} depth of brackets, in mm. See **Table 10.2.3**

C slenderness coefficient as defined in **Table 10.2.3**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

2.4.2.2 Where it can be demonstrated that the bracket is only subjected to tensile stresses, e.g. in way of internal brackets in a tank surrounded by void space, the requirement in 2.4.2.1 need not be complied with.

Table 10.2.3
Buckling Coefficient, *C*, for Proportions of Brackets

Mode	C
(a) Brackets without edge stiffener 	$C = 20\left(\frac{d_{bkt}}{l_{bkt}}\right) + 16$ Where: $0.25 \le \frac{d_{bkt}}{l_{bkt}} \le 1.0$
(b) Brackets with edge stiffener 	C = 70
Where: l_{bkt} effective length of edge of bracket, in mm	

2.4.2.3 Tripping brackets on primary support members are to be stiffened by a flange or edge stiffener if the effective length of the edge, l_{bkt}, is greater than:

$$l_{bkt} = 75t_{bkt-net} \quad \text{mm}$$

Where:

$t_{bkt\text{-}net}$ bracket thickness, in mm

2.4.3 Requirements to edge reinforcements in way of openings and bracket edges

2.4.3.1 The depth of stiffener web, d_w, of edge stiffeners in way of openings and bracket edges is not to be less than:

$$d_w = Cl\sqrt{\frac{\sigma_{yd}}{235}}$$ mm, or 50 mm, whichever is greater

Where:

l length of edge stiffener, in m

σ_{yd} specified minimum yield stress of the material, in N/mm^2

C slenderness coefficient

75 for end brackets

50 for tripping brackets

50 for edge reinforcements in way of openings

2.4.3.2 The net thickness of the web plate and flange of the edge stiffener is not to be less than that required in **2.2.1.**

3 Prescriptive Buckling Requirements

3.1 General

3.1.1 Scope

3.1.1.1 This Sub-Section contains the methods for determination of the buckling capacity, definitions of buckling utilisation factors and other measures necessary to control buckling of plate panels, stiffeners and primary support members.

3.1.1.2 The buckling utilisation factor, η,istosatisfythefollowingcriteria:

$$\eta \le \eta_{allow}$$

Where:

η_{allow} allowable buckling utilisation factor as defined in **Sec 8** and **Sec 9**

η buckling utilisation factor, as defined in **3.2.1.1, 3.3.2.2, 3.3.3.1, 3.4.1.1** and **3.5.1.1**

3.1.1.3 For structural idealisation and definitions see also **Sec 4/2**. The thickness and section properties of plates and stiffeners are to be taken as specified by the appropriate rule requirements.

3.2 Buckling of Plates

3.2.1 Uni-axial buckling of plates

3.2.1.1 The buckling utilisation factor, η, for uni-axial stress is to be taken as:

$$\eta = \frac{\sigma_x}{\sigma_{xcr}}$$ for compressive stresses in x-direction

$$\eta = \frac{\sigma_y}{\sigma_{ycr}}$$ for compressive stresses in y-direction

$$\eta = \frac{\tau}{\tau_{cr}}$$ for shear stress

Where:

σ_x, σ_y actual compressive stresses, in N/mm^2

τ actual shear stress, in N/mm^2

σ_{xcr}, σ_{ycr} critical compressive stress, in N/mm^2, as defined in **3.2.1.3**

τ_{cr} critical shear stress, in N/mm^2, as defined in **3.2.1.3**

3.2.1.2 Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{yd}}{K\sigma_E}}$$

Where:

K buckling factor, see **Table 10.3.1**

σ_E reference stress, in N/mm^2

$$= 0.9\,E\left(\frac{t_{net}}{l_a}\right)^2$$

E modulus of elasticity, 206 000 N/mm^2

t_{net} net thickness of plate panel, in mm

l_a length of the side of the plate panel as defined in **Table 10.3.1**, in mm

σ_{yd} specified minimum yield stress of the material, in N/mm^2

3.2.1.3 The critical stresses, σ_{xcr}, σ_{ycr} or τ_{cr}, of plate panels subject to compression or shear, respectively, is to be taken as:

$$\sigma_{xcr} = C_x \sigma_{yd}$$

$$\sigma_{ycr} = C_y \sigma_{yd}$$

$$\tau_{cr} = C_\tau \frac{\sigma_{yd}}{\sqrt{3}}$$

Where:

C_x, C_y, C_τ reduction factors, as given in **Table 10.3.1**

Table 10.3.1
Buckling Factor and Reduction Factor for Plane Plate Panels

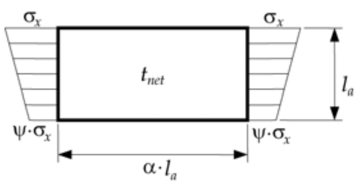
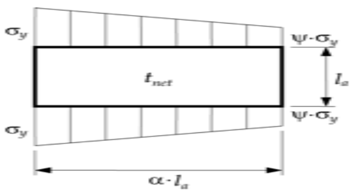
<table>
<tr><th>Case</th><th>Stress ratio Ψ</th><th>Aspect ratio α</th><th>Buckling factor K</th><th>Reduction factor C</th></tr>
<tr><td rowspan="3">1
</td><td>$1 \ge \Psi \ge 0$</td><td rowspan="3">$\alpha > 1$</td><td>$K=\frac{8.4}{\Psi+1.1}$</td><td rowspan="3">$C_x = 1$ for $\lambda \le \lambda_c$
$C_x = c\left(\frac{1}{\lambda}-\frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$
Where: $c=(1.25-0.12\Psi) \le 1.25$
$\lambda_c=\frac{c}{2}\left(1+\sqrt{1-\frac{0.88}{c}}\right)$</td></tr>
<tr><td>$0 > \Psi > -1$</td><td>$K=7.63-\Psi(6.26-10\Psi)$</td></tr>
<tr><td>$\Psi \le -1$</td><td>$K=5.975(1-\Psi)^2$</td></tr>
<tr><td rowspan="5">2
</td><td>$1 \ge \Psi \ge 0$</td><td>$\alpha \ge 1$</td><td>$K=\left(1+\frac{1}{\alpha^2}\right)^2\frac{2.1}{(\Psi+1.1)}$</td><td rowspan="5">$C_y = c\left(\frac{1}{\lambda}-\frac{R+F^2(H-R)}{\lambda^2}\right)$
Where: $c=(1.25-0.12\Psi) \le 1.25$
$R=\lambda(1-\lambda/c)$ for $\lambda < \lambda_c$
$R=0.22$ for $\lambda \ge \lambda_c$
$\lambda_c=0.5c\left(1+\sqrt{1-0.88/c}\right)$
$F=\left(1-\left(\frac{K}{0.91}-1\right)/\lambda_p^2\right)c_1 \ge 0$
$\lambda_p^2=\lambda^2-0.5$ and $1 \le \lambda_p^2 \le 3$
$c_1=1$ for σ_y due to direct loads(3)
$c_1=(1-1/\alpha) \ge 0$ for σ_y due to bending (in general)(2)
$c_1=0$ for σ_y due to bending in extreme load cases (e.g. w/t. bhds.)
$H=\lambda-\frac{2\lambda}{c\left(T+\sqrt{T^2-4}\right)} \ge R$
$T=\lambda+\frac{14}{15\lambda}+\frac{1}{3}$</td></tr>
<tr><td rowspan="2">$0 > \Psi > -1$</td><td>$1 \le \alpha \le 1.5$</td><td>$K=\left[1+\frac{1}{\alpha^2}\right]^2\frac{2.1(1+\Psi)}{1.1}$
$-\frac{\Psi}{\alpha^2}(13.9-10\Psi)$</td></tr>
<tr><td>$\alpha > 1.5$</td><td>$K=\left[1+\frac{1}{\alpha^2}\right]^2\frac{2.1(1+\Psi)}{1.1}$
$-\frac{\Psi}{\alpha^2}(5.87+1.87\alpha^2$
$+\frac{8.6}{\alpha^2}-10\Psi)$</td></tr>
<tr><td rowspan="2">$\Psi \le -1$</td><td>$1 \le \alpha \le \frac{3(1-\Psi)}{4}$</td><td>$K=\left(\frac{1-\Psi}{\alpha}\right)^2 5.975$</td></tr>
<tr><td>$\alpha > \frac{3(1-\Psi)}{4}$</td><td>$K=\left(\frac{1-\Psi}{\alpha}\right)^2 3.9675$
$+0.5375\left(\frac{1-\Psi}{\alpha}\right)^4+1.87$</td></tr>
</table>

Table 10.3.1 (Continued)
Buckling Factor and Reduction Factor for Plane Plate Panels

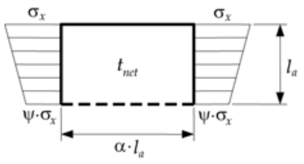
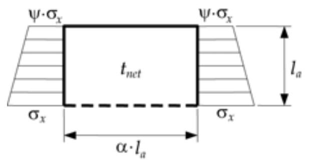
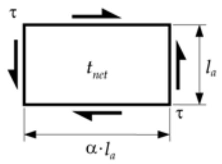
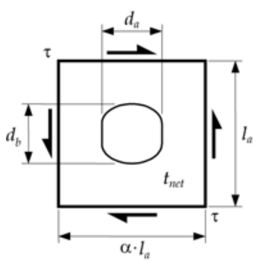
Case	Stress ratio Ψ	Aspect ratio α	Buckling factor K	Reduction factor C
3 	$1 \geq \Psi \geq 0$	$\alpha > 0$	$K = \frac{4(0.425 + 1/\alpha^2)}{3\Psi + 1}$	$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \frac{1}{\lambda^2 + 0.51}$ for $\lambda > 0.7$
	$0 > \Psi > -1$		$K = 4(0.425 + 1/\alpha^2)(1+\Psi) - 5\Psi(1 - 3.42\Psi)$	
4 	$1 \geq \Psi \geq -1$	$\alpha > 0$	$K = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3 - \Psi}{2}$	
5 	-		$K = K_\tau \sqrt{3}$	$C_\tau = 1$ for $\lambda \leq 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
		$\alpha \geq 1$	$K_\tau = \left[5.34 + \frac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \frac{5.34}{\alpha^2}\right]$	
6 	-		$K = K' r$ K' = K according to Case 5 r = opening red. factor $r = \left(1 - \frac{d_a}{\alpha l_a}\right)\left(1 - \frac{d_b}{l_a}\right)$ $\frac{d_a}{a l_a} \leq 0.7$ and $\frac{d_b}{l_a} \leq 0.7$	

Table 10.3.1 (Continued)
Buckling Factor and Reduction Factor for Plane Plate Panels

Where:

Ψ	the ratio between smallest and largest compressive stress as shown for Case 1-4
l_a	length in mm, of the shorter side of the plate panel for Cases 1 and 2
l_a	length in mm, of the side of the plate panel as defined for Cases 3, 4, 5 and 6
α	aspect ratio of the plate panel

Edge boundary conditions:

————	plate edge free
— — — — -	plate edge simply supported

Notes

(1) Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.

(2) c_1 due to bending (in general) corresponds to straight edges (uniform displacement) of a plate panel integrated in a large structure. This value is to be applied for hull girder buckling and buckling of web plate of primary support members in way of openings.

(3) c_1 for direct loads corresponds to a plate panel with edges not restrained from pull-in which may result in non-straight edges

3.3 Buckling of Stiffeners

3.3.1 Critical compressive stress

3.3.1.1 The buckling utilisation factor of stiffeners is to be taken as the maximum of the column and torsional buckling mode as given in **3.3.2** and **3.3.3.**

3.3.2 Column buckling mode

3.3.2.1 Stiffeners are to be verified against the column buckling mode as given in **3.3.2.2** with the allowable buckling utilisation factor, η_{allow}, see **3.1.1.2**. Stiffeners not subjected to lateral pressure and that have a net moment of inertia, I_{net}, complying with **3.3.2.4** have acceptable column buckling strength and need not be verified against **3.3.2.2.**

3.3.2.2 The buckling utilisation factor for column buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x + \sigma_b}{\sigma_{yd}}$$

Where:

σ_x compressive axial stress in the stiffener, in N/mm^2, in way of the midspan of the stiffener. See **Sec 3/5.2.3.1**

σ_b bending stress at the midspan of the stiffener according to **3.3.2.3**, in N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

3.3.2.3 The bending stress, σ_b, in N/mm^2, in the stiffener is equal to:

$$\sigma_b = \frac{M_o + M_1}{1000\, Z_{net}}$$

Where:

Z_{net} net section modulus of stiffener, in cm^3, including effective breadth of plating according to **3.3.4.1**

a) if lateral pressure is applied to the stiffener:

Z_{net} is the section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener.

Z_{net} is the section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener.

b) if no lateral pressure is applied on the stiffener:

Z_{net} is the minimum section modulus among those calculated at flange and attached plate.

M_1 bending moment, in Nmm, due to the lateral load P

$$= \frac{P s l_{stf}^{\;2}}{24} 10^3$$

P lateral load, in kN/m^2

s stiffener spacing as defined in **Sec 4/2.2.1**, in mm

l_{stf} span of stiffener, in m, equal to spacing between primary support members

M_0 bending moment, in Nmm, due to the lateral deformation w of stiffener

$$= F_E \left(\frac{P_z w}{c_f - P_z} \right) \quad \text{where } (c_f - P_z) > 0$$

F_E ideal elastic buckling force of the stiffener, in N

$$= \left(\frac{\pi^2}{l_{stf}^{\ 2}} \right) E I_{net} \, 10^{-2}$$

E modulus of elasticity, 206 000 N/mm^2

I_{net} moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to **3.3.4.1**. I_{net} is to comply with the following requirement:

$$I_{net} \geq \frac{s \, t_{net}^{\ 3}}{12} 10^{-4}$$

t_{net} net thickness of plate flange, to be taken as the mean thickness of the two attached plate panels, in mm

P_z nominal lateral load, in N/mm^2, acting on the stiffener due to membrane stresses, σ_x, σ_y and τ_1, in the attached plate in way of the stiffener midspan:

$$= \frac{t_{net}}{s} \left(\sigma_{xl} \left(\frac{\pi s}{1000 l_{stf}} \right)^2 + 2 \, c_y \, \sigma_y + \sqrt{2} \tau_1 \right)$$

σ_{xl} $= \sigma_x \left(1 + \frac{A_{net}}{s \, t_{net}} \right)$ N/mm^2

τ_1 $= \left[\tau - t_{net} \sqrt{\sigma_{yd} \, E \left(\frac{m_1}{(1000 l_{stf})^2} + \frac{m_2}{s^2} \right)} \right] \geq 0$

with m_1 and m_2 taken equal to

$m_1 = 1.47 \quad m_2 = 0.49$ for $\frac{1000 \, l_{stf}}{s} \geq 2.0$

$m_1 = 1.96 \quad m_2 = 0.37$ for $\frac{1000 \, l_{stf}}{s} < 2.0$

σ_x compressive axial stress in the stiffener, in N/mm^2, in way of the midspan of the stiffener. See **Sec 3/5.2.3.1**

A_{net} net sectional area of the stiffener without attached plating, in mm^2

c_y factor taking into account the membrane stresses in the attached plating acting perpendicular to the stiffener's axis

$= 0.5 \, (1 + \psi)$ for $0 \leq \psi \leq 1$

$= \frac{0.5}{1 - \psi}$ for $\psi < 0$

ψ edge stress ratio for Case 2 according to **Table 10.3.1**

σ_y membrane compressive stress in the attached plating acting perpendicular to the stiffener's axis, in N/m^2

τ shear membrane stress in the attached plating, in N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

w deformation of stiffener, in mm

$= w_0 + w_1$

w_0 assumed imperfection, in mm.

$$= \min\left[\frac{1000\, l_{stf}}{250},\ \frac{s}{250},\ 10\right]$$

For stiffeners sniped at both ends w_0 is not to be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to **3.3.4.1**

w_l deformation of stiffener at midpoint of stiffener span due to lateral load P, in mm. In case of uniformly distributed load the w_l is to be taken as:

$$= \frac{P\, s\, l_{stf}^{\ 4}}{384 \cdot E\, I_{net}} 10^5$$

c_f elastic support provided by the stiffener, in $\mathrm{N/mm^2}$

$$= F_E \frac{\pi^2}{l_{stf}^{\ 2}} (1 + c_p) 10^{-6}$$

c_p

$$= \frac{1}{1 + \frac{0.91}{c_a}\left(\frac{12\, I_{net}\, 10^4}{s\, t_{net}^{\ 3}} - 1\right)}$$

$$c_a = \left[\frac{1000 l_{stf}}{2s} + \frac{2s}{1000 l_{stf}}\right]^2 \quad \text{for} \quad l_{stf} \geq \frac{2s}{1000}$$

$$c_a = \left[1 + \left(\frac{1000 l_{stf}}{2s}\right)^2\right]^2 \quad \text{for} \quad l_{stf} < \frac{2s}{1000}$$

3.3.2.4 Stiffeners not subjected to lateral pressure are considered as complying with the requirements of **3.3.2.2** if their net moments of inertia, in $\mathrm{cm^4}$, satisfy the following requirement:

$$I_{net} \geq 100 \frac{P_z\, l_{stf}^{\ 2}}{\pi^2} \left[\frac{w_o \left(e_f - 0.5 t_{f-net}\right)}{\eta_{allow} \sigma_{yd} - \sigma_x} + \frac{l_{stf}^{\ 2}}{E \pi^2} 10^6\right]$$

Where:

e_f distance from connection to plate (C as shown in **Fig 10.3.1**) to centre of flange, in mm

$= (d_w - 0.5 t_{f-net})$ for bulb flats

$= (d_w + 0.5 t_{f-net})$ for angles and T bars

d_w depth of web plate, in mm, as shown in **Fig 10.3.1**

t_{f-net} net flange thickness, in mm

η_{allow} allowable buckling utilisation factor as defined in **Sec 8** and **Sec 9**

Note

Other parameters are as defined in **3.3.2.3**

3.3.3 Torsional buckling mode

3.3.3.1 The torsional buckling mode is to be verified against the allowable buckling utilisation factor, η_{allow}, see **3.1.1.2**. The buckling utilisation factor for torsional buckling of stiffeners is to betaken as:

$$\eta = \frac{\sigma_x}{C_T\, \sigma_{yd}}$$

Where:

σ_x compressive axial stress in the stiffener, in N/mm^2, in way of the midspan of the stiffener. See **Sec 3/5.2.3.1**

C_T torsional buckling coefficient

$= 1.0$ for $\lambda_T \le 0.2$

$= \dfrac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}}$ for $\lambda_T > 0.2$

$\Phi = 0.5(1 + 0.21(\lambda_T - 0.2) + \lambda_T^2)$

λ_T reference degree of slenderness for torsional buckling

$= \sqrt{\dfrac{\sigma_{yd}}{\sigma_{ET}}}$

σ_{ET} reference stress for torsional buckling, in N/mm^2

$= \dfrac{E}{I_{p-net}}\left(\dfrac{\varepsilon \pi^2 I_{\omega-net} 10^{-4}}{l_t^2} + 0.385 I_{T-net}\right)$

σ_{yd} specified minimum yield stress of the material, in N/mm^2

E modulus of elasticity, 206 000 N/mm^2

I_{P-net} net polar moment of inertia of the stiffener about point C, in cm^4, as shown in **Fig 10.3.1** and **Table 10.3.2**

I_{T-net} net St. Venant's moment of inertia of the stiffener, in cm^4, as shown in **Table 10.3.2**

$I_{\omega-net}$ net sectorial moment of inertia of the stiffener about point C, in cm^6, as shown in **Fig 10.3.1** and **Table 10.3.2**

ε degree of fixation

$$1 + 1000\sqrt{\dfrac{l_t^4}{\dfrac{3}{4}\pi^4 I_{\omega-net}\left(\dfrac{s}{t_{net}^3} + \dfrac{4(e_f - 0.5t_{f-net})}{3t_{w-net}^3}\right)}}$$

l_t torsional buckling length to be taken equal the distance between tripping supports, in m

d_w depth of web plate, in mm

t_{w-net} net web thickness, in mm

b_f flange breadth, in mm

t_{f-net} net flange thickness, in mm

e_f distance from connection to plate (C in **Fig 10.3.1**) to centre of flange, in mm

$= (d_w - 0.5t_{f-net})$ for bulb flats

$= (d_w + 0.5t_{f-net})$ for angles and T bars

A_{w-net} net web area, in mm^2

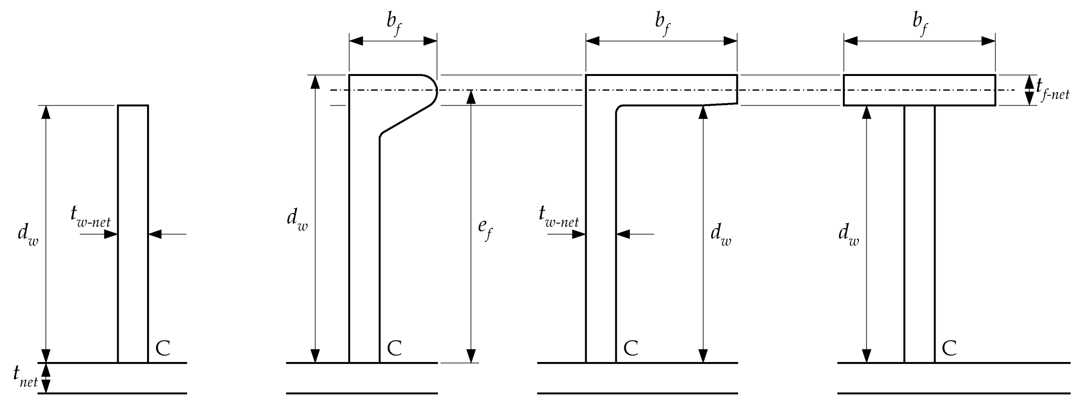
$= (e_f - 0.5t_{f-net})t_{w-net}$

A_{f-net} net flange area, in mm^2

$= b_f t_{f-net}$

s stiffener spacing as defined in **Sec 4/2.2.1**, in mm

Fig 10.3.1
Stiffener cross sections



Note:
1. Measurements of breadth and depth are based on gross scantlings as described in **Sec 4/2.4.1.2.**
2. Characteristic flange data for bulb profiles are given in **Appendix C/Table C.1.2**

Table 10.3.2
Moments of Inertia

Section property	Flat bars	Bulb flats, angles and T bars
I_{P-net}	$\dfrac{d_w^3 t_{w-net}}{3x10^4}$	$\left(\dfrac{A_{w-net}(e_f-0.5t_{f-net})^2}{3}+A_{f-net}e_f^2\right)10^{-4}$
I_{T-net}	$\dfrac{d_w t_{w-net}^3}{3x10^4}\left(1-0.63\dfrac{t_{w-net}}{d_w}\right)$	$\dfrac{(e_f-0.5t_{f-net})t_{w-net}^3}{3x10^4}\left(1-0.63\dfrac{t_{w-net}}{e_f-0.5t_{f-net}}\right)$ + $\dfrac{b_f t_{f-net}^3}{3x10^4}\left(1-0.63\dfrac{t_{f-net}}{b_f}\right)$
$I_{\omega-net}$	$\dfrac{d_w^3 t_{w-net}^3}{36x10^6}$	for bulb flats and angles: $\dfrac{A_{f-net}e_f^2 b_f^2}{12x10^6}\left(\dfrac{A_{f-net}+2.6A_{w-net}}{A_{f-net}+A_{w-net}}\right)$ for T bars: $\dfrac{b_f^3 t_{f-net} e_f^2}{12x10^6}$

3.3.4 Effective breadth of attached plating

3.3.4.1 The effective breadth of attached plating of ordinary stiffeners is to be taken as:
$b_{eff}=\min(C_x s,\ \chi_s s)$

Where:

$$\chi_s=0.0035\left(\frac{1000\,l_{eff}}{s}\right)^3-0.0673\left(\frac{1000\,l_{eff}}{s}\right)^2+0.4422\left(\frac{1000\,l_{eff}}{s}\right)-0.0056\ \le\ 1.0$$

s stiffener spacing as defined in **Sec 4/2.2.1**, in mm

C_x average reduction factor for buckling of the two attached plate panels, according to Case 1 in **Table 10.3.1**

l_{stf} span of stiffener, in m, equal to spacing between primary support members

l_{eff} effective span of stiffeners in m

l_{eff} = l_{stf} if simply supported at both ends

l_{eff} = 0.6 l_{stf} if fixed at both ends

3.4 Primary Support Members

3.4.1 Buckling of web plate of primary support members in way of openings

3.4.1.1 The web plate of primary support members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses. The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in **Table 10.3.3**. The buckling utilisation factor, η, is to be taken as:

$$\eta = \left(\frac{|\sigma_{av}|}{C\,\sigma_{yd}}\right)^{e} + \left(\frac{|\tau_{av}|\sqrt{3}}{C_\tau\,\sigma_{yd}}\right)^{e_\tau}$$

Where:

σ_{av} average compressive stress in the area of web plate being considered according to case: 1, 2 or 3 in **Table 10.3.1**, in N/mm^2

τ_{av} average shear stress in the area of web plate being considered according to case 5 or 6 in **Table 10.3.1**, in N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

$e = 1 + C^4$ exponent for compressive stress

$e_\tau = 1 + C C_\tau^2$ exponent for shear stress

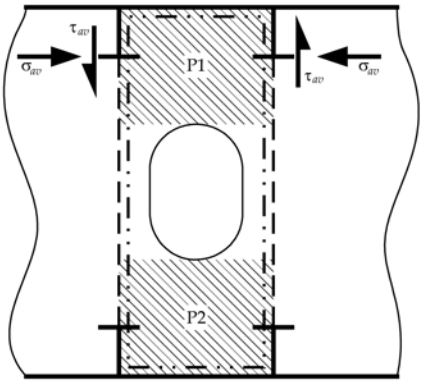
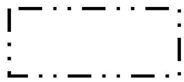
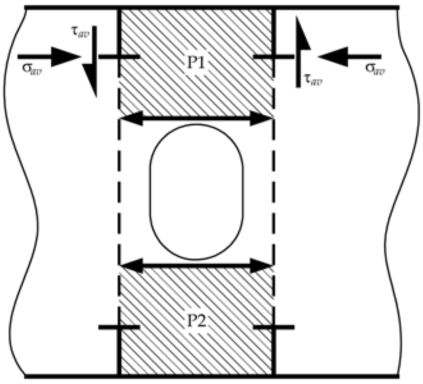
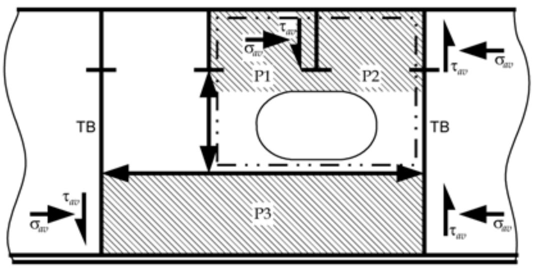
$C = C_x$ reduction factor according to Case 1 or 3, **Table 10.3.1**

$C = C_y$ reduction factor according to Case 2, **Table 10.3.1**

C_τ reduction factor according to Case 5 or 6, **Table 10.3.1**

3.4.1.2 The reduction factors, C_x or C_y in combination with C_τ, of the plate panel(s) of the web adjacent to the opening is to be taken as shown in **Table 10.3.3.**

Table 10.3.3
Reduction Factors

Mode	C_x, C_y	C_τ
(a) without edge reinforcements 	Separate reduction factors are to be applied to areas P1 and P2 using Case 3, **Table 10.3.1**, with edge stress ratio: $\psi = 1.0$	A common reduction factor is to be applied to areas P1 and P2 using Case 6, **Table 10.3.1** for area marked: 
(b) with edge reinforcements 	Separate reduction factors are to be applied for areas P1 and P2 using: C_x for Case 1 or C_y for Case 2, see **Table 10.3.1** with stress ratio $\psi = 1.0$	Separate reduction factors are to be applied for areas P1 and P2 using Case 5, **Table 10.3.1**
(c) example of hole in web 	Panels P1 and P2 are to be evaluated in accordance with (a). Panel P3 is to be evaluated in accordance with (b)	

Note
1. Web panels to be considered for buckling in way of openings are shown shaded and numbered P1, P2, etc.

3.5 Other Structures

3.5.1 Struts, pillars and cross ties

3.5.1.1 The critical buckling stress for axially compressed struts, pillars and cross ties is to be taken as the lesser of the column and torsional critical buckling stresses. The buckling utilisation factor, η, is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

Where:

σ_{av} average axial compressive stress in the member, in N/mm^2

σ_{cr} minimum critical buckling stress according to **3.5.1.2**, in N/mm^2

3.5.1.2 The critical buckling stress in compression, σ_{cr}, for each mode is to be taken as:

$$\sigma_{cr} = \sigma_E \quad \text{for} \quad \sigma_E \le 0.5\sigma_{yd}$$

$$\sigma_{cr} = \left(1 - \frac{\sigma_{yd}}{4\sigma_E}\right)\sigma_{yd} \quad \text{for} \quad \sigma_E > 0.5\sigma_{yd}$$

Where:

σ_E elastic compressive buckling stress, in N/mm^2, given for each buckling mode, see **3.5.1.3** to **3.5.1.5**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

3.5.1.3 The elastic compressive column buckling stress, σ_E, of pillars subject to axial compression is to be taken as:

$$\sigma_E = 0.001 E f_{end} \frac{I_{net50}}{A_{pill-net50} l_{pill}^2} \quad N/mm^2$$

Where:

I_{net50} net moment of inertia about the weakest axis of the cross-section, in cm^4

$A_{pill-net50}$ net cross-sectional area of the pillar, in cm^2

f_{end} end constraint factor:

1.0 where both ends are pinned

2.0 where one end is pinned and the other end is fixed

4.0 where both ends are fixed

A pillar end may be considered fixed when effective brackets are fitted. These brackets are to be supported by structural members with greater bending stiffness than the pillar. Column buckling capacity for cross tie shall be calculated using f_{end} equal to 2.0 and span as defined in **8/2.6.8.1**

E modulus of elasticity, 206 000, in N/mm^2

l_{pill} unsupported length of the pillar, in m

3.5.1.4 The elastic torsional buckling stress, σ_{ET}, with respect to axial compression of pillars is to be taken as:

$$\sigma_{ET} = \frac{G I_{sv-net50}}{I_{pol-net50}} + \frac{0.001 f_{end} E c_{warp}}{I_{pol-net50} l_{pill}^2} \quad N/mm^2$$

Where:

G shear modulus

$$= \frac{E}{2(1+\upsilon)}$$

E modulus of elasticity, 206 000, in N/mm^2

v Poisson's ratio, 0.3

$I_{sv-net50}$ net St. Venants moment of inertia, in cm^4, see **Table 10.3.4**

$I_{pol-net50}$ net polar moment of inertia about the shear centre of cross section, in cm^4

$$= I_{y-net50} + I_{z-net50} + A_{net50}\left(y_0^2 + z_0^2\right)$$

f_{end} end constraint factor:

1.0 where both ends are pinned

2.0 where one end is pinned and the other end is fixed

4.0 where both ends are fixed

Elastic torsional buckling capacity for cross tie shall be calculated using f_{end} equal to 2.0 and span as defined in **8/2.6.8.1**

c_{warp} warping constant, in cm^6, see **Table 10.3.4**

l_{pill} unsupported length of the pillar, in m

y_0 position of shear centre relative to the cross-sectional centroid, in cm, see **Table 10.3.4**

z_0 position of shear centre relative to the cross-sectional centroid, in cm, see **Table 10.3.4**

A_{net50} net cross-sectional area, in cm^2

$I_{y\text{-}net50}$ net moment of inertia about y-axis, in cm^4

$I_{z\text{-}net50}$ net moment of inertia about z-axis, in cm^4

3.5.1.5 For cross-sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling mode is to be examined. The elastic torsional/column buckling stress, σ_{ETF}, with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[(\sigma_E + \sigma_{ET}) - \sqrt{(\sigma_E + \sigma_{ET})^2 - 4\zeta\sigma_E\sigma_{ET}}\right]$$

Where:

ζ $= 1 - \dfrac{(y_0{}^2 + z_0{}^2)A_{net50}}{I_{pol-net50}}$

y_o Position of shear centre relative to the cross-sectional centroid, in cm, see **Table 10.3.4**

z_0 position of shear centre relative to the cross-sectional centroid, in cm, see **Table 10.3.4**

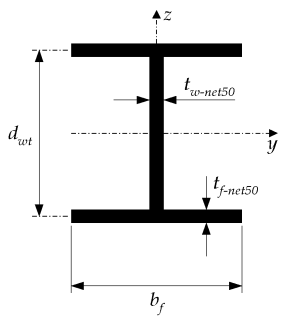
A_{net50} net cross-sectional area, in cm^2

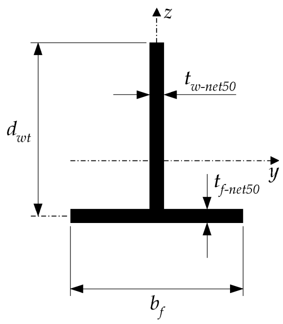
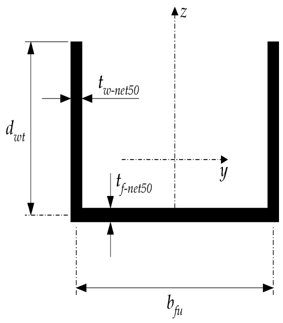
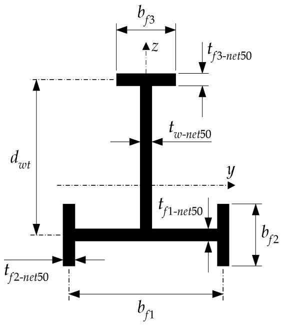
$I_{pol\text{-}net50}$ net polar moment of inertia about the shear centre of cross section, as defined in **3.5.1.4**

σ_{ET} elastic torsional buckling stress, as defined in **3.5.1.4**

σ_E elastic column compressive buckling stress, as defined in **3.5.1.3**

Table 10.3.4
Cross Sectional Properties

double symmetrical sections		
	$I_{sv-net50} = \frac{1}{3}\left(2b_f t_{f-net50}^3 + d_{wt} t_{w-net50}^3\right)10^{-4}$	cm^4
	$c_{warp} = \frac{d_{wt}^2 b_f^3 t_{f-net50}}{24} 10^{-6}$	cm^6

<table>
<tr><th colspan="2">Table 10.3.4 (Continued)
Cross Sectional Properties</th></tr>
<tr><td colspan="2">single symmetrical sections</td></tr>
<tr><td rowspan="2">
</td><td>$I_{sv-net50} = \frac{1}{3}\left(b_f t_{f-net50}^3 + d_{wt} t_{w-net50}^3\right)10^{-4}$ cm^4</td></tr>
<tr><td>y0 = 0 cm
$z_0 = -\frac{0.5 d_{wt}^2 t_{w-net50}}{d_{wt} t_{w-net50} + b_f t_{f-net50}} 10^{-1}$ cm
$c_{warp} = \frac{b_f^3 t_{f-net50}^3 + 4 d_{wt}^3 t_{w-net50}^3}{144} 10^{-6}$ cm^6</td></tr>
<tr><td rowspan="2">
</td><td>$I_{sv-net50} = \frac{1}{3}\left(b_{fu} t_{f-net50}^3 + 2 d_{wt} t_{w-net50}^3\right)10^{-4}$ cm^4</td></tr>
<tr><td>y0 = 0 cm
$z_0 = -\frac{d_{wt}^2\ t_{w-net50} 10^{-1}}{2 d_{wt}\ t_{w-net50} + b_f\ t_{f-net50}} - \frac{0.5\, d_{wt}^2\ t_{w-net50} 10^{-1}}{d_{wt}\ t_{w-net50} + b_{fu}\ t_{f-net50} / 6}$ cm
$c_{warp} = \frac{b_{fu}^2 d_{wt}^3 t_{w-net50}\left(3 d_{wt} t_{w-net50} + 2 b_{fu} t_{f-net50}\right)}{12\left(6 d_{wt} t_{w-net50} + b_{fu} t_{f-net50}\right)} 10^{-6}$ cm^6</td></tr>
<tr><td rowspan="2">
</td><td>$I_{sv-net50} = \frac{1}{3}\left(b_{f1} t_{f1-net50}^3 + 2 b_{f2} t_{f2-net50}^3 + b_{f3} t_{f3-net50}^3 + d_{wt} t_{w-net50}^3\right)10^{-4}$ cm^4</td></tr>
<tr><td>y0 = 0 cm
$z_o = z_s - \frac{\left(b_{f3}\ d_{wt}\ t_{f3-net50} + 0.5 d_{wt}^2\ t_{w-net50}\right)10^{-1}}{d_{wt}\ t_{w-net50} + b_{f1}\ t_{f1-net50} + 2 b_{f2}\ t_{f2-net50} + b_{f3}\ t_{f3-net50}}$ cm
$c_{warp} = I_{f1} z_s^2 + \frac{I_{f2}\, b_{f1}^2}{200} + I_{f3}\left(\frac{d_{wt}}{10} - z_s\right)^2$ cm^6
$I_{f1} = \left(\frac{\left(b_{f1} - t_{f2\text{-net50}}\right)^3 t_{f1-net50}}{12} + \frac{b_{f2}\ t_{f2-net50}\ b_{f1}^2}{2}\right)10^{-4}$ cm^4
$I_{f2} = \frac{b_{f2}^3\ t_{f2-net50}}{12} 10^{-4}$ cm^4
$I_{f3} = \frac{b_{f3}^3\ t_{f3-net50}}{12} 10^{-4}$ cm^4
$z_s = \frac{I_{f3}\ d_{wt}}{I_{f1} + I_{f3}} 10^{-1}$ cm</td></tr>
<tr><td colspan="2">Note
1. All dimensions of thickness, breadth and depth are in mm
2. Cross sectional properties not covered by this table are to be obtained by direct calculation.</td></tr>
</table>

3.5.2 Corrugated bulkheads

3.5.2.1 Local buckling of a unit flange of corrugated bulkheads is to be controlled according to **3.2.1.1**, for Case 1, as shown in **Table 10.3.1**, applying stress ratio $\Psi = 1.0$

3.5.2.2 The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling according to **3.5.1** (e.g. horizontally corrugated longitudinal bulkheads, vertically corrugated bulkheads subject to localised vertical forces). End constraint factor corresponding to pinned ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation.

4 Advanced Buckling Analyses

4.1 General

4.1.1 Assessment

4.1.1.1 For the assessment of buckling of plates and stiffened panels subjected to combined stress fields, the advanced buckling assessment method is to be followed.

4.1.1.2 The advanced buckling assessment method is to consider the following effects in deriving the buckling capacity:

(a) non linear geometrical behaviour

(b) inelastic material behaviour

(c) initial imperfections (geometrical out-of flatness of plate and stiffeners)

(d) welding residual stresses

(e) interactions between structural elements; plates, stiffeners, girders etc.

(f) simultaneous acting loads; bi-axial compression/tension, shear and lateral pressure

(g) boundary conditions

4.1.1.3 All effects are to be modelled to represent a lower bound of structural strength. The modelling shape and amplitude of geometrical imperfections is to be such that they trigger the most critical failure modes.

4.1.1.4 The buckling strength is to be derived in accordance with the method described in **Appendix D.**

4.1.1.5 Alternative advanced buckling analysis tools may be used provided they give comparable results with the bench mark results obtained from implementing the advanced buckling methodology described in **Appendix D.**

4.1.1.6 Theoretical background, assumptions, models, verifications, calibrations, etc., for alternative advanced buckling analysis are to be submitted for review and acceptance.

Section 11

General Requirements

1 Hull Openings and Closing Arrangements

1.1 Shell and Deck Openings

1.1.1 General

1.1.1.1 For closing appliances for openings in superstructures, deck house sides and ends see **1.4.** For overflows and vents, and for discharges and inlets, see **1.5.**

1.1.1.2 For testing requirements, see **Sub-Sec 5.**

1.1.2 Cargo tank hatches - materials

1.1.2.1 Covers for access hatches, tank cleaning and other openings for cargo tanks and adjacent spaces are to be manufactured from the following material:

(a) normal strength steel in accordance with **Sec 6/1**

(b) non-ferrous material such as bronze or brass may be considered; however, aluminium alloy is not to be used for covers of any opening to cargo tanks and spaces adjacent thereto

(c) synthetic materials may also be considered, taking into account their fire resistance and physical and chemical properties in relation to the intended operating conditions. Details of the properties of the material, the design of the cover, and the method of manufacture are to be submitted for approval.

1.1.2.2 The hatch cover packing material is to be compatible with the cargoes that are intended to be carried and is to be effectively held in place.

1.1.3 Cargo tank access coamings

1.1.3.1 The height of the hatch coaming above the upper surface of the freeboard deck is not to be less than 600 mm. Lower heights may be permitted by the Flag Administration. The top of the hatch coaming is also not to be lower than the highest point of the tank over which it is fitted and is to be of sufficient height for the purpose of damage stability.

1.1.3.2 The gross thickness of the coaming plate is not to be less than 10 mm. Where the coaming height, as fitted, exceeds 600 mm, the thickness may be required to be increased or edge stiffening fitted. The scantlings of coaming plates of tank access coamings that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, may be subject to additional requirements.

1.1.4 Cargo tank access hatch covers

1.1.4.1 The gross thickness of unstiffened plate covers with an area less than 1.2 m^2 is not to be less than 12.5 mm. The gross thickness of covers of a larger area will need to be increased or the cover will require stiffening.

1.1.4.2 Flat and unstiffened covers on circular hatchways are to be secured by fastenings with a spacing of not more than 600 mm.

1.1.4.3 On rectangular hatchways, the spacing of fastenings is generally not to be greater then 450 mm and the distance between hatch corners, and adjacent fastenings, is not to be greater than 230 mm.

1.1.4.4 The requirements of **1.1.4.1** to **1.1.4.3** do not apply to dished covers or covers of other specially approved design.

1.1.4.5 Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be considered securing devices for the cover and should be designed so as to prevent the gasket from being over tightened.

1.1.5 Machinery access openings - protection

1.1.5.1 Machinery casings are generally to be protected by an enclosed poop or bridge; or by a deck house structure complying with the strength requirements of **1.4.**

1.1.5.2 Where a vessel is intended to operate at the freeboard allowed by the *International Convention on Load Lines* for Type-A freeboard vessels, the height of such structure is not to be less than 2.3 m. The bulkheads at the forward ends of these structures are to have scantlings at least equivalent to those required for bridge-front bulkheads, see **1.4.9** and **1.4.13.**

1.1.6 Small hatches on the exposed fore deck

1.1.6.1 Openings to forward spaces as defined in **1.1.6.2** are to comply with the requirements of **1.1.6.3** to **1.1.6.14.**

1.1.6.2 These requirements apply to small hatches (generally openings 2.5 m^2 or less) on the exposed deck within 0.25 L from the F.P. and at a height less than 0.1 L or 22 m, whichever is less, from the summer load water line at the location of the hatch.

1.1.6.3 Hatches designed for emergency escape need not comply with **1.1.6.9(a), 1.1.6.9(b), 1.1.6.13** and **11.6.14.**

1.1.6.4 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with **Table 11.1.1** and **Fig 11.1.1.**

1.1.6.5 Stiffeners, where fitted, are to be aligned with the metal to metal contact points required by **1.1.6.10** and **1.1.6.11**. See also **Fig 11.1.1**. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener. See **Fig 11.1.2.**

1.1.6.6 The upper edge of the hatchway coaming is to be suitably reinforced by a horizontal member, normally not more than 190 mm from the upper edge of the coaming.

1.1.6.7 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength and stiffness equivalent to the requirements for small rectangular hatches.

1.1.6.8 For small hatch covers constructed of materials other than normal strength steel, the required scantlings are to provide equivalent strength and stiffness.

1.1.6.9 The primary securing devices are to be such that the hatch cover can be secured in place and be made weathertight by means of a closing mechanism employing any one of the following methods:

(a) butterfly nuts tightening onto forks (clamps)

(b) quick acting cleats, or

(c) a central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

1.1.6.10 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged.

1.1.6.11 The metal to metal contacts are to be arranged close to each securing device as shown in **Fig 11.1.1**, and are to be of sufficient capacity to withstand the bearing force.

1.1.6.12 The primary securing method is to be designed and manufactured such that the designed compression pressure can be achieved by one person without the need for any tools.

1.1.6.13 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use, by means of curving the forks upward and raising the surface on the free end, or a similar method. The gross plate thickness of unstiffened steel forks is not to be less than 16 mm. An example arrangement is shown in **Fig 11.1.2.**

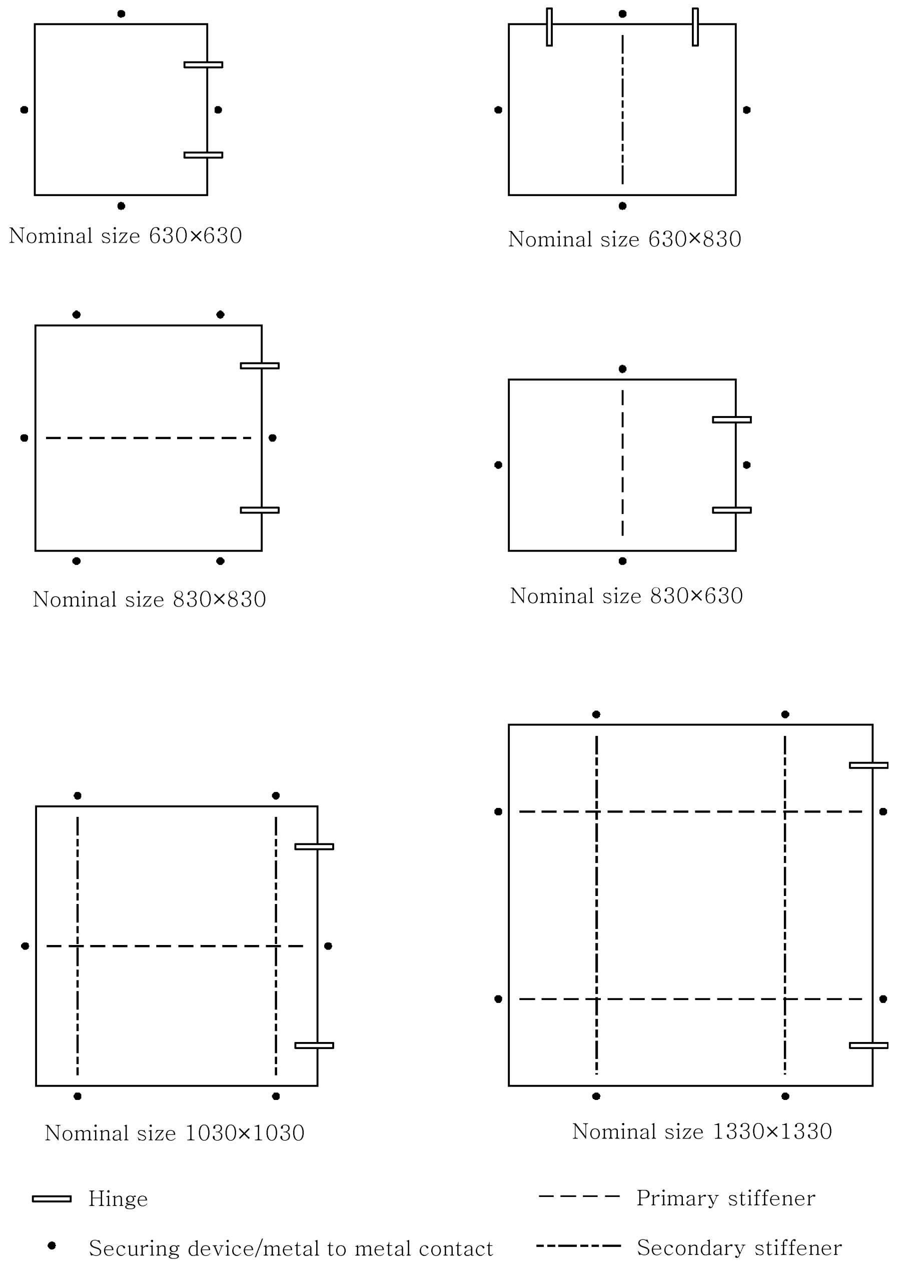
1.1.6.14 Small hatches on the exposed fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device becomes loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

1.1.6.15 For small hatch covers located on the exposed deck within the forward 0.25 L from the F.P., the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

Table 11.1.1
Scantlings for Small Steel Hatch Covers on the Fore Deck

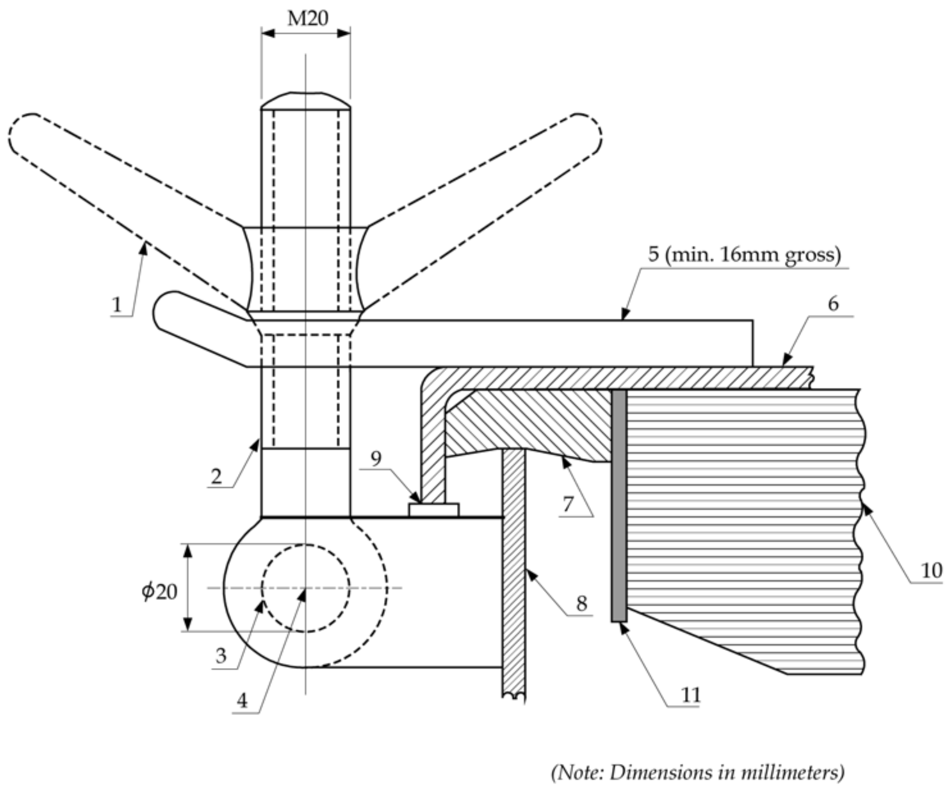
Nominal size (mm × mm)	Cover plate gross thickness (mm)	Primary stiffeners	Secondary stiffeners
		Gross flat bar scantlings (mm × mm); number	
630 × 630	8	---	---
630 × 830	8	100 × 8; 1	---
830 × 630	8	100 × 8; 1	---
830 × 830	8	100 × 10; 1	---
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2

Fig 11.1.1
Arrangement of Stiffeners



Note
1. Size dimensions are in millimeter

Fig 11.1.2
Example of a Primary Securing Method



1: butterfly nut
2: bolt
3: pin
4: center of pin
5: fork (clamp) plate
6: hatch cover
7: gasket
8: hatch coaming
9: bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10: stiffener
11: inner edge stiffener

1.1.7 Manholes and flush deck scuttles

1.1.7.1 Manholes and flush deck scuttles in Position 1 or Position 2, as defined in **Sec 4/1.2**, or within superstructures, other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight.

1.1.7.2 The strength of watertight manholes is to be equivalent to that of the deck.

1.1.7.3 Unless secured by closely spaced bolts, the covers are to be permanently attached.

1.1.8 Other openings

1.1.8.1 Openings in freeboard decks other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure, or by a deck house or companionway of equivalent strength and weathertightness. Any such opening in an exposed superstructure deck, or in the top of a deck house on the freeboard deck, which gives access to a space below the freeboard deck or a space within an enclosed superstructure, is to be protected by an efficient deck house or companionway, as defined in **1.4.**

1.1.9 Escape openings

1.1.9.1 The closing appliances of escape openings are to be readily operable from each side.

1.1.10 Rope hatches

1.1.10.1 Rope hatches may be accepted with reduced coaming height, but generally not less than 380mm, provided that they are well secured and can be opened only at the Master's discretion. The gross thickness of the coaming is to be not less than the Rule minimum gross thickness for hull envelope plating for that position, or 11 mm, whichever is the lesser.

1.1.11 Portable plates

1.1.11.1 Where portable plates are required in casings or decks, for unshipping machinery or other similar reasons, they may be accepted provided that they are of equivalent strength to the un-pierced bulkhead or deck. Portable plates may be fitted with flush covers and they are to be secured by gaskets and closely spaced bolts at a distance not greater than five bolt diameters.

1.1.11.2 The sill heights of access openings and the coaming heights of deck openings, closed by covers which are kept permanently closed at sea will be specially considered.

1.1.12 Tank cleaning and ullage openings

1.1.12.1 Tank cleaning and ullage openings are to be fitted with watertight covers or an equivalent. Flush covers may be accepted for tank cleaning and ullage openings where they comply with the applicable requirements of **1.1.11.**

Table 11.1.2
900 mm High Ventilator Thickness and Bracket Standards

Nominal pipe Size	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height of brackets, in mm
80A	6.3	-	460
100A	7.0	-	380
150A	8.5	-	300
200A	8.5	550	-
250A	8.5	880	-
300A	8.5	1200	-
350A	8.5	2000	-
400A	8.5	2700	-
450A	8.5	3300	-
500A	8.5	4000	-

1.2 Ventilators

1.2.1 General

1.2.1.1 Ventilators are to comply with the requirements of **1.2.2** through **1.2.6** and are also to be in accordance with any relevant requirements for machinery of the individual Classification Societies.

1.2.2 Details, arrangements and scantlings for ventilators

1.2.2.1 For standard ventilators of 900 mm in height, closed by heads of not more than the tabulated projected area, the minimum pipe thickness and bracket heights are to be as specified in **Table 11.1.2.**

1.2.2.2 For ventilators of height greater than 900 mm, brackets or alternative means of support are to be provided. Brackets, where fitted, are to be of suitable thickness and length according to their height.

1.2.2.3 Ventilators are to have coamings constructed of steel or other equivalent material and are to meet the requirements indicated in **Table 11.1.3.**

1.2.2.4 All component parts and connections of ventilators are to be capable of withstanding the loads defined in **1.2.3.**

1.2.2.5 Rotating type mushroom ventilator heads are not to be used for application in the areas specified in **1.2.3.1.**

1.2.2.6 Ventilators passing through superstructures, other than enclosed superstructures, are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck. Ventilators of deep tanks or tunnels passing through tween decks are to be watertight with scantlings to withstand the expected pressure.

Table 11.1.3
Coamings for Ventilators

Feature	Requirement
Height[4]	h_{coam} = 900 at Position 1 h_{coam} = 760 at Position 2[1]
Thickness[2],[3]	$d_{coam} \leq 130$ $t_{coam\text{-}grs} = 7.5$ $165 < d_{coam} < 320$ $t_{coam\text{-}grs} = 8.5$ $d_{coam} \geq 470$ $t_{coam\text{-}grs} = 10.0$ Intermediate values are to be obtained by linear interpolations
Support[3]	Where h_{coam} exceeds 900 the coaming is to be specially supported

Where:
h_{coam} height of coaming, in mm
d_{coam} external diameter of coaming, in mm
$t_{coam\text{-}grs}$ gross thickness of coaming, in mm

Note
1. The coaming height may need to be increased to satisfy any applicable subdivision and damage stability requirements.
2. Where the height of the ventilator exceeds that given, the gross thickness given above may be gradually reduced, above that height, to a minimum of 6.5 mm.
3. See also **1.2.3** and for **1.2.4** ventilators in the forward part of the ship.
4. Heights are measured above sheathing, if fitted.

1.2.3 Applied loading on ventilators

1.2.3.1 Ventilators on an exposed deck within the forward 0.25 L, and where the height of the exposed deck at the ventilator is less than 0.1 L or 22 m, whichever is less, from the summer load waterline are to comply with the requirements of **1.2.3.2** through **1.2.3.3** and **1.2.4.1.**

1.2.3.2 The pressures acting on ventilators, P_{vent}, and their closing devices are given by:

$$P_{vent} = 0.5 \rho_{sw} v_{sea}^2 C_1 C_2 C_3 \quad \text{kN/m}^2$$

Where:

ρ_{sw} density of sea water, 1.025 tonnes/m^3

v_{sea} velocity of water over the fore deck, 13.5 m/sec

C_1 shape coefficient:

- 0.5 for pipes
- 1.3 for pipe or ventilator heads in general
- 0.8 for pipe or ventilator heads of cylindrical form with its axis in the vertical direction

C_2 slamming coefficient, 3.2

C_3 protection coefficient:

- 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle
- 1.0 elsewhere, including immediately behind a bulwark

1.2.3.3 Forces acting in the horizontal direction on the ventilator and its closing device may be calculated from the above pressure, using the largest projected area of each component.

1.2.4 Strength requirements for ventilators and their closing devices

1.2.4.1 Bending moments and stresses in ventilators are to be calculated at critical positions:

(a) at penetration pieces

(b) at weld or flange connections

(c) at toes of supporting brackets.

Bending stresses in the net section are not to exceed 0.8 σ_{yd}, where σ_{yd} is the specified minimum yield stress or 0.2 % proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2 mm is then to be applied.

1.2.5 Closing appliances

1.2.5.1 Except as indicated otherwise in this paragraph, ventilator openings are to be provided with efficient, permanently attached, closing appliances. Ventilators in Position 1, the coamings of which extend to more than 4.5 m above the deck, and in Position 2, the coamings of which extend to more than 2.3 m above the deck, need not be fitted with closing arrangements unless unusual features of the design make it necessary. Position 1 and Position 2 are defined in **Sec 4/1.2.**

1.2.6 Fire dampers

1.2.6.1 Where a fire damper is located within a ventilation coaming, an inspection port or opening at least 150 mm in diameter is to be provided in the coaming to facilitate survey of the damper without disassembling the coaming or the ventilator. The closure provided for the inspection port or opening is to maintain the weathertight integrity of the coaming and, if appropriate, the fire integrity of the coaming.

1.3 Air Pipes

1.3.1 General

1.3.1.1 Air pipes are to comply with the requirements of **1.3.2** through **1.3.6** and are also to be in accordance with any relevant requirements for machinery of the individual Classification Societies.

1.3.2 Height

1.3.2.1 The minimum height for air pipes on decks exposed to weather is given as:

(a) 760 mm for those on the freeboard deck; and

(b) 450 mm for those on the superstructure deck.

The height is to be measured from the top of the sheathing, if fitted, to the point where water may have access below.

1.3.2.2 Where these heights may interfere with the working of the vessel, a lower height may be accepted subject to the fitting of an approved closing appliance at the open end of the vent.

1.3.2.3 The height may need to be increased to satisfy any applicable subdivision and damage stability requirements.

1.3.2.4 Where air pipes are led through the side of superstructures, the height of their opening is to be at least 2.3 m above the summer load waterline. Automatic vent heads of approved design are to be provided.

1.3.3 Details, arrangement and scantlings for air pipes

1.3.3.1 The wall thicknesses of air pipes, where exposed to weather, are not to be taken less than that given in **Table 11.1.4.**

Table 11.1.4
Minimum wall Thickness for Air Pipes

External diameter, in mm	Gross minimum wall thickness, in mm
$d_{air} \leq 80$	6.0
$d_{air} \geq 165$	8.5

Where:
d_{air} external diameter of pipe, in mm

Note
1. Intermediate values are to be obtained by linear interpolations.
2. See also **1.3.4** and **1.3.5** for ventilators in forward par of the ship.

1.3.3.2 For standard air pipes of 760 mm in height, closed by heads of not more than the tabulated projected area, the minimum pipe thickness and bracket heights are to be as specified in **Table 11.1.5**. Where brackets are required, three or more radial brackets are to be fitted. In addition, the relevant requirements of **1.3.4** are to be applied.

1.3.3.3 Brackets are to have a gross thickness of 8 mm or more, minimum length of 100 mm, and height according to **Table 11.1.5**, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported. In addition, loads according to **1.3.4** are to be applied. Brackets, where fitted, are to be of suitable thickness and length according to their height.

1.3.3.4 Gross pipe thickness is to be in accordance with the relevant requirements for machinery of the individual Classification Societies.

1.3.4 Applied loading on air pipes

1.3.4.1 Air pipes on an exposed deck within the forward 0.25 L, where the height of the exposed deck at the air pipe or sounding pipe is less than 0.1 L or 22 m, whichever is less, from the summer load waterline are to comply with the requirements of **1.3.4.2** through **1.3.4.3** and **1.3.5.1.**

Table 11.1.5
Thickness and Bracket Standards for 760 mm High Air Pipes

Nominal pipe size	Minimum fitted gross thickness, in mm	Maximum projected area of head, in cm^2	Height(1) of brackets, in mm
65A	6.0	-	480
80A	6.3	-	460
100A	7.0	-	380
125A	7.8	-	300
150A	8.5	-	300
175A	8.5	-	300
200A	8.5(2)	1900	300(2)
250A	8.5(2)	2500	300(2)
300A	8.5(2)	3200	300(2)
350A	8.5(2)	3800	300(2)
400A	8.5(2)	4500	300(2)

Note
1. Brackets (see **1.3.3.2**) need not extend over the joint flange for the head.
2. Brackets are required where the gross thickness of the pipe section is less than 10.5 mm, or where the tabulated projected head area is exceeded.

1.3.4.2 The pressures acting on air pipes and their closing devices, P_{pipe}, are given by:

$$P_{pipe} = 0.5\rho_{sw} v_{sea}^2 C_1 C_2 C_3 \quad \text{kN/m}^2$$

Where:

ρ_{sw} density of sea water, 1.025 tonnes/m^3

v_{sea} velocity of water over the fore deck, 13.5 m/sec

C_1 shape coefficient:

- 0.5 for pipes
- 1.3 for pipe or ventilator heads in general
- 0.8 for pipe or ventilator heads of cylindrical form with its axis in the vertical direction

C_2 slamming coefficient, 3.2

C_3 protection coefficient:

- 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle
- 1.0 elsewhere, including immediately behind a bulwark

1.3.4.3 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from the above pressure, using the largest projected area of each component.

1.3.5 Strength requirements for air pipes and their closing devices

1.3.5.1 Bending moments and stresses in air pipes are to be calculated at critical positions:
(a) at penetration pieces
(b) at weld or flange connections
(c) at toes of supporting brackets.

Bending stresses in the net section are not to exceed 0.8 σ_{yd}, where σ_{yd} is the specified minimum yield stress or 0.2 % proof stress of the steel at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2 mm is then to be applied.

1.3.6 Closing appliances for air pipes

1.3.6.1 All air pipes terminating on the weather deck are to be fitted with return bends (gooseneck), or other equivalent arrangement to prevent water from passing inboard.

1.3.6.2 A weathertight permanent means of closure is to be provided for the outlet. The closing device is to be of an automatic type, i.e. close automatically upon submergence (e.g. ball float or equivalent) for any one of the following cases:

(a) the outlet is submerged, with the ship at its summer load water line at an angle of 40 degrees, or the angle of down flooding if this is less than 40 degrees

(b) to comply with damage stability requirements.

1.3.6.3 Air pipes are not to be fitted with valves that may impair the venting function.

1.4 Deck Houses and Companionways

1.4.1 Applicability

1.4.1.1 The requirements of this section are applicable to steel deck houses and companionways, as defined in **1.4.3.1** and **1.4.3.2.**

1.4.1.2 Scantling requirements depend on the vertical location of the item relative to the waterline. This location is categorized in terms of “tiers”.

1.4.2 Materials

1.4.2.1 The scantlings in **1.4** apply to structures constructed of hull structural steel, in accordance with the requirements of **Sec 6/1**. Scantlings of aluminium alloy deck houses will be considered by the individual Society, supported by the submission of a specification of the proposed alloys.

1.4.3 Definitions

1.4.3.1 A deck house is defined as a decked structure, above the strength deck, with the side plating being inboard of the shell plating by more than 4 % of the ship’s breadth, *B*.

1.4.3.2 A companionway is defined as a weathertight deck structure; protecting an access opening leading below the freeboard deck, or into a space within an enclosed superstructure.

1.4.3.3 A tier is defined as a measure of the extent of a deck house. A deck house tier consists of a deck and external bulkheads. In general, the first tier is the tier situated on the freeboard deck.

1.4.4 Structural continuity

1.4.4.1 In deck houses aft, the front bulkhead is to be in line with a transverse bulkhead in the hull below or is to be supported by a combination of partial transverse bulkheads, girders and pillars.

1.4.4.2 The aft end bulkhead is to be effectively supported.

1.4.4.3 At the corners of the deck house attachment at the strength deck, attention is to be given to the connection of the deck house to the deck and the arrangements to transmit load into the under-deck supporting structure.

1.4.4.4 As far as practicable, exposed sides and main longitudinal and transverse bulkheads are to be located above bulkheads and/or deep girder frames in the hull structure, and are to be in line in the various tiers of accommodation. Where such structural arrangement in line is not possible, there is to be other effective support.

1.4.4.5 Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well-rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings.

1.4.5 Deck plating

1.4.5.1 The gross thickness of the plating, $t_{dk\text{-}grs}$, is not to be less than:

$t_{dk\text{-}grs} = 7.5\sqrt{\frac{k\,s}{s_{std}}}$ mm, on first tier deck houses

$t_{dk\text{-}grs} = 7.0\sqrt{\frac{k\,s}{s_{std}}}$ mm, on second tier deck houses

$t_{dk\text{-}grs} = 6.5\sqrt{\frac{k\,s}{s_{std}}}$ mm, on third tier and above deck house

Where:

s spacing of stiffeners, in m

k higher strength steel factor, as defined in **Sec 6/1.1.4**

σ_{yd} specified minimum yield stress of the material, in $\mathrm{N/mm^2}$

s_{std} standard reference spacing of longitudinals or beams, in m: $= 0.470 + 0.00167 L_1$

L_1 rule length, as defined in **Sec 4/1.1.1.1**, but is not to be taken greater than 250 m

1.4.5.2 The plating thickness inside deck houses may be reduced by 10 percent provided that the reduced gross thickness, $t_{dh\text{-}grs}$, is not less than:

$t_{dh\text{-}grs} = (5.8s + 1)\sqrt{k}$ mm, but is not to be less than 5.5 mm

Where:

s spacing of stiffeners, in m

k higher strength steel factor, as defined in **Sec 6/1.1.4**

σ_{yd} specified minimum yield stress of the material, in $\mathrm{N/mm^2}$

1.4.6 Deck longitudinals and beams

1.4.6.1 For each longitudinal or beam, in association with the plating to which it is attached, the gross section modulus, $Z_{lng\text{-}grs}$, is not to be less than:

$Z_{lng\text{-}grs} = 4.563 s\, l_{bdg}^{2} h_{tier} k$ cm^3

Where:

s spacing of stiffeners, in m

l_{bdg} effective bending span, as defined in **Sec 4/2.1.1**, in m

B as defined in **Sec 4/1.1.3.1**

h_{tier} load head in relation to the deck house tier, in m:

1.68 for poop and first tier above freeboard deck

1.30 for second tier above freeboard deck

0.91 for third and higher tiers above freeboard deck

For decks with position second tier or higher above the freeboard deck, generally used only as weather covering, the value of h_{tier} may be reduced, but in no case is it to be less than 0.46

k higher strength steel factor, as defined in **Sec 6/1.1.4**

σ_{yd} specified minimum yield stress of the material, in $\mathrm{N/mm^2}$

1.4.7 Deck girders and transverses

1.4.7.1 Deck girders and transverses are to be arranged to support beams or deck longitudinals. Where arrangements of deck girders and transverses are such that these members act as a grillage structure, additional analysis may be carried out to consider grillage effects and justify that scantlings are equivalent to those required by **1.4.7.2** and **1.4.7.3.** In this analysis gross scantlings are to be used, basic geometry parameters are to be as indicated in **1.4.7.2**, the load is to be taken as the head required by **1.4.7.2** with a unit density of 0.715 tonnes/m^3 and the permissible bending stress is to be taken as 0.67 σ_{yd}. For the determination of equivalent scantlings to those required by **1.4.7.3**, equivalency is to be based on the deflection at girder/transverse intersection points and at midspan of the members, and the permissible deflection is to be taken as the deflections calculated for a simple beam meeting the requirements of **1.4.7.2** and with depth d_{grd} as required by **1.4.7.3.**

1.4.7.2 For each deck girder or transverse web, the gross section modulus, $Z_{t\text{-}grs}$, is not to be less than:

$$Z_{t\text{-}grs} = 4.74 b_{dk} l_{bdg}^2 h_{tier} k \quad \text{cm}^3$$

Where:

b_{dk} mean breadth of the area of deck supported, in m

l_{bdg} effective bending span, to be taken as the distance between centres of supporting pillars, or between pillars, transverse members, girders and/or bulkheads supporting them, in m. Where an effective bracket is fitted at the bulkhead, the length l_{bdg} may be modified, see **Sec 4/2.1.4**

h_{tier} load head in relation to the deck house tier, in m:

1.68 for poop and first tier above freeboard deck

1.30 for second tier above freeboard deck

0.91 for third and higher tiers above freeboard deck

For decks with position second tier or higher above the freeboard deck, generally used only as weather covering, the value of h_{tier} may be reduced, but in no case is it to be less than 0.46

k higher strength steel factor, as defined in **Sec 6/1.1.4**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

1.4.7.3 The depth of girders and transverse webs, d_{grd}, is not to be less than:

$$d_{grd} = 0.0583 l_{bdg} \quad \text{m}$$

Where:

l_{bdg} effective bending span, to be taken as the distance between centres of supporting pillars, or between pillars, transverse members, girders and/or bulkheads supporting them, in m. Where an effective bracket is fitted at the bulkhead, the length l_{bdg} may be modified, see **Sec 4/2.1.4**

Where girders and transverse webs intersect, consideration may be given to accept a lesser depth for the longer member, where the shorter member provides full support to the longer member.

1.4.7.4 The gross thickness of girders or transverse webs is not to be taken as less than 1 mm per 100mm of depth, plus an additional 4 mm. Where web shear strength and buckling capacity are demonstrated to be satisfactory, lesser thicknesses may be accepted. For shear strength analysis gross scantlings are to be used, basic geometry parameters are to be as indicated in **1.4.7.2**, the load is to be taken as the head required by **1.4.7.2** with a unit density of 0.715 tonnes/m^3 and the permissible shear stress is to be taken as 0.39 σ_{yd}. Bucking capacity is demonstrated as satisfactory when the depth to gross thickness ratio of the web is less than 75.

1.4.8 Pillars

1.4.8.1 The gross scantlings of pillars are to be such that the permissible load, determined in accordance with **1.4.8.2**, is greater than the design load, determined in accordance with **1.4.8.3**, considering the requirement of **1.4.8.4.**

1.4.8.2 The permissible loading on a pillar, W_{perm}, is given by:

$$W_{perm} = (f_{s1} - h_{pill}\, f_{s2}/r_{gyr\text{-}grs})A_{pill\text{-}grs} \quad \text{kN}$$

Where:

f_{s1} steel factor:

12.09	normal strength steel
13.59	HT27 strength steel
16.11	HT32 strength steel
17.12	HT34 strength steel
18.12	HT36 strength steel
20.14	HT40 strength steel

h_{pill} distance between the top of the pillar supporting deck or other structure to the underside of the supported beam or girder, in m

f_{s2} steel factor:

4.44	normal strength steel
5.57	HT27 strength steel
7.47	HT32 strength steel
8.24	HT34 strength steel
9.00	HT36 strength steel
10.52	HT40 strength steel

$r_{gyr\text{-}grs}$ radius of gyration for gross pillar section, in cm

$A_{pill\text{-}grs}$ gross cross sectional area of pillar, in cm^2

1.4.8.3 The design load for a specific pillar, W_{des}, is given by:

$$W_{des} = 7.04\, b_{dk}\, h_{tier}\, l_{dk} \quad \text{kN}$$

Where:

b_{dk} mean breadth of the area of deck supported, in m

h_{tier} load head in relation to the deck house tier, in m:

1.68	for poop and first tier above freeboard deck
1.30	for second tier above freeboard deck
0.91	for third and higher tiers above freeboard deck

For decks with position second tier or higher above the freeboard deck, generally used only as weather covering, the value of h_{tier} may be reduced, but in no case is it to be less than 0.46

l_{dk} mean length of the area of deck supported, in m

1.4.8.4 Where pillars are arranged in a vertical line, the design load on the pillar at each level is to be calculated by summing the design load for the deck directly above the pillar and one-half of the design load for each pillar above.

1.4.9 Exposed bulkheads

1.4.9.1 The scantlings of the exposed bulkheads of deck houses and companionways are to be in accordance with **1.4.10** to **1.4.13.** Increased scantlings may be required where the structure supports loads from deck equipment, fittings, etc.

1.4.9.2 Special consideration may be given to the bulkhead scantlings of deck houses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deck house. Special consideration may also be given to the bulkhead scantlings of deck houses which do not protect machinery casings, provided they do not contain accommodation or do not protect equipment essential to the operation of the vessel.

1.4.9.3 Long deck houses may need additional support in order to provide resistance to racking, see **1.4.13.**

1.4.10 Exposed bulkhead plating

1.4.10.1 The gross thickness of plating, $t_{blk\text{-}grs}$, is not to be less than that calculated from **1.4.10.2** and that given by:

$$t_{blk\text{-}grs} = 3s\sqrt{k\,h_{des}} \quad \text{mm}$$

Where:

s spacing of stiffeners, in m

k higher strength steel factor, as defined in **Sec 6/1.1.4**

σ_{yd} specified minimum yield stress of the material, in N/mm²

h_{des} design head, in m:

$$C_4[(C_5 f) - z]c$$

but is not to be taken less than given below for the specified location:

$2.5 + L_1/100$ unprotected front bulkheads on the lowest tier

$1.25 + L_2/200$ elsewhere

L_1 rule length, L, as defined in **Sec 4/1.1.1.1**, but is not to be taken greater than 250 m

L_2 rule length, L, as defined in **Sec 4/1.1.1.1**, but is not to be taken greater than 300 m

C_4 coefficient as given in **Table 11.1.6**

C_5 coefficient:

$$1.0 + \left[\frac{(x/L) - 0.45}{C_{b1} + 0.2}\right]^2 \quad \text{where } x/L \le 0.45$$

$$1.0 + 1.5\left[\frac{(x/L) - 0.45}{C_{b1} + 0.2}\right]^2 \quad \text{where } x/L > 0.45$$

C_{b1} block coefficient as defined in **Sec 4/1.1.9.1**, but is not to be taken as less than 0.60 or greater than 0.80. For aft end bulkheads forward of amidships, C_{b1} may be taken as 0.80

x distance between the A.P. and the bulkhead being considered, in m. Deck house side bulkheads are to be divided into equal parts not exceeding $0.15L$ in length, and x is to be measured from the A.P. to the centre of each part considered

L rule length, as defined in **Sec 4/1.1.1.1**

f as defined in **Table 11.1.7**

z vertical distance from the summer load waterline measured to the middle of the plate, in m

c $0.3 + 0.7 b_{dh}/B_1$

but is not to be taken as less than 1.0 for exposed machinery casing bulkheads and in no case is b_{dh}/B_1 to be taken as less than 0.25

b_{dh} breadth of deck house at the position being considered, in m

B_1 actual breadth of the vessel at the freeboard deck at the position being considered, in m

Table 11.1.6
Values of 'C_4'

Bulkhead location	Value of 'C4'
Unprotected front, lowest tier	$2.0 + L_2/120$
Unprotected front, 2nd tier	$1.0 + L_2/120$
Unprotected front, 3rd tier	$0.5 + L_2/150$
Protected front, all tiers	$0.5 + L_2/150$
Sides, all tiers	$0.5 + L_2/150$
Aft ends, aft of amidships, all tiers	$0.7 + (L_2/1000) - 0.8\,x/L$
Aft ends, forward of amidships, all tiers	$0.5 + (L_2/1000) - 0.4\,x/L$

Table 11.1.7
Values of 'f'

L, in m	f, in m
90	6.00
100	6.61
120	7.68
140	8.65
160	9.39
180	9.88
200	10.27
220	10.57
240	10.78
260	10.93
280	11.01
$\geq$ 300	11.03

Note
1. This Table is based on the equations given in **Table 11.1.8**

Table 11.1.8 Origin of 'f'Values	
L, in m	f, in m
$L \le 150$	$(L/10)(e^{-L/300})-[1-(L/150)^2]$
$150 < L < 300$	$(L/10)(e^{-L/300})$
$L \ge 300$	11.03

1.4.10.2 The gross thickness for the lowest tier bulkheads, $t_{blk\text{-}tier\text{-}grs}$, is not to be less than:

$$t_{blk-tier-grs} = 5.0 + L_1/100 \quad \text{mm}$$

For other tiers, the gross thickness of bulkheads is not to be less than:

$$t_{blk\text{-}tier\text{-}grs} = 4.0 + L_1/100 \quad \text{mm, or 5.0 mm, whichever is greater}$$

Where:

L_1 rule length, L, as defined in **Sec 4/1.1.1.1**, but is not to be taken greater than 250 m

1.4.11 Exposed bulkhead stiffeners

1.4.11.1 Each stiffener, in association with the plating to which it is attached, is to have a gross section modulus, $Z_{blk\text{-}grs}$, not less than:

$$Z_{blk\text{-}grs} = 3.5\, s\, h_{tween}{}^2 h_{des}\, k \quad \text{cm}^3$$

Where:

s spacing of stiffeners, in m

h_{tween} tween deck height, in m

h_{des} design head, as defined in **1.4.10.1**, with z taken as the vertical distance from the summer load waterline to midpoint of the stiffener span, in m

k higher strength steel factor, as defined in **Sec 6/1.1.4**

σ_{yd} specified minimum yield stress of the material, in N/mm^2

1.4.12 Stiffener end attachments for stiffeners on exposed bulkheads

1.4.12.1 Both ends of the webs of lowest tier bulkhead stiffeners are to be effectively attached. The scantlings of stiffeners having other types of end connection will be specially considered.

1.4.13 Web arrangements for webs on exposed bulkheads

1.4.13.1 In long deck houses with multiple tiers, web frames or partial bulkheads are to be fitted within the first tier, spaced a maximum of approximately 9 m apart and arranged, where practicable, in line with watertight bulkheads below.

1.4.13.2 Webs are also to be arranged in way of large openings, boats davits and other points of high loading.

1.4.14 Closing arrangements for openingsin deck houses and companionways

1.4.14.1 All openings in the bulkheads of deck houses and companionways, which give direct access to enclosed superstructures or to spaces below the freeboard, are to be provided with efficient means of closing so that in any sea condition, water will not penetrate the vessel.

1.4.14.2 Doors of such openings are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead. The doors are to be provided with gaskets and clamping devices, or other equivalent arrangements, which are to be permanently attached to the bulkhead or to the doors themselves. The doors are to be so arranged that they can be operated from both sides of the bulkhead. Doors complying with a recognized national or international standard will generally be accepted.

1.4.14.3 Access openings are to be framed and stiffened so that the whole structure is equivalent to the un-pierced bulkhead when closed.

1.4.14.4 Except as permitted by **1.4.14.5**, access doors, air inlets and openings to accommodation spaces, control stations and machinery spaces, are not to face the cargo tank region. They are to be located on the transverse bulkhead or on the side of the deck house at a distance of at least $0.04\,L$ and not less than 3 m from the end of the deck house facing the cargo tank region. This distance need not exceed 5 m.

1.4.14.5 Access doors in boundary bulkheads facing the cargo tank region, or within the 5 m limits specified in **1.4.14.4**, leading to the main cargo control stations and to such service spaces used as provision rooms, store rooms and lockers, may be permitted, provided they do not give access directly or indirectly to any other space containing or providing for accommodation, control stations or service spaces such as galley, pantries or work shops, or similar spaces containing source of vapour ignition. The boundary of such a space is to be insulated to “A-60” class standard, with the exception of the boundary facing the cargo tank region.

1.4.15 Sills of access openings

1.4.15.1 The height of the sills of access openings, in the bulkheads of deck houses and companionways, which give direct access to enclosed superstructures or to spaces below the freeboard deck, is to be a minimum of 600 mm in Position 1 and 380 mm in Position 2, as defined in **Sec 4/1.2.**

1.4.16 Access openings in machinery casings on Type ‘A’ freeboard tankers

1.4.16.1 In general, there are to be no openings giving direct access from the freeboard deck to the machinery space in exposed machinery casings.

1.4.16.2 A door complying with the requirements of **1.4.14.1** to **1.4.14.3** may be permitted in the exposed machinery casing provided that it leads to a space or passageway which is as strongly constructed as the casing, and is separated from the engine room by a second door complying with the requirements of **1.4.14.1** to **1.4.14.3**. The sill of the exterior door is not to be taken less than 600 mm and the sill of the second door is not to be taken less than 230 mm.

1.4.17 Windows and side scuttles

1.4.17.1 Side scuttles, in the external bulkheads of deck houses and weathertight doors, are to be of substantial construction in accordance with a recognised national or international standard.

1.4.17.2 Windows and side scuttles, fitted in the boundaries of deck houses protecting direct access into superstructures, or to spaces below the freeboard deck, are to be fitted with efficient hinged inside deadlights.

1.4.17.3 Windows and portlights facing the cargo tank region, and on the side of the superstructures or deck houses within the limits specified in **1.4.14.4** and **1.4.14.5**, shall be of a fixed (non-opening) type. Such windows and portlights, except wheelhouse windows, shall be constructed to “A-60” class standard.

1.5 Scuppers, Inlets and Discharges

1.5.1 Drains – enclosed spaces

1.5.1.1 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deck houses on the freeboard deck, fitted with doors complying with the requirements of the *International Convention on Load Lines, Regulation 12*, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard, provided that:

(a) the freeboard is such that the deck edge is not immersed when the ship heels to five degrees either way, and

(b) each drain is fitted with means of preventing water from passing inboard, in accordance with **1.5.3.**

1.5.2 Drains – open spaces

1.5.2.1 Drains leading from superstructures or deck houses not fitted with doors complying with the requirements of *International Convention on Load Lines, Regulation 12* are to be led overboard.

1.5.3 Prevention of water passing inboard

1.5.3.1 Drains either from spaces below the freeboard deck or from within superstructures and deck houses on the freeboard deck, where permitted to be led overboard, see **1.5.1.1(a)**, are to be fitted with efficient and accessible means for preventing water from passing inboard, in accordance with **1.5.3.2** to **1.5.3.7.**

1.5.3.2 For drains which remain open during normal operation of the ship, such as sanitary discharges, means for preventing water passing inboard are to be in accordance with those given below for the area described. h_{disc} is the height from the summer load line to the inboard end of the discharge, in m:

(a) $h_{disc} \leq 0.01 L_L$:

- one automatic non-return valve with a positive means of closing it from a position above the freeboard deck
- alternatively, one automatic non-return valve and one positive closing valve controlled from above the freeboard deck may be accepted.

(b) $0.01 L_L < h_{disc} \leq 0.02 L_L$:

- two automatic non-return valves, without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions
- the inboard valve is to be located above the deepest salt water load line
- if this is not practicable, additional locally controlled positive closing may be provided outboard, or the outboard non-return valve may be provided with a locally controlled positive closing feature, in which case the inboard valve need not be located above the deepest salt water load line.

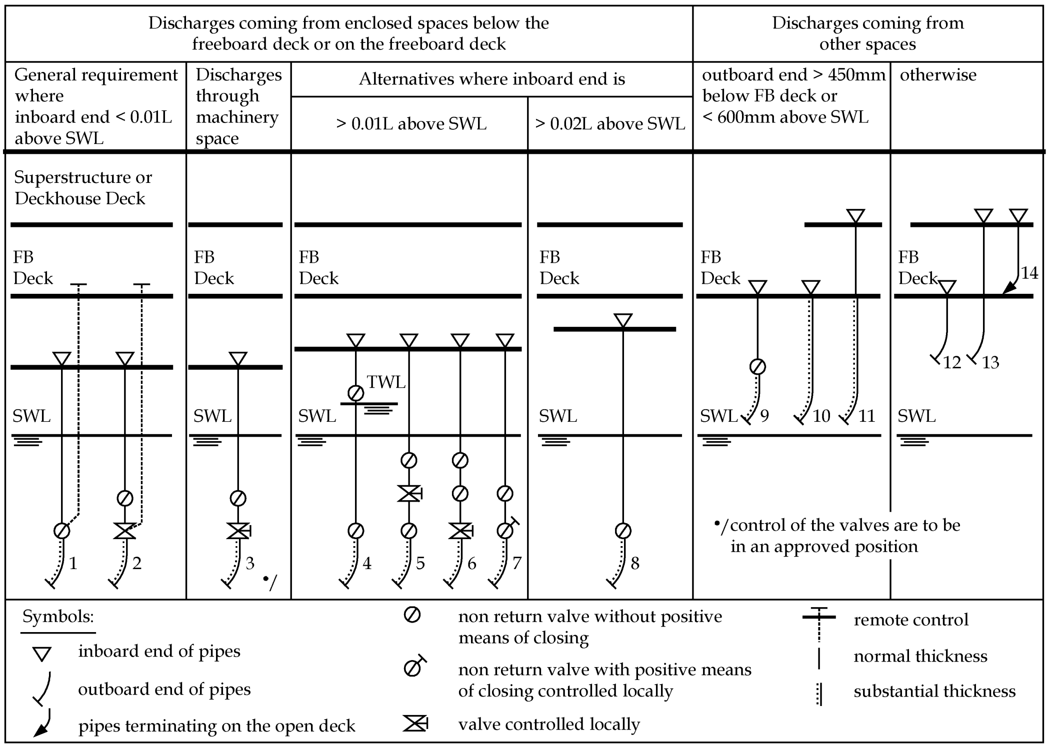
(c) $h_{disc} > 0.02 L_L$:

- one single automatic non-return valve without positive means of closing.

1.5.3.3 For overboard discharges in way of machinery spaces, a locally operated positive closing valve at shell together with a non-return valve inboard, may be accepted in lieu of those required by **1.5.3.2.**

1.5.3.4 For acceptable arrangements for discharges and scuppers, see **Fig 11.1.3.**

Fig 11.1.3
Diagrammatic Arrangement of Discharge and Scupper Systems



1.5.3.5 For drains which are closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from the deck may be accepted.

1.5.3.6 The means for operating the positive closing valve are to be readily accessible and provided with an indicator showing whether the valve is open or closed.

1.5.3.7 Drain pipes originating at any level and penetrating the shell either more than 450 mm below the freeboard deck or less than 600 mm above the summer load waterline are to be provided with a non-return valve at the shell. This valve, unless required by **1.5.3.2** through **1.5.3.4**, may be omitted if the pipe is of substantial thickness, in accordance with **1.5.7.3.**

1.5.4 Sea inlets

1.5.4.1 In manned machinery spaces, main and auxiliary sea inlets and discharges in connection with the operation of machinery may be controlled locally. The control is to be readily accessible and provided with indicators showing whether the valves are open or closed.

1.5.5 Shell valves and fittings

1.5.5.1 For installation; the shell valves are to be mounted on the shell (or sea chest). However, where it is impracticable to do so, a distance piece, of substantial thickness in accordance with **1.5.7.3**, may be fitted. Shell outlets are to be so located as to prevent any discharge falling onto a lowered survival craft.

1.5.5.2 For material; all required shell valves and fittings are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

1.5.5.3 Material readily rendered ineffective by heat is not to be used for shell connection where the failure of the material in case of fire would give rise to danger of flooding.

1.5.6 Unattended machinery space

1.5.6.1 For unattended machinery space; the control of any valve serving a sea inlet, a discharge below the waterline, or a bilge injection system, is to be so sited as to allow adequate time to reach and operate the control, in case of ingress of water to the space with the ship in the fully loaded condition.

1.5.6.2 For application of **1.5.6.1** in an unattended machinery space; where it can be demonstrated by calculation that the damaged water line will not be above the tank top floor level after 10 minutes from the initiation of the uppermost bilge level alarm, the valve control may be from the tank top floor.
Guidance Note:
Various Flag Administrations have interpretations of this requirement. Where the ship is flagged by an Administration having an interpretation of this requirement, the interpretation of the Flag Administration shall take precedence or the requirements of **1.5.6.2.**

1.5.7 Pipes

1.5.7.1 All pipes from shell to the first valve are to be of steel or other equivalent material.

1.5.7.2 The gross wall thickness of steel piping inboard of the valve is not to be less than that given in **Table 11.1.9**, unless substantial thickness is required.

Table 11.1.9
Thickness of Normal Steel Piping

External diameter, in mm	Gross wall thickness, in mm
≤ 155	4.5
≥ 230	6.0

Note
1. Intermediate values are to be obtained by linear interpolation.

1.5.7.3 The gross wall thickness of steel piping, where required to be of substantial thickness, see **1.5.3.7** and **1.5.5.1**, is not to be less than given in **Table 11.1.10.**

Table 11.1.10
Thickness of Substantial Steel Piping

External diameter, in mm	Gross wall thickness, in mm
≤ 80	7.0
180	10.0
≥ 220	12.5

Note
1. Intermediate values are to be obtained by linear interpolation.

1.5.8 Rubbish chutes, offal and similar discharges

1.5.8.1 Rubbish chutes, offal, and similar discharges are to be constructed of mild steel piping or plating equal to the shell thickness. Other materials will be specially considered.

1.5.8.2 Openings are to be kept clear of the sheer strake and areas of high stress concentration.

1.5.8.3 Rubbish chute hoppers are to be provided that comprise a hinged weathertight cover at the inboard end with an interlock so that the discharge flap and hopper cover cannot be open at the same time.

1.5.8.4 The hopper cover is to be secured closed when not in use, and a suitable notice is to be displayed at the control position.

1.5.8.5 Where the inboard end of the hopper is less than 0.01 L_L, a positive closing valve is to be provided in addition to the cover and flap, in an easily accessible position above the deepest salt water load line.

1.5.8.6 The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a notice to that effect is to be displayed at the valve operating position.

2 Crew Protection

2.1 Bulwarks and Guardrails

2.1.1 General

2.1.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks, at the boundary of first tier deck houses and at the ends of superstructures.

2.1.1.2 Bulwarks, or guard rails, are to be a minimum of 1.0m in height, measured above sheathing, and are to be constructed as required in **2.1.2.** Where this height would interfere with the normal operation of the vessel, a lesser height may be approved. Where approval of a lower height is requested, justifying information is to be submitted.

2.1.1.3 Within 0.6 L amidships, bulwarks are to be arranged to ensure that they are free from hull girder stresses.

2.1.1.4 Satisfactory means in the form of guard rails, life lines, gangways, under deck passages or an equivalent are to be provided for the protection of crew during passage from their quarters, the machinery space, and all other locations necessary for the crewing of the ship, see **2.3.1.1.**

2.1.2 Construction of bulwarks

2.1.2.1 The gross thickness of bulwark plating, at the boundaries of exposed freeboard and superstructure decks, is not to be less than that given in **Table 11.2.1.**

Table 11.2.1
Thickness of Bulwark Plates

Height of Bulwark	Gross Thickness
1.8 m or more	As required for superstructure in the same position
1.0 m	6.5 mm
Intermediate height	To be determined by linear interpolation

2.1.2.2 Plate bulwarks are to be stiffened by a top rail. Plate bulwarks on the freeboard deck and forecastle deck are to be supported by stays having a spacing generally not greater than 2.0 m.

2.1.2.3 The free edge of the stay is to be stiffened.

2.1.2.4 The gross section modulus of stays, $Z_{stay\text{-}grs}$, is not to be less than that given below. In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck. Where, at the ends of the ship, the bulwark plating is connected to the sheer strake, a width of attached plating, not exceeding 600 mm, may also be included.

$$Z_{stay\text{-}grs} = 77 h_{blwk}^{2} s_{stay} \quad \text{cm}^3$$

Where:

h_{blwk} height of bulwark from the top of the deck plating to the top of the rail, in m

s_{stay} spacing of the stays, in m

2.1.2.5 Where mooring fittings subject the bulwark to large forces, the strength of the stays is to be suitably upgraded.

2.1.2.6 Bulwark stays are to be supported by, or are to be in line with, suitable under deck stiffening. The stiffening is to be connected by double continuous fillet welds in way of bulwark stay connections.

2.1.2.7 Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of openings.

2.1.2.8 Bulwarks are to be adequately strengthened and increased in thickness in way of mooring pipes.

2.1.2.9 Cuts in bulwarks for gangways or other openings are to be kept clear of breaks of superstructures.

2.1.2.10 Where bulwarks are fitted, freeing ports are to be provided as required in **2.1.5**. The freeing ports are to comply with the requirements of the individual Classification Society.

2.1.3 Construction of guard rails

2.1.3.1 Stanchions of guard rails required by **2.1.1.1** are to comply with the following requirements:

(a) fixed, removable or hinged stanchions are to be fitted approximately 1.5 m apart

(b) at least every third stanchion is to be supported by a bracket or stay

(c) removable or hinged stanchions are to be capable of being locked in the upright position

(d) in the case of ships with rounded gunwales, the stanchions are to be placed on the flat of the deck

(e) in the case of ships with sheer strake, the stanchions are not to be attached to the sheer strake, upstand or a continuous gutter bar.

2.1.3.2 The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230 mm. The distance between other courses is not to be greater than 380 mm.

2.1.3.3 Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

2.1.3.4 Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks.

2.1.4 Additional requirements for bulwarks and guard rails related to spill containment

2.1.4.1 Generally, open guard rails are to be fitted on the upper deck. Plate bulwarks, with a 230 mm high continuous opening, at the lower edge, may be accepted provided the arrangement allows for the acceptable handling of spillage on deck and minimises the possibility for accumulation of volatile gas.

2.1.4.2 Deck spills are to be prevented from spreading to the accommodation and service areas and from discharge into the sea by a permanent continuous coaming with a minimum height of 100mm surrounding the cargo deck. Along the sides at the aft end of the cargo deck, the coaming is to have a minimum height of 200 mm extending a minimum of 4.5 m forward from each corner. At the aft end of the cargo deck, the coaming is to have a minimum height of 300 mm and is to extend from ship-side to ship-side.

2.1.4.3 Where a continuous gutter bar deck coaming is fitted, it is to be constructed of the same material strength and grade as the deck plating to which it is attached.

2.1.4.4 Scupper plugs of mechanical type are to be provided. Means of draining or removing oil or oily water within the coaming are also to be provided.

2.1.5 Additional requirements for deeper loading

2.1.5.1 Ships with Type A or B-100 Freeboard (i.e. a freeboard less than that based on Type B-60) are to have open rails fitted for a minimum of half the length of the exposed parts of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 % of the total area of the bulwark. The freeing area is to be located in the lower part of the bulwark.

2.1.5.2 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

2.1.5.3 Ships with Type B-60 Freeboard (i.e. a freeboard less than that based on Type B but not less than Type B-60) are to have a minimum freeing area of at least 25 % of the total area of the bulwark. The freeing area is to be located in the lower part of the bulwark.

2.2 Tank Access

2.2.1 Access to tanks in the cargo tank region

2.2.1.1 Access to tanks in the cargo tank region is to be in accordance with **Sec 5/5**.

2.3 Bow Access

2.3.1 General

2.3.1.1 The ship is to be provided with means to enable the crew to gain safe access to the bow even in severe weather conditions, see **Table 11.2.2.**

Table 11.2.2
Acceptable Arrangements for Access

<table>
<tr><th rowspan="2">Locations of access</th><th rowspan="2">Assigned summer freeboard</th><th colspan="4">Acceptable arrangements according to type of freeboard assigned(6)(7)(8)</th></tr>
<tr><th>Type A</th><th>Type B-100</th><th>Type B-60</th><th>Type B & B+</th></tr>
<tr><td rowspan="2">Access to bow
Between poop and bow, or

Between a deck house containing living accommodation or navigation equipment, or both, and bow, or

In the case of a flush deck vessel, between crew accommodation and the forward end of vessel.</td><td>≤ $(h_{FB}+h_{ss})$</td><td colspan="4">a
e
f(1)
f(5)</td></tr>
<tr><td>> $(h_{FB}+h_{ss})$</td><td colspan="4">a
e
f(1)
f(2)</td></tr>
<tr><td rowspan="2">Access to aft end
In the case of a flush deck vessel, between crew accommodation and the aft end of vessel.</td><td>≤ 3000 mm</td><td>a
b
c(1)
e
f(1)</td><td>a
b
c(1)
c(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(1)
e
f(1)
f(2)</td><td rowspan="2">a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
<tr><td>> 3000 mm</td><td>a
b
c(1)
d(1)
e
f(1)</td><td>a
b
c(1)
c(2)
d(1)
d(2)
e
f(1)
f(2)</td><td>a
b
c(1)
c(2)
c(4)
d(1)
d(2)
d(3)
e
f(1)
f(2)
f(4)</td></tr>
</table>

Table 11.2.2 (Continued)
Acceptable Arrangements for Access

Where:

h_{ss} the standard height of a superstructure as defined in ICLL Regulation 33

h_{FB} freeboard from the summer load waterline amidships, in m, calculated as a Type A ship, regardless of the type of freeboard actually assigned

a a well lit and ventilated under deck passageway with a clear opening with a minimum width of 0.8 m, and a minimum height of 2.0 m, providing access to the locations under consideration and located as close as practicable to the freeboard deck

b a permanently constructed gangway fitted at or above the level of the superstructure deck, on or as near as practicable to the centreline of the vessel, providing a continuous platform of a non-slip surface at least 0.6 m in width, with a foot-stop and guard rails extending on each side along its length. Guard rails are to be as required in **2.1.3**, except that stanchions are to be fitted with a maximum spacing of 1.5 m

c a permanent walkway with a minimum width of 0.6 m, fitted at the freeboard deck level, consisting of two rows of guard rails, the stanchions of which, are to have a maximum spacing of 3 m. The number of courses of rails and their spacing are to be as given in **2.1.3**. On Type B freeboard ships, hatchway coamings with a height equal to or greater than 0.6 m may be regarded as forming one side of the walkway provided that two rows of guard rails are fitted between the hatchways

d a rope lifeline with a minimum diameter of 10 mm, supported by stanchions approximately 10 m apart, or a single hand rail or wire rope attached to the hatch coamings, continued and adequately supported between hatchways

e a permanently constructed gangway fitted at or above the level of the superstructure deck on, or as near as practicable, to the centreline of the vessel:

- located so as not to hinder easy access across the working areas of the deck
- providing a continuous platform with a minimum width of 1.0 m
- constructed of fire resistant and non-slip material
- fitted with guard rails extending on each side throughout its length. Guard rails are to be as required in **2.1.3**, except that stanchions are to be fitted with a maximum spacing of 1.5 m
- provided with a foot stop on each side
- having openings, with ladders to and from the deck, where appropriate. Openings are to be spaced a maximum of 40 m apart
- having shelters of substantial construction set in way of the gangway at intervals not exceeding 45 m, if the length of the exposed deck to be traversed is greater than 70 m. Every such shelter is to be capable of accommodating at least one person and be so constructed as to afford weather protection on the forward, port and starboard sides

f a permanent and efficiently constructed walkway fitted at the freeboard deck level on, or as near as practicable, to the centreline of the vessel, having the same specifications as those defined for a permanent gangway in 'e' above, except for foot-stops. On Type B freeboard ships the hatch coamings may be accepted as forming one side of the walkway, provided that the combined height of the hatch coaming and hatch cover, in the closed condition, is not less than 1m, and that two rows of guard rails are fitted between the hatchways

Note

1. At or near the centreline of the vessel, or fitted on hatchways at or near the centreline of the vessel
2. Fitted on each side of the vessel
3. Fitted on one side of the vessel, provision being made for fitting on either side
4. Fitted on one side only
5. Fitted on each side of the hatchways as near to the centreline as far as practicable
6. In all cases where wire ropes are fitted, adequate devices are to be provided to enable the maintaining of their tautness
7. A means of passage over obstructions, if any, such as pipes or other fittings of a permanent nature is to be provided
8. Generally, the width of the gangway or walkway is not to exceed 1.5 m.

Guidance Note

Deviations from some or all of these requirements may be allowed, subject to agreement on a case-by-case basis with the relevant Flag Administration.

3 Support Structure and Structural Appendages

3.1 Support Structure for Deck Equipment

3.1.1 General

3.1.1.1 Information pertaining to the support structure of deck equipment and fittings, as listed in **3.1.2** to **3.1.7**, is to be submitted for approval.

3.1.1.2 This sub-section includes scantling requirements for the support structure and foundations of the following pieces of equipment and fittings:

(a) anchor windlasses
(b) anchoring chain stoppers
(c) mooring winches
(d) deck cranes, derricks and lifting masts
(e) emergency towing arrangements
(f) bollards and bitts, fairleads, stand rollers, chocks and capstans
(g) other deck equipment and fittings which are subject to specific approval
(h) miscellaneous deck fittings which are not subject to specific approval.

3.1.1.3 Where deck equipment is subject to multiple load cases, such as an operational load and a green seas load, the operational load and green seas load are be applied independently for the evaluation of strength of foundations and support structure.

3.1.2 Supporting structures for anchoring windlass and chain stopper

3.1.2.1 The windlass is to be efficiently bedded and secured to the deck. The deck thickness in way of the windlass and chain stopper is to be compatible with the deck attachment design.

3.1.2.2 In addition to complying with the requirements of **3.1.2.6**, the shipbuilder and the windlass manufacturer are to satisfy themselves that the foundation is suitable for the safe operation and maintenance of the windlass equipment.

3.1.2.3 The Breaking Strength is defined as the minimum breaking strength of the chain.

3.1.2.4 The following plans and information are to be submitted for approval:

(a) details of the supporting structure for the anchor windlass
(b) details of the windlass foundation design, including material specifications for holding down bolts and the connection of the foundation to the deck
(c) details of the chain stopper foundation design, including material specification and the connection of the foundation to the deck.

3.1.2.5 The following supporting information is also to be submitted:

(a) general arrangement drawing of anchoring equipment.
(b) design loads as specified in **3.1.2.8** and **3.1.2.9** and associated reaction forces applied to the foundation and supporting structure.

3.1.2.6 The scantlings of the support structure are to be dimensioned to ensure that for each of the load scenarios specified in **3.1.2.8** and **3.1.2.9**, the calculated stresses in the support structure does not exceed the permissible stress levels given in **3.1.2.15** to **3.1.2.18.**

3.1.2.7 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using gross scantlings.

3.1.2.8 The following load cases are to be examined for the anchoring operation, as appropriate:

(a) windlass where chain stopper is provided:	45 % of Breaking Strength
(b) windlass where chain stopper is not provided:	80 % of Breaking Strength
(c) chain stopper:	80 % of Breaking Strength

Breaking Strength is defined in **3.1.2.3.**

3.1.2.9 The following forces are to be applied separately in the load cases that are to be examined for the design loads due to green seas in the forward 0.25 L, see **Fig 11.3.1**:

$P_x = 200A_x$ kN, acting normal to the shaft axis

$P_y = 150A_y f$ kN, acting parallel to the shaft axis (inboard and outboard directions to be examined separately)

Where:

A_x projected frontal area, in m^2

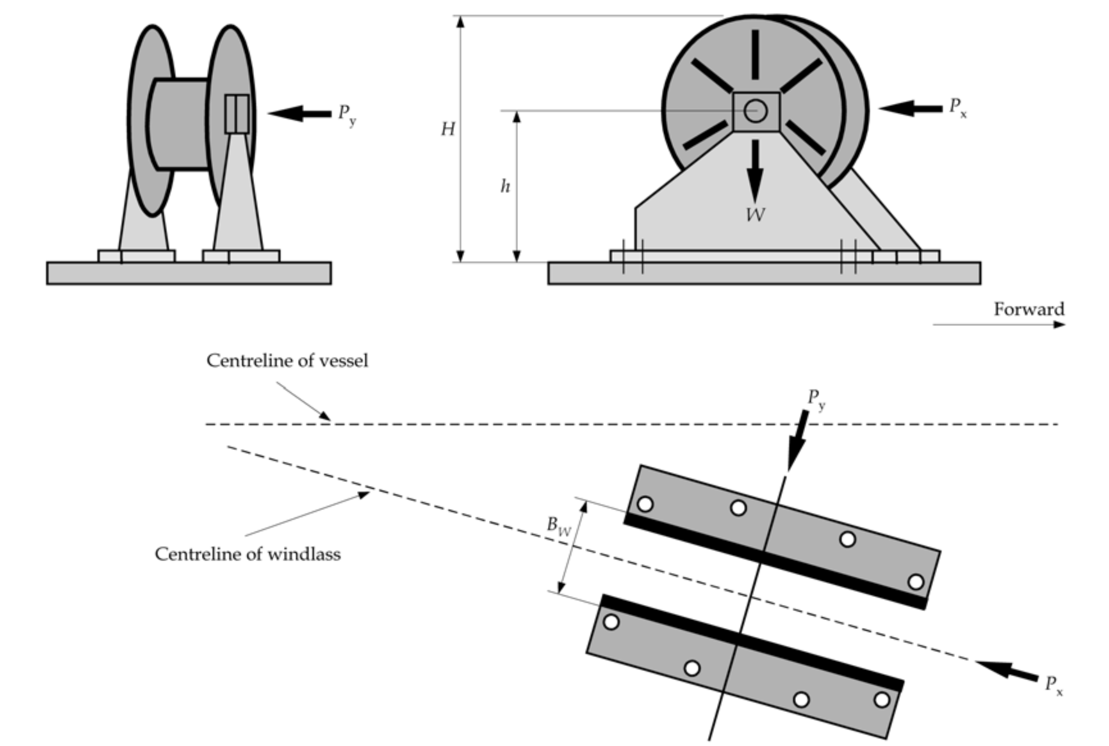
A_y projected side area, in m^2

f = $1+B_W/H$, but not to be taken greater than 2.5

B_W breadth of windlass measured parallel to the shaft axis, in m. See **Fig 11.3.1**

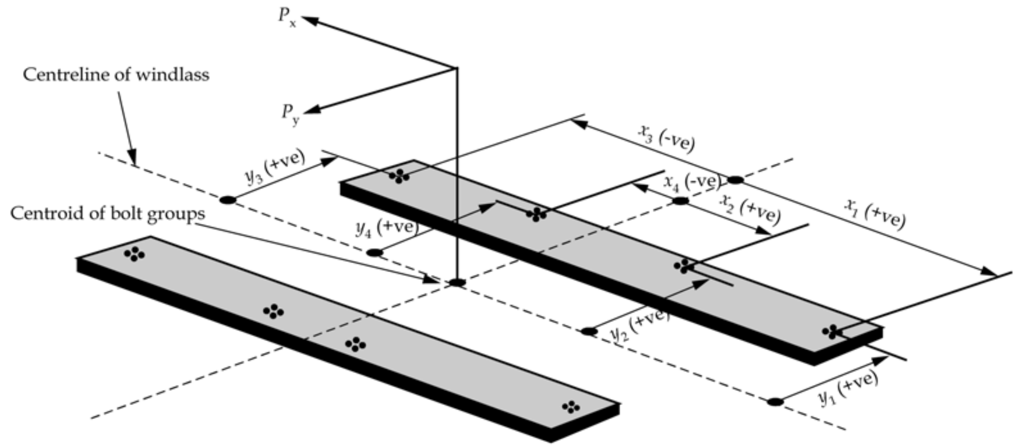
H overall height of windlass, in m, see **Fig 11.3.1**

Fig 11.3.1
Direction of Forces and Weight



3.1.2.10 Forces resulting from green sea design loads in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by a number of bolt groups, N, each containing one or more bolts. See **Fig 11.3.2.**

Fig 11.3.2
Bolting Arrangements and Sign Conventions



3.1.2.11 The axial forces, R_{xi} and R_{yi}, in bolt group (or bolt) i, positive in tension, are given by:

$$R_{xi} = P_x h x_i A_i / I_x$$

$$R_{yi} = P_y h y_i A_i / I_y$$

$$R_i = R_{xi} + R_{yi} - R_{si}$$

Where:

P_x force acting normal to the shaft axis, in kN

P_y force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in bolt group i, in kN

h shaft centre height above the windlass mounting, in cm, see **Fig 11.3.1**

x_i, y_i x and y coordinates of bolt group i from the centroid of all N bolt groups, in cm. Positive in the direction opposite to that of the applied force

A_i cross sectional area of all bolts in group i, in cm^2

I_x = $\sum A_i x_i^2$ for N bolt groups, in cm^4

I_y = $\sum A_i y_i^2$ for N bolt groups, in cm^4

R_{si} static reaction at bolt group i, due to the weight of windlass, in kN

3.1.2.12 The shear forces, F_{xi} and F_{yi}, applied to the bolt group i, and the resultant combined force F_i, are given by:

$$F_{xi} = (P_x - C_1 g m)/N$$

$$F_{yi} = (P_y - C_1 g m)/N$$

$$F_i = \sqrt{F_{xi}^2 + F_{yi}^2}$$

Where:

C_1 coefficient of friction, 0.5

m mass of windlass, in tonnes

g acceleration due to gravity, 9.81 $\mathrm{m/s^2}$

N number of bolt groups

3.1.2.13 The resultant forces from the application of the loads specified in **3.1.2.8** and **3.1.2.9** are to be considered in the design of the supporting structure.

3.1.2.14 Where a separate foundation is provided for the windlass brake, the distribution of resultant forces is to be calculated on the assumption that the brake is applied for load cases (a) and (b) defined in **3.1.2.8.**

3.1.2.15 The stresses resulting from anchoring design loads induced in the supporting structure are not to be greater than the permissible values given below, based on the gross thickness of the structure:

Normal stress 1.00 σ_{yd}

Shear stress 0.58 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.2.16 The tensile axial stresses resulting from green sea design loads in the individual bolts in each bolt group i are not to exceed 50 % of the bolt proof strength under the above forces. The load is to be applied in the direction of the chain. Where fitted bolts are designed to support these shear forces in one or both directions, the von Mises equivalent stresses are not to exceed 50 % of the bolt proof strength.

3.1.2.17 The horizontal forces resulting from the green sea design loads F_{xi} and F_{yi} may be reacted by shear chocks. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculation.

3.1.2.18 The stresses resulting from green sea design loads induced in the supporting structure are not to be greater than the permissible values given below, based on the gross thickness of the structure:

Normal stress 1.00 σ_{yd}

Shear stress 0.58 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.3 Supporting structure for mooring winches

3.1.3.1 Mooring winches are to be efficiently bedded and secured to the deck. The deck thickness in way of mooring winches is to be compatible with the deck attachment design.

3.1.3.2 In addition to complying with the requirements of **3.1.3.6**, the shipbuilder and mooring winch manufacturer are to satisfy themselves that the foundation is suitable for the safe operation and maintenance of the mooring winch equipment.

3.1.3.3 The Rated Pull is defined as the maximum load which the mooring winch is designed to exert during operation and is to be stated on the mooring winch foundation/support plan.

3.1.3.4 The Holding Load is defined as the maximum load which the mooring winch is designed to resist during operation and is to be taken as the design brake holding load or equivalent and is to be stated on the mooring winch foundation/support plan.

3.1.3.5 The following plans and information are to be submitted for approval:

(a) details of the supporting structure for mooring winches

(b) details of the mooring winch foundation design, including material specifications for hold down bolts and the connection of the foundation to the deck

(c) design loads as specified in **3.1.3.8** and **3.1.3.9** and associated reaction forces applied to the foundation and supporting structure.

3.1.3.6 The scantlings of the support structure are to be dimensioned to ensure that, for each of the load cases specified in **3.1.3.8** and **3.1.3.9**, the calculated stresses in the support structure do not exceed the permissible stress levels specified in **3.1.3.13** and **3.1.3.14**, respectively.

3.1.3.7 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using net scantlings.

3.1.3.8 Each of the following load cases are to be examined for design loads due to mooring operation:

(a) mooring winch at maximum pull: 100 % of the rated pull

(b) mooring winch with brake effective: 100 % of the holding load

(c) line strength: 125 % of the breaking strength of the mooring line (hawser) required by **Table 11.4.2** for the ship's corresponding equipment number

Rated pull and holding load are defined in **3.1.3.3** and **3.1.3.4**. The design load is to be applied through the mooring line according to the arrangement shown on the mooring arrangement plan.

3.1.3.9 For mooring winches situated within the forward 0.25 L, the load cases for green seas are to be applied as indicated in **3.1.2.9.**

3.1.3.10 For mooring winches situated within the forward 0.25 L, the resultant forces in the bolts obtained from green sea design loads are to be calculated in accordance with **3.1.2.10** to **3.1.2.12.**

3.1.3.11 The resultant forces from the application of the loads specified in **3.1.3.8** and **3.1.3.9** are to be considered in the design of the supporting structure.

3.1.3.12 Where a separate foundation is provided for the mooring winch brake, the distribution of resultant forces is to take account of the different load path. The brake is only to be considered in relation to the forces in **3.1.3.8**, load case (b).

3.1.3.13 The stresses resulting from mooring operation design loads, induced in the supporting structure, are not to exceed those given in **3.1.2.15.**

3.1.3.14 For mooring winches situated within the forward 0.25 L, the stresses resulting from green sea design loads, induced in the bolts and supporting structure, are not to exceed values indicated in **3.1.2.16** through **3.1.2.18.**

3.1.4 Supporting structure for cranes, derricks and lifting masts

3.1.4.1 Support structures of cranes, derricks and lifting masts with a Safe Working Load greater than 30 kN, or a maximum overturning moment to the supporting structure greater than 100 kNm, are to comply with the following requirements.

3.1.4.2 These requirements apply to the connection to the deck and the supporting structure of cranes, derricks and lifting masts. Where the crane, derrick or lifting mast is to be certified by the Classification Society, additional requirements may be applied by the individual Society.

3.1.4.3 These requirements do not cover the following items:

(a) supports of lifting appliances for personnel or passengers, see **3.1.7.5**

(b) the structure of the lifting appliance pedestals or post above the area of the deck connection

(c) holding down bolts and their arrangement, which are considered part of the lifting appliance.

3.1.4.4 The term, Lifting Appliance, is defined as a crane, derrick or lifting mast.

3.1.4.5 The Safe Working Load is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.

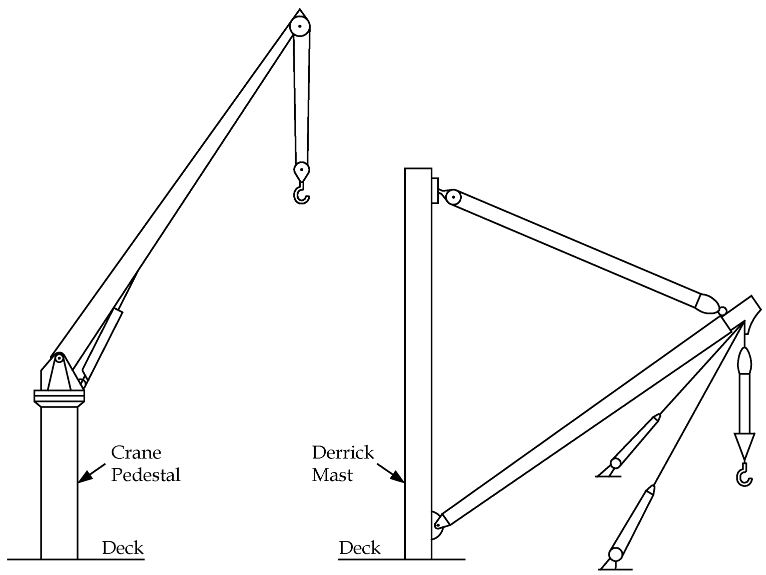
3.1.4.6 The Self Weight is the calculated gross self weight of the lifting appliance, including the weight of any lifting gear.

3.1.4.7 The Overturning Moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at Safe Working

Load, taking into account outreach and self weight.

3.1.4.8 The Crane Pedestal and Derrick Mast are as defined in **Fig 11.3.3.**

Fig 11.3.3
Crane Pedestal and Derrick Mast



3.1.4.9 The following plans and information are to be submitted for approval:
(a) details of the supporting structure of the lifting appliance, including its connection of the deck
(b) details of the Safe Working Load, self weight, vertical reaction forces and the maximum overturning moment in the supporting structure of the lifting appliance
(c) for offshore operation, the maximum sea state in which the lifting appliance is to be used.

3.1.4.10 The following supporting information is also to be submitted:
(a) a general arrangement drawing of the crane/derrick/lifting mast.

3.1.4.11 Deck plating and under deck structure is to provide adequate support for derrick masts against the calculated vertical loads and maximum overturning moment. Where the deck is penetrated, the deck plating is to be suitably strengthened.

3.1.4.12 Deck plating and under deck structure is to provide adequate support for crane pedestals against the calculated vertical loads and maximum overturning moment.

3.1.4.13 In general, structural continuity of the deck structure is to be maintained and deep under-deck members are to be provided to support the crane pedestal.

3.1.4.14 Depending on the arrangement of the deck connection in way of crane pedestals, the following additional requirements are to be complied with:
(a) where the pedestal is directly connected to the deck, without above deck brackets, adequate under deck structure directly in line with the crane pedestal is to be provided. Where the crane pedestal is attached to the deck without bracketing or where the crane pedestal is not continuous through the deck, welding to the deck of the crane pedestal and its under deck support structure is to be made by suitable full penetration welding. This could include a deep penetration welding procedure with a maximum root face of 3 mm provided this results in full penetration and consequently enable ultrasonic lamination testing after welding has been completed. The design of the weld connection is to be adequate for the calculated stress in the welded connection, in accordance with **3.1.4.21.**
(b) where the pedestal is directly connected to the deck with brackets, under deck support struc-

ture is to be fitted to ensure a satisfactory transmission of the load, and to avoid structural hard spots. Above deck brackets may be fitted inside or outside of the pedestal and are to be aligned with deck girders and webs. The design is to avoid stress concentrations caused by an abrupt change of section. Brackets and other direct load carrying structure and under deck support structure are to be welded to the deck by suitable full penetration welding. This could include a deep penetration welding procedure with a maximum root face of 3mm provided this results in full penetration and consequently enables ultrasonic lamination testing after welding has been completed. The design of the connection is to be adequate for the calculated stress, in accordance with **3.1.4.21.**

3.1.4.15 Deck plates are to be of a thickness and material strength compatible with the crane pedestal. Where necessary, a thicker insert plate is to be fitted. In no case are doublers to be used where structures are subject to tension.

3.1.4.16 The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in **3.1.4.18** and **3.1.4.19**, the calculated stresses in the support structure do not exceed those given in **3.1.4.21.**

3.1.4.17 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or beam element finite-element analysis using gross scantlings.

3.1.4.18 For lifting appliances which are limited to use in harbour, the following load scenario is to be examined:

(a) 130 % of the Safe Working Load added to the lifting appliances self weight.

3.1.4.19 For lifting appliances which may be used for offshore operations the following is to be submitted for approval purposes:

(a) the maximum sea state in which the lifting appliance is to be used

(b) the worst case vertical and horizontal accelerations

(c) the worst case wind loadings for the specified design sea state and wind environment.

The load scenario to be examined is to account for these environmental loads. As a minimum, the following load scenario is to be examined:

(a) 150 % of the Safe Working Load added to the lifting appliances self weight.

When a crane cab is fitted above the slewing ring, the load scenario is to be specially considered.

3.1.4.20 The vertical reaction force and maximum overturning moment, corresponding to the design loads specified in **3.1.4.18** and **3.1.4.19**, are to be calculated and used in the assessment of the structure.

3.1.4.21 The stresses induced in the supporting structure are not to exceed the permissible values given below, based on the gross thickness of the structure:

Normal stress 0.67 σ_{yd}

Shear stress 0.39 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.4.22 The capability of the supporting structure to resist buckling failure is also to be assured.

3.1.5 Supporting structures for components used in emergency towing arrangements on tankers

3.1.5.1 Tankers having a deadweight of greater than or equal to 20,000 tonnes are to be fitted with an emergency towing arrangement at both ends, complying with *Maritime Safety Committee Resolution MSC 35(63)*.

3.1.5.2 The Safe Working Load of emergency towing arrangements is as specified in *IMO Resolution MSC 35(63)*, as follows:
(a) 1,000 kN for vessels having a deadweight greater than or equal to 20,000 tonnes, but less than 50,000 tonnes
(b) 2,000 kN for vessels having a deadweight greater than or equal to 50,000 tonnes.

3.1.5.3 The following plans are to be submitted for approval:
(a) details of the supporting structure for the emergency towing arrangement, including the connection to the deck.

3.1.5.4 The following supporting information is also to be submitted:
(a) details of the emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.1.5.5 The deck in way of strong-points and fairleads is to have a minimum gross thickness of 15 mm.

3.1.5.6 The structural arrangement is to provide continuity of strength.

3.1.5.7 The structural arrangement of the ship's structure in way of the emergency towing equipment is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

3.1.5.8 The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in **3.1.5.10** and **3.1.5.11**, the calculated stresses in the support structure do not exceed the permissible stress levels specified in **3.1.5.12.**

3.1.5.9 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using gross scantlings.

3.1.5.10 The design load for the connection of the strong-point and fittings to the deck and its supporting structure is to be taken as twice the Safe Working Load.

3.1.5.11 The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed. See *IMO MSC 35(63)*.

3.1.5.12 For the design load specified in **3.1.5.10** and **3.1.5.11** the stresses induced in the supporting structure and welds, in way of strong-points and fairleads, are not to exceed the permissible values given below based on the gross thickness of the structure:

Normal stress 1.00 σ_{yd}

Shear stress 0.58 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.5.13 The capability of the structure to resist buckling failure is also to be assured.

3.1.6 Supporting structure for bollards and bitts, fairleads, stand rollers, chocks and capstans

3.1.6.1 In general, shipboard fittings (bollards and bitts, fairleads, stand rollers and chocks) and capstans used for mooring, and towing (other than as specified in **3.1.5**) of the vessel are to be fitted to the deck or bulwark structures using a purpose designed base or attachment.

3.1.6.2 The attachment of shipboard fittings to sheer strakes or sheer strake upstands is to be avoided, as required by **Sec 8/2.2.5.2** and **Sec 8/2.2.5.3.**

3.1.6.3 Where fairleads are fitted in bulwarks and the imposed loads from mooring or towing lines are high, the thickness of bulwarks may need to be increased. See also **2.1.2.**

3.1.6.4 The following plans are to be submitted for approval:
(a) details of the supporting structure for the shipboard fitting and capstan arrangements, including the connection of shipboard fittings and their seats to the deck.

3.1.6.5 The following supporting information is also to be submitted:
(a) details of the shipboard fittings and capstans including the Safe Working Load of shipboard fittings and arrangements showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.1.6.6 The structural arrangement is to provide continuity of strength.

3.1.6.7 The structural arrangement of the ship's structure in way of the shipboard fittings and their seats and in way of capstans is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

3.1.6.8 The scantlings of the support structure are to be dimensioned to ensure that for the loads specified in **3.1.6.10**, **3.1.6.11** and **3.1.6.12**, the calculated stresses in the support structure do not exceed the permissible stress levels specified in **3.1.6.13.**

3.1.6.9 These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two-dimensional grillage or finite-element analysis using net scantlings. The required gross thickness is obtained by adding the relevant full corrosion addition specified in **Sec 6/3** to the required net thickness.

3.1.6.10 The design load for the connection of shipboard fittings and their seats to the deck and its supporting structure is to be based on the line load as the greater of the following requirements, as applicable for the particular fitting and its intended use:
(a) in the case of normal towing in harbour or maneuvering operations, 125 % of the maximum towline load as indicated on the towing and mooring arrangement plan, or
(b) in the case of towing service other than that experienced in harbour or maneuvering operations, such as escort service, the nominal breaking strength of towline according to **Table 11.4.2** for the ship's corresponding equipment number, or
(c) in the case of mooring operations 125 % of the nominal breaking strength of the mooring line (hawser) or towline according to **Table 11.4.2** for the ship's corresponding equipment number.

3.1.6.11 The design load for the supporting structure for capstans is to be based the following:
(a) 125 % of the maximum hauling in force.

3.1.6.12 The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed, however, the total load applied for towing and mooring scenarios described in **3.1.6.10** need not be more than twice the design load on the mooring line or towline. The acting point for the force on the shipboard fittings is to be taken as the attachment point of the mooring line or towline, or at a change in its direction.

3.1.6.13 For the design load specified in **3.1.6.10**, **3.1.6.11** and **3.1.6.12** the stresses induced in the supporting structure and welds are not to exceed the permissible values given below based on the net thickness of the structure. The required gross thickness is obtained by adding the relevant full corrosion addition specified in **Sec 6/3** to the required net thickness.

Normal stress 1.00 σ_{yd}

Shear stress 0.60 σ_{yd}

Where:

σ_{yd} specified minimum yield stress of the material, in N/mm^2

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress.

3.1.6.14 The capability of the structure to resist buckling failure is also to be assured.

3.1.6.15 The following requirements on Safe Working Load apply for a single post basis (no more than one turn of one cable).

(a) The Safe Working Load used for normal towing operations (e.g., harbour/maneuvering is not to exceed 80 % of the design load per **3.1.6.10(a)** and the Safe Working Load used for other towing operations (e.g., escort) is not to exceed the design load per **3.1.6.10(b)**. For deck fittings used for both normal and other towing operations, the greater of the design loads of **3.1.6.10(a)** and **3.1.6.10(b)** is to be used.

(b) The Safe Working Load for mooring operations is not to exceed 80% of the design load per **3.1.6.10(c).**

(c) The Safe Working Load of each deck fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing and/or mooring.

(d) The towing and mooring arrangements plan mentioned in **3.1.6.16** is to define the method of use of towing lines and/or mooring lines.

3.1.6.16 The Safe Working Load for the intended use for each deck fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. Information provided on the plan is to include in respect of each deck fitting:

(a) Location on the ship;

(b) Fitting type;

(c) SWL;

(d) Purpose (mooring/harbour towing/escort towing); and

(e) Manner of applying towing or mooring line load including limiting fleet angles.

This information is to be incorporated into the pilot card in order to provide the pilot proper information on harbour/escorting operations.

3.1.7 Supporting structures for other deck equipment or fittings which are subject to specific approval

3.1.7.1 The following requirements relate to other items of deck equipment which are not covered by **3.1.2** to **3.1.6**. The scantlings and arrangements of support structure for such items are to be in accordance with the following requirements and the additional requirements of the individual Classification Society.

3.1.7.2 The support structure of items not mentioned in this sub-section will be independently considered by the individual Classification Society.

3.1.7.3 The following details are to be submitted for approval. They may be indicated separately or may be included on the main structural drawings:

(a) plans showing the supporting structure for deck equipment/fittings

(b) details of the loads imposed on the structure by the deck equipment/fittings.

3.1.7.4 The support structure is to be arranged in order to resist both in-plane and out-of-plane loads acting on the deck structure.

3.1.7.5 Support for lifting appliances for personnel is to be provided as follows:

(a) in general, lifesaving appliances (lifeboats, life-rafts and rescue boats) are to be stowed on a purpose built cradle, seat or deployment appliance. The design load imposed on the ship structure is to be established by the supplier of the lifesaving appliance

(b) the support structure is to be adequate for the design loads. Local stiffening and a local increase in plating thickness is to be provided. Deep supporting members may be required. Additional National and International Regulations are to be applied, where applicable

(c) support structure for crew lifts is to be provided in way of the anchor points of lift operating equipment

(d) support structure for boarding (accommodation) ladders is to be provided in way of the anchor points of accommodation ladders.

3.1.7.6 Support for mast structures fitted with navigation aids is to be provided as follows:

(a) adequate primary support members for the mast are to be arranged in the form of bulkheads, deep beams or girders. Such members are to be arranged below or close to the mast structure

(b) in order to transmit the loads from the mast structure to the primary support members, under-deck stiffening members are to be arranged below the mast structure forming the attachment of the mast to the deck

(c) the deck thickness may be required to be increased to provide an adequate thickness for the weld attachments.

3.1.7.7 Supporting structure for breakwaters is to be designed to withstand the same design load as the breakwater itself. It is to be suitable for transmitting the loads from the breakwater into the primary supporting members of the ship. Efficient under-deck stiffening is to be provided in way of the breakwater structure that forms the deck connection.

3.1.8 Support and attachment of miscellaneous deck fittings which are not subject to specific approval

3.1.8.1 The following general requirements are to be considered in the design of the support and attachment of miscellaneous fittings which impose relatively small loads on the ship's structure and are not subject to specific approval. The arrangements of such details do not require the approval of plans by the Classification Society.

3.1.8.2 Support positions are to be arranged so that the attachment to the ship structure is clear of deck openings and stress concentrations, such as the toes of end brackets. Design of supports is to be such that the attachment to the deck minimises the creation of hard points.

3.1.8.3 A cargo manifold support is a self-contained, fabricated assembly designed to support the main pipework used for loading and unloading the ship. The design of the cargo manifold support is to be such as to distribute the loads imposed on the pipework during loading and unloading into the ship structure. To achieve this, the connection of the cargo manifold support to the deck is normally to be arranged to align with stiffening members of the main hull structure. Where this is impracticable, additional stiffening is to be fitted in order to avoid the creation of hard points. Attention is to be paid to the detail design of the structure forming the deck attachment in order to minimise the effects of change of section.

3.2 Docking

3.2.1 Docking arrangements

3.2.1.1 The dry docking arrangement itself is not covered explicitly in these Rules.

3.2.1.2 The structure of bottom girders is to be sufficiently stiffened to withstand the forces imposed by dry docking the ship.

3.2.1.3 For ships of unusual form, or where the Owner of the vessel has specific requirements for docking strength, the builder may need to carry out additional calculations. Such calculations are outside of the scope of Classification, but may be reviewed upon request.

3.2.2 Docking plan

3.2.2.1 It is recommended that consideration be given to providing a docking plan for a vessel. The docking plan is to indicate any and all assumptions made during the design, including but not limited to, the arrangement of docking blocks, the maximum permissible loading during docking and the corresponding load at each block.

3.2.2.2 The docking plan does not require approval by the Society as a condition of Classification.

Guidance Note:

1. It is recommended that bottom plugs are not fitted in way of the keel plate.

3.3 Bilge Keels

3.3.1 Construction and materials

3.3.1.1 The bilge keel is to be of the same material tensile properties as the bilge strake to which it is attached.

3.3.1.2 Bilge keels of a different design, from that shown in **Fig 11.3.4**, will be specially considered.

3.3.1.3 A plan of all bilge keels is to be submitted for the approval of the material strength and grades, welded connections and detail design.

3.3.1.4 The design of single web bilge keels is to ensure that failure to the web occurs before failure of the ground bar. In general, this may be achieved by ensuring the web thickness of the bilge keel does not exceed that of the ground bar.

3.3.2 Ground bars

3.3.2.1 Bilge keels, where fitted, are to be attached to the shell by a ground bar, or doubler, as shown in **Fig 11.3.4** and **11.3.5**. In general, the ground bar is to be continuous.

3.3.2.2 The gross thickness of the ground bar is not to be less than the gross thickness of the bilge strake or 14 mm, whichever is the lesser.

3.3.2.3 The ground bar is to be of the same material strength as the bilge strake to which it is attached and constructed of the steel grade given in **Sec 6/1.2**, **Tables 6.1.2** and **6.1.3** for bilge strakes.

3.3.3 End details

3.3.3.1 The ends of the bilge keel are to be suitably tapered and are to terminate on an internal stiffening member. Typical arrangements complying with the requirements of this subsection are shown in **Fig 11.3.5**. Alternative end arrangements will be accepted, provided that they are considered equivalent.

3.3.3.2 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with a minimum ratio of 3:1. See **Fig 11.3.5(a), 11.3.5(b), 11.3.5(d)** and **11.3.5(e)**. Where the ends are rounded, details are to be as shown in **Fig 11.3.5(c)**. Cut outs on the bilge keel web, within zone ‘A’, see **Fig 11.3.5(b)** and **11.3.5(e)**, are not permitted.

3.3.3.3 The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground bar. See **Fig 11.3.5(a)** and **11.3.5(d).**

3.3.3.4 An internal transverse support member is to be positioned between the end of the bilge keel web and the halfway point between the end of the bilge keel web and the end of the ground bar. See **Fig 11.3.5(a), 11.3.5(b)** and **11.3.5(c).**

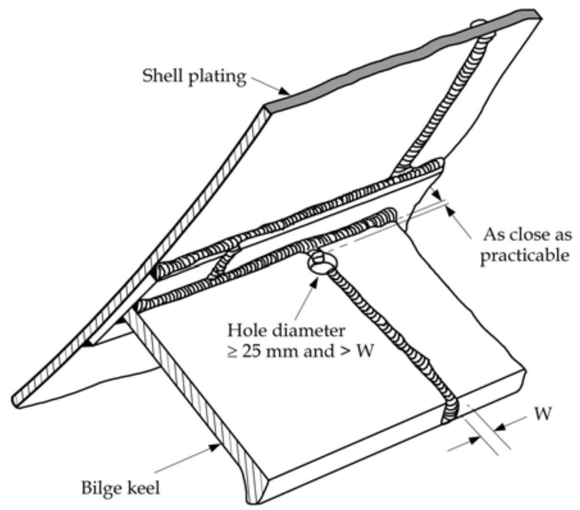
3.3.3.5 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member forward and aft of zone ‘A’. See **Fig 11.3.5(b)** and **11.3.5(e)**. In this case, the requirement in **3.3.3.4** relating to the internal transverse support does not apply.

3.3.4 Welding

3.3.4.1 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a light continuous fillet weld, in accordance with **Table 11.3.1.**

3.3.4.2 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

Fig 11.3.4
Bilge Keel Construction



3.3.4.3 In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of hole is to be greater than the width of the butt weld and is to be a minimum of 25 mm in diameter, as illustrated in **Fig 11.3.4**. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

3.3.4.4 Welds at the end of the ground bar and shell plating, and at the end of the bilge keel web and ground bar connection, within Zone ‘B’, see **Fig 11.3.5(a)** and **11.3.5(d)** are to have a throat thickness as given in **Table 11.3.1** for “A tends”. The toes of these welds are to be ground to blend them smoothly with the base materials.

Fig 11.3.5 (a) – (c)
Bilge Keel End Design

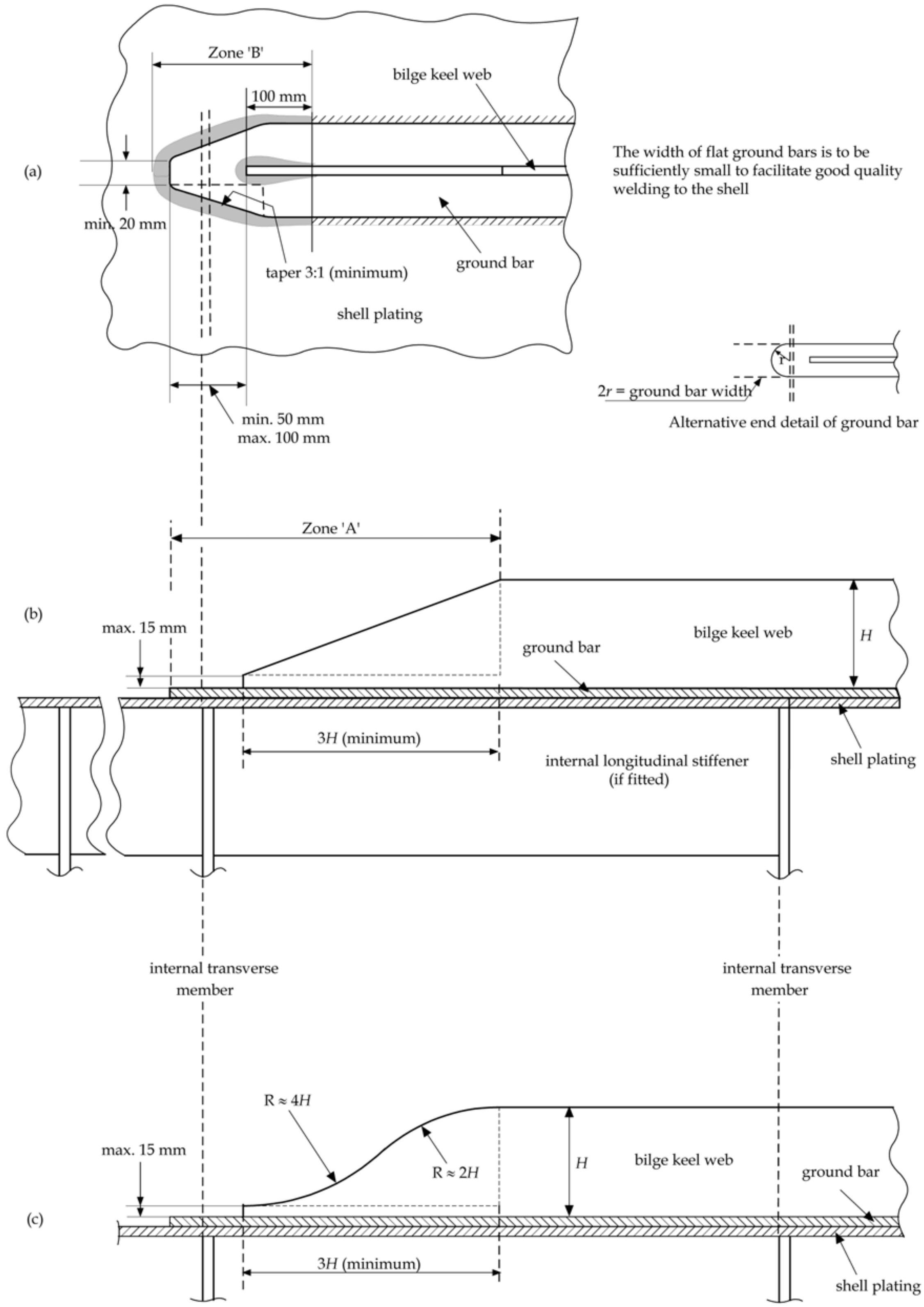


Fig 11.3.5 (d) – (e)
Bilge Keel End Design

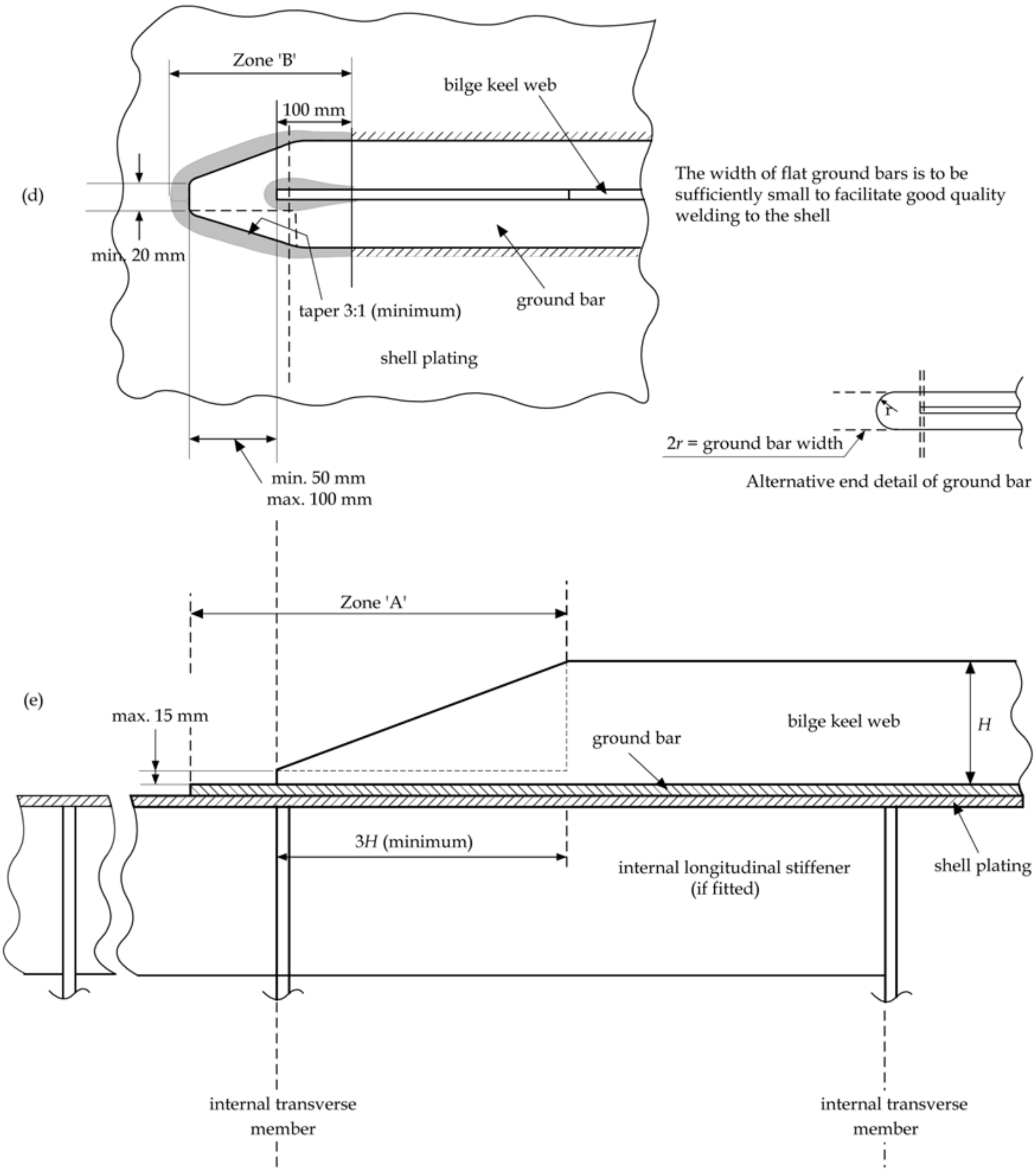


Table 11.3.1
Welding Requirements for End Connections of Bilge Keels

Structural items being joined	Throat thickness, in mm	
	At ends	Elsewhere
Ground bar to shell	0.44 t_{grs}	0.34 t_{grs}
Bilge keel web to ground bar	0.34 t_{grs}	0.21 t_{grs}
Where: t_{grs} gross thickness of the item being attached, in mm		

4 Equipment

4.1 Equipment Number Calculation

4.1.1 Requirements

4.1.1.1 Anchors and chains are to be in accordance with **Table 11.4.1** and the quantity, mass and sizes of these are to be determined by the equipment number (*EN*), given by:

$$EN = \Delta^{2/3} + 2Bh_{dk} + 0.1A$$

Where:

Δ	moulded displacement, in tonnes, as defined in **Sec 4/1.1.7.1**
B	moulded breadth, in m, as defined in **Sec 4/1.1.3.1**
h_{dk}	$h_{FB}+h_1+h_2+h3+...$, as shown in **Fig 11.4.1**. In the calculation of h, sheer, camberand trim may be neglected
hFB	freeboard from the summer load waterline amidships, in m
$h_1, h_2, h_3 \cdots h_n$	height on the centreline of each tier of houses having a breadth greater than $B/4$, in m
A	profile area of the hull, superstructure and houses above the summer load waterline which are within the length L, in m^2. Superstructures or deck houses having a breadth equal to or less than $B/4$ at any point may be excluded. With regard to determining A, when a screen or bulwark is more than 1.5 m high, the area shown in **Fig 11.4.2** as A_2 is to be included in A
L	rule length, as defined in **Sec 4/1.1.1.1**

Fig 11.4.1
Effective Heights of Deck Houses

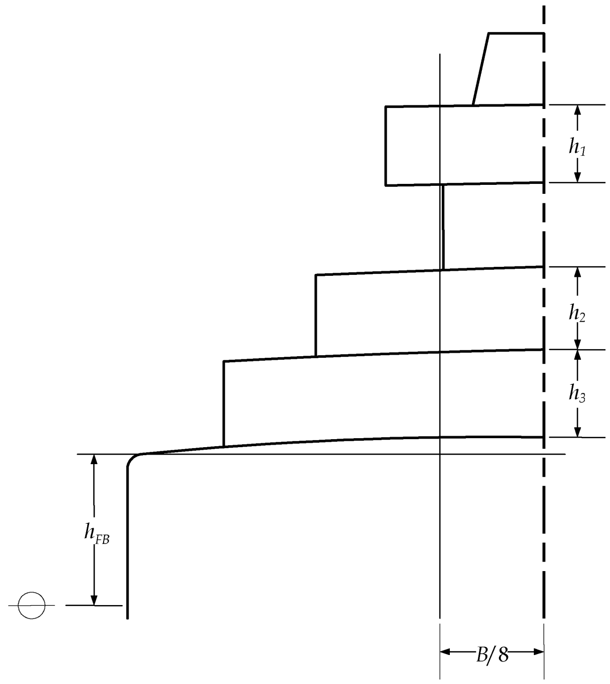
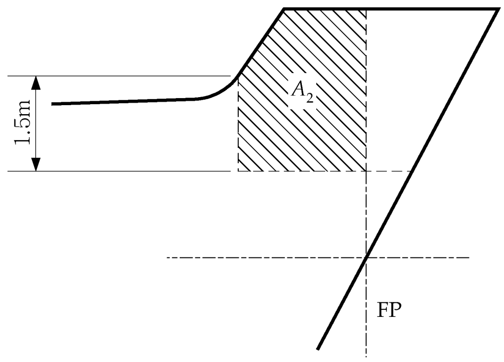


Fig 11.4.2
Profile Areas of Screens and Bulwarks



4.2 Anchors and Mooring Equipment

4.2.1 General

4.2.1.1 The following anchoring equipment specification is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

4.2.2 Limitations

4.2.2.1 The equipment specified is not intended to be adequate to hold a ship off fully exposed coasts in rough weather or to stop a ship that is moving or drifting. In such a condition, the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost.

4.2.2.2 The anchoring equipment specified is intended to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground, the ability of the anchors to hold the ship will be significantly reduced.

4.2.3 Assumptions

4.2.3.1 The Equipment Number (*EN*) formula for the required anchoring equipment is based on an assumed current speed of 2.5 m/s, wind speed of 25 m/s and a scope of chain cable between 6 and 10. The scope of chain cable is defined as the ratio between the length of chain paid out and the waters depth.

4.2.3.2 It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

4.2.4 Documentation

4.2.4.1 The following plans and particulars are to be submitted for approval:

(a) equipment number calculations

(b) list of equipment including type of anchor, grade of anchor chain, type and breaking load of steel and fibre ropes

(c) anchor design, if different from standard or previously approved anchor types, including material specification

(d) windlass design; including material specifications for cable lifters, shafts, couplings and brakes

(e) chain stopper design and material specification

(f) emergency towing, towing and mooring arrangement plans and applicable Safe Working Load data, and other information related to emergency towing and mooring arrangements that will be available onboard the ship for the guidance of the Master.

4.2.5 Anchors

4.2.5.1 Two bower anchors are to be connected to chain cable and stowed in position ready for use.

4.2.5.2 A third anchor is recommended to be provided as a spare bower anchor and is listed for guidance only; it is not required as a condition of classification.

4.2.5.3 Anchors are to be of an approved design. The design of anchor heads is to be such as to minimize stress concentrations. In particular, the radii, on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

4.2.5.4 The mass per anchor of bower anchors given in **Table 11.4.1** is for anchors of equalmass. The mass of individual anchors may vary 7 % above or below the tabulated value, provided that the combined mass of all anchors is not less than that required for anchors of equal mass.

4.2.6 Ordinary anchors

4.2.6.1 Anchors are to be of the stockless type. The mass of the head of a stockless anchor, including pins and fittings, is not to be less than 60 % of the total mass of the anchor.

4.2.7 High holding power anchors

4.2.7.1 Where agreed by the Owner, consideration will be given to the use of special types of anchors. Where these are of a proven increased holding ability, consideration may also be given to some reduction in the basic requirement of anchor mass, up to a maximum of 25 percent from the mass specified in **Table 11.4.1.**

4.2.7.2 An anchor for which approval is sought as a high holding power (HHP) anchor is to be tested at sea to show that it has a holding power of twice that approved for a standard stockless anchor of the same mass.

4.2.7.3 If approval is sought for a range of sizes then at least two are to be tested. The smaller of the two anchors is to have a mass not less than one-tenth of that of the larger anchor. The larger of the two anchors tested is to have a mass not less than one-tenth of that of the largest anchor for which approval is sought.

4.2.7.4 Each test is to comprise a comparison between at least two anchors, one ordinary stockless bower anchor and one HHP anchor. The masses of the anchors are to be approximately equal.

4.2.7.5 The tests are to be conducted on at least three different types of bottom, which may be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

4.2.7.6 The tests are generally to be carried out by means of a tug. The pull is to be measured by a dynamometer or determined from recently verified data of the tug's bollard pull as a function of propeller rpm.

4.2.7.7 The diameter of the chain cables connected to the anchors is to be as required for the relevant Equipment Number. During the test, the length of the chain cable on each anchor is to be sufficient to obtain an approximately horizontal pull on the anchor. Generally, a horizontal distance between anchor and tug equal to 10 times the water depth will be sufficient.

4.2.7.8 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by **4.2.7.2**, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. A demonstration of these abilities may be required.

4.2.7.9 The design approval of high holding power anchors may be given as a general/type approval, and listed in a published document by the Society.

4.2.8 Chain cables

4.2.8.1 The total length of chain required to be carried onboard, as given in **Table 11.4.1**, is to be divided approximately equally between the two bower anchors.

4.2.8.2 Where the Owner requires equipment for anchoring at depths greater than 82.5 m, it is the Owner's responsibility to specify the appropriate total length of the chain cable required. In such a case, consideration can be given to dividing the chain cable into two unequal lengths

4.2.8.3 Chain cables which are intended to form part of the equipment are not to be used as check chains when the vessel is launched.

4.2.9 Chain lockers

4.2.9.1 The chain locker is to have adequate capacity and be of a suitable form to provide for the proper stowage of the chain cable, allowing an easy direct lead for the cable into the chain pipes when the cable is fully stowed. Port and starboard cables are to have separate spaces.

4.2.9.2 The chain locker boundaries and access openings are to be watertight. Provisions are to be made to minimize the probability of the chain locker being flooded in bad weather. Adequate drainage facilities for the chain locker are to be provided.

4.2.9.3 Chain or spurling pipes are to be of suitable size and provided with chafing lips.

4.2.9.4 Chain lockers fitted aft the collision bulkhead are to be watertight and the space is to be efficiently drained.

4.2.10 Securing and emergency release of chain cable

4.2.10.1 Provisions are to be made for securing the inboard ends of the chain to the structure. This attachment is to be able to withstand a force of not less than 15 % or more than 30 % of the minimum breaking strength of the as fitted chain cable. The structure to which it is attached is to be adequate for this load.

4.2.10.2 The fastening of the chain to the ship is to be arranged in such a way that in case of an emergency, when the anchor and chain have to be sacrificed, the chain can be readily released from an accessible position outside the chain locker. The proposed arrangement for slipping the chain cable must be made as watertight as possible

4.2.11 Chain stoppers

4.2.11.1 Means are to be provided to secure each chain cable once it is paid out. This is normally achieved by means of chain stoppers.

4.2.11.2 Securing arrangements of chain stoppers are to be capable of withstanding a load equal to 80 % of the breaking load of the chain cable as required by **4.2.8**, without undergoing permanent deformation.

4.2.12 Tests

4.2.12.1 All anchors and chain cables are to be tested at establishments and on machines recognised by the Society, under the supervision of Surveyors or other Representatives of the Society and in accordance with the relevant requirements for materials of the individual Classification Society.

4.2.12.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be available. These certificates are to be examined by the Surveyor when the anchors and cables are placed onboard the ship.

4.2.12.3 Steel wire and fibre ropes are to be tested in

4.2.13 Mooring lines and towlines

4.2.13.1 Except as indicated in **4.3**, mooring lines and towlines are not required as a condition of Classification. The hawsers and towlines listed in **Table 11.4.2** are intended as a guide. Where the tabular breaking strength is greater than 490 kN, the breaking strength and the number of individual hawsers given in the Table may be modified, provided that their product is not less than that of the breaking strength and the number of hawsers given in the Table.

4.2.14 Increased number or strength of mooring lines

4.2.14.1 On a ship regularly using exposed berths, it is recommended that the total strength of mooring lines is twice that indicated in **4.2.13.1.**

4.2.14.2 Attention is also drawn to the Oil Companies International Marine Forum document, *Mooring Equipment Guidelines*, for guidance on mooring of tankers at exposed locations.

4.2.15 Alternative mooring arrangement

4.2.15.1 For ease of handling, fibre ropes should not to be less than 20 mm in diameter.

4.2.15.2 All ropes having breaking strengths greater than 736 kN and used in normal mooring operations should be handled by, and stored on, suitably designed winches. Alternative methods of storing are to give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490 kN. In such cases, the breaking strength and the number of individual hawsers given in **Table 11.4.2** may be modified, but their product is not to be less than that of the breaking strength and the number of hawsers given in the Table. However, the number of mooring lines is not be less than six, and no line should have a breaking strength less than 490 kN.

4.2.16 Securing mooring lines

4.2.16.1 Means should be provided to enable mooring lines to be adequately secured onboard ship. It is recommended that the total number of suitably placed bollards on either side of the ship and/or the total brake holding power of mooring winches is to be capable of holding not less than 1.5 times the sum of the maximum breaking strengths of the mooring lines.

4.2.17 Bollards and bitts, fairleads, stand rollers and chocks

4.2.17.1 The strength of shipboard fittings used for normal and/or emergency operations at bow, sides and stern are to comply with the requirements of **4.2.17.2** and **4.2.17.3**. The requirements for the support structure of these shipboard fittings are specified in **3.1.6.**

4.2.17.2 Shipboard fittings are to be designed and constructed in accordance with recognized standards (e.g. ISO3913 Shipbuilding Welded Steel Bollards). The design load used to assess shipboard fittings and their attachments to the hull are to be in accordance with **3.1.6.**

4.2.17.3 The following requirements on Safe Working Load (SWL) apply to shipboard fittings used for mooring and/or emergency towing:

(a) the SWL is not to exceed 80 % of the design load specified in **3.1.6.10(a)** and **3.1.6.10(c)** or 100 % of the design load specified in **3.1.6.10(b)**, as applicable

(b) the SWL of each fitting is to be marked by weld bead or equivalent

(c) the SWL with its intended use, i.e., mooring, towing or emergency towing operations or some combination thereof, for each fitting is to be indicated in the towing/emergency towing and mooring arrangement plans available onboard the ship for the guidance of the Master. The arrangement plans or information is to include information on each fitting detailing location on the ship, fitting type, Safe Working Load, purpose, method of applying load and limiting fleet angle, and it is to explicitly prohibit the use of mooring and/or towing lines outside of their intended function and/or different characteristics

(d) the requirements of this paragraph apply for a single post basis (no more than one turn of one cable).

4.2.18 Mooring winches

4.2.18.1 Mooring winch design and capacity are not subject to approval by the Society as a condition of Classification. Mooring winch plans and information are to be submitted for approval of the supporting structure in way of the winch and for the connection of the mooring winch to its foundation and the connection of the foundation to the deck, as required by **3.1.3.**

Guidance Note:

Mooring winches should be fitted with drum brakes, the strength of which is to be sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 percent of that for a rope with breaking strength equal to the greater of the maximum breaking strength of the rope specified on the mooring arrangement plan or that according to **Table 11.4.2** for the ship's corresponding equipment number, as fitted on the first layer on the winch drum.

4.2.19 Windlass

4.2.19.1 A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship in accordance with the requirements of the Classification Society. Where an Owner requires equipment significantly in excess of Rule requirements, it is the Owner's responsibility to specify increased windlass power.

4.2.19.2 The windlass is to be capable of heaving in either cable.

4.2.19.3 The design of the windlass is to be such that access to the chain pipe is adequate to permit the fitting of a cover or seal of sufficient strength over the spurring pipe.
Special consideration will be given to the acceptance of equivalent arrangements that minimize the probability of the chain locker or forecastle being flooded in bad weather.

4.2.20 Anchor windlass trial

4.2.20.1 Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation. Each unit is to be independently tested for the following:

(a) braking
(b) clutch functioning
(c) lowering and hoisting of chain cable and anchor
(d) proper riding of the chain over the chain lifter
(e) proper transit of the chain through the hawse pipe and the chain pipe
(f) effecting proper stowage of the chain and the anchor.

4.2.20.2 During trials onboard ship, the windlass is to be shown to:

(a) for all specified design anchorage depths, raise the anchor from a depth of 82.5 m to a depth of 27.5 m at a mean speed of 9 m/min
(b) for specified design anchorage depths greater than 82.5 m, in addition to (a), raise the anchor from the specified design anchorage depth to a depth of 82.5 m at a mean speed of 3 m/min.

Where the depth of the water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

4.2.21 Stowage and deployment arrangements for anchors

4.2.21.1 Arrangements are to be provided to ensure the simple deployment, recovery and stowage of anchors. Such arrangements generally consist of a hawse pipe and anchor housing which may be in the form of a fabricated anchor box or pocket.

4.2.21.2 Where hawse pipes are not fitted, alternative arrangements will be specially considered.

4.2.22 Dimensions and scantlings of hawse pipes and anchor pockets

4.2.22.1 Hawse pipes are to be of a suitable size and configuration to ensure adequate clearance and an easy lead of the chain cable from the chain stopper through the ship's side.

4.2.22.2 Hawse pipes are to be of sufficient strength.

4.2.22.3 Anchor pockets are to be of substantial thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor, caused by wave action.

4.2.22.4 Hawse pipes and anchor pockets are to have full-rounded flanges or rubbing bars in order to minimize the nip on the cables and to minimize the probability of cable links being subjected to high bending stresses. The radius of curvature is to be such that at least three links of chain will bear simultaneously on the rounded parts of the upper and lower ends of the hawse pipes in those areas where the chain cable is supported during paying out and hoisting and when the vessel is at anchor.

4.2.23 Hull reinforcement

4.2.23.1 Hawse pipes are to be securely attached to thick, doubling or insert plates, by continuous welds.

4.2.23.2 Framing in way of hawse pipes or anchor pockets is to be reinforced as necessary to ensure a rigid fastening to the hull.

4.2.23.3 On ships provided with a bulbous bow, where it is not possible to obtain a suitable clearance between shell plating and the anchors during anchor handling, local reinforcements of the bulbous bow are to be provided in the form of increased shell plate thickness.

4.2.24 Testing

4.2.24.1 The anchors are to be shipped and unshipped so that the Surveyor is satisfied that there is no risk of the anchor jamming in the hawse pipe.

4.2.24.2 During the windlass trials at sea, the Surveyor is to be satisfied that upon release of the brake, the anchor immediately starts falling by its own weight.

4.2.24.3 When in position, hawse pipes and anchor pockets are to be thoroughly tested for watertightness by means of a hose in which the water pressure is in accordance with the requirements given in **Sub-sec 5.**

Table 11.4.1
Equipment - Bower Anchors and Chain Cables

Equipment number		Stockless bower anchors		Chain cable stud link bower chain diameter			
greater than or equal to	less than	Number of anchors	Mass per anchor, in kg	Length, in m	Normal strength steel (Grade1), in mm	Higher strength steel (Grade2), in mm	Extra higher strength steel (Grade3), in mm
150	175	2	480	275	22	19	
175	205	2	570	302.5	24	20.5	
205	240	2	660	302.5	26	22	20.5
240	280	2	780	330	28	24	22
280	320	2	900	357.5	30	26	24
320	360	2	1020	357.5	32	28	24
360	400	2	1140	385	34	30	26
400	450	2	1290	385	36	32	28
450	500	2	1440	412.5	38	34	30
500	550	2	1590	412.5	40	34	30
550	600	2	1740	440	42	36	32
600	660	2	1920	440	44	38	34
660	720	2	2100	440	46	40	36
720	780	2	2280	467.5	48	42	36
780	840	2	2460	467.5	50	44	38
840	910	2	2640	467.5	52	46	40
910	980	2	2850	495	54	48	42
980	1060	2	3060	495	56	50	44
1060	1140	2	3300	495	58	50	46
1140	1220	2	3540	522.5	60	52	46

Table 11.4.1
Equipment - Bower Anchors and Chain Cables

Equipment number		Stockless bower anchors		Chain cable stud link bower chain diameter			
greater than or equal to	less than	Number of anchors	Mass per anchor, in kg	Length, in m	Normal strength steel (Grade1), in mm	Higher strength steel (Grade2), in mm	Extra higher strength steel (Grade3), in mm
1220	1300	2	3780	522.5	62	54	48
1300	1390	2	4050	522.5	64	56	50
1390	1480	2	4320	550	66	58	50
1480	1570	2	4590	550	68	60	52
1570	1670	2	4890	550	70	62	54
1670	1790	2	5250	577.5	73	64	56
1790	1930	2	5610	577.5	76	66	58
1930	2080	2	6000	577.5	78	68	60
2080	2230	2	6450	605	81	70	62
2230	2380	2	6900	605	84	73	64
2380	2530	2	7350	605	87	76	66
2530	2700	2	7800	632.5	90	78	68
2700	2870	2	8300	632.5	92	81	70
2870	3040	2	8700	632.5	95	84	73
3040	3210	2	9300	660	97	84	76
3210	3400	2	9900	660	100	87	78
3400	3600	2	10500	660	102	90	78
3600	3800	2	11100	687.5	105	92	81
3800	4000	2	11700	687.5	107	95	84
4000	4200	2	12300	687.5	111	97	87
4200	4400	2	12900	715	114	100	87
4400	4600	2	13500	715	117	102	90
4600	4800	2	14100	715	120	105	92
4800	5000	2	14700	742.5	122	107	95
5000	5200	2	15400	742.5	124	111	97
5200	5500	2	16100	742.5	127	111	97
5500	5800	2	16900	742.5	130	114	100
5800	6100	2	17800	742.5	132	117	102
6100	6500	2	18800	742.5	*	120	107
6500	6900	2	20000	770	*	124	111
6900	7400	2	21500	770	*	127	114
7400	7900	2	23000	770	*	132	117
7900	8400	2	24500	770	*	137	122
8400	8900	2	26000	770	*	142	127
8900	9400	2	27500	770	*	147	132
9400	10000	2	29000	770	*	152	132
10000	10700	2	31000	770	*	*	137
10700	11500	2	33000	770	*	*	142
11500	12400	2	35500	770	*	*	147
12400	13400	2	38500	770	*	*	152
13400	14600	2	42000	770	*	*	157
14600	16000	2	46000	770	*	*	162

Note
1. Spare anchors are not included in the number of required anchors.
2. ‘*’ chain grade not to be used at this diameter.

Table 11.4.2
Equipment - Towline and Hawsers

Equipment number		Towline wire or rope		Hawsers		
greater than or equal to	less than	Length, in m	Breaking strength, in kN	Number	Length of each, in m	Breaking strength, in kN
150	175	180	98.0	3	120	54.0
175	205	180	112.0	3	120	59.0
205	240	180	129.0	4	120	64.0
240	280	180	150.0	4	120	69.0
280	320	180	174.0	4	140	74.0
320	360	180	207.0	4	140	78.0
360	400	180	224.0	4	140	88.0
400	450	180	250.0	4	140	98.0
450	500	180	277.0	4	140	108.0
500	550	190	306.0	4	160	123.0
550	600	190	338.0	4	160	132.0
600	660	190	371.0	4	160	147.0
660	720	190	406.0	4	160	157.0
720	780	190	441.0	4	170	172.0
780	840	190	480.0	4	170	186.0
840	910	190	518.0	4	170	201.0
910	980	190	559.0	4	170	216.0
980	1060	200	603.0	4	180	230.0
1060	1140	200	647.0	4	180	250.0
1140	1220	200	691.0	4	180	270.0
1220	1300	200	738.0	4	180	284.0
1300	1390	200	786.0	4	180	309.0
1390	1480	200	836.0	4	180	324.0
1480	1570	220	888.0	5	190	324.0
1570	1670	220	941.0	5	190	333.0
1670	1790	220	1024.0	5	190	353.0
1790	1930	220	1109.0	5	190	378.0
1930	2080	220	1168.0	5	190	402.0
2080	2230	240	1259.0	5	200	422.0
2230	2380	240	1356.0	5	200	451.0
2380	2530	240	1453.0	5	200	480.0
2530	2700	260	1471.0	6	200	480.0
2700	2870	260	1471.0	6	200	490.0
2870	3040	260	1471.0	6	200	500.0
3040	3210	280	1471.0	6	200	520.0
3210	3400	280	1471.0	6	200	554.0
3400	3600	280	1471.0	6	200	588.0
3600	3800	300	1471.0	6	200	618.0
3800	4000	300	1471.0	6	200	647.0
4000	4200	300	1471.0	7	200	647.0
4200	4400	300	1471.0	7	200	657.0
4400	4600	300	1471.0	7	200	667.0
4600	4800	300	1471.0	7	200	677.0
4800	5000	300	1471.0	7	200	686.0
5000	5200	300	1471.0	8	200	686.0
5200	5500	300	1471.0	8	200	696.0
5500	5800	300	1471.0	8	200	706.0
5800	6100	300	1471.0	8	200	706.0
6100	6500	300	1471.0	9	200	716.0
6500	6900	300	1471.0	9	200	726.0
6900	7400	300	1471.0	10	200	726.0
7400	7900	300	1471.0	11	200	726.0
7900	8400	300	1471.0	11	200	735.0
8400	8900	300	1471.0	12	200	735.0
8900	9400	300	1471.0	13	200	735.0
9400	10000	300	1471.0	14	200	735.0

Table 11.4.2
Equipment – Towline and Hawsers

Equipment number		Towline wire or rope		Hawsers		
greater than or equal to	less than	Length, in m	Breaking strength, in kN	Number	Length of each, in m	Breaking strength, in kN
10000	10700	-	-	15	200	735.0
10700	11500	-	-	16	200	735.0
11500	12400	-	-	17	200	735.0
12400	13400	-	-	18	200	735.0
13400	14600	-	-	19	200	735.0
14600	16000	-	-	21	200	735.0

4.3 Emergency Towing

4.3.1 General requirements

4.3.1.1 Emergency towing arrangements are to be fitted at both the bow and stern of every tanker with a deadweight of 20,000 tonnes or more, as required by the *International Convention for the Safety of Life at Sea, 1974, as amended (Regulation II-1/3-4)*.

4.3.1.2 The design and construction of the towing arrangements is to be approved by the applicable Flag Administration, based on *IMO MSC.35(63), Guidelines for Emergency Towing Arrangements on Tankers*. See also **3.1.5** for requirements relating to the support structure of emergency towing equipment.

5 Testing Procedures

5.1 Tank Testing

5.1.1 Application

5.1.1.1 The following tanks and boundaries are to be tested in accordance with the requirements given in **5.1.3** to **5.1.9**, as follows:

(a) gravity tanks, excluding independent tanks of less than 5 m^3 in capacity, for their structural adequacy and tightness

(b) watertight boundaries, other than tank boundaries, for watertightness

(c) weathertight boundaries for weathertightness.

5.1.2 Definitions

5.1.2.1 Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed.

5.1.2.2 Weathertight means that in any sea conditions water will not penetrate into the ship.

5.1.2.3 Structural Testing is a hydrostatic test carried out in order to demonstrate structural adequacy of the design. Where severe practical limitations prevail and hydrostatic testing is not feasible, hydropneumatic testing may be carried out instead.

5.1.2.4 Leak Testing is an air or other medium test, carried out in order to demonstrate the tightness of the structure.

5.1.2.5 Hose Testing is carried out by a jet of water in order to demonstrate the tightness of the structure items which are not subjected to hydrostatic or leak testing, and to other components which contribute to the watertight or weathertight integrity of the hull.

5.1.2.6 Hydropneumatic Testing is a combination of hydrostatic and air testing, undertaken by filling the tank with water and applying an additional air pressure. It is carried out in order to demonstrate the tightness of the tanks and the structural adequacy of the design as an alternative to a hydrostatic test.

5.1.2.7 Hydrostatic Testing is a test to verify the structural adequacy of the design and the tightness of the tank's structure by means of water pressure, produced by filling water to the level given in **Table 11.5.1**. Hydrostatic testing is the normal means for structural testing, with exception, where severe practical limitations prevent it or where air testing is permitted.

5.1.2.8 Shop Primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

5.1.2.9 Protective Coating is the coating system applied to protect the structure from corrosion. This excludes the shop primer.

5.1.3 Test procedures

5.1.3.1 Tests are to be carried out in the presence of, and to the satisfaction of the Surveyor. The construction is to be at a stage sufficiently close to completion, after all attachments, outfittings or penetrations, which may affect the strength or tightness of the structure, have been completed, such that the strength and tightness are not subsequently impaired, and before any ceiling and cement work is applied over joints.

5.1.3.2 Specific test requirements are given in **Table 11.5.1.**

5.1.3.3 For the timing of the application of coating in relation to testing, see **5.1.8.**

5.1.4 Structural testing

5.1.4.1 Where structural testing is specified by **Table 11.5.1**, hydrostatic testing will be acceptable, except where practical limitations prevent it or where leak testing is permitted by Note 1 to

Table 11.5.1. Hydropneumatic testing may be approved in lieu of hydrostatic testing.

5.1.4.2 Hydrostatic testing is to consist of a head of water to the level specified in **Table 11.5.1.**

5.1.4.3 Hydropneumatic testing, where approved, is to simulate the actual loading as far as practicable in relation to the combined water level and air pressure. The requirements and recommendations in **5.1.5** relative to air pressure will also apply.

5.1.4.4 Structural testing may be carried out afloat where testing using water is undesirable in dry dock or on the building berth. When structural testing is carried out afloat it is to be performed by filling each tank and cofferdam separately to the test head given in **Table 11.5.1.**

5.1.4.5 With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the lower side shell is to be examined when the water has been transferred to the remaining tanks.

5.1.4.6 Tank boundaries are to be tested from at least from one side. Tanks to be tested for structural adequacy (see Note 1 to **Table 11.5.1**) are to be selected so that all representative structural members are tested for the expected tension and compression.

5.1.5 Leak testing

5.1.5.1 All boundary welds, erection joints, and penetrations including pipe connections, are to be examined in accordance with the approved procedure and under a pressure of at least 0.15 bar with a leak indicating solution (e.g. soapy water solution). Pressures greater than 0.20 bar are not recommended.

5.1.5.2 It is recommended that the air pressure in the tank be raised to and maintained at 0.20 bar for approximately one hour, with a minimum number of personnel around the tank, before being lowered to the test pressure.

5.1.5.3 A U-tube filled with water up to a height corresponding to the required test pressure is to be fitted for verification and to avoid over pressure. The cross sectional area of the U-tube is to be not less than that of the pipe supplying the air. In addition to the U-tube, a master gauge or other approved means is to be provided to verify the pressure.

5.1.5.4 Other effective methods of leak testing, including compressed air fillet weld testing or vacuum testing may be considered upon submission of full particulars.

5.1.6 Hose testing

5.1.6.1 Hose testing is applied to structures not subjected to structural or air testing but that are required to be watertight or weathertight as specified in **Table 11.5.1.**

5.1.6.2 Hose testing is to be carried out with a pressure in the hose of at least 2.0 bar for the duration of the test. The nozzle is to have minimum inside diameter of 12 mm and is to be directed at the joint being tested from a distance not exceeding 1.5 m.

5.1.6.3 Leak testing or structural testing may be accepted in lieu of hose testing.

5.1.7 Other methods of testing

5.1.7.1 Other methods of testing may be considered upon submission of the full particulars.

5.1.8 Application of coating – protective coating

5.1.8.1 Final coating may be applied prior to the hydrostatic testing provided that leak testing is carried out before the application of the final coating.

5.1.8.2 The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

5.1.8.3 For all manual or semi-automatic erection welds, and all fillet weld tank boundary connections, including penetrations, final coating is to be applied after leak testing has taken place. For other welds, the final coating may be applied prior to leak testing, provided the Surveyor, after careful examination prior to the application of coating, is satisfied with the weld. The Surveyor may require leak testing to be carried out prior to final coating of automatic erection welds and manual or automatic pre-erection welds, taking account of the quality control procedure of the shipyard.

5.1.8.4 Final coating is to be applied after all required hose testing is completed.

5.1.9 Temporary coating

5.1.9.1 Temporary coatings which may conceal defects or leaks are to be applied as specified for protective coating, see **5.1.8**. This requirement does not apply to shop primer applied before fabrication.

5.1.9.2 Silicate based shop primer may be applied to welds before leak testing. The layer of the primer is to be applied with a maximum thickness of 50 microns. Other primers of uncertain chemical composition are to be applied with a maximum thickness of 30 microns.

Table 11.5.1
Testing Requirements for Tanks and Boundaries

	Structures to be tested	Type of testing	Hydrostatic testing head or pressure	Remarks
1	Double bottom tanks	Structural(1)	The greater of - to the top of overflow, or - to the bulkhead deck	Tank boundaries tested from at least one side
2	Double side tanks	Structural(1)	The greater of - to the top of overflow, or - to 2.4 m above top of tank(2)	Tank boundaries tested from at least one side
3	Cargo tanks	Structural(1)	The greatest of - to the top of overflow, - to 2.4 m above top of tank(2), or - to the top of tank(2) plus setting of any pressure relief valve	Tank boundaries tested from at least one side
	Fuel oil bunkers	Structural		
4	Cofferdams	Structural(3)	The greater of - to the top of overflow, or - to 2.4 m above top of cofferdam	
5a	Peak tanks	Structural	The greater of - to the top of overflow, or - to 2.4 m above top of tank(2)	Aft peak tank test to be carried out after installation of stern tube.
5b	Fore peak not used as a tank	Refer to SOLAS II.1 Reg.14		
5c	Aft peak not used as a tank	Leak		
6	Watertight bulkheads in way of dry space	Hose(4)		Including steps and recesses
7	Watertight doors below freeboard or bulkhead deck	Hose		For testing before installation(5)
8	(void)			
9	Watertight hatch covers of tanks on combination carriers	Structural testing	The greater of - to 2.4 m above the top of hatch cover, or - setting pressure of the pressure relief valve	At least every second hatch cover is to be tested

Table 11.5.1
Testing Requirements for Tanks and Boundaries

	Structures to be tested	Type of testing	Hydrostatic testing head or pressure	Remarks
10	Weathertight hatch covers, doors and other closing appliances	Hose[(4)]		
11	sShell plating in way of pump room	Visual examination		To be carefully examined with the vessel afloat
12	Chain locker (aft collision bulkhead)	Structural	To the top of chain locker spurling pipe	
13	Independent tanks	Structural	The greater of - to the top of overflow, or - to 0.9 m above top of tank	
14	Ballast ducts	Structural	Ballast pump maximum pressure or setting of any relief valve for the ballast duct if that is less	
15	Hawse pipes	Hose		

Note
1. Leak or hydropneumatic testing may be accepted under the conditions specified in **5.1.5**, provided that at least one tank for each type is structurally tested, and selected in connection with the approval of the design. In general, the structural testing need not be repeated for subsequent vessels of a series of identical new buildings unless the Survey or deems the repetition necessary. The structural testing of cargo space boundaries and tanks for segregated cargoes or pollutants on subsequent vessels of a series of identical new buildings are to be in accordance with the requirements of the individual Classification Society.
2. Top of tank is defined as the deck forming the top of the tank excluding hatchways.
3. Leak testing in accordance with **5.1.5** may be accepted, except that hydropneumatic testing may be required in consideration of the construction techniques and welding procedures employed.
4. Where hose testing is impractical due to the stage of outfitting (machinery, cables, switchboard, insulation etc.), it may be replaced at the individual Society's discretion, by a careful visual examination of all the crossings and welded joints. A dye penetrant test, leak test or ultrasonic leak test may be required.
5. Before installation (i.e. normally at manufacture) the watertight access doors or hatches are to be hydrostatically tested with a head of water equivalent to the bulkhead deck at centre, from the side which is most prone to leakage. The acceptance criteria are as follows:
   - no leakage for doors or hatches with gaskets
   - a maximum water leakage of one litre per minute for doors or hatches with metallic sealing.
6. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0.30 bar is applied.

Section 12

Ship in Operation Renewal Criteria

1 Allowable Thickness Diminution for Hull Structure

1.1 General

1.1.1 Applicability

1.1.1.1 The purpose of this Section is to provide criteria for the allowable thickness diminution of the ships' hull structure.

1.1.1.2 The criteria apply only to ships in operation that are designed and built in accordance with these Rules.

1.1.1.3 Thickness measurements are to be used to assess the ships' structure against the specified renewal criteria.

1.1.2 Wastage allowance concept

1.1.2.1 Wastage allowance is comprised of two aspects; local wastage allowance and overall hull girder wastage allowance. Local wastage allowance is defined in **1.4** and the overall hull girder wastage allowance is defined in **1.5.**

1.1.2.2 Assessment against both local and overall hull girder wastage criteria is required during the operational life of the vessel.

1.1.2.3 Steel renewal is required if either the local or overall hull girder wastage allowance is exceeded.

1.1.2.4 The new building requirements within these Rules incorporate corrosion additions, see **Sec 6/3**, and consider all relevant loads and failure modes (e.g. yielding, buckling, and fatigue). No further assessment of the scantlings against the requirements within these Rules is required during the operational life of the ship provided that the thickness of any structural member remains greater than the renewal thickness specified herein.

1.1.3 Requirements for documentation

1.1.3.1 The plans to be supplied onboard the ship, see **Sec 3/2.2.3**, are to include both the as-built and renewal thickness as defined in **1.4.2**. Any owner's extra thickness is also to be clearly indicated on the drawings.

1.1.3.2 The "as-built" Midship Section plan provided by the builder and carried on board the ship is to include a table showing the minimum allowable hull girder sectional properties, as defined in **1.5**, for the mid-tank transverse section in all cargo tanks.

1.2 Assessment of Thickness Measurements

1.2.1 General

1.2.1.1 The minimum survey requirements for the maintenance of class of double hull oil tankers are defined in IACS Unified Requirement Z10.4.

1.2.1.2 Thickness measurements are to be conducted in accordance with the requirements of the individual Classification Society and IACS Unified Requirement Z10.4.

1.2.2 Assessment of local wastage

1.2.2.1 Thickness measurements are to be taken to confirm that the measured thickness is not less than the renewal thickness for general corrosion and local pitting/edge corrosion as defined in **1.4.2** and **1.6** respectively. See also **1.3.**

1.2.2.2 When a survey identifies that steel renewal is required or structural defects are present which, in the opinion of the Surveyor, will impair the ships' fitness for continued service, remedial measures are to be implemented before the ship continues in service.

1.2.2.3 Re-examination and additional thickness measurements at Annual and Intermediate Surveys are required where the measured thickness, t_m, is less than the allowable thickness at annual survey, t_{annual}, defined as:

$$t_{annual} = t_{as-built} - t_{own} - t_{was} \quad \text{mm}$$

Where:

$t_{as\text{-}.built}$ as built thickness, in mm

t_{was} wastage allowance, as defined in **1.4.2.2**

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

1.2.2.4 Where re-examination and additional thickness measurements are required by **1.2.2.3** then additional measurements are to be carried out in accordance with **Table 12.1.1** to determine the full extent of the corrosion pattern.

Table 12.1.1
Additional Thickness Measurement in way of Structure Identified with $t_m < t_{annual}$

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect areas and adjacent plates	5 point pattern over 1 m^2
Stiffeners	Suspect areas	3 measurements in line across web 3 measurements in line across flange

1.2.2.5 At each Special Survey, thickness measurements are to be taken in way of critical areas, as considered necessary by the Surveyor. Critical areas are to include locations throughout the ship with corrosion levels that are likely to contravene **1.2.2.3** and/or are considered prone to rapid wastage.

1.2.3 Assessment of overall hull girder wastage

1.2.3.1 The hull girder sectional properties of the ship are to be calculated for the cross-sections as specified in IACS Unified Requirement Z10.4, based on the thicknesses given by the thickness measurements, to confirm that the resulting hull girder sectional properties are not less than the minimum allowable defined in **1.5.2**. The actual sectional properties calculated based on measured thicknesses and in accordance with IACS Unified Requirement Z10.4, are to be submitted to the Classification Society.

1.3 Categories of Corrosion

1.3.1 General corrosion

1.3.1.1 General corrosion is defined as areas where general uniform reduction of material thickness is found over an extensive area.

1.3.1.2 Renewal criteria for general corrosion are given in **1.4.**

1.3.2 Pitting corrosion

1.3.2.1 Pitting corrosion is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area.

1.3.2.2 The pitting intensity is defined in **Fig 12.1.1.**

1.3.2.3 Renewal criteria for pitting corrosion are given in **1.6.2.**

1.3.3 Edge corrosion

1.3.3.1 Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion is shown in **Fig 12.1.2.**

1.3.3.2 Renewal criteria for edge corrosion are given in **1.6.3.**

1.3.4 Groove corrosion

1.3.4.1 Groove corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion is shown in **Fig 12.1.3.**

1.3.4.2 Renewal criteria for groove corrosion are given in **1.6.4.**

Fig 12.1.1
Pitting Intensity Diagrams

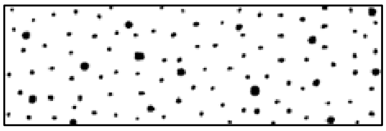
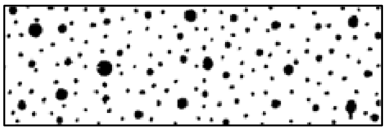
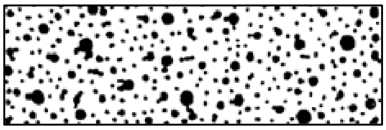
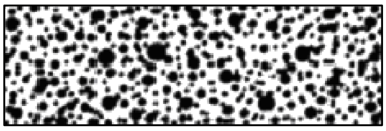
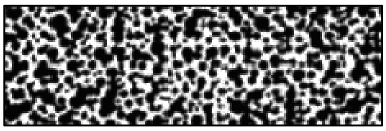
5% Scattered	
10% Scattered	
20% Scattered	
30% Scattered	
50% Scattered	

Fig 12.1.2
Edge Corrosion

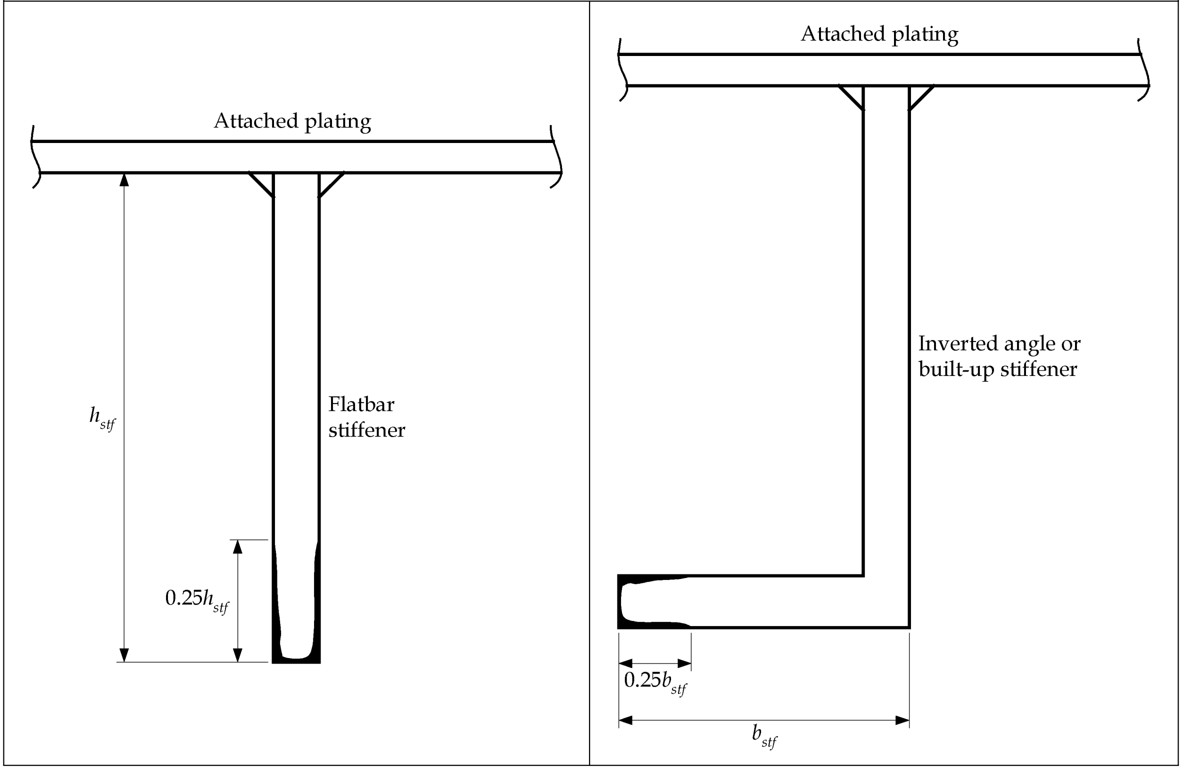
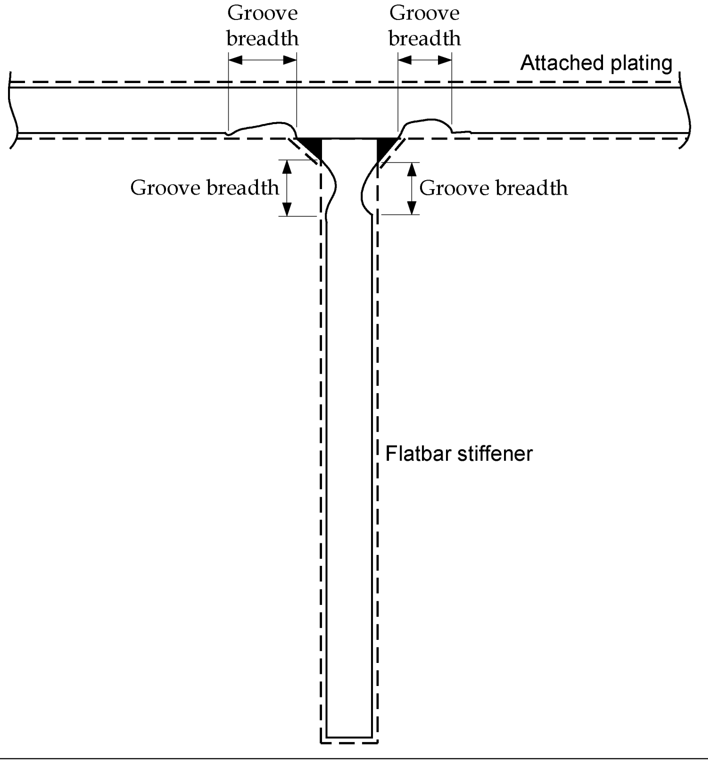


Fig 12.1.3
Groove Corrosion



1.4 Renewal Criteria of Local Structure for General Corrosion

1.4.1 Application

1.4.1.1 The renewal criteria in **1.4.2** generally apply to areas of structural members with general corrosion.

1.4.2 Renewal criteria

1.4.2.1 Steel renewal is required if the measured thickness, t_{tm}, is less than the renewal thickness, t_{ren}, defined as:

$$t_{ren} = t_{as-built} - t_{was} - t_{own} - t_{corr-2.5} \quad \text{mm}$$

Where:

$t_{as\text{-}.built}$ as built thickness, in mm

t_{was} wastage allowance, as defined in **1.4.2.2**

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

$t_{corr-2.5}$ 0.5 mm, wastage allowance in reserve for corrosion occurring in the two and a half years between Intermediate and Special surveys

1.4.2.2 The wastage allowance, t_{was}, is given by:

$$t_{was} = t_{was-1} + t_{was-2} \quad \text{mm} \quad \text{and rounded up to the nearest 0.5 mm}$$

Where:

t_{was} total wastage allowance of the considered structural member, in mm

t_{was-1} wastage allowance for side one of the structural member considering the contents of the compartment to which it is exposed, in mm, as given **Table 12.1.2**

t_{was-2} wastage allowance for side two of the structural member considering the contents of the compartment to which it is exposed, in mm, as given **Table 12.1.2**

1.4.2.3 In no case is the wastage allowance, t_{was}, to be less than 1.5 mm, except in way of internals of dry spaces and pump room where 1.0 mm is applicable.

1.4.2.4 Wastage allowances for compartments not listed in **Table 12.1.2** will be subject to special consideration.

1.4.2.5 Areas which need to be renewed based on the renewal criteria in **1.4.2.1** are, in general, to be repaired with inserted material which is to have the same or greater grade/strength as the original and to have a thickness, t_{repair}, not less than:

$$t_{repair} = t_{as-built} - t_{own} \quad \text{mm}$$

Where:

$t_{as\text{-}built}$ as built thickness, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

Table 12.1.2
Local Wastage Allowance for One Side of Structural Elements

Compartment type	Structural member		Ship in operation component wastage allowance, t_{was-1} or t_{was-2} (mm)
Ballast water tank and chain locker	Face plate of PSM	Within 3 m below top of tank(1)	2.0
		Elsewhere	1.5
	Other members(3)	Within 3 m below top of tank(1)	1.7
		Elsewhere	1.2
Cargo oil tank	Face plate of PSM	Within 3 m below top of tank(1)	1.7
		Elsewhere	1.4
	Inner-bottom plating/bottom of tank		2.1
	Other members	Within 3 m below top of tank(1)	1.7
		Elsewhere	1.0
Exposed to atmosphere	Weather deck plating		1.7
	Other members		1.0
Exposed to sea water	Shell plating(2)		1.0
Fuel and lube oil tank(4)	Top of tank and attached internal stiffeners		1.0
	Elsewhere		0.7
Fresh water tank	Top of tank and attached internal stiffeners		1.0
	Elsewhere		0.7
Void spaces	Spaces not normally accessed, e.g. access only via bolted manhole openings, pipe tunnels, etc.		0.7
Dry spaces	Internals of deckhouses, machinery spaces, pump room, store rooms, steering gear space, etc.		0.5

Notes
1. Only applicable to cargo and ballast tanks with weather deck as the tank top.
2. 0.5 mm to be added for side plating in the quay contact region as defined in **Sec 8/Fig 8.2.2.**
3. 0.5 mm to be added to the plate surface exposed to ballast for plate boundary between water ballast and heated cargo oil tanks. 0.3 mm to be added to each surfaces of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks. Heated cargo oil tanks are defined as tank arranged with any form of heating capability (most common type is heating coils).
4. 0.7 mm to be added for plate boundary between water ballast and heated fuel oil tanks

1.5 Renewal Criteria of Hull Girder Sectional Properties for General Corrosion

1.5.1 General

1.5.1.1 The following actual hull girder sectional properties are required to be verified, see **1.5.2-3**:
(a) vertical hull girder moment of inertia, about the horizontal axis, I_v
(b) hull girder section modulus about the horizontal axis - at deck-at-side, $Z_{v\text{-}dk}$
(c) hull girder section modulus about the horizontal axis - at keel, $Z_{v\text{-}kl}$
(d) hull girder section modulus about the vertical axis - at side, $Z_{h\text{-}side}$
(e) hull girder vertical shear area, $A_{v\text{-}shr}$

1.5.2 Renewal criteria

1.5.2.1 Steel renewal is required if the actual hull girder sectional properties, $I_{v\text{-}tm}$, $Z_{v\text{-}tm\text{-}dk}$, $Z_{v\text{-}tm\text{-}kl}$, $Z_{h\text{-}tm\text{-}side}$, $A_{v\text{-}tm\text{-}shr}$, calculated using the actual thickness measurements are less than the minimum allowable hull girder sectional properties defined in accordance with **1.5.3.**

1.5.2.2 The actual hull girder sectional properties listed in **1.5.2.1** are to be calculated in accordance with **Sec 4/2.6**, using the measured thicknesses.

1.5.2.3 If steel renewal is required due to reduced hull girder sectional properties this is to be done by replacing local corroded structural elements. Any combination of structural elements may be replaced provided that the resulting hull girder sectional properties satisfy **1.5.2.1.** Local structural elements being renewed are to be replaced in accordance with the requirements of **1.4.2.3.**

1.5.3 Calculation of the minimum allowable hull girder sectional properties

1.5.3.1 The minimum allowable hull girder sectional properties listed in **1.5.1.1** are to be calculated in accordance with **Sec 4/2.6**, using the thicknesses defined in **1.5.3.2.**

1.5.3.2 The minimum allowable hull girder sectional properties in the corroded condition are calculated using the same corrosion thickness reductions that are used during the new building stage, thus linking the new building and ship in operation criteria. Therefore the calculation of the minimum allowable hull girder sectional properties is to be based on a member thickness, t, given by:

$$t = t_{as-built} - 0.5t_{corr} - t_{own} \quad \text{mm}$$

Where:

$t_{as\text{-}built}$ as built thickness, in mm

t_{corr} corrosion addition, as defined in **Sec 6/3.2**

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

1.6 Allowable Material Diminution for Pitting, Grooving and Edge Corrosion

1.6.1 General

1.6.1.1 Steel renewal for pitting, grooving and edge corrosion is required if the measured thickness is less than the criteria defined in **1.6.2**, **1.6.3** and **1.6.4** respectively.

1.6.2 Pitting

1.6.2.1 For plates with pitting intensity less than 20 %, see **Fig 12.1.1**, the measured thickness, t_{tm}, of any individual measurement is to meet the lesser of the following criteria:

$$t_{tm} \geq 0.7(t_{as-built} - t_{own}) \quad \text{mm}$$

$$t_{tm} \geq t_{ren} - 1 \quad \text{mm}$$

Where:

$t_{as\text{-}built}$ as built thickness of the member, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

t_{ren} renewal criteria for general corrosion as defined in **1.4.2.1**

1.6.2.2 The average thickness across any cross section in the plating is not to be less than the renewal criteria for general corrosion given in **1.4.2.1.**

1.6.3 Edge corrosion

1.6.3.1 Provided that the overall corroded height of the edge corrosion of the flange, or web in the case of flat bar stiffeners, is less than 25 %, see **Fig 12.1.2**, of the stiffener flange breadth or web height, as applicable, the measured thickness, t_{tm}, is to meet the lesser of the following criteria:

$t_{tm} \geq 0.7(t_{as-built} - t_{own})$ mm

$t_{tm} \geq t_{ren} - 1$ mm

Where:

$t_{as-built}$ as built thickness of the member, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

t_{ren} renewal criteria for general corrosion as defined in **1.4.2.1**

1.6.3.2 The average measured thickness across the breadth or height of the stiffener is not to be less than that defined in **1.4.2.**

1.6.3.3 Plate edges at openings for manholes, lightening holes etc. may be below the minimum thickness given in **1.4.2** provided that:

(a) the maximum extent of the reduced plate thickness, below the minimum given in **1.4.2**, from the opening edge is not more than 20 % of the smallest dimension of the opening and does not exceed 100 mm

(b) rough or uneven edges may be cropped-back provided that the maximum dimension of the opening is not increased by more than 10 %.

1.6.4 Grooving

1.6.4.1 Where the groove breadth is a maximum of 15 % of the web height, but not more than 30 mm, see **Fig 12.1.3**, the measured thickness, t_{tm}, in the grooved area is to meet the lesser of the following criteria:

$t_{tm} \geq 0.75(t_{as-built} - t_{own})$ mm

$t_{tm} \geq t_{ren} - 0.5$ mm

but is not to be less than

$t_{tm} = 6$ mm

Where:

$t_{as-built}$ as built thickness of the member, in mm

t_{own} owner/builder specified additional wastage allowance, if applicable, in mm

t_{ren} renewal criteria for general corrosion as defined in **1.4.2.1**

Appendix A

Hull Girder Ultimate Strength

1 General

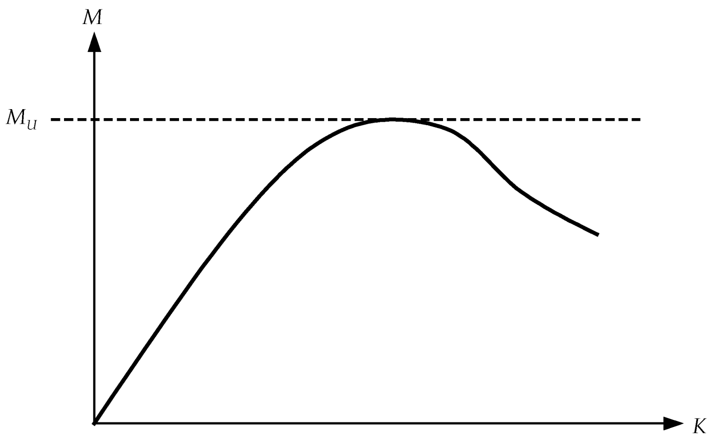
1.1 Definitions

1.1.1 Hull girder bending moment capacity

1.1.1.1 The hull girder ultimate bending moment capacity, M_U, is defined as the maximum bending capacity of the hull girder beyond which the hull will collapse. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.1.1.2 The sagging hull girder ultimate capacity of a hull girder section, is defined as the maximum value on the static non-linear bending moment-curvature relationship M-k, see **Fig A.1.1**. The curve represents the progressive collapse behaviour of hull girder under vertical bending.

Fig A.1.1
Bending Moment - Curvature Curve *M-k*



1.1.1.3 The curvature of the critical inter-frame section, k, is defined as:

$$\kappa = \frac{\theta}{l}$$

Where:

Θ the relative angle rotation of the two neighbouring cross-sections at transverse frame positions

l the transverse frame spacing, i.e. span of longitudinals

1.2 Application

1.2.1 General

1.2.1.1 The sagging hull girder ultimate bending capacity is to be assessed by the single step method in **2.1** or the incremental-iterative method in **2.2.** This is only applicable to longitudinally framed double hull tankers in the sagging bending condition.

1.2.1.2 The magnitudes of the partial safety factors in **Sec 9/1.4** have been calibrated for this single step method in **2.1** and are also appropriate for the incremental iterative method in **2.2.**

1.3 Assumptions

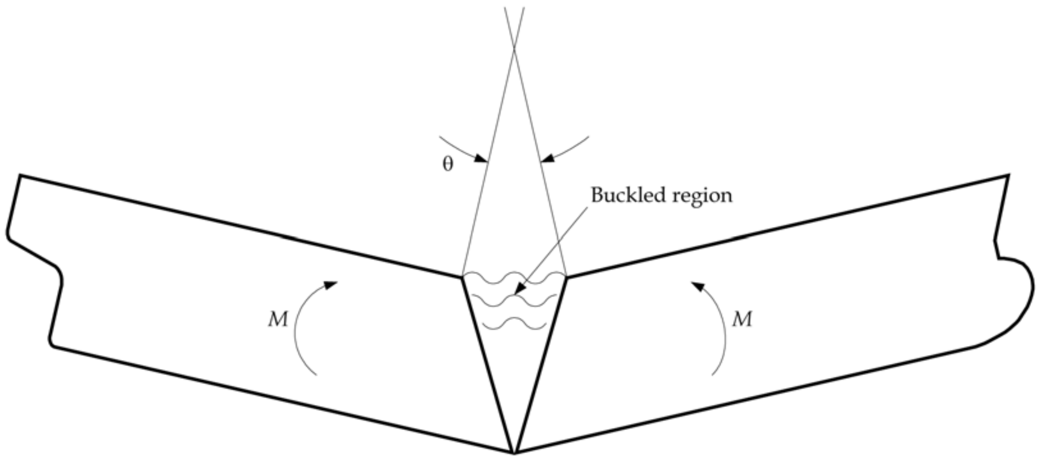
1.3.1 General

1.3.1.1 The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements. For tankers, in sagging, the critical mode is generally inter-frame buckling of deck structures, as shown in **Fig A.1.2.**

1.3.1.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as: plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling; and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.1.3 For tankers in the sagging condition, only vertical bending is considered. The effects of shear force, torsional loading, horizontal bending moment and lateral pressure are neglected.

Fig A.1.2
Ship in Extreme Sagging Inter-Frame Buckling Failure



1.4 Alternative Methods

1.4.1 General

1.4.1.1 Principles for alternative methods for the calculation of the hull girder ultimate bending capacity; e.g. incremental-iterative procedure that may differ from the one defined in **2.2**, and non-linear finite element analysis, are given in **Sub-Sec 3**.

1.4.1.2 Application of alternative methods is to be agreed with the individual Classification Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results with those of the individual Classification Societies' procedures are to be submitted for review and acceptance. The use of such methods may require the partial safety factors in **Sec 9/1.4** to be re-calibrated.

2 Calculation of Hull Girder Ultimate Capacity

2.1 Single Step Ultimate Capacity Method

2.1.1 Procedure

2.1.1.1 The single step procedure for calculation of the sagging hull girder ultimate bending capacity is a simplified method based on a reduced hull girder bending stiffness accounting for buckling of the deck, see **Fig A.2.1**. The hull girder ultimate bending moment capacity, M_U, is to be taken as:

$$M_U = Z_{red}\sigma_{yd} \cdot 10^3 \quad \text{kNm}$$

Where:

Z_{red} reduced section modulus of deck (to the mean deck height)

$$= \frac{I_{red}}{z_{dk-mean} - z_{NA-red}} \quad \text{m}^3$$

I_{red} reduced hull girder moment of inertia, in m4. The inertia is to be calculated in accordance with **Sec 4/2.6.1.1**, using:

- a hull girder net thickness of t_{net50} for all longitudinally effective members
- the effective net area after buckling of each stiffened panel of the deck, A_{eff}

A_{eff} effective net area after buckling of the stiffened deck panel. The effective area is the proportion of stiffened deck panel that is effectively able to be stressed to yield:

$$= \frac{\sigma_U}{\sigma_{yd}} A_{net50} \quad \text{m}^2$$

Note
The effective area of deck girders is to be taken as the net area of the girders using a thickness of t_{net50}.

A_{net50} net area of the stiffened deck panel, in m^2

σ_U buckling capacity of stiffened deck panel, in N/mm^2. To be calculated for each stiffened panel using:

- the advanced buckling analysis method, see **Sec 10/4** and **Appendix D**
- the net thickness t_{net50}

σ_{yd} specified minimum yield stress of the material, in N/mm^2, that is used to determine the hull girder section modulus. In the case of the stiffener and plate having different specified minimum yield stress, σ_{yd}, is to be taken as the lesser of the two.

$z_{dk-mean}$ vertical distance to the mean deck height, taken as the mean of the deck at side and the deck at centre line, measured from the baseline, in m

z_{NA-red} vertical distance to the neutral axis of the reduced section measured from the baseline, in m

2.1.1.2 It is to be shown that the ultimate bending moment capacity, M_U, does not give stresses exceeding the specified minimum yield stress of the material, σ_{yd}, in the bottom shell plating. Therefore the ultimate hull girder bending moment capacity, M_U, is not to be greater than:

$$M_U = \sigma_{yd} \frac{I_{red}}{z_{NA-red}} \cdot 10^3 \quad \text{kNm}$$

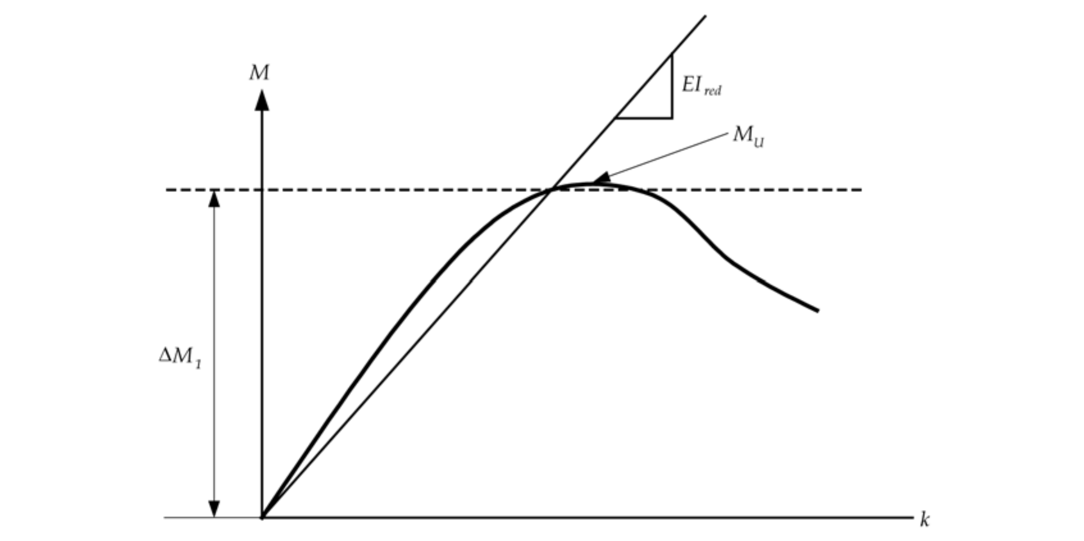
Where:

σ_{yd} specified yield stress of material, in N/mm^2

I_{red} reduced hull girder moment of inertia, as defined in **2.1.1.1**

z_{NA-red} vertical distance to the neutral axis of the reduced section measured from the baseline, in m

Fig A.2.1
Moment - Curvature of Hull Girder Single Step Procedure



2.1.2 Assumption

2.1.2.1 The assumption behind this procedure is that the ultimate sagging capacity of tankers is the point at which the ultimate capacity of the stiffened deck panels is reached. If the structural configuration is such that this assumption is not valid, then an alternative method to derive the ultimate capacity is to be used.

2.2 Simplified Method Based on an Incremental-iterative Approach

2.2.1 Procedure

2.2.1.1 In this approach, the ultimate hull girder bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature κ of the ship cross section as shown in **Fig A.1.1.**

2.2.1.2 The curve M-κ is obtained by means of an incremental-iterative approach; the steps involved in the procedure are given in **2.2.1.7** and illustrated in the flow char tin **Fig A.2.2.**

2.2.1.3 The bending moment M_i which acts on the hull girder transverse section due to the imposed curvature κ_i is calculated for each step of the incremental procedure. This imposed curvature corresponds to an angle of rotation of the hull girder transverse section about its effective horizontal neutral axis, which induces an axial strain ε in each hull structural element. In the sagging condition, the structural elements below the neutral axis are lengthened, whilst elements above the neutral axis are shortened.

2.2.1.4 The stress σ induced in each structural element by the strain ε is obtained from the stress-strain curve σ-ε of the element, which takes into account the behaviour of the structural element in the non-linear elasto-plastic domain.

2.2.1.5 The force in each structural element is obtained from its area times the stress and these force are summated to derive the total axial force on the transverse section. Note the element area is taken as the total net area of the structural element. This total force may not be zero as the effective neutral axis may have moved due to the non linear response. Hence it is necessary to adjust the neutral axis position, recalculate the element strains, forces and total sectional force and iterate until the total force is zero.

2.2.1.6 Once the position of the new neutral axis is known, then the correct stress distribution in the structural elements is obtained. The bending moment Mi about the new neutral axis due to the imposed curvature κ_i is then obtained by summating the moment contribution given by the force in each structural element.

2.2.1.7 The main steps of the incremental-iterative approach are summarised as follows (see also **Fig A.2.2**):

Step 1 Divide the hull girder transverse section into structural elements, ie longitudinal stiffened panels (one stiffener per element), hard corners and transversely stiffened panels, see **2.2.2.2.**

Step 2 Derive the stress-strain curves (or so called load-end shortening curves) for all structural elements, see **2.3.**

Step 3 Derive the expected maximum required curvature κ_F, see **2.2.1.8**. The curvature step size $\Delta\kappa$ is to be taken as $\kappa_F/300$. The curvature for the first step, κ_1 is to be taken as $\Delta\kappa$.

Derive the neutral axis $z_{NA\text{-}i}$ for the first incremental step ($i = 1$) with the value of the elastic hull girder section modulus, $z_{v\text{-}net50}$, see **Sec 4/2.6.1**

Step 4 For each element (index j), calculate the strain $\varepsilon_{ij} = \kappa_i(z_j - z_{NA\text{-}i})$ corresponding to κ_i, the corresponding stress σ_j, see **2.2.1.9**, and hence the force in the element $\sigma_j A_j$.

Step 5 Determine the new neutral axis position $z_{NA\text{-}i}$ by checking the longitudinal force equilibrium over the whole transverse section. Hence adjust z_{NA_i} until

$$F_i = 0.1\sum A_j\sigma_j \text{ kN}=0$$

Note σ_j is positive for elements under compression and negative for elements under tension. Repeat from step 4 until equilibrium is satisfied. Equilibrium is satisfied when the change in neutral axis position is less than 0.0001 m.

Step 6 Calculate the corresponding moment by summating the force contributions of all elements as follows:

$$M_i = 0.1\sum \left|\sigma_j A_j \left(z_j - z_{NA-i}\right)\right| \quad \text{kNm}$$

Step 7 Increase the curvature by $\Delta\kappa$, use the current neutral axis position as the initial value for the next curvature increment and repeat from step 4 until the maximum required curvature is reached. The ultimate capacity is the peak value M_u from the M-κ curve. If the peak does not occur in the curve, then κ_F is to be increased until the peak is reached

2.2.1.8 The expected maximum required curvature, κ_F, in m^{-1}, for the sagging condition is to be taken as:

$$\kappa_F = 3\frac{M_{yd}}{EI_{v-net50}}10^{-3} \quad \text{m}^{-1}$$

Where:

M_{yd} vertical bending moment given by a linear elastic bending stress of yield in the deck or keel. To be taken as the greater of :

$Z_{v-net50-dk}\sigma_{yd}10^3$ kNm

$Z_{v-net50-kl}\sigma_{yd}10^3$ kNm

$Z_{v\text{-}net50\text{-}dk}$, $Z_{v\text{-}net50\text{-}kl}$ section modulus at deck or bottom, in m^3, see **Sec 8/1.2.2.3** and **1.2.2.4**,

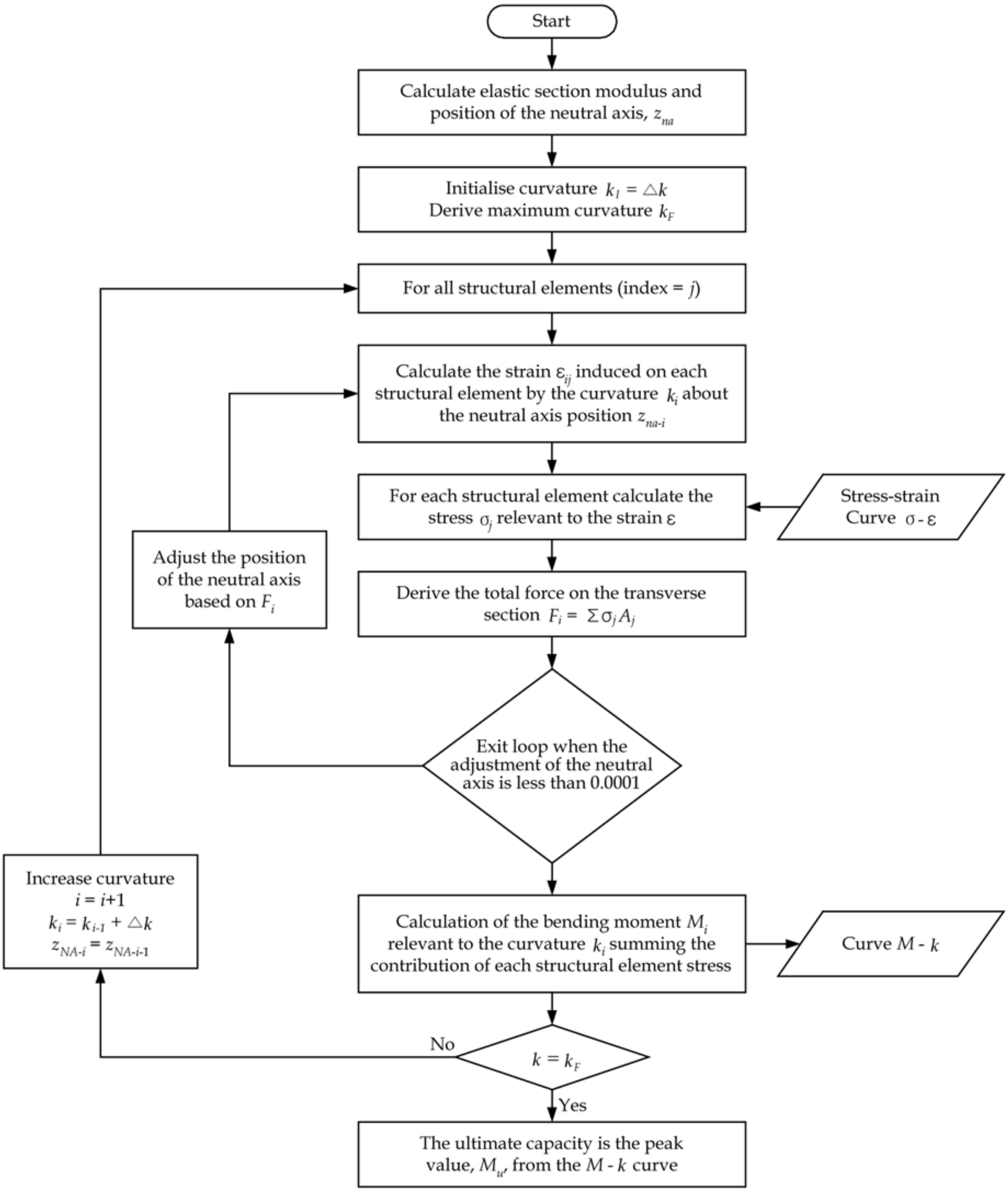
E modulus of elasticity, 2.06×10^5 N/mm^2

σ_{yd} specified minimum yield stress of the material, in N/mm^2

$I_{v-net50}$ hull girder moment of inertia, in m^4, see **Sec 8/1.2.1.1**

2.2.1.9 For each structural element, the stress σ_j corresponding to the element strain ε_{ij} is to be taken as the minimum stress value from all applicable stress-strain curves σ-ε for that element.

Fig A.2.2
Flow Chart of the Procedure for the Evaluation of the Curve $M-\chi$



2.2.2 Assumptions and modelling of the hull girder cross-section

2.2.2.1 In applying the procedure described in **2.2.1**, the following assumptions are to be made:

(a) The ultimate strength is calculated at a hull girder transverse section between two adjacent transverse webs.

(b) The hull girder transverse section remains plane during each curvature increment.

(c) The material properties of steel are assumed to be elastic, perfectly plastic.

(d) The hull girder transverse section can be divided into a set of elements which act independently of each other.

2.2.2.2 The elements making up the hull girder transverse section are:

(a) longitudinal stiffeners with attached plating, the structural behaviour is given in **2.3.1**

(b) transversely stiffened plate panels, the structural behaviour is given in **2.3.1**

(c) hard corners, as defined in **2.2.2.3**, the structural behaviour is given in **2.3.2**

2.2.2.3 The following structural areas are to be defined as hard corners:

(a) the plating area adjacent to intersecting plates

(b) the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees.

(c) plating comprising rounded gunwales

An illustration of hard corner definition for girders on longitudinal bulkheads is given in **Fig A.2.3**. The hard corner size is defined in **2.2.2.4.**

2.2.2.4 The size and modelling of hard corner elements is to be as follows:

(a) it is to be assumed that the hard corner extends up to $s/2$ from the plate intersection for longitudinally stiffened plate, where s is the stiffener spacing

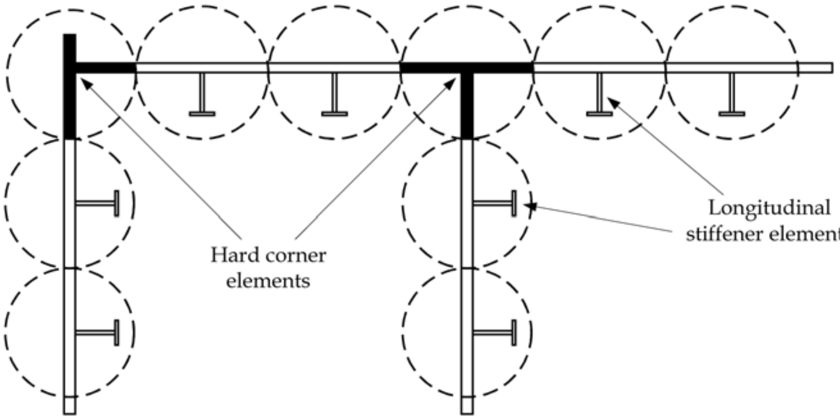
(b) it is to be assumed that the hard corner extends up to $20\,t_{grs}$ from the plate intersection for transversely stiffened plates, where t_{grs} is the gross plate thickness.

Note

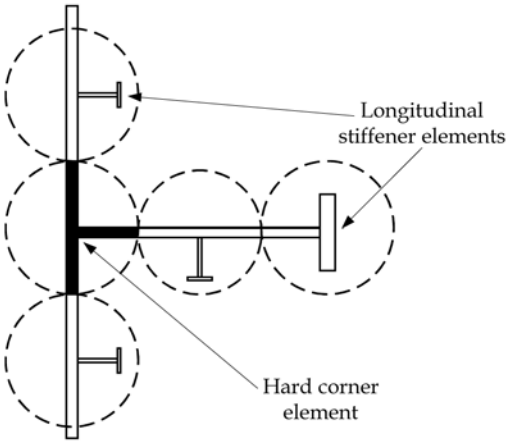
For transversely stiffened plate, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as the full plate breadth, i.e. to the intersection of other plates - not from the end of the hard corner if any. The area on which the value of σ_{CR5} defined in **2.3.8.1** applies is to be taken as the breadth between the hard corners, i.e. excluding the end of the hard corner if any.

Figure A.2.3
Example of Defining Structural Elements

a) Example showing side shell, inner hull and deck



b) Example showing girder on longitudinal bulkhead



2.3 Stress-strain Curves σ-ε (or Load-end Shortening Curves)

2.3.1 Plate panels and stiffeners

2.3.1.1 Plate panels and stiffeners are assumed to fail according to one of the modes of failure specified in **Table A.2.1**. The relevant stress-strain curve σ-ε is to be obtained for lengthening and shortening strains according to **Table A.2.1.**

2.3.2 Hard corners

2.3.2.1 Hard corners are sturdier elements which are assumed to buckle and fail in an elastic, perfectly plastic manner. The relevant stress strain curve σ-ε is to be obtained for lengthened and shortened hard corners according to **2.3.3.**

Table A.2.1
Modes of Failure of Plate Panels and Stiffeners

Element	Mode of failure	Stress-strain curve σ-ε defined in
Lengthened transversely framed plate panels or stiffeners	Elastic, perfectly plastic failure	See **2.3.3**
Shortened stiffeners	Beam column buckling Torsional buckling Web local buckling of flanged profiles Web local buckling of flat bars	See **2.3.4** See **2.3.5** See **2.3.6** See **2.3.7**
Shortened transversely framed plate panels	Plate buckling	See **2.3.8**

2.3.3 Elasto-plastic failure of structural elements

2.3.3.1 The equation describing the stress-strain curve σ-ε or the elasto-plastic failure of structural elements is to be obtained from the following formula, valid for both positive (compression or shortening) of hard corners and negative (tension or lengthening) strains of all elements (see **Fig A.2.4**):

$\sigma = \Phi\, \sigma_{yd}$

Where:

Φ edge function:

Φ = -1 for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

Φ = 1 for $\varepsilon > 1$

ε relative strain:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_{yd}}$$

ε_E element strain

ε_{yd} strain corresponding to yield stress in the element:

$$\varepsilon_{yd} = \frac{\sigma_{yd}}{E}$$

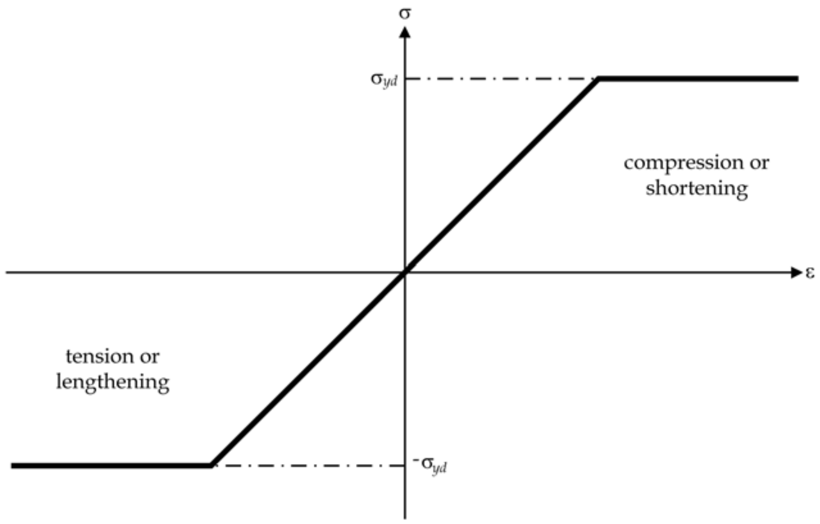
σ_{yd} specified minimum yield stress of the material, in N/mm^2

Note

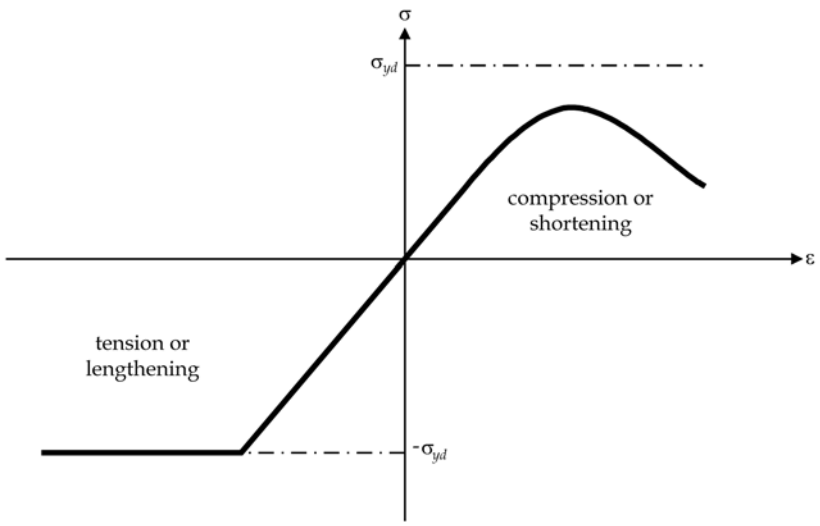
The signs of the stresses and strains in this Appendix are opposite to those in the rest of the Rules

Fig A.2.4
Example of Stress Strain Curves σ-ε

a) Stress strain curve σ-ε for elastic, perfectly plastic failure of a hard corner



b) Typical stress strain curve σ-ε for elasto-plastic failure of a stiffener



2.3.4 Beam column buckling

2.3.4.1 The equation describing the shortening portion of the stress strain curve σ_{CR1}-ε for the beam column buckling of stiffeners is to be obtained from the following formula:

$$\sigma_{CR1} = \Phi \sigma_{C1} \left(\frac{A_{s-net50} + 10^{-2} b_{eff-p} t_{net50}}{A_{s-net50} + 10^{-2} s t_{net50}} \right) \qquad \text{N/mm}^2$$

Where:

Φ edge function defined in **2.3.3.1**

$A_{s-net50}$ net area of the stiffener, in cm^2, without attached plating

σ_{C1} critical stress, in N/mm^2:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \qquad for \quad \sigma_{E1} \le \frac{\sigma_{yd}}{2}\varepsilon$$

$$\sigma_{C1} = \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E1}}\right) \quad for \quad \sigma_{E1} > \frac{\sigma_{yd}}{2}\varepsilon$$

ε relative strain defined in **2.3.3.1**

σ_{E1} Euler column buckling stress, in N/mm^2:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-net50}}{A_{E-net50} l_{stf}^2} 10^{-4}$$

E modulus of elasticity, 2.06×105 N/mm^2

$I_{E-net50}$ net moment of inertia of stiffeners, in cm^4, with attached plating of width b_{eff-s}

b_{eff-s} effective width, in mm, of the attached plating for the stiffener:

$$b_{eff-s} = \frac{s}{\beta_p} \qquad \text{for} \quad \beta_p > 1.0$$

$$b_{eff-s} = s \qquad \text{for} \quad \beta_p \le 1.0$$

β_p $= \frac{s}{t_{net50}}\sqrt{\frac{\varepsilon\sigma_{yd}}{E}}$

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in **Sec 4/2.2.1**

t_{net50} net thickness of attached plating, in mm

$A_{E-net50}$ net area, in cm^2, of stiffeners with attached plating of width b_{eff-p}

l_{stf} span of stiffener, in m, equal to spacing between primary support members

b_{eff-p} effective width, in mm, of the plating:

$$b_{eff-p} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)s \qquad \text{for} \quad \beta_p > 1.25$$

$$b_{eff-p} = s \qquad \text{for} \quad \beta_p \le 1.25$$

2.3.5 Torsional buckling of stiffeners

2.3.5.1 The equation describing the shortening portion of the stress-strain curve σ_{CR2}-ε for the lateral-flexural buckling of stiffeners is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-net50}\sigma_{C2} + 10^{-2} s t_{net50}\sigma_{CP}}{A_{s-net50} + 10^{-2} s t_{net50}} \qquad \text{N/mm}^2$$

Where:

Φ edge function defined in **2.3.3.1**

$A_{s-net50}$ net area of the stiffener, in cm^2, without attached plating

σ_{C2} critical stress, in N/mm^2:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \qquad \text{for} \quad \sigma_{E2} \le \frac{\sigma_{yd}}{2}\varepsilon$$

$$\sigma_{C2} = \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E2}}\right) \qquad \text{for} \quad \sigma_{E2} > \frac{\sigma_{yd}}{2}\varepsilon$$

σ_{E2} Euler torsional buckling stress, in N/mm^2

$\sigma_{E2} = \sigma_{ET}$

σ_{ET} reference stress for torsional buckling, in N/mm^2, defined in **Sec 10/3.3.3.1**, calculated based on gross thickness minus the corrosion addition 0.5 t_{corr}.

ε relative strain defined in **2.3.3.1**

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in **Sec 4/2.2.1**

t_{net50} net thickness of attached plating, in mm

σ_{CP} ultimate strength of the attached plating for the stiffener, in N/mm²:

$$\sigma_{CP} = \left(\frac{2.25}{\beta_p} - \frac{1.25}{\beta_p^2}\right)\sigma_{yd} \quad \text{for} \quad \beta_p > 1.25$$

$$\sigma_{CP} = \sigma_{yd} \quad \text{for} \quad \beta_p \le 1.25$$

β_p coefficient defined in **2.3.4**

2.3.6 Web local buckling of stiffeners with flanged profiles

2.3.6.1 The equation describing the shortening portion of the stress strain curve σ_{CR3}-ε for the web local buckling of flanged stiffeners is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi\sigma_{yd}\left(\frac{b_{eff-p}t_{net50} + d_{w-eff}t_{w-net50} + b_f t_{f-net50}}{st_{net50} + d_w t_{w-net50} + b_f t_{f-net50}}\right) \quad \text{N/mm}^2$$

Where:

Φ edge function defined in **2.3.3.1**

b_{eff-p} effective width, in mm, of the plating, defined in **2.3.4**

t_{net50} net thickness of plate, in mm

d_w depth of the web, in mm

$t_{w-net50}$ net thickness of web, in mm

b_f breadth of the flange, in mm

$t_{f-net50}$ net thickness of flange, in mm

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in **Sec 4/2.2.1**

d_{w-eff} effective depth of the web, in mm:

$$d_{w-eff} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right)d_w \quad \text{for} \quad \beta_w > 1.25$$

$$d_{w-eff} = d_w \quad \text{for} \quad \beta_w \le 1.25$$

β_w $\dfrac{d_w}{t_{w-net50}}\sqrt{\dfrac{\varepsilon\sigma_{yd}}{E}}$

ε relative strain defined in **2.3.3.1**

E modulus of elasticity, 2.06 × 105 N/mm²

2.3.7 Web local buckling of flat bar stiffeners

2.3.7.1 The equation describing the shortening portion of the stress-strain curve σ_{CR4}-ε for the web local buckling of flat bar stiffeners is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi\left(\frac{st_{net50}\sigma_{CP} + 10^{-2}A_{s-net50}\sigma_{C4}}{st_{net50} + 10^{-2}A_{s-net50}}\right)$$

Where:

Φ edge function defined in **2.3.3.1**

σ_{CP} ultimate strength of the attached plating, in N/mm², defined in **2.3.5**

σ_{C4} critical stress, in N/mm²:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \le \frac{\sigma_{yd}}{2}\varepsilon$$

$$\sigma_{C4} = \sigma_{yd}\left(1 - \frac{\sigma_{yd}\varepsilon}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{\sigma_{yd}}{2}\varepsilon$$

σ_{E4} Euler buckling stress, in N/mm²:

$$\sigma_{E4} = 160000\left(\frac{t_{w-net50}}{d_w}\right)^2$$

ε relative strain defined in **2.3.3.1.**

$A_{s-net50}$ net area of stiffener, in cm², see **2.3.5.1**

$t_{w-net50}$ net thickness of web, in mm

d_w depth of the web, in mm

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in **Sec 4/2.2.1**

t_{net50} net thickness of attached plating, in mm

2.3.8 Buckling of transversely stiffened plate panels

2.3.8.1 The equation describing the shortening portion of the stress-strain curve σ_{CR5}-ε for the buckling of transversely stiffened panels is to be obtained from the following formula:

$$\sigma_{CR5} = \min \begin{cases} \Phi\sigma_{yd}\left[\dfrac{s}{1000 l_{stf}}\left(\dfrac{2.25}{\beta_p} - \dfrac{1.25}{\beta_p^2}\right) + 0.1\left(1 - \dfrac{s}{1000 l_{stf}}\right)\left(1 + \dfrac{1}{\beta_p^2}\right)^2\right] \\ \sigma_{yd}\Phi \end{cases} \quad \text{N/mm}^2$$

Where:

β_p coefficient defined in **2.3.4.1**

Φ edge function defined in **2.3.3.1**

s plate breadth, in mm, taken as the spacing between the stiffeners, as defined in **Sec 4/2.2.1**

l_{stf} stiffener span, in m, equal to spacing between primary support members

σ_{yd} specified minimum yield stress of the material, in N/mm²

3 Alternative Methods

3.1 General

3.1.1 Considerations for alternative models

3.1.1.1 The bending moment-curvature relationship, *M-k*, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

(a) non-linear geometrical behaviour

(b) inelastic material behaviour

(c) geometrical imperfections and residual stresses (geometrical out-of flatness of plate and stiffeners)

(d) simultaneously acting loads:

- bi-axial compression
- bi-axial tension
- shear and lateral pressure

(e) boundary conditions

(f) interactions between buckling modes

(g) interactions between structural elements such as plates, stiffeners, girders etc.

(h) post-buckling capacity.

3.2 Methods

3.2.1 Incremental-iterative procedure

3.2.1.1 The most generally used method to assess the hull girder ultimate moment capacity is to derive the non-linear moment-curvature relationship, *M-k*, by incrementally increasing the bending curvature, *k*, of the hull section between two adjacent transverse frames and then identifying the maximum moment along this curve as the ultimate bending capacity, M_U.

3.2.1.2 The *M-k* curve is to be based on the axial non-linear *P-e* (load/strain) load-shortening curves for individual structural component in the cross-section. The *P-e* curves shall consider all relevant structural effects as listed in **3.1.1.1.**

3.2.2 Non-linear finite element analysis

3.2.2.1 Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in **3.1.1.1.**

3.2.2.2 Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

Appendix B

Structural Strength Assessment

1 General

1.1 Application

1.1.1 General

1.1.1.1 In accordance with **Sec 9/2.1**, a finite element (FE) assessment is to be carried out to verify the strength of the hull structure.

1.1.1.2 The structural assessment is to be carried out in accordance with the requirements given in this Appendix. The structural assessment is to verify that the acceptance criteria specified are complied with.

1.1.1.3 The requirements in this Appendix apply to the assessment of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads of the tanks in the midship cargo region and, in addition, the assessment of strengthening of longitudinal hull girder shear structural members, as defined in **Sec 9/2.2.1.1** and **Sec 4/Table 4.1.1**, in way of transverse bulkheads for hull girder vertical shear loads in the forward and aft cargo regions. The strength assessment of longitudinal hull girder shear structural members given in this Appendix is not applicable for forward transverse collision bulkhead, engine room transverse bulkhead and slop tank transverse bulkheads.

1.1.1.4 For the purpose of the FE structural assessment the cargo tank regions are as defined in **Fig B.1.1.**

1.1.1.5 Cargo tank structural strength analysis, in accordance with **Appendix B/2**, for the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in tanks within the midship cargo region, is mandatory. The assessment is to be based on the maximum permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) between and including the forward bulkhead of the aft most cargo tank and 0.65 L from AP, but not including the engine room and slop tank transverse bulkheads, see **Fig B.1.1(a)**.

1.1.1.6 The assessment of longitudinal hull girder shear structural members in the forward cargo region, in accordance with **Appendix B/2**, is mandatory. The strengthening of these structural members in way of transverse bulkheads in the tanks of the forward cargo region may be based on the maximum permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) at the bulkhead positions forward of 0.65 L from AP, but not including the forward collision bulkhead, see **Fig B.1.1(b)**.

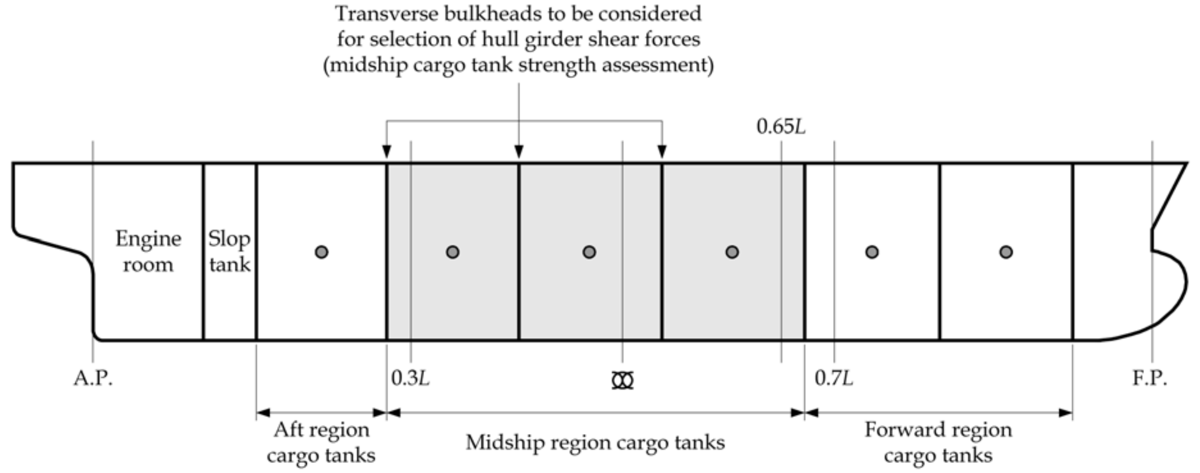
1.1.1.7 Strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads of the tanks in the midship cargo region and the aft cargo region, in accordance with **Appendix B/2**, may be based on the scantling result obtained from the midship cargo tank analysis as described in **1.1.1.5.**

1.1.1.8 Alternatively, optional assessment may be carried out to determine the strengthening requirement of longitudinal hull girder shear structural members in way of individual transverse bulkheads based on the permissible still water (load combination S) and combined permissible still water and wave hull girder vertical shear forces (load combination S+D) at the transverse bulkhead position under consideration, see **Fig B.1.1(b).**

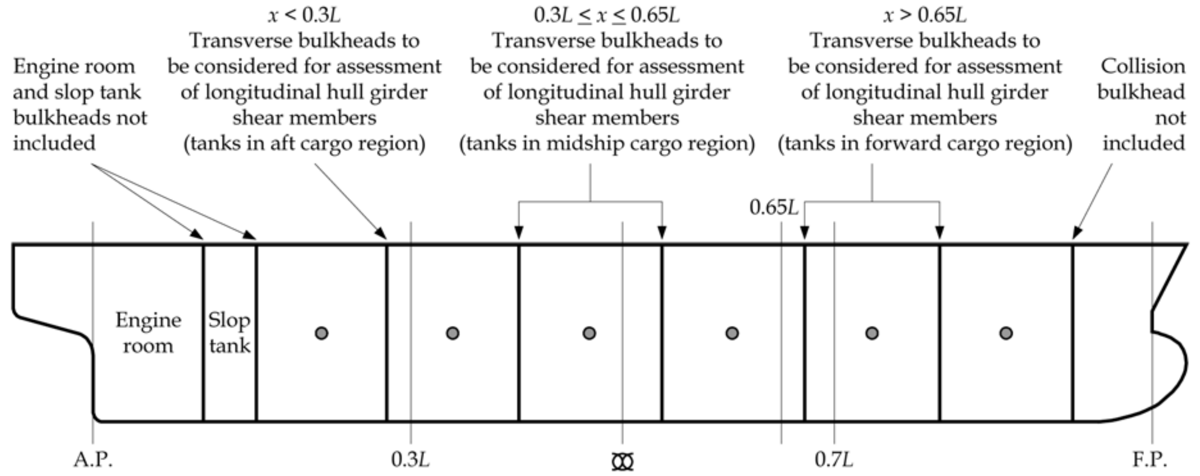
1.1.1.9 Fine mesh finite element analysis, in accordance with **Appendix B/3**, and the finite element based fatigue assessment of lower hopper knuckle joint, in accordance with **Appendix B/4**, are mandatory for the midship cargo region.

Fig B.1.1
Definition of Cargo Tank Regions for FE Structural Assessment

(a) Midship cargo tank strength assessment



(b) Assessment of longitudinal hull girder shear structural members



Note
1. Tanks in the forward cargo region are defined as tanks with their longitudinal centre of gravity position forward of 0.7 L from A.P.
2. Tanks in the midship cargo region are defined as tanks with their longitudinal centre of gravity position at or forward of 0.3 L from AP and at or aft of 0.7 L from A.P.
3. Tanks in the aft cargo region are defined as tanks with their longitudinal centre of gravity position aft of 0.3 L from A.P.

1.2 Symbols, Units and Definitions

1.2.1 General

1.2.1.1 The symbols and definitions, applicable to this section, are given in **Sec 4/1, Sec 7** and as follows:

a_v vertical acceleration, taken at centre of gravity of tank

a_t transverse acceleration, taken at centre of gravity of tank

a_{lng} longitudinal acceleration, taken at centre of gravity of tank

E Modulus of Elasticity of steel, 2.06×105 N/mm^2

M_{wv} vertical wave bending moment for a dynamic load case

M_{sw} vertical still water bending moment for a finite element loading pattern

M_h horizontal wave bending moment for a dynamic load case

Q_{wv} vertical wave shear force for a dynamic load case

Q_{sw} vertical still water shear force for a finite element loading pattern

T_{LC} draught at the loading condition being considered

T_{sc} scantling draught, as defined in **Sec 4/1.1.5.5**

$T_{bal\text{-}em}$ emergency draught of ship

t_{grs} proposed new building gross thickness excluding Owner's extras, see **Sec 2/6.3.4**

t_{corr} corrosion addition, as defined in **Sec 6/3.2**

σ_{yd} specified minimum yield stress of the material, N/mm^2

σ_{vm} von Mises stress

$$= \sqrt{\sigma_x{}^2 + \sigma_y{}^2 - \sigma_x \sigma_y + 3\tau_{xy}{}^2}$$

σ_x axial stress in element x direction

σ_y axial stress in element y direction

τ_{xy} element shear stress in x-y plane

δ_x displacement in x direction, in accordance with the coordinate system defined in **Sec 4/1.4**

δ_y displacement in y direction, in accordance with the coordinate system defined in **Sec 4/1.4**

δ_z displacement in z direction, in accordance with the coordinate system defined in **Sec 4/1.4**

θ_x rotation about x axis, in accordance with the coordinate system defined in **Sec 4/1.4**

θ_y rotation about y axis, in accordance with the coordinate system defined in **Sec 4/1.4**

θ_z rotation about z axis, in accordance with the coordinate system defined in **Sec 4/1.4**

1.2.1.2 The nomenclature of structural components is defined in **Sec 4/1.5.**

1.2.1.3 Consistent co-ordinate and unit systems are to be used throughout all parts of the structural analysis. However, in calculations using Rule Formulae, the units and co-ordinate system as specified are to be used. Where output values from Rule formulae are in a different unit and/or co-ordinate system as used in the structural analysis, the output values are to be converted to the appropriate unit and co-ordinate system.

1.2.2 Finite element types

1.2.2.1 The structural assessment is to be based on linear finite element analysis of three dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in **Table B.1.1.**

1.2.2.2 Two node line elements and three or four node plate/shell elements are considered sufficient for the representation of the hull structure. The mesh requirements given in this Appendix are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

Table B.1.1
Types of Finite Element

Rod (or truss) element	Line element with axial stiffness only and constant cross-sectional area along the length of the element
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element
Membrane (or plane-stress) plate element	Plate element with bi-axial and in-plane plate element stiffness with constant thickness
Shell (or bending plate) element	Plate element with in-plane stiffness and out-of-plane bending stiffness with constant thickness

1.2.2.3 For the cargo tank and fine mesh strength analyses as specified in **Appendix B/2** and **B/3**, the assessment against stress acceptance criteria is to be based on membrane (or in-plane) stresses of plate elements. For the fatigue assessment as specified in **Appendix B/4**, the calculation of dynamic stress range for the determination of fatigue life is to be based on surface stresses of plate elements.

2 Cargo Tank Structural Strength Analysis

2.1 Assessment

2.1.1 General

2.1.1.1 For tankers of conventional arrangements, the finite element strength assessment of the hull girder and primary supporting structural members is to be in accordance with the requirements in this section.

2.2 Structural Modelling

2.2.1 General

2.2.1.1 The longitudinal extent of the midship cargo tank finite element (FE) model is to cover three cargo tank lengths about midships. Where the tanks in the midship cargo region are of different lengths, the middle tank of the finite element model is to represent the cargo tank of the greatest length. The finite element model may be prismatic. The transverse bulkheads at the ends of the model are to be represented. Where corrugated transverse bulkheads are fitted, the model is to include the extent of the bulkhead stool structure forward and aft of the tanks at the model ends. The length of the model extending beyond the end transverse bulkheads is to be kept equal, at both ends. The web frames at the ends of the model are to be modelled. Typical finite element models representing the midship cargo tank region of different tanker configurations are shown in **Fig B.2.1**.

2.2.1.2 The assessment of longitudinal hull girder shear structural members, as defined in **Sec 9/2.2.1.1** and **Sec 4/Table 4.1.1**, against hull girder vertical shear loads in the forward and aft cargo regions may be based on the midship cargo tank finite element model with modification of plate and stiffener properties where appropriate. Where a separate cargo tank finite element model is used for the assessment of shear strength, the model is to cover three tank lengths.

2.2.1.3 Both port and starboard sides of the ship are to be modelled. The full depth of the ship is to be modelled.

2.2.1.4 All main longitudinal and transverse structural elements are to be modelled. These include inner and outer shell, double bottom floor and girder system, transverse and vertical web frames, stringers and transverse and longitudinal bulkhead structures. All plates and stiffeners on the structure, including web stiffeners, are to be modelled, see **2.2.1.11.**

2.2.1.5 The reduced thickness used in the FE model of the cargo tanks, applicable to all plating and stiffener's web and flanges is to be calculated as follows:

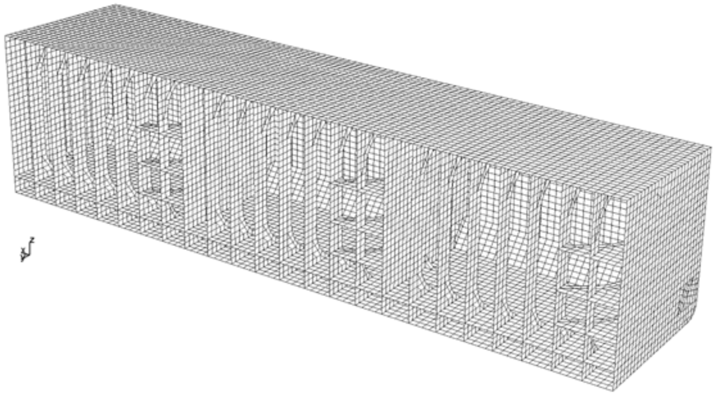
$$t_{FEM-net50} = t_{grs} - 0.5\,t_{corr}$$

Where:

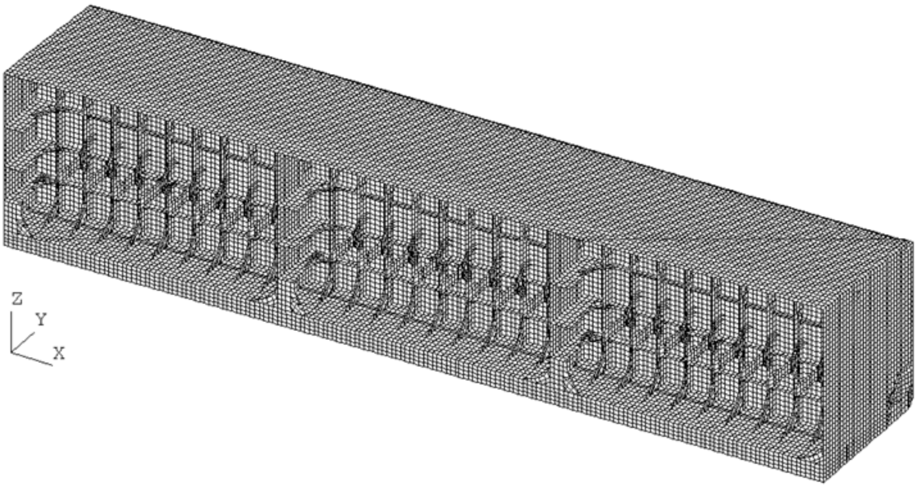
t_{grs} gross thickness, as defined in **1.2**

t_{corr} corrosion addition, as defined in **Sec 6/3.2**

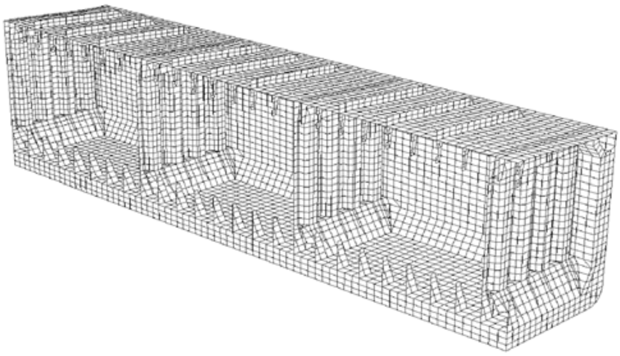
Fig B.2.1
Typical 3-Tank FE Models Representing Midship Cargo Tank Region of Tankers



Typical Cargo Tank Model of an AfraMax Oil Tanker (shows only starboard side of the full breadth model)



Typical Cargo Tank Model of a VLCC (shows only port side of the full breadth model)



Typical Cargo Tank Model of a Product Tanker (shows only port side of the full breadth model)

2.2.1.6 The plate element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the plate element mesh is to satisfy the following requirements:

(a) one element between every longitudinal stiffener, see **Fig B.2.2**. Longitudinally, the element length is not to be greater than 2 longitudinal spaces

(b) one element between every vertical stiffener on transverse bulkheads, see **Fig B.2.3**

(c) one element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see **Fig B.2.2** and **Fig B.2.4**

(d) at least three elements over the depth of double bottom girders and floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads. For cross ties, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, representation using two elements over the depth is acceptable provided that there is at least one element between every web stiffener. The mesh size of adjacent structure is to be adjusted to suit

(e) the mesh on the hopper tank web frame shall be fine enough to represent the shape of the web ring opening, see **Fig B.2.2**

(f) the curvature of the free edge on large brackets of primary support members is to be modelled accurately to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point provided that the modelled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, see F**ig B.2.5**. The modelling of the tapering part of the flange is to be in accordance with **2.2.1.14**. An acceptable mesh is shown in **Fig B.2.5**. A finer mesh is to be used for the determination of detailed stress at the bracket toe, see **Appendix B/3**.

2.2.1.7 Corrugated bulkheads and bulkhead stools are to be modelled using shell plate elements, see **Fig B.2.6**. Diaphragms in the stools and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modelling is to be carried out as follows:

(a) the shell element mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool

(b) where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stools in way of the corrugations in order that the corrugation bulkhead will retain its original geometrical shape. However, if the shape of the corrugation is adjusted in order to simplify the modelling procedure, this effect is to be taken into account in evaluation of stresses as described in **2.7.2.6.**

(c) for a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in order to simplify the modelling. The adjustment is to be made such that the shape and position of the corrugations and primary support members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary.

2.2.1.8 The aspect ratio of the plate elements is in general not to exceed three. The use of triangular plate elements is to be kept to a minimum. Where possible, the aspect ratio of plate elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to one and the use of triangular elements is to be avoided.

2.2.1.9 Typical mesh arrangements of the cargo tank structure are shown in **Fig B.2.7.**

2.2.1.10 Shell elements, in association with beam elements, are to be used to represent stiffened panels in areas under lateral pressure. Shell elements are to be used to represent unstiffened panels in areas under lateral pressure. Membrane and rod elements may be used to represent non-tight structure under no pressure loads.

Fig B.2.2
Typical Finite Element Mesh on Web Frame

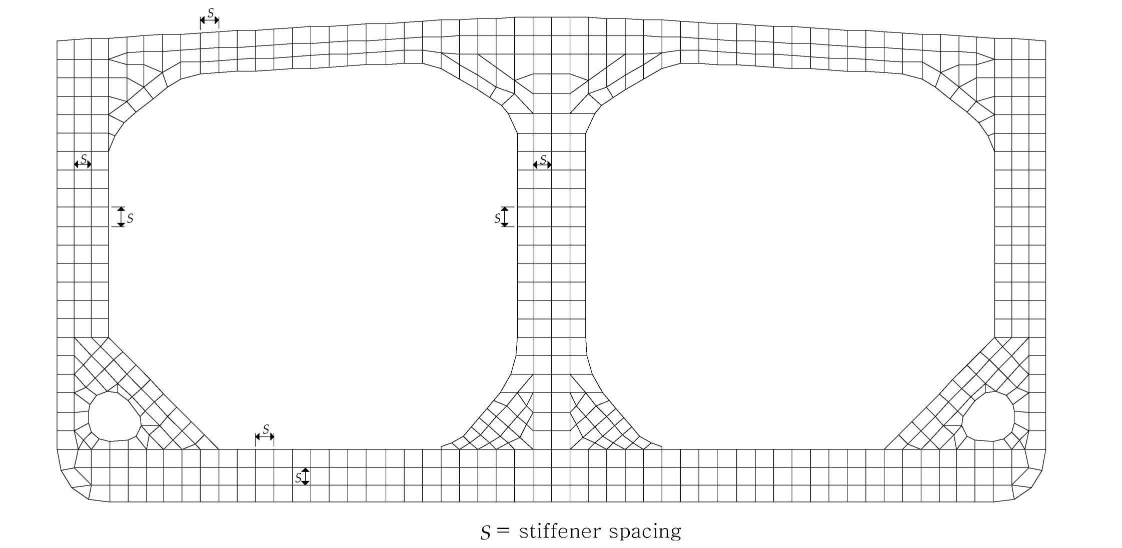


Fig B.2.3
Typical Finite Element Mesh on Transverse Bulkhead

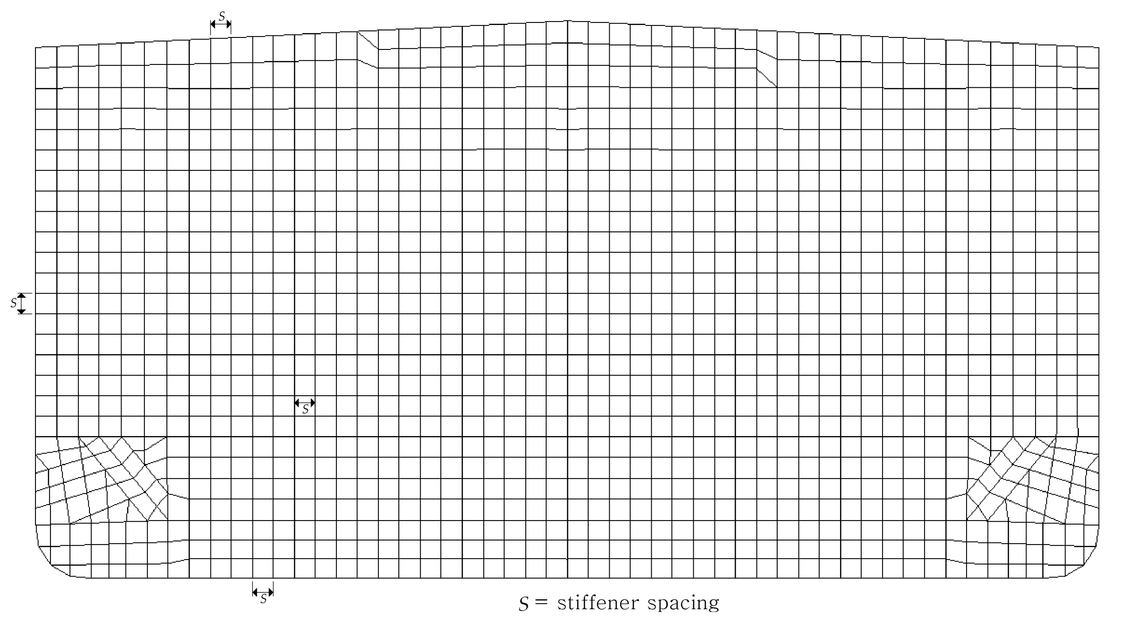


Fig B.2.4
Typical Finite Element Mesh on Horizontal Transverse Stringer on Transverse Bulkhead

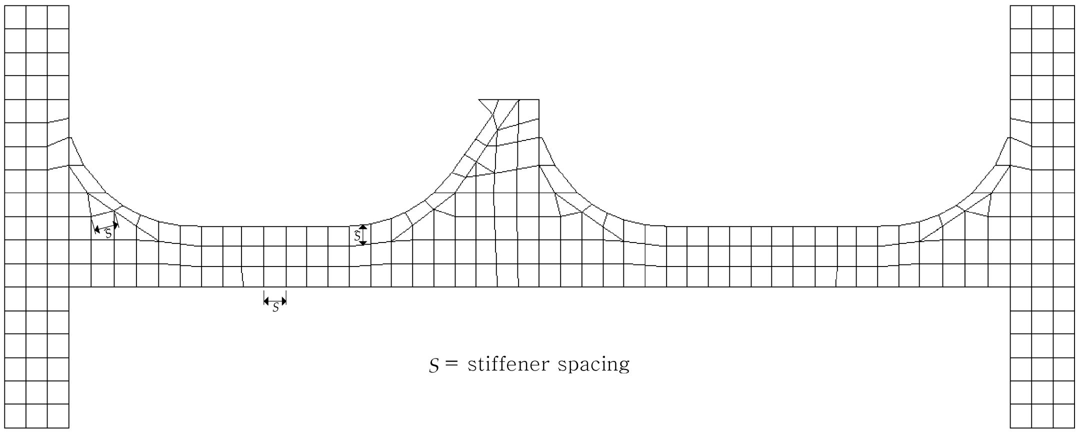


Fig B.2.5
Typical Finite Element Mesh on Transverse Web Frame Main Bracket

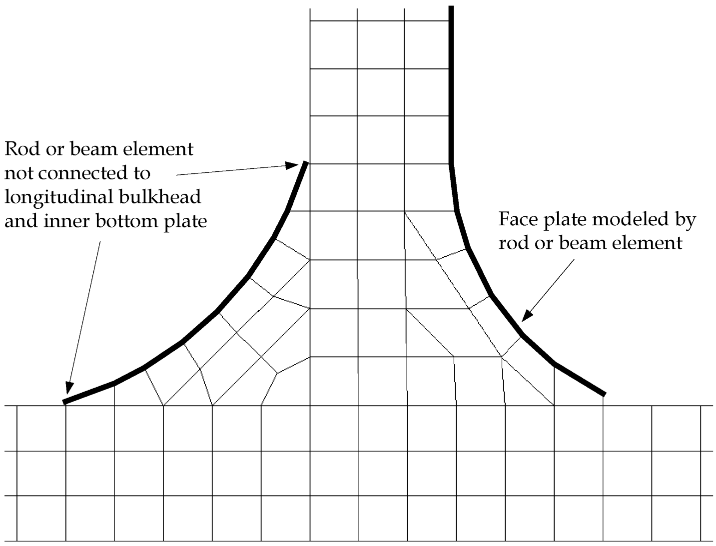


Fig B.2.6
Typical Finite Element Mesh on Transverse Corrugated Bulkhead Structure

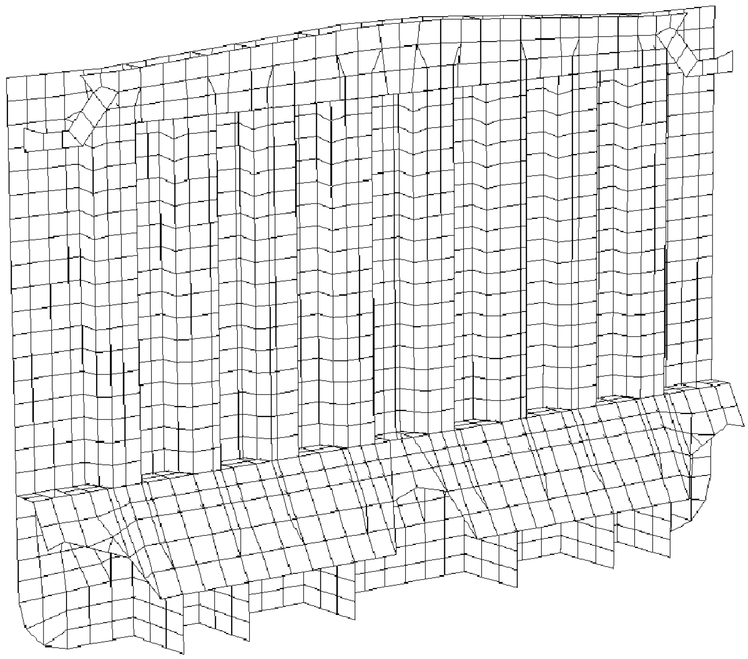


Fig B.2.7
Typical Finite Element Mesh Arrangements of Cargo Tank Structure

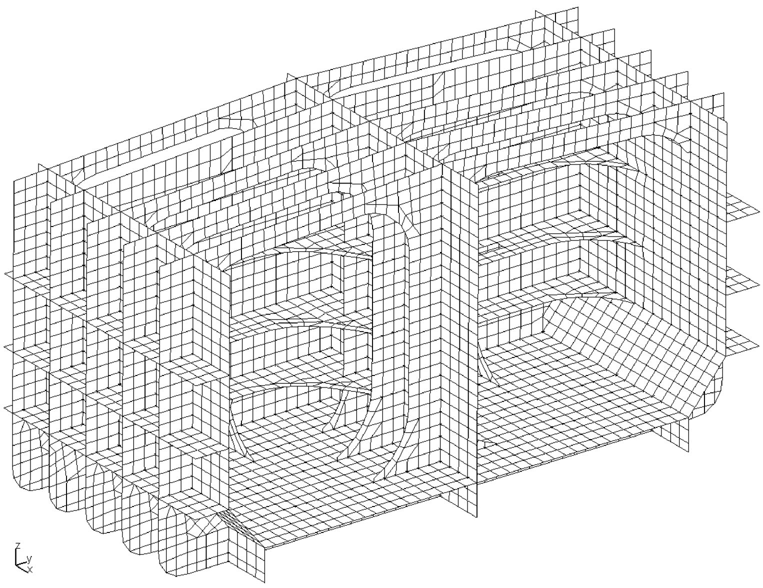
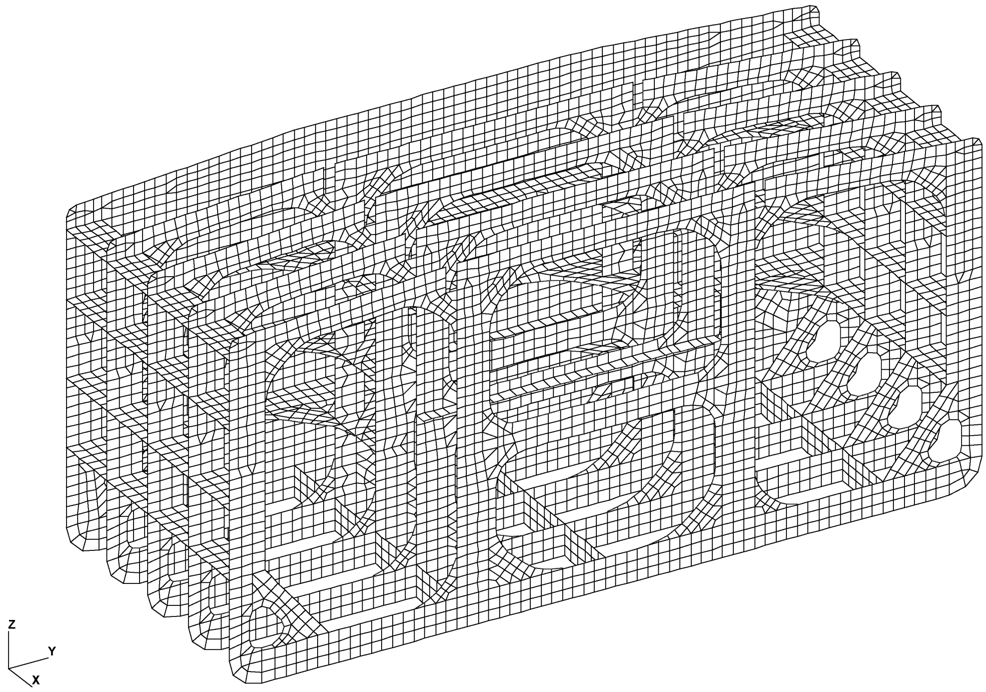
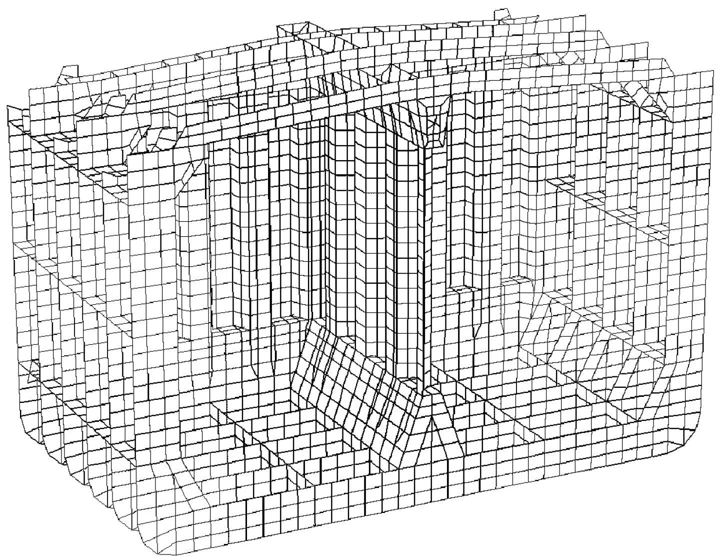


Fig B.2.7 (Continued)
Typical Finite Element Mesh Arrangements of Cargo Tank Structure



VLCC



Product tanker

2.2.1.11 All local stiffeners are to be modelled. These stiffeners may be modelled using line elements positioned in the plane of the plating. Beam elements are to be used in areas under the action of lateral loads whilst rod (truss) elements may be used to represent local stiffeners on internal structural members under no lateral loads. The line elements are to have the following properties:

(a) for beam elements, out of plane bending properties are to represent the inertia of the combined plating and stiffener. The width of the attached plate is to be taken as ½ + ½ stiffener spacing on each side of the stiffener. The eccentricity of the neutral axis is not required to be modelled.

(b) for beam and rod elements, other sectional properties are to be based on a cross sectional area representing the stiffener area, excluding the area of the attached plating.

2.2.1.12 The effective cross sectional area of non-continuous stiffeners is to be calculated in accordance with **Table B.2.1.**

Table B.2.1
Effective Cross Sectional Area of Stiffener Line Elements

Structure represented by line element	Effective area A_e	
Stiffener within a distance 2 d_w from a sniped (non-continuous) end	All sections	A_e=25%$A_{n-net50}$
Stiffener outside a distance 2 d_w from a sniped (non-continuous) end	All sections	A_e=100%$A_{n-net50}$

Where:
$A_{n-net50}$ average cross sectional area over length of line element
d_w depth of stiffener web, excluding attached plate

2.2.1.13 Web stiffeners on primary support members are to be modelled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modelled. These stiffeners may be modelled using rod elements.

2.2.1.14 Face plates of primary support members and brackets may be modelled using rod elements. The effective cross sectional area at the curved part of the face plate is to be calculated in accordance with **Sec 4/2.3.4**. The cross sectional area of a rod element representing the tapering part of the face plate is to be based on the average cross sectional area of the face plate in way of the element length.

2.2.1.15 Methods of representing openings in webs of primary support members are to be in accordance with **Table B.2.2.** Cut-outs for local stiffeners, scallops, drain and air holes need not be represented.

Table B.2.2
Representation of Openings in Primary Support Member Webs

$h_0/h < 0.35$ and $g_0 < 1.2$	Openings do not need to be modelled
$0.5 > h_0/h \geq 0.35$ and $g_0 < 1.2$	The plate modelled with mean thickness $t_{1\text{-}net50}$
$h_0/h < 0.5$ and $2 > g_0 \geq 1.2$	The plate modelled with mean thickness $t_{2\text{-}net50}$
$h_0/h \geq 0.5$ or $g_0 \geq 2.0$	The geometry of the opening is to be modelled

Where:

$$g_0 = 1 + \frac{l_o^2}{2.6(h-h_o)^2}$$

$$t_{1\text{-}net50} = \frac{h-h_o}{h} t_{w-net50}$$

$$t_{2\text{-}net50} = \frac{h-h_o}{hg_o} t_{w-net50}$$

$t_{w\text{-}net50}$ net web thickness
l_0 length of opening parallel to primary support member web direction, see **Fig B.2.8**
h_0 height of opening parallel to depth of web, see **Fig B.2.8**
h height of web of primary support member in way of opening, see **Fig B.2.8**
t_{corr} corrosion addition, as defined in **Sec 6/3.2**

Note
1. For sequential openings where the distance, d_0, between openings is less than 0.25 h, the length l_0 is to be taken as the length across openings as shown in **Fig B.2.9.**
2. The same unit is to be used for l_0, h_0 and h.

Fig B.2.8
Openings in Web

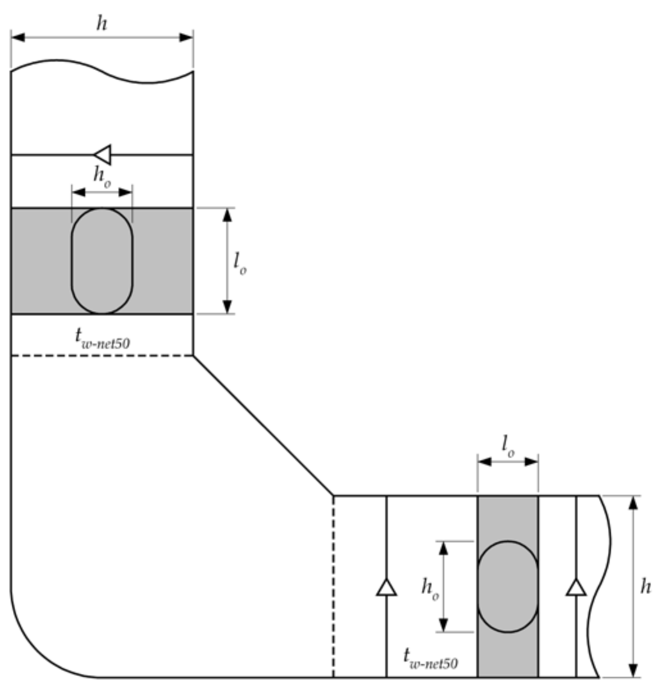
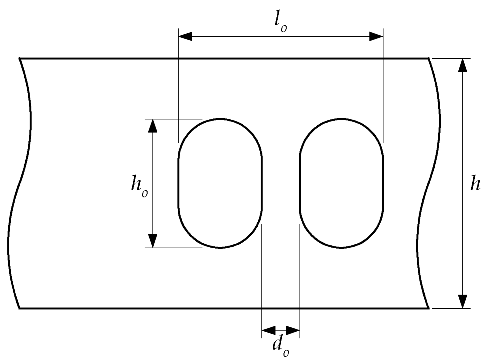


Fig B.2.9

Length l_0 for Sequential Openings with $d_0 < \frac{h}{4}$



2.3 Loading Conditions

2.3.1 Finite element load cases

2.3.1.1 The standard design load combinations to be used in the structural analysis are given in **Tables B.2.3** and **B.2.4** for tankers with two oil-tight longitudinal bulkheads and one centreline oil-tight longitudinal bulkhead respectively.

2.3.1.2 For S+D design load combinations (seagoing load cases) the number of dynamic load cases required to be investigated for each loading pattern is indicated by the dynamic load case numbers specified for each loading pattern in **Tables B.2.3** and **B.2.4**. Each S+D design load combination consists of two parts:

(a) static loads, as described by the loading pattern, ship draught, hull girder still water bending moment and shear force specified, and

(b) dynamic loads defined in **Sec 7/Table 7.6.2** for the dynamic load case number specified.

2.3.1.3 For tankers with two oil-tight longitudinal bulkheads and a cross tie arrangement in the centre cargo tanks, loading patterns A7 and A12 in **Table B.2.3** are to be examined for the possibility that unequal filling levels in transversely paired wing cargo tanks would result in a more onerous stress response. Loading pattern A7 is required to be analysed only if such a non-symmetric seagoing loading conditionis included in the ship loading manual. Loading patterns A7 and A12 need not be examined for tankers without a cross tie arrangement in the centre cargo tanks.

2.3.1.4 For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A3 and harbour loading pattern A13, with all cargo tanks abreast empty, are to be analysed with a ship draught of 0.55 T_{sc} and 0.65 T_{sc} respectively. If conditions in the ship loading manual specify greater draughts for loading pattern A3 or A13, then the maximum specified draught in the ship's loading manual for the loading pattern is to be used.

2.3.1.5 For tankers with two oil-tight longitudinal bulkheads, seagoing loading pattern A5 and harbour loading pattern A11, with all cargo tanks abreast fully loaded, are to be analysed with a ship draught of 0.8 T_{sc} and 0.7 T_{sc} respectively. If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the minimum specified draught in the ship's loading manual for the loading pattern is to be used.

2.3.1.6 For loading patterns A1, A2, B1, B2 and B3, with cargo tank(s) empty, a minimum ship draught of 0.9 T_{sc} is to be used in the analysis. If conditions in the ship loading manual specify greater draughts for loading patterns with empty cargo tank(s), then the maximum specified draught for the actual condition is to be used.

2.3.1.7 Where a ballast condition is specified in the ship loading manual with ballast water filled in one or more cargo tanks, loading patterns A8 and B7 in **Tables B.2.3** and **B.2.4** are to be examined. If this loading is un-symmetrical then additional strength assessment is to be carried out according to the requirements of the individual Classification Society.

Table B.2.3
FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

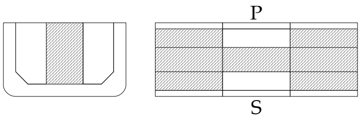
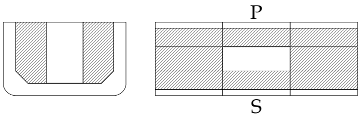
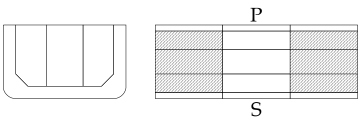
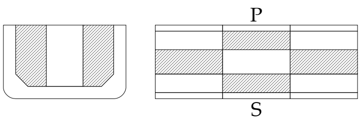
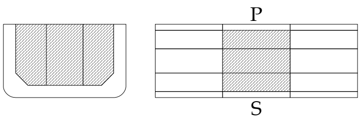
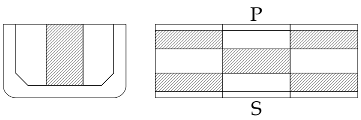
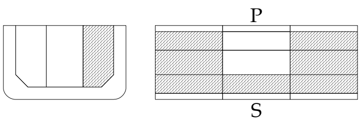
Loading pattern	Figure	Still water loads			Dynamic load cases		
		Draught	% of Perm. SWBM(2)	% of Perm. SWSF(2)	Strength assessment (1a)	Strength assessment against hull girder shear loads(1b)	
					Midship region	Forward region	Midship and aft regions
Design load combination S + D (Sea-going load cases)							
A1		0.9 T_{sc}	100 % (sag)	See note 3	1	\	\
			100 % (hog)	100 % (-ve fwd) See note 4	2, 5a	\	\
A2		0.9 T_{sc}	100 % (sag)	See note 3	1	\	\
			100 % (hog)	100 % (-ve fwd) See note 4	2, 5a	\	\
A3		0.55 T_{sc} see note 6	100 % (hog)	100 % (-ve fwd) See note 5	2	4	2
				100 % (-ve fwd) See note 4	5a	\	\
A4		0.6 T_{sc}	100 % (sag)	100 % (+ve fwd) See note 4	1, 5a	\	\
A5		0.8 T_{sc} See note 7	100 % (sag)	100 % (+ve fwd) See note 5	1	3	1
				100 % (+ve fwd) See note 4	5a	\	\
A6		0.6 T_{sc}	100 % (hog)	100 % (-ve fwd) See note 4	5a	\	\
A7(8)		T_{LC}	100 % (hog)	100 % (-ve fwd) See note 4	5a	\	\

Table B.2.3
FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

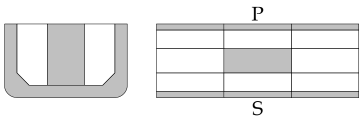
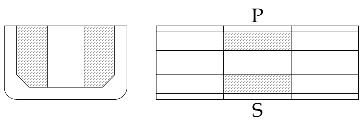
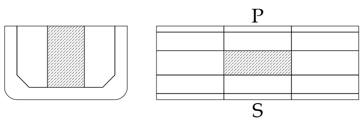
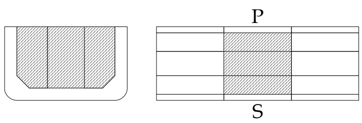
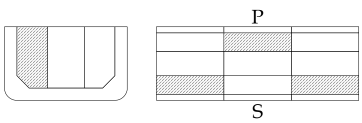
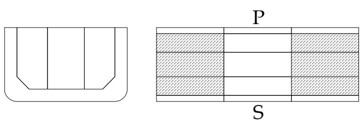
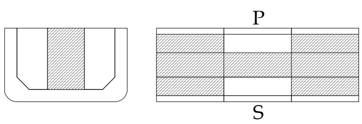
Loading pattern	Figure	Still water loads			Dynamic load cases		
		Draught	% of Perm. SWBM(2)	% of Perm. SWSF(2)	Strength assessment (1a)	Strength assessment against hull girder shear loads(1b)	
					Midship region	Forward region	Midship and aft regions
A8(9)		T_{bal-em}	100 % (sag)	100 % (+ve fwd) See note 4	1	\	\
Design load combination S (Harbour and tank testing load cases)							
A9(13)		1/4 T_{sc}	100 % (sag)	100 % (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
A10(13)		1/4 T_{sc}	100 % (sag)	100 % (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
A11(12,13)		0.7 T_{sc} see note 12	100 % (sag)	100 % (+ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
A12(10,13)		1/3 T_{sc}	See note 10	See note 10	Only applicable to strength assessment of midship region (see note 1(a))		
A13(11,13)		0.65 T_{sc} see note 11	100 % (Hog)	100 % (-ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
A14(13)		T_{sc}	100 % (Hog)	100 % (-ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		

Table B.2.3 (Continued)
FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

Note

1.
   (a) For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads within midship cargo region, see **1.1.1.5**.
   (b) For the assessment of strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads for hull girder vertical shear loads, see **1.1.1.6, 1.1.1.7** and **1.1.1.8.**
2. The selection of permissible SWBM and SWSF for the assessment of different cargo regions of the ship is to be in accordance with **Table B.2.6**. The percentage of the permissible SWBM and SWSF to be applied are to be in accordance with this table.
3. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
4. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used. Where this shear force exceeds the target SWSF (design load combination S) or target combined SWSF and VWSF, calculated in accordance with **2.4.5.2**, (design load combination S+D) as specified in the table, correction vertical loads are to be applied to adjust the shear force down to the required value.
5. Correction vertical loads are to be applied to adjust the shear force to the required value specified.
6. For loading pattern A3, with all cargo tanks abreast empty in sea-going condition, a draught of $0.55\,T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught greater than $0.55\,T_{sc}$, the maximum specified draught for those loading conditions is to be used in the FE analysis.
7. For loading pattern A5, with all cargo tanks abreast fully loaded in sea-going condition, a draught of $0.8\,T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught lesser than $0.8\,T_{sc}$, the minimum specified draught for those loading conditions is to be used in the FE analysis.
8. Loading pattern A7 is only required to be analysed for tankers with a cross tie arrangement in the centre cargo tanks if the ship's loading manual includes a non-symmetrical loading condition with only one of the wing tanks filled. The actual draught from the loading manual for the condition is to be used in the analysis, see **Table B.2.5**.
9. Ballast loading pattern A8 with ballast filled in one or more cargo tanks (i.e. gale ballast/emergency ballast conditions etc.) is only required to be analysed if the condition is specified in the ship's loading manual. The actual loading pattern and draught from the loading manual for the condition is to be used in the analysis, see **Table B.2.5.**
10. Loading patterns A12 is only required for tankers with a cross tie arrangement in the centre cargo tanks. The actual shear force and bending moment that results from the application of local loads to the FE model are to be used. Adjusting vertical loads and bending moments are not applied.
11. For loading pattern A13, with all cargo tanks abreast empty in harbour condition, a draught of $0.65\,T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught greater than $0.65\,T_{sc}$, the maximum specified draught for those loading conditions is to be used in the FE analysis.
12. For loading pattern A11, with all cargo tanks abreast fully loaded in harbour condition, a draught of $0.7\,T_{sc}$ is to be used in the analysis. Where such conditions are specified in the ship's loading manual with a draught less than $0.7\,T_{sc}$, the minimum specified draught for those loading conditions is to be used in the FE analysis.
13. No dynamic loads are to be applied to Design Load Combination S (harbour and tank testing load cases).

Table B.2.4
Load Cases for Tankers with One Centreline Oil-tight Longitudinal Bulkhead

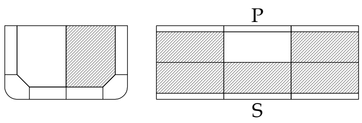
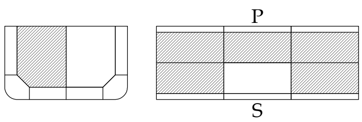
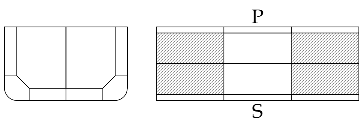
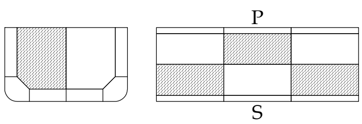
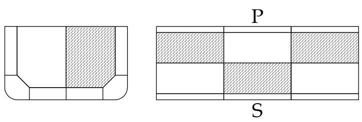
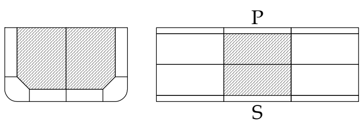
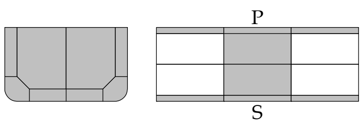
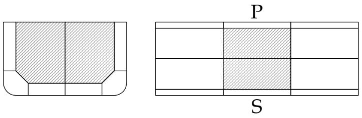
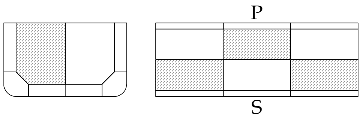
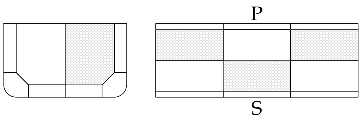
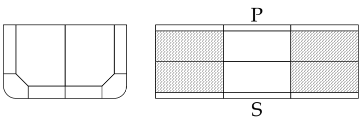
Loading pattern	Figure	Still water loads			Dynamic load cases		
		Draught	% of Perm. SWBM(2)	% of Perm. SWSF(2)	Strength assessment (1a)	Strength assessment against hull girder shear loads(1b)	
					Midship region	Forward region	Midship and aft regions
Design load combination S + D (Sea-going load cases)							
B1		0.9 T_{sc}	100 % (sag)	See note 3	1	\	\
			100 % (hog)	100 % (-ve fwd) See note 4	2, 5a	\	\
B2(6)		0.9 T_{sc}	100 % (sag)	See note 3	1	\	\
			100 % (hog)	100 % (-ve fwd) See note 4	2, 5b	\	\
B3		0.9 T_{sc}	100 % (hog)	100 % (-ve fwd) See note 5	2	4	2
				100 % (-ve fwd) See note 4	5a, 5b, 6a, 6b	\	\
B4		0.6 T_{sc}	100 % (sag)	75 % (+ve fwd) See note 4	1, 5a	\	\
B5(6)		0.6 T_{sc}	100 % (sag)	75 % (+ve fwd) See note 4	1, 5b	\	\
B6		0.6 T_{sc}	100 % (sag)	100 % (+ve fwd) See note 5	1	3	1
				100 % (+ve fwd) See note 4	5a, 5b	\	\
B7(7)		T_{bal-em}	100 % (sag)	100 % (+ve fwd) See note 4	1	\	\

Table B.2.4
Load Cases for Tankers with One Centreline Oil-tight Longitudinal Bulkhead

Loading pattern	Figure	Still water loads			Dynamic load cases		
		Draught	% of Perm. SWBM[2]	% of Perm. SWSF[2]	Strength assessment [1a]	Strength assessment against hull girder shear loads[1b]	
					Midship region	Forward region	Midship and aft regions
Design load combination S (Harbour and tank testing load cases)							
B8[8]		1/3 T_{sc}	100 % (sag)	100 % (+ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		
B9[8]		1/3 T_{sc}	100 % (sag)	75 % (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
B10[6,8]		1/3 T_{sc}	100 % (sag)	75 % (+ve fwd) See note 4	Only applicable to strength assessment of midship region (see note 1(a))		
B11[8]		T_{sc}	100 % (Hog)	100 % (-ve fwd) See note 5	Applicable to strength assessment of midship region (see 1(a)) and strength assessment against hull girder shear loads (see 1(b))		

Note

1.
   (a) For the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads within midship region, see **1.1.1.5.**
   (b) For the assessment of strengthening of longitudinal hull girder shear structural members in way of transverse bulkheads for hull girder vertical shear loads, see **1.1.1.6, 1.1.1.7** and **1.1.1.8.**
2. The selection of permissible SWBM and SWSF for the assessment of different cargo regions of the ship is to be in accordance with **Table B.2.6**. The percentage of the permissible SWBM and SWSF to be applied are to be accordance with this table.
3. The actual shear force that results from the application of static and dynamic local loads to the FE model are to be used.
4. The actual shear force that results from the application of static and dynamic local loads are to be used. Where this shear force exceeds the target SWSF (design load combination S) or target combined SWSF and VWSF, calculated in accordance with **2.4.5.2**, (design load combination S+D) as specified in the table, correction vertical loads are to be applied to adjust the shear force down to the required value.
5. Correction vertical loads are to be applied to adjust the shear force to the required value specified.
6. Load cases B2, B5 and B10 are only required if the structure is not symmetrical about the ship's centreline.
7. Ballast loading pattern B7 with ballast filled in cargo tanks (i.e. gale ballast/emergency ballast conditions etc.) is only required to be analysed if the condition is specified in the ship's loading manual. The actual loading pattern and draught from the loading manual for the condition is to be used in the analysis, see **Table B.2.5**. If the actual loading pattern is different from load case B7 then:
   (a) An operational restriction corresponding to the analysed condition is to be added in the Loading Manual.
   (b) 100 % of the permissible SWBM is to be applied when analyzing loading pattern with ballast in cargo tanks.
8. No dynamic loads are to be applied to Design Load Combination S (harbour and tank testing load cases).

2.3.2 Dynamic load cases

2.3.2.1 The dynamic load cases to be used for the finite element analysis are specified in **Sec 7/6.4.**

2.4 Application of Loads

2.4.1 General

2.4.1.1 The application of loads to the finite element model is to be in accordance with **Sec 7/6** and the requirements specified in **B/2.4.**

2.4.1.2 The load parameters and locations to be used for the calculation of the applied loads and accelerations are to be in accordance with **Table B.2.5** and **Table B.2.6.**

2.4.1.3 Constant pressure load, evaluated at the element's centroid, may be applied to a finite plate element. Alternately, a linear pressure distribution between the element's nodal points can be applied.

Table B.2.5
Parameters for Calculation of Loads and Accelerations

Parameter	Standard conditions			Optional conditions	
	Draught T_{sc}	Draught 0.9 T_{sc}	Draught 0.6 T_{sc}	Loaded conditions: A3 (draught > 0.6 T_{sc}) and A7	Gale/emergency ballast conditions: A8 and B7
L	Rule Length			Rule Length	
C_b	block coefficient, as defined in **Sec 4/1.1.1.1**			block coefficient, as defined in **Sec 4/1.1.1.1**	
Ship speed	0.0			0.0	
Roll response					
GM	0.12 B	0.12 B	0.24 B	Corrected GM in the ship's loading manual for the loaded or gale/emergency ballast pattern under consideration, see Note 1	
$r_{roll-gyr}$	0.35 B	0.35 B	0.4 B	See Note 2	
Pitch response, longitudinal and transverse accelerations, horizontal wave bending moment and sea pressures					
Ship draught	T_{sc}	0.9 T_{sc}	0.6 T_{sc}	Maximum mean draught in the loading manual for the loading pattern under consideration	Minimum mean draught in the loading manual for the loading pattern under consideration

Note
1. Where GM for optional loaded or gale/emergency ballast conditions is not given in the ship's loading manual, GM is to be determined in accordance with **Sec 7/3.1.3.2.**
2. Where $r_{roll-gyr}$ for optional loaded or gale/emergency ballast conditions is not given in the ship's loading manual, $r_{roll-gyr}$ is to be determined in accordance with **Sec 7/3.1.3.3.**
3. A gale/emergency ballast condition is defined as a ballast condition with one or more cargo tanks filled with ballast.

<table>
<tr><th colspan="5">Table B.2.6
Locations for the Determination of Loads and Accelerations</th></tr>
<tr><td rowspan="2"></td><td>Strength assessment(1a)</td><td colspan="3">Strength assessment against hull girder shear loads(1b)</td></tr>
<tr><td>Midship cargo region</td><td>Forward cargo region</td><td>Midship cargo region</td><td>Aft cargo region</td></tr>
<tr><td colspan="5">Design load combinations S + D (Sea-going load cases)</td></tr>
<tr><td>Dynamic wave pressure and green sea load</td><td>Transverse section at 0.5L from AP</td><td>Transverse section at 0.75L from AP</td><td>Transverse section at 0.5L from AP</td><td>Transverse section at 0.25L from AP</td></tr>
<tr><td>Acceleration
a_v, a_t, a_{lng}</td><td>at CG position of midship tanks (i.e. 0.5L from AP is within the tank boundary)</td><td>at CG position of forward tanks (i.e. 0.75L from AP is within the tank boundary)</td><td>at CG position of midship tanks (i.e. 0.5L from AP is within the tank boundary)</td><td>at CG position of aft tanks (i.e. 0.25L from AP is within the tank boundary)</td></tr>
<tr><td>VWBM and SWBM (SWBM is to be based on sea-going permissible values, as defined in Sec 7/2.1.1 and 2.1.2)</td><td>at 0.5L from AP</td><td>at 0.75L from AP</td><td>at 0.5L from AP</td><td>at 0.25L from AP</td></tr>
<tr><td>HWBM</td><td>at 0.5L from AP</td><td>\</td><td>\</td><td>\</td></tr>
<tr><td>VWSF and SWSF (SWSF is to be based on sea-going permissible values, as defined in Sec 7/2.1.3 and 2.1.4)</td><td>at the transverse bulkhead with maximum combined seagoing permissible SWSF and VWSF in the region (see 1.1.1.5)</td><td>at the transverse bulkhead with maximum combined seagoing permissible SWSF and VWSF in the region (see 1.1.1.6) or at individual bulkhead position (see 1.1.1.8)</td><td colspan="2">based on midship cargo tank strength assessment (see 1.1.1.7) or seagoing permissible SWSF and VWSF at individual transverse bulkhead position (see 1.1.1.8)</td></tr>
<tr><td colspan="5">Design load combination S (Harbour and tank testing load cases)</td></tr>
<tr><td>SWBM (SWBM is to be based on harbour permissible values, as defined in Sec 7/2.1.1 and 2.1.2)</td><td>at 0.5L from AP</td><td>at 0.75L from AP</td><td>at 0.5L from AP</td><td>at 0.25L from AP</td></tr>
<tr><td>SWSF (SWSF is to be based on harbour permissible values, as defined in Sec 7/2.1.3 and 2.1.4)</td><td>maximum harbour permissible SWSF in the region (see 1.1.1.5)</td><td>maximum harbour permissible SWSF in the region (see 1.1.1.6) or at individual bulkhead position (see 1.1.1.8)</td><td colspan="2">based on midship cargo tank strength assessment (see 1.1.1.7) or harbour permissible SWSF at individual transverse bulkhead position (see 1.1.1.8)</td></tr>
<tr><td colspan="5">Note
1. The following assessments are to be carried out:
(a) for the assessment of scantlings of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads in tanks within midship cargo region, see 1.1.1.5
(b) for the assessment of strengthening of longitudinal hull girder shear structural members in way of individual transverse bulkheads for hull girder shear loads, see 1.1.1.6, 1.1.1.7 and 1.1.1.8.
2. For each FE load case, accelerations are to be calculated at the centre of gravity position of the ballast and/or cargo in accordance with this table. The acceleration calculated for each reference tank is to be applied to the 3 corresponding cargo or ballast tanks along the length of the FE model.
3. Longitudinal distances used in the calculation of loads refer to distance measured forward from the A.P., as defined in Sec 4/1.1.12
4. Dynamic wave pressure calculated at the specified section is to be applied to the full length of the FE model
5. Dynamic load combination factors applied to dynamic loads for design load combination S+D (sea-going load cases) as defined in Sec 7/6.4.
6. The SWBM and SWSF to be applied are to be in accordance with Tables B.2.3 and B.2.4.</td></tr>
</table>

2.4.2 Structural weight, cargo and ballast density

2.4.2.1 The design cargo density is to be taken as 1.025 tonnes/m^3, see **2.4.7.2.**

2.4.2.2 The density of sea water is to be taken as 1.025 tonnes/m^3.

2.4.2.3 The weight of the structure is to be included in the FE analysis. The density of steel is to be taken as 7.85 tonnes/m^3.

2.4.3 Static sea pressure

2.4.3.1 The static sea pressure applied to a plate element due to draught immersion is to be calculated in accordance with **Sec 7/2.2.2.**

2.4.3.2 The still water draught to be considered for each finite element load case is to be in accordance with **Tables B.2.3** and **B.2.4.** A constant draught is to be applied over the full length of the cargo tank FE model.

2.4.3.3 The static sea pressure due to immersed draught for the ship in an upright condition is to be applied for all finite element load cases. The static sea pressure change due to rolling of the ship is included in the dynamic wave pressure formulation.

2.4.4 Dynamic wave pressure

2.4.4.1 The dynamic wave pressure distribution is to be determined at a transverse section of the hull at the longitudinal position as defined in **Table B.2.6.** The dynamic wave pressure distribution is to be calculated in accordance with **Sec 7/6.3.5**. This pressure distribution is to be applied over the full length of the FE model.

2.4.4.2 The pressure distribution due to green sea load on the weather deck is to be calculated in accordance with **Sec 7/6.3.6** at the longitudinal position as defined in **Table B.2.6**. This pressure distribution is to be applied to the weather deck over the full length of the FE model.

2.4.5 Hull girder vertical bending moment and vertical shear force

2.4.5.1 The hull girder vertical bending moment is to reach the following required value, $M_{v\text{-}targ}$, at a section within the length of the middle tank of the three tanks FE model:

$$M_{v-targ} = M_{sw} + M_{wv}$$

Where:

M_{sw} is the still water bending moment to be applied to the FE load case, as specified in **Tables B.2.3** and **B.2.4.**

M_{wv} is the vertical wave bending moment for the dynamic load case under consideration, calculated in accordance with **Sec 7/6.3.2**

2.4.5.2 Hull girder vertical shear force is to reach the following required Q_{targ} value at the forward transverse bulkhead position of the middle tank:

$$Q_{targ} = Q_{sw} + Q_{wv}$$

Where:

Q_{sw} is the vertical still water shear force to be applied to the FE load case, as specified in **Tables B.2.3** and **B.2.4.**

Q_{wv} is the vertical wave shear force for the dynamic load case under consideration, calculated in accordance with **Sec 7/6.3.4.**

2.4.5.3 The required hull girder vertical bending moment and shear force are to be achieved in the same load case where required by **Tables B.2.3** and **B.2.4**. The procedure to apply the required shear force and bending moment distributions is described in **2.5.**

2.4.6 Hull girder horizontal wave bending moment

2.4.6.1 Hull girder horizontal wave bending moment at a section within the length of the middle tank of the three tanks FE model is to reach the value required by the dynamic load case under consideration, calculated in accordance with **Sec 7/6.3.3.**

2.4.6.2 The procedure to adjust the required hull girder horizontal bending moment is described in **2.5.**

2.4.7 Pressure in cargo and ballast tanks

2.4.7.1 The total tank pressure, P_{in}, to be applied at the boundary of a cargo or ballast tank in the finite element analysis is to include the static and dynamic components specified in **Sec 7/Table 7.6.1** and **Table B.2.6.**

2.4.7.2 For the seagoing load cases (design combination S + D) the cargo tank pressure is to be taken as:

$$P_{in} = f_{density} (P_{in-tk} + P_{in-dyn}) \quad \text{kN/m}^2$$

where:

$f_{density}$ factor for joint probability of occurrence of cargo density and maximum sea state in 25 years design life

$= \rho_{max-LM} \,/\, \rho_{allowable}$

ρ_{max-LM} maximum cargo density associated with a full tank from any loading condition in the ship's loading manual. ρ_{max-LM} is not to be taken as less than 0.9 tonnes/m^3 for cargo loaded conditions and 1.025 tonnes/m^3 for the optional emergency ballast condition (i.e. A8 and B7 in **Tables B.2.3** and **B.2.4** respectively)

$\rho_{allowable}$ design cargo density associated with a full tank to be taken as 1.025 tonnes/m^3 unless a higher density is specified by the builder, see **Sec 2/3.1.8.1**

Pi_{n-tk} static tank pressure as given in **Sec 7/2.2.3.1**, in kN/m^2, and with density of fluid in tank equal to the design cargo density, $\rho_{allowable}$

P_{in-dyn} simultaneously acting dynamic pressure given in **Sec 7/6.3.7.1**, in kN/m^2, with simplification given in **2.4.7.3** and with density of fluid in tank equal to the design cargo density, $\rho_{allowable}$

2.4.7.3 The envelope vertical acceleration, a_v, at the centre of gravity of tanks is calculated in accordance with **Sec 7/3.3.3** with the following simplifications:

(a) for head sea conditions, a_{roll-z} is taken as 0

(b) for beam sea conditions, $a_{pitch-z}$ is taken as 0.

2.4.7.4 The vertical, transverse and longitudinal accelerations are to be calculated at the centre of gravity of the abreast tanks at the longitudinal position as specified in **Table B.2.6.** These accelerations are to be applied to all corresponding tanks along the length of the three-tank FE model.

2.4.7.5 The dynamic tank pressure is to be calculated in accordance with **Sec 7/6.3.7.1**, also see **Table B.2.6.**

2.4.7.6 For ballast tanks which utilise ballast water exchange by flow-through method, the following are to be considered when calculating tank pressure for seagoing load cases (design combination S + D) as required by **Sec 7/Table 7.6.1**:

- Maximum vertical height of the air pipe or overflow pipe, i.e. h_{air} as defined in **Sec 7/2.2.3.2** and **Fig 7.2.3**, of all ballast tanks in the cargo region is to be used in the calculation of the dynamic tank pressure due to vertical acceleration (see **Sec 7/6.3.7.1**).
- Maximum value of h_{air} and P_{drop}, as defined in **Sec 7/2.2.3.3**, of all ballast tanks in the cargo region are to be used to calculate the static tank pressure.

2.4.7.7 The following are to be considered when calculating the static tank pressure in cargo tanks for harbour/tank testing load cases (design combination S) as required by **Sec 7/Table 7.6.1**:

- Maximum setting of pressure relief valve, P_{valve} as defined in **Sec 7/2.2.3.5**, of all cargo tanks and, where applicable, maximum h_{air}, as defined in **Sec 7/2.2.3.2** and **Fig 7.2.3**, of all cargo tanks in the cargo region are to be considered in the calculation of Pin-test, see **Sec 7/2.2.3.5.**

2.4.7.8 Where the length of the model is extended beyond the end transverse bulkheads, see **2.2.1.1**, tank pressure is only to be applied to the complete tanks within the model length.

2.5 Procedure to Adjust Hull Girder Shear Forces and Bending Moments

2.5.1 General

2.5.1.1 The procedure described in this section is to be applied to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distributions on the three cargo tanks FE model to achieve the required values.

2.5.1.2 Vertical distributed loads are applied to each frame position, together with a vertical bending moment applied to the model ends to produce the required value of vertical shear force at the forward bulkhead of the middle tank of the FE model, and the required value of vertical bending moment at a section within the length of the middle tank of the FE model. The required values are specified in **2.4.5.**

2.5.1.3 A horizontal bending moment is applied to the ends of the model to produce the required target value of horizontal bending moment at a section within the length of the middle tank of the FE model. The required values are specified in **2.4.6.**

2.5.2 Shear force and bending moment due to local loads

2.5.2.1 The vertical shear forces generated by the local loads are to be calculated at the transverse bulkhead positions of the middle tank of the FE model. The vertical bending moment distribution generated by the local loads is to be calculated along the length of the middle tank of the three cargo tank FE model. The FE model can be used to calculate the shear forces and bending moments. Alternatively, a simple beam model representing the length of the 3-tank FE model with simply supported ends may be used to determine the shear force and bending moment values.

2.5.2.2 For beam and oblique sea conditions, the horizontal bending moment distribution due to dynamic sea pressure and dynamic tank pressure is to be calculated along the length of the middle tank of the FE model.

2.5.2.3 The following local loads are to be applied for the calculation of hull girder shear forces and bending moments:

(a) ship structural weight distribution over the length of the 3-tank model (static loads). Where a simple beam model is used, the weight of the structure of each tank can be distributed evenly over the length of the cargo tank. The structural weight is to be calculated based on a thickness deduction of $0.5\, t_{corr}$, as used in the construction of the cargo tank FE model, see **2.2.1.5.**

(b) weight of cargo and ballast (static loads)

(c) static sea pressure, dynamic wave pressure and, where applicable, green sea load. For the Design Load Combination S (harbour/tank testing load cases), only static sea pressure needs to be applied

(d) dynamic tank pressure load for Design Load Combination S + D (seagoing load cases).

2.5.3 Procedure to adjust vertical shear force distribution

2.5.3.1 The required adjustment in shear forces at the transverse bulkhead positions (ΔQ_{aft} and ΔQ_{fwd} as shown in **Fig B.2.10**) are to be generated by applying vertical load at the frame positions as shown in **Fig B.2.11**. It is to be noted that vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward tank and any frames aft of the aft tank of the FE model. The sum of the total vertical correction loads applied is equal to zero.

2.5.3.2 The required adjustment in shear forces at the aft and forward transverse bulkheads of the middle tank of the FE model in order to generate the required shear forces at the bulkheads are given by:

$\Delta Q_{aft} = - Q_{targ} - Q_{aft}$

$\Delta Q_{fwd} = Q_{targ} - Q_{fwd}$

Where:

ΔQ_{aft} required adjustment in shear force at aft bulkhead of middle tank

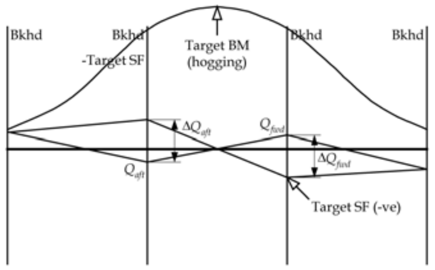
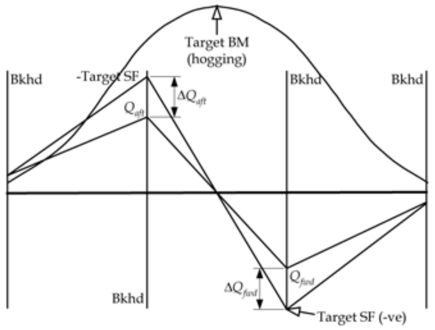
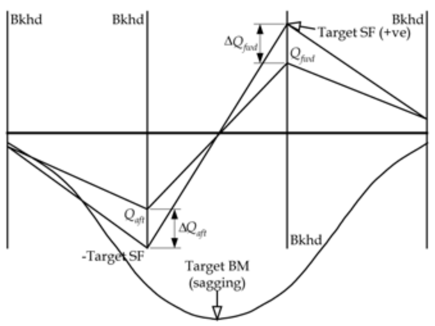
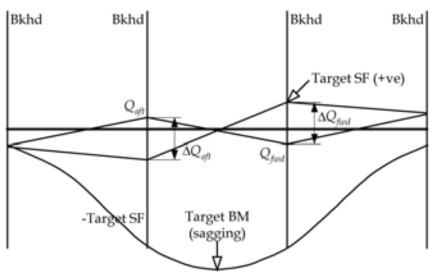
ΔQ_{fwd} required adjustment in shear force at fore bulkhead of the middle tank

Q_{targ} required shear force value to be achieved at forward bulkhead of middle tank, see **2.4.5.**

Q_{aft} shear force due to local loads at aft bulkhead of middle tank, see **2.5.2**

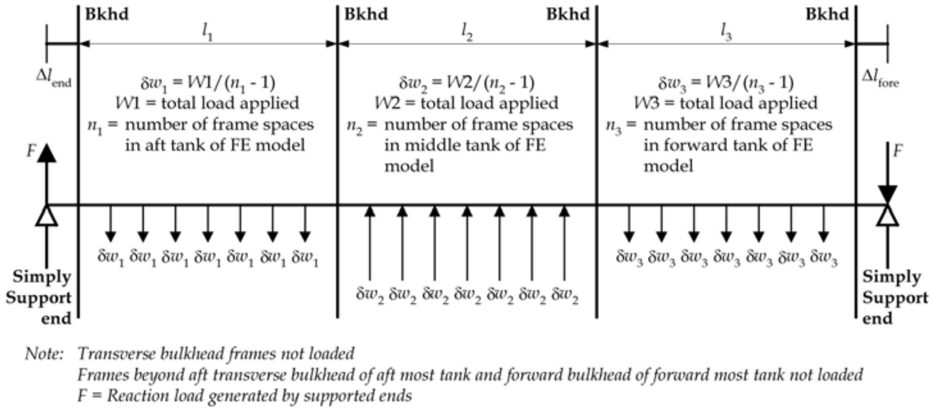
Q_{fwd} shear force due to local loads at fore bulkhead of middle tank, see **2.5.2**

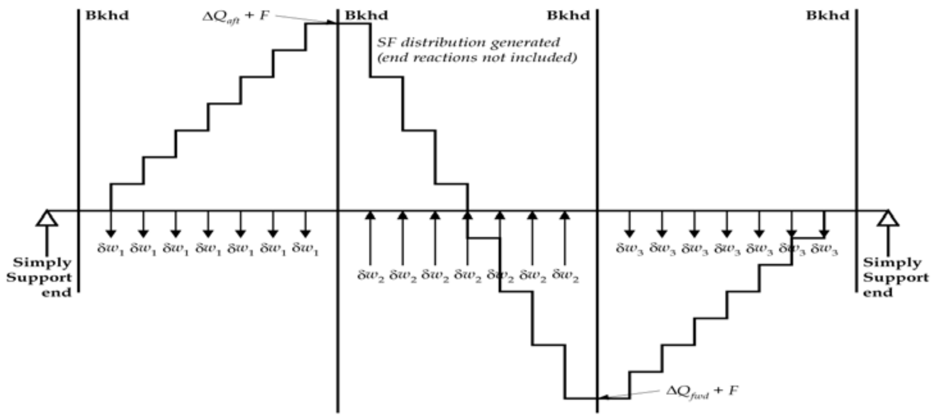
Fig B.2.10
Position of Target Shear Force and Required Shear Force Adjustment at Transverse Bulkhead Positions

Condition	Target			Aft Bkhd		Fore Bkhd	
	BM	SF	Bkhd pos	SF	ΔQ_{aft}	SF	ΔQ_{fwd}
	*Hog*	-ve	*Fore*	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (-ve)	$Q_{targ} - Q_{fwd}$
	*Hog*	-ve	*Fore*	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (-ve)	$Q_{targ} - Q_{fwd}$
	*Sag*	+ve	*Fore*	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (+ve)	$Q_{targ} - Q_{fwd}$
	*Sag*	+ve	*Fore*	$-Q_{targ}$	$-Q_{targ} - Q_{aft}$	Q_{targ} (+ve)	$Q_{targ} - Q_{fwd}$

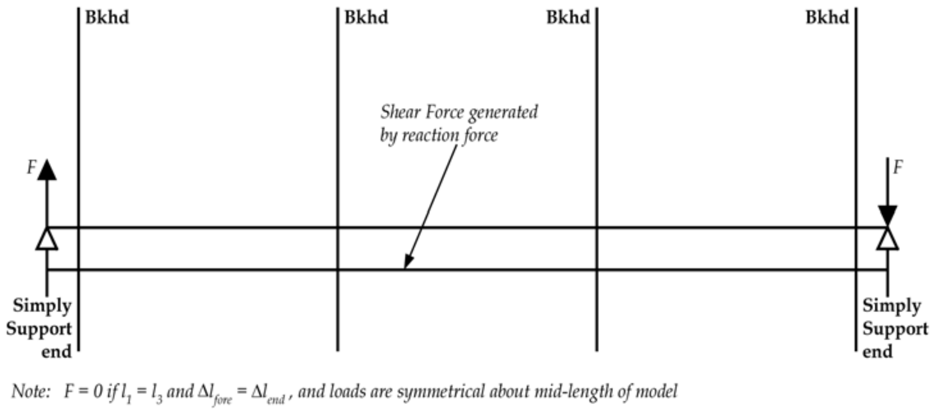
Note
For definition of symbols, see **2.5.3.2.**

Fig B.2.11
Distribution of Adjusting Vertical Force at Frames and Resulting Shear Force Distributions





Shear Force distribution due to adjusting vertical force at frames



Note
For definition of symbols, see **Table B.2.7.**

2.5.3.3 The value of the vertical loads to be applied to each frame to generate the increase in shear force at the bulkheads maybe calculated using a simple beam model. For the case where an uniform frame spacing is used within each tank, the amount of vertical force to be distributed at each frame may be calculated in accordance with **Table B.2.7**. The length and frame spacing of individual cargo tanks may be different.

Table B.2.7
Formulae for Calculation of Vertical Loads for Adjusting Vertical Shear Forces

$$\delta w_1 = \frac{\Delta Q_{aft}(2l - l_2 - l_3) + \Delta Q_{fwd}(l_2 + l_3)}{(n_1 - 1)(2l - l_1 - 2l_2 - l_3)} \qquad F = 0.5\left(\frac{W1(l_2 + l_1) - W3(l_2 + l_3)}{l}\right)$$

$$\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$$

$$\delta w_3 = \frac{-\Delta Q_{fwd}(2l - l_1 - l_2) - \Delta Q_{aft}(l_1 + l_2)}{(n_3 - 1)(2l - l_1 - 2l_2 - l_3)}$$

Where:

l_1	length of aft cargo tank of model
l_2	length of middle cargo tank of model
l_3	length of forward cargo tank of model
ΔQ_{aft}	required adjustment in shear force at aft bulkhead of middle tank, see **Fig B.2.10**
ΔQ_{fwd}	required adjustment in shear force at fore bulkhead of middle tank, see **Fig B.2.10**
F	end reactions due to application of vertical loads to frames, see **2.5.3**
$W1$	total evenly distributed vertical load applied to aft tank of FE model, $(n_1 - 1)\delta w_1$
$W2$	total evenly distributed vertical load applied to middle tank of FE model, $(n_2 - 1)\delta w_2$
$W3$	total evenly distributed vertical load applied to forward tank of FE model, $(n_3 - 1)\delta w_3$
n_1	number of frame spaces in aft cargo tank of FE model
n_2	number of frame spaces in middle cargo tank of FE model
n_3	number of frame spaces in forward cargo tank of FE model
δw_1	distributed load at frame in aft cargo tank of FE model
δw_2	distributed load at frame in middle cargo tank of FE model
δw_3	distributed load at frame in forward cargo tank of FE model
Δl_{end}	distance between end bulkhead of aft cargo tank to aft end of FE model
Δl_{fore}	distance between fore bulkhead of forward cargo tank to forward end of FE model
l	total length of FE model (beam) including portions beyond end bulkheads: $= l_1 + l_2 + l_3 + \Delta l_{end} + \Delta l_{fore}$

Notes
1. Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with **Fig B.2.10** and **B.2.11.**
2. $W1 + W3 = W2$
3. Note that the above formulae are only applicable if an uniform frame spacing is used within each tank, see **2.5.3.3**. The length and frame spacing of individual cargo tanks may be different.

2.5.3.4 The amount of adjusting load to be applied to the structural parts of each transverse frame section to generate the vertical load, δw_1, is to be in accordance with **Fig B.2.12**. This load is to be distributed at the finite element grid points of the structural parts. Where 4-node or 3-node finite plate elements are used, the load to be applied at each grid point of a plate element is given by:

$$F_{i-grid} = \frac{\sum_{1}^{n} 0.5 A_{i-elem-net50}}{A_{s-net50}} F_s$$

Where:

F_{i-grid} load to be applied to the i^{th} FE grid point on the individual structural member under consideration, i.e. side shell, longitudinal bulkheads and bottom girders, inner hull longitudinal bulkheads, hopper plates, upper slope plates of inner hull and outboard girders as defined in **Fig B.2.12**

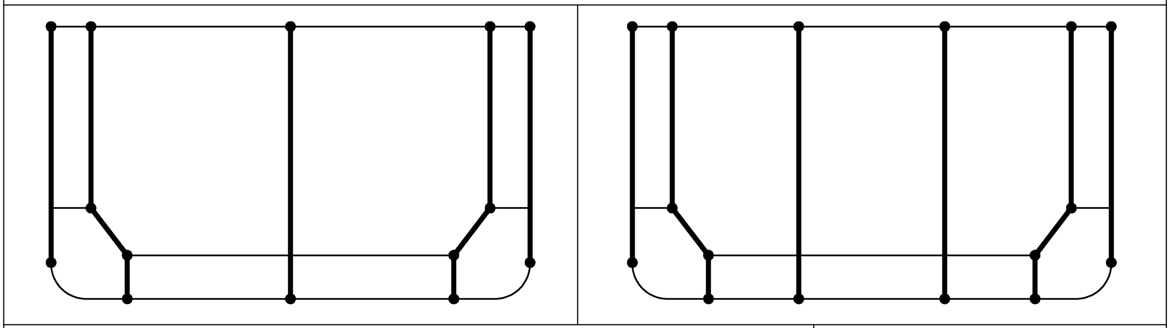
$A_{i-elem-net50}$ sectional area of each plate element in the individual structural member under consideration (see **Fig B.2.12**), which is connected to the i^{th} grid point

n number of plate elements connected to the i^{th} grid point

F_s total load applied to individual structural member under consideration, as specified in **Fig B.2.12**

$A_{s-net50}$ plate sectional area of the individual structural member under consideration, i.e. side shell, longitudinal bulkheads, bottom girders, inner hull longitudinal bulkheads, hopper plates, upper slope plates of inner hull and outboard girders as defined in **Fig B.2.12**

Fig B.2.12
Distribution of Adjusting Load on a Transverse Section



Structural member	Applied load F_s
Side shell	$f \bullet \delta w_i$
Longitudinal bulkhead including bottom girder beneath	$f \bullet \delta w_i$
Inner hull longitudinal bulkhead (vertical part)	$f \bullet \delta w_i \bullet \dfrac{A_{Ih-net50}}{A_{2-net50}}$
Hopper plate	$f \bullet \delta w_i \bullet \dfrac{A_{Hp-net50}}{A_{2-net50}}$
Upper slope plating of inner hull	$f \bullet \delta w_i \bullet \dfrac{A_{Usp-net50}}{A_{2-net50}}$
Outboard girder	$f \bullet \delta w_i \bullet \dfrac{A_{Og-net50}}{A_{2-net50}}$

Where

δw_i vertical load to be applied to each transverse frame section, see **2.5.3.3** and **Table B.2.7**

f shear force distribution factor of structural part calculated at the mid-tank position in accordance with **Table B.2.8**

$A_{Ih-net50}$ plate sectional area of individual inner hull longitudinal bulkhead

$A_{Hp-net50}$ plate sectional area of individual hopper plate

$A_{Usp-net50}$ Plate sectional area of individual upper slope plate of inner hull

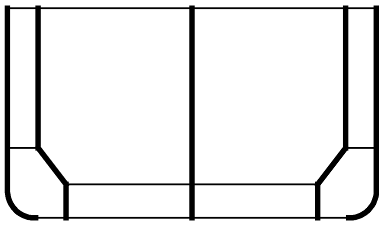
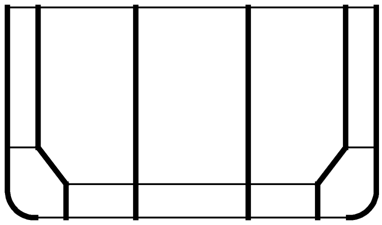
$A_{Og-net50}$ plate sectional area of individual outboard girder

$A_{2-net50}$ plate sectional area calculated in accordance with **Table B.2.8**

Note

1. Adjusting load is to be applied in plane to the hopper slope plate and upper slope plate of inner hull.
2. Adjusting load given is to be applied to individual structural member.

Table B.2.8
Shear Force Distribution Factors

	Side shell	$f = 0.055 + 0.097\dfrac{A_{1-net50}}{A_{2-net50}} + 0.020\dfrac{A_{2-net50}}{A_{3-net50}}$
	Inner hull	$f = 0.193 - 0.059\dfrac{A_{1-net50}}{A_{2-net50}} + 0.058\dfrac{A_{2-net50}}{A_{3-net50}}$
	CL longitudinal bulkhead	$f = 0.504 - 0.076\dfrac{A_{1-net50}}{A_{2-net50}} - 0.156\dfrac{A_{2-net50}}{A_{3-net50}}$
	Side shell	$f = 0.028 + 0.087\dfrac{A_{1-net50}}{A_{2-net50}} + 0.023\dfrac{A_{2-net50}}{A_{3-net50}}$
	Inner hull	$f = 0.119 - 0.038\dfrac{A_{1-net50}}{A_{2-net50}} + 0.072\dfrac{A_{2-net50}}{A_{3-net50}}$
	Longitudinal bulkhead	$f = 0.353 - 0.049\dfrac{A_{1-net50}}{A_{2-net50}} - 0.095\dfrac{A_{2-net50}}{A_{3-net50}}$

Where:

$A_{1-net50}$ plate sectional area of individual side shell (i.e. on one side), including bilge

$A_{2-net50}$ plate sectional area of individual inner hull longitudinal bulkhead (i.e. on one side), including hopper slope plate, double bottom side girder in way and, where fitted, upper slope plating of inner hull.

$A_{3-net50}$ plate sectional area of individual longitudinal bulkhead, including double bottom girder in way

Note

1. Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction.
2. All plate areas are to be calculated based on the modelled thickness of the cargo tank FE model, see **2.2.1.5.**
3. For corrugated longitudinal bulkheads, the corrugation thickness for the calculation of shear force distribution factor, f, is to be corrected according to **Sec 4/2.6.4.**

2.5.4 Procedure to adjust vertical and horizontal bending moments

2.5.4.1 An additional vertical bending moment is to be applied at both ends of the cargo tank finite element model to generate the required vertical bending moment in the middle tank of the model. This end vertical bending moment can be calculated as follows:

$M_{v-end} = M_{v-targ} - M_{v-peak}$

Where:

$M_{v\text{-}end}$ additional vertical bending moment to be applied at both ends of finite element model

$M_{v\text{-}targ}$ required hogging (positive) or sagging (negative) vertical bending moment, as specified in **2.4.5**

$M_{v\text{-}peak}$ maximum or minimum bending moment within the length of the middle tank due to the local loads described in **2.5.2.3** and the additional vertical loads applied to generate the required shear force, see **2.5.3**. $M_{v\text{-}peak}$ is to be taken as the maximum bending moment if $M_{v\text{-}targ}$ is hogging (positive) and as the minimum bending moment if $M_{v\text{-}targ}$ is sagging (negative).

$M_{v\text{-}peak}$ can be obtained from FE analysis. Alternatively, $M_{v\text{-}peak}$ may be calculated as follows based on a simply supported beam model:

$M_{v-peak} = Max\{M_o + xF + M_{lineload}\}$

M_o vertical bending moment at position x, due to the local loads described in **2.5.2.3.**

$M_{lineload}$ vertical bending moment at position x, due to application of vertical line loads at frames to generate required shear force, see **2.5.3**

F reaction force at ends due to application of vertical loads to frames, see **2.5.3**

x longitudinal position of frame in way of the middle tank of FE model from end, see **2.5.4.2**

2.5.4.2 For beam and oblique sea load cases, an additional horizontal bending moment is to be applied at the ends of the cargo tank FE model to generate the required horizontal bending moment at a section within the length of the middle tank of the model. The additional horizontal bending moment can be calculated as follows:

$$M_{h-end} = M_{h-targ} - M_{h-peak}$$

Where:

M_{h-end} additional horizontal bending moment to be applied to ends of FE model

M_{h-targ} required positive or negative horizontal bending moment, see **2.4.6**

M_{h-peak} maximum or minimum horizontal bending moment within the length of the middle tank due to the local loads described in **2.5.2.3**. M_{h-peak} is to be taken as the maximum horizontal bending moment if M_{h-targ} is positive (starboard side in tension) and as the minimum horizontal bending moment if M_{h-targ} is negative (port side in tension).

2.5.4.3 The vertical and horizontal bending moments should be calculated over the length of the middle tank of the FE model to identify the position and value of each maximum/minimum bending moment as specified in **2.5.4.1** and **2.5.4.2.**

2.5.4.4 The additional vertical bending moment, M_{v-end}, and horizontal bending moment, M_{h-end}, are to be applied to both ends of the cargo tank model. The bending moments may be applied by either of the methods described in **2.5.4.5** and **2.5.4.6.**

2.5.4.5 The vertical and horizontal bending moments may be applied at the model ends by distributing axial nodal forces to all longitudinal elements according to the simple beam theory as follows:

$$(F_x)_i = \frac{M_{v-end}}{I_{y-net50}} \frac{A_{i-net50}}{n_i} z_i$$ for vertical bending moment

$$(F_x)_i = \frac{M_{h-end}}{I_{z-net50}} \frac{A_{i-net50}}{n_i} y_i$$ for horizontal bending moment

Where:

M_{v-end} vertical bending moment to be applied to the ends of the model

M_{h-end} horizontal bending moment to be applied to the ends of the model

$(F_x)_i$ axis force applied to a node of the i^{th} element

$I_{y-net50}$ hull girder vertical moment of inertial of the end section about its horizontal neutral axis

$I_{z-net50}$ hull girder horizontal moment of inertial of the end section about its vertical neutral axis (normally centreline)

z_i vertical distance from the neutral axis to the centre of the cross sectional area of the i^{th} element

y_i horizontal distance from the neutral axis to the centre of the cross sectional area of the i^{th} element

$A_{i-net50}$ cross sectional area of the i^{th} element

n_i number of nodal points of i^{th} element on the cross section, $n_i = 2$ for 4-node plate element

2.5.4.6 The vertical and horizontal bending moments may alternatively be applied to an independent grid point at the intersection of the vertical neutral axis (normally centreline) and the horizontal neutral axis, see **Fig B.2.13**. All nodal points of the longitudinal elements on the end section are to be rigidly linked to the independent point in θ_y (for vertical bending), θ_z (for horizontal bending) and δ_x. This independent point is not to be connected to the model except by the rigid link. The rigid links are to maintain the end plane of the model in keeping plane under the action of the applied bending moment, which is equivalent to imposing a prescribed displacement to the nodal points in accordance with the simple beam theory.

2.6 Boundary Conditions

2.6.1 General

2.6.1.1 All boundary conditions described in this section are in accordance with the global co-ordinate system defined in **Sec 4/1.4**. The boundary conditions to be applied at the ends of the cargo tank FE model are given in **Table B.2.9**. The analysis may be carried out by applying all loads to the model as a complete load case or by combining the stress responses resulting from several separate sub-cases.

2.6.1.2 Ground spring elements, i.e. spring elements with one end constrained in all 6 degrees of freedom, with stiffness in global y degree of freedom are to be applied to the grid points along deck, inner bottom and bottom shell as shown in **Fig B.2.13.**

2.6.1.3 Ground spring elements with stiffness in global z degree of freedom are to be applied to the grid points along the vertical part of the side shells, inner hull longitudinal bulkheads and oil-tight longitudinal bulkheads as shown in **Fig B.2.13.**

Fig B.2.13
Spring Constraints at Model Ends

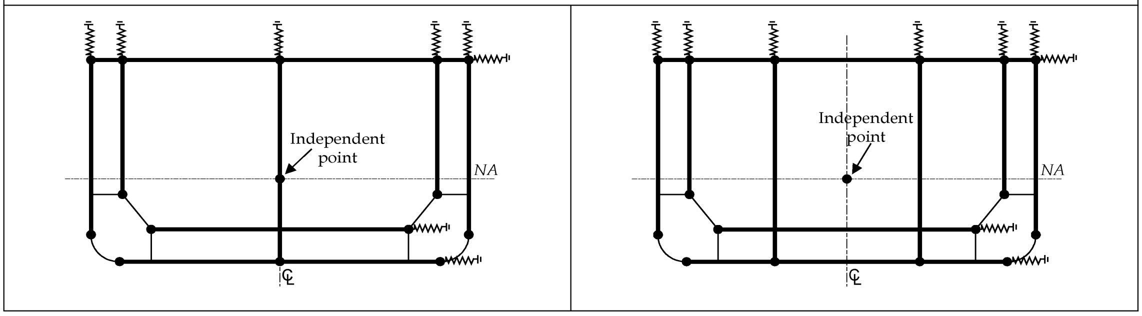


Table B.2.9
Boundary Constraints at Model Ends

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Aft End						
Aft end (all longitudinal elements)	*RL*	-	-	-	*RL*	*RL*
Independent Point aft end, see Figure B.2.13	Fix	-	-	-	$M_{v\text{-}end}$	$M_{h\text{-}end}$
Deck, inner bottom and outer shell	-	Springs	-	-	-	-
Side, inner skin and longitudinal bulkheads	-	-	Springs	-	-	-
Fore End						
Fore end (all longitudinal elements)	*RL*	-	-	-	*RL*	*RL*
Independent point fore end, see Figure B.2.13	-	-	-	-	$M_{v\text{-}end}$	$M_{h\text{-}end}$
Deck, inner bottom and outer shell	-	Springs	-	-	-	-
Side, inner skin and longitudinal bulkheads	-	-	Springs	-	-	-

Where:
- no constraint applied (free)
RL nodal points of all longitudinal elements rigidly linked to independent point at neutral axis on centre-line

Note
1. All translation and rotation displacements are in accordance with the global coordinate system defined in **Sec 4/1.4.**
2. Where $M_{h\text{-}end}$ is not applied, the independent points at the fore and aft ends are to be free in θ_z.
3. Where $M_{v\text{-}end}$ is not applied, the independent points at the fore and aft ends are to be free in θ_y.
4. Where no bending moment is applied, the independent points at the fore and aft ends are to be free in θ_y and θ_z.
5. Where bending moment is applied as nodal forces, the independent points at the fore and aft ends are to be free in the corresponding degree of freedom of rotations (i.e. θ_y and/or θ_z).

2.6.2 Calculation of spring stiffness

2.6.2.1 The stiffness, c, of individual spring elements for each structural member, to be applied at each end of the cargo tank model, is given by:

$$c = \left(\frac{E}{1+\nu}\right)\frac{A_{s-net50}}{l_{tk}\ n} = 0.77\ \frac{A_{s-net50}E}{l_{tk}\ n} \qquad \text{N/mm}$$

Where:

$A_{s\text{-}net50}$ shearing area of the individual structural member under consideration, i.e. plating of deck, inner bottom, bottom shell, side shell, inner hull longitudinal bulkheads or oil-tight longitudinal bulkhead. $A_{s\text{-}net50}$ is to be calculated based on the thickness of the cargo tank finite element model for areas indicated in **Table B.2.10** for the appropriate structural member under consideration, in mm^2

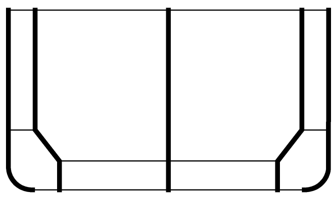
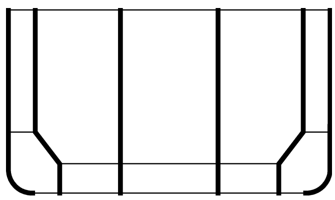
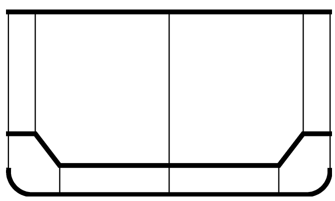
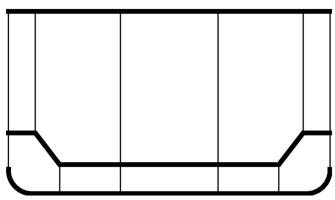
v Poisson's ratio of the material

l_{tk} length of cargo tank, between bulkheads of the middle tank of the FE model, in mm^2

E Modulus of Elasticity, in N/mm^2

n number of nodal points to which the spring elements are applied to the structural member under consideration

Table B.2.10
Shear Areas to be Considered for the Calculation of Spring Stiffness

Vertical springs		
	Side	Area of side shell plating, including bilge
	Inner hull longitudinal bulkheads	Area of inner skin plating, including hopper slope plate and double bottom side girder in way
	Longitudinal bulkheads	Area of longitudinal bulkhead plating, including double bottom girder in way
	Note Where part of the structural member is not vertical, the area is to be calculated using the projected area in the vertical direction.	
Horizontal springs		
	Deck	Area of deck plating
	Inner bottom	Area of inner bottom plating, including hopper slope plate and horizontal stringer in way
	Bottom shell	Area of bottom shell plating, including bilge
	Note Where part of the structural member is not horizontal the area is to be calculated using the projected area in the horizontal direction.	

2.6.2.2 For vertical corrugated longitudinal bulkheads, the corrugation thickness for the calculation of spring stiffness, *c*, shall be calculated according to **Sec 4/2.6.4.**

2.6.2.3 Alternatively, rod elements may be used instead of spring elements, the equivalent cross section area of the rod is $(c \cdot l)/E$, where l is the length of the rod. One end of the rod is to be constrained in all 6 degrees of freedom.

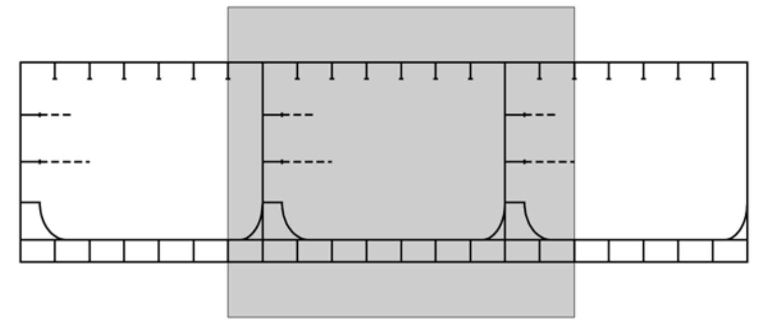
2.7 Result Evaluation

2.7.1 General

2.7.1.1 Verification of result against acceptance criteria is to be carried out for structural members within longitudinal extent shown in **Fig B.2.14**, which includes the middle tanks of the three cargo tanks FE model and the region forward and aft of the middle tanks up to the extent of the transverse bulkhead stringer and buttress structure. For the strength assessment of tanks in the midship cargo region, stress level and buckling capability of longitudinal hull girder structural members, primary supporting structural members and transverse bulkheads are to be verified. For the assessment of required strengthening in way of transverse bulkheads against hull girder shear load, stress level and buckling capability of inner hull longitudinal bulkheads including upper sloped plate where fitted, side shell, hopper, bottom girders and longitudinal bulkheads are to be verified.

2.7.1.2 Assessment of results is to be carried out for the standard load cases specified in **2.3.1**, and any other load cases specially considered as required by **Sec 9/2.2.3.**

Fig B.2.14
Extent of FE Model for Verification against Acceptance Criteria



2.7.2 Stress assessment

2.7.2.1 Stresses are not to exceed the permissible values given in **Sec 9/2.2.5.**

2.7.2.2 The maximum permissible stresses are based on the mesh sizes and element types described in **2.2.**

2.7.2.3 The von Mises stress, σ_{vm}, is to be calculated based on the membrane direct and shear stresses of the plate element. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element. Where plate elements are used, the stresses are to be evaluated at the element centroid.

2.7.2.4 Except as indicated in **2.7.2.5**, the element shear stress in way of openings in webs is to be corrected for loss in shear area in accordance with the following formula. The corrected element shear stress is to be used to calculate the von Mises stress of the element for verification against the acceptance criteria.

$$\tau_{cor} = \frac{h \ t_{mod-net50}}{A_{s-net50}} \tau_{elem}$$

Where:

τ_{cor} corrected element shear stress

h height of web of girder in way of opening, see **Fig B.2.8**. Where the geometry of the opening is modelled, h is to be taken as the net height with the height of the modelled opening deducted.

$t_{mod-net50}$ modelled web thickness in way of opening, see **Table B.2.2.**

$A_{s-net50}$ actual effective shear area of web, including area lost due to slots for stiffeners, calculated in accordance with **Sec 4/2.5.** The thickness of the web is to be based on net thickness obtained by deducting 0.5 t_{corr} from the gross thickness

τ_{elem} element shear stress before correction

2.7.2.5 Correction of element shear stress due to presence of openings is not required provided that:
(a) all slots for local support stiffeners are fitted with lugs or collar plates;
(b) the difference between the modelled shear area of the plate and the actual effective shear area, As-net50calculated in accordance with **Sec 4/2.5.1**, is less than 20 % of the modelled shear area, and
(c) the yield utilisation factor is less than 80% of the permissible yield utilisation factor given in **Sec 9/Table 9.2.1.**

2.7.2.6 Where the corrugation is not modelled with its exact geometric shape, the corrected axial stress in the flange of the corrugation, $\sigma_{fl\text{-}act}$, is to be taken as the greater of:

$$\sigma_{fl-act} = \sigma_{fl-FEM} \frac{Z_{corr-FEM-net50}}{Z_{corr-act-net50}} \frac{l_{corr-act}}{l_{corr-FEM}}$$

$$\sigma_{fl-act} = \sigma_{fl-FEM}$$

Where:

$\sigma_{fl\text{-}FEM}$ axial stress obtained from the finite element analysis, see **Fig B.2.15**

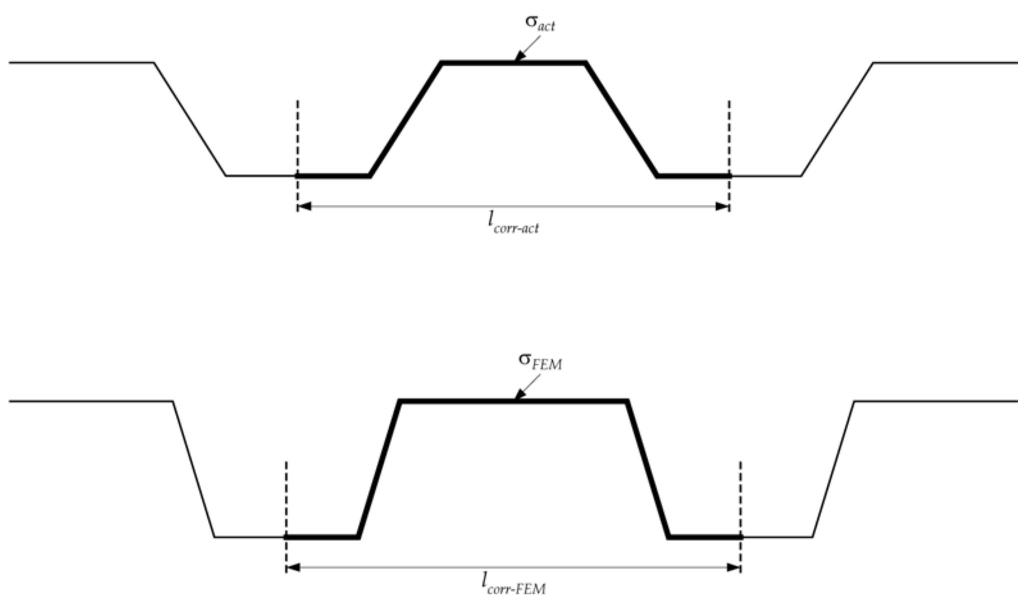
$Z_{corr\text{-}FEM\text{-}net50}$ is the section modulus of the modelled corrugation calculated in accordance with **Fig B.2.15**

$Z_{corr\text{-}act\text{-}net50}$ is the section modulus of the actual corrugation calculated in accordance with **Fig B.2.15**

$l_{corr\text{-}act}$ length of corrugation section, as given in **Fig B.2.15**

$l_{corr\text{-}FEM}$ length of corrugation section, as given in **Fig B.2.15**

Fig B.2.15
Axial Bending Stress in Flange Corrugation



Note
$l_{corr\text{-}act}$ = length of corrugation section, for the calculation of $Z_{corr\text{-}act\text{-}net50}$
$l_{corr\text{-}FEM}$ = length of corrugation section, for the calculation of $Z_{corr\text{-}FEM\text{-}net50}$

2.7.3 Buckling assessment

2.7.3.1 Buckling capability is to be assessed for the plating and stiffened panels of longitudinal hull girder structural members, primary support members and transverse bulkheads, including deck, double side, side, bottom, double bottom, hopper, transverse and vertical web frames, stringers, transverse and longitudinal bulkhead structures. Buckling capability of curved panels (e.g. bilge), face plate of primary support members and tripping brackets is not assessed based on stress result obtained by the finite element analysis.

2.7.3.2 The utilisation factor against buckling for all plates and stiffened panels is not to exceed the permissible values given in **Sec 9/2.2.5**. The method for carrying out buckling assessment of plates and stiffened panels is described in **Appendix D/5**.

2.7.3.3 The buckling assessment is to be based on the stresses obtained from the finite element analysis in conjunction with buckling capacity model based on net thickness obtained by deducting the full corrosion addition, t_{corr}, and any Owner's extras from the proposed thickness. This thickness deduction applies to all plating, stiffener webs and face plates.

2.7.3.4 The buckling assessment is to be based on membrane stress evaluated at the centroid of the plate elements. Where shell elements are used, stresses at the mid plane of the element are to be used for the buckling assessment.

2.7.3.5 The combined interaction of bi-axial compressive stresses, shear stress and lateral pressure loads are to be considered in the buckling calculation. Where a stress correction is to be applied to the finite element stresses as required by **2.7.2**, the buckling assessment is to be based on the corrected stresses.

2.7.3.6 For tankers with a cross tie arrangement, the pillar buckling capability of the cross tie structure is to be assessed based on the buckling formulae given in **Sec 10/3.5.1**. The average axial compressive stress at the mid span of the cross tie in the ship's transverse direction, weighted by cross section area, is to be used for the buckling assessment.

2.7.3.7 In the absence of a suitable advanced buckling method described in Appendix D/5 for the modelling of bulkhead corrugation, assessment of local buckling of unit corrugation flanges is to be in accordance with **Sec 10/3.5.2** and criteria given in **Sec 9/2.2.5**. The assessment is to be based only on uni-axial stress (membrane stress evaluated at element centroid) parallel to the corrugation knuckles. Averaged stress between elements is not to be used. For the part of the corrugated plate flange from the lower bulkhead stool top to a level of $s/2$ above, where s is the breadth of the flange, the stress used for the buckling assessment needs not be taken as greater than the value obtained at $s/2$ above the bulkhead stool top. The stress value at $s/2$ may be obtained by interpolation if the stress value cannot be obtained directly from a plate element.

2.7.3.8 In the absence of a suitable advanced buckling assessment method described in **Appendix D/5** for the modelling of panel with opening, local buckling of web plates of primary support members in way of openings is to be assessed in accordance with **Sec 10/3.4** based on acceptance criteria on buckling utilisation factor given in **Sec 9/2.2.5**. The assessment is to be based on FE membrane stress evaluated at the centroid of plate elements. Stresses in the area of the web required for buckling assessment are to be obtained as averaged stresses of the plate elements within the required area. Stress obtained from either the cargo tank analysis or local fine mesh analysis may be used for the assessment. Where the effect of opening is not taken into account in the cargo tank analysis, the stresses obtained from the finite element analysis are to be corrected in accordance with **2.7.2.4** and **2.7.2.5.**

3 Local Fine Mesh Structural Strength Analysis

3.1 General

3.1.1 Application

3.1.1.1 For tankers of conventional arrangements, finite element fine mesh analysis of structural details is to be in accordance with the requirements given in this section.

3.1.1.2 Additional requirements of fine mesh analysis are to be in accordance with **Sec 9/2.3.1.3** and **Sec 9/2.3.1.4.**

3.1.2 Transverse web frame and wash bulkhead

3.1.2.1 Upper hopper knuckle connections as indicated in **Fig B.3.1** are to be evaluated by fine mesh analysis on a typical transverse web frame in the middle tank of the cargo tank model. Main bracket toes and openings as indicated in **Fig B.3.1** are to be evaluated by fine mesh analysis if the screening criteria given in **3.1.6** are not complied with.

3.1.2.2 Where a wash bulkhead is fitted, main bracket toes and openings of the transverse and vertical webs as indicated in **Fig B.3.1** are to be evaluated by fine mesh analysis if the screening criteria given in **3.1.6** are not complied with.

3.1.2.3 The web frame which indicates highest von Mises stresses in way of each structural detail from the cargo tank analysis is to be selected for the fine mesh analysis.

Fig B.3.1
Areas Requiring Consideration for Fine Mesh Analysis on a Typical Transverse Web Frame, Wash Bulkhead and Web Frame adjacent to Transverse Bulkhead

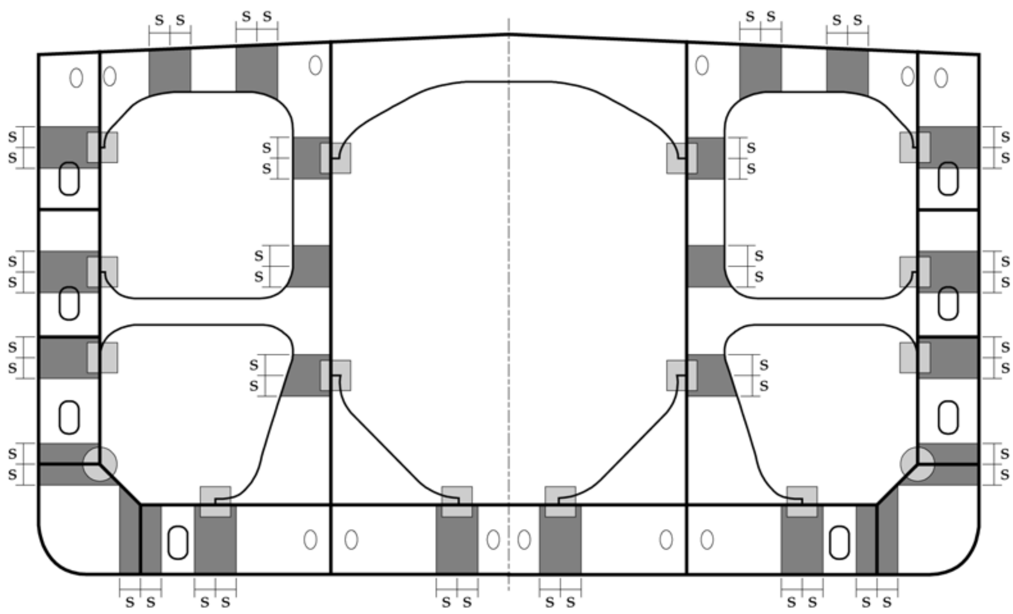


Fig B.3.1 (Continued)
Areas Requiring Consideration for Fine Mesh Analysis on a Typical Transverse Web Frame, Wash Bulkhead and Web Frame adjacent to Transverse Bulkhead

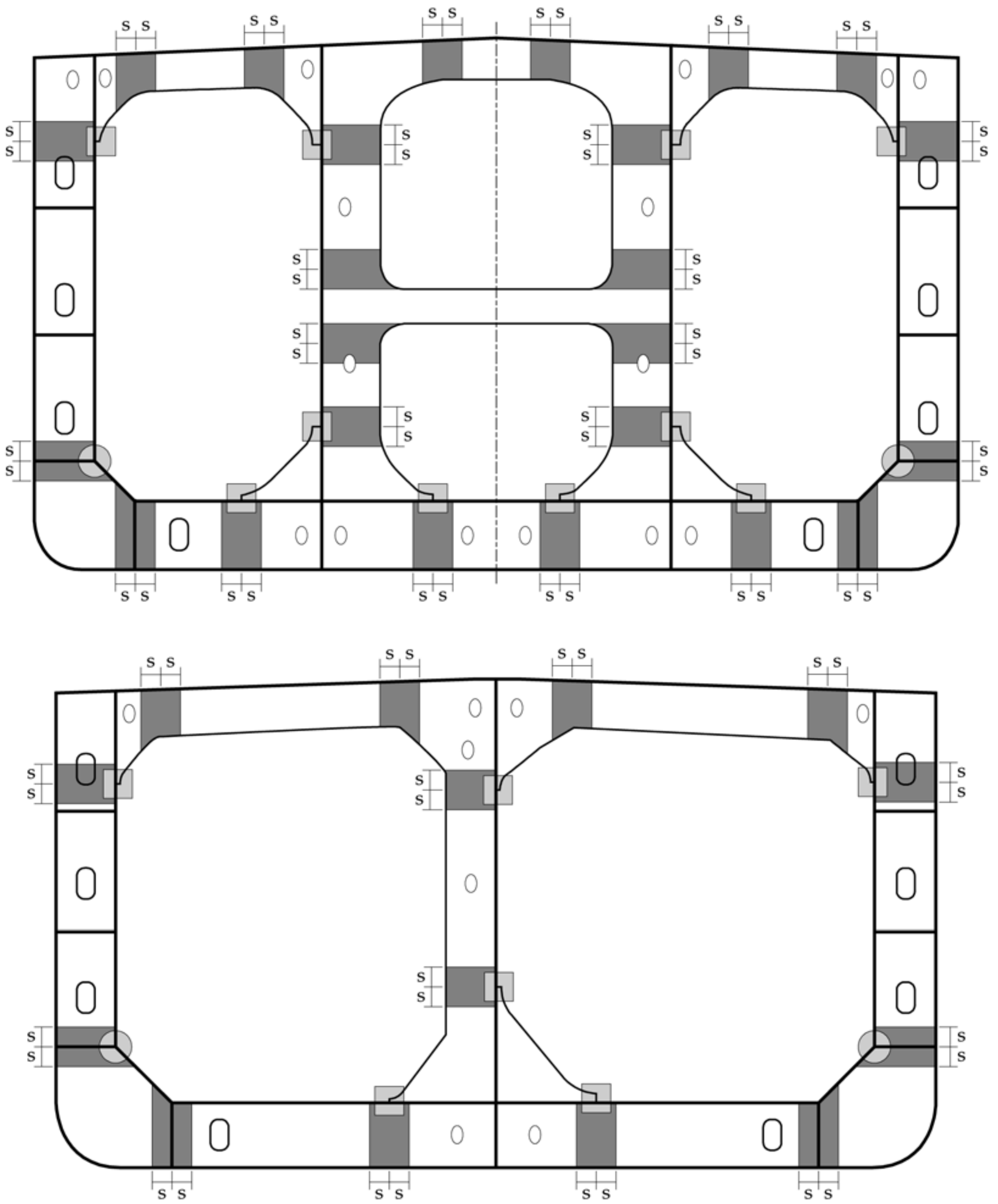
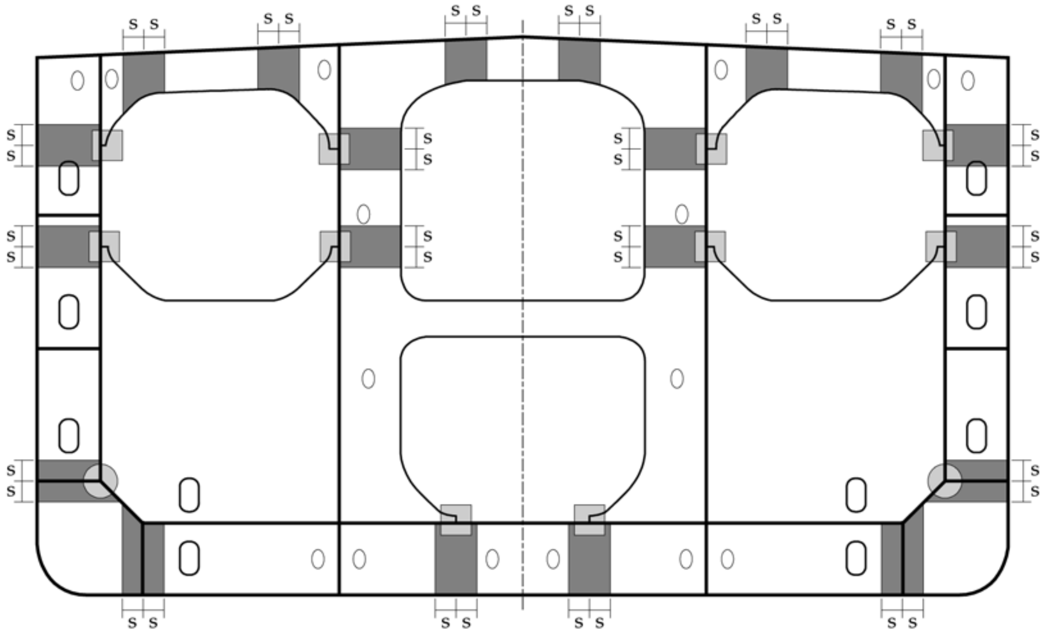


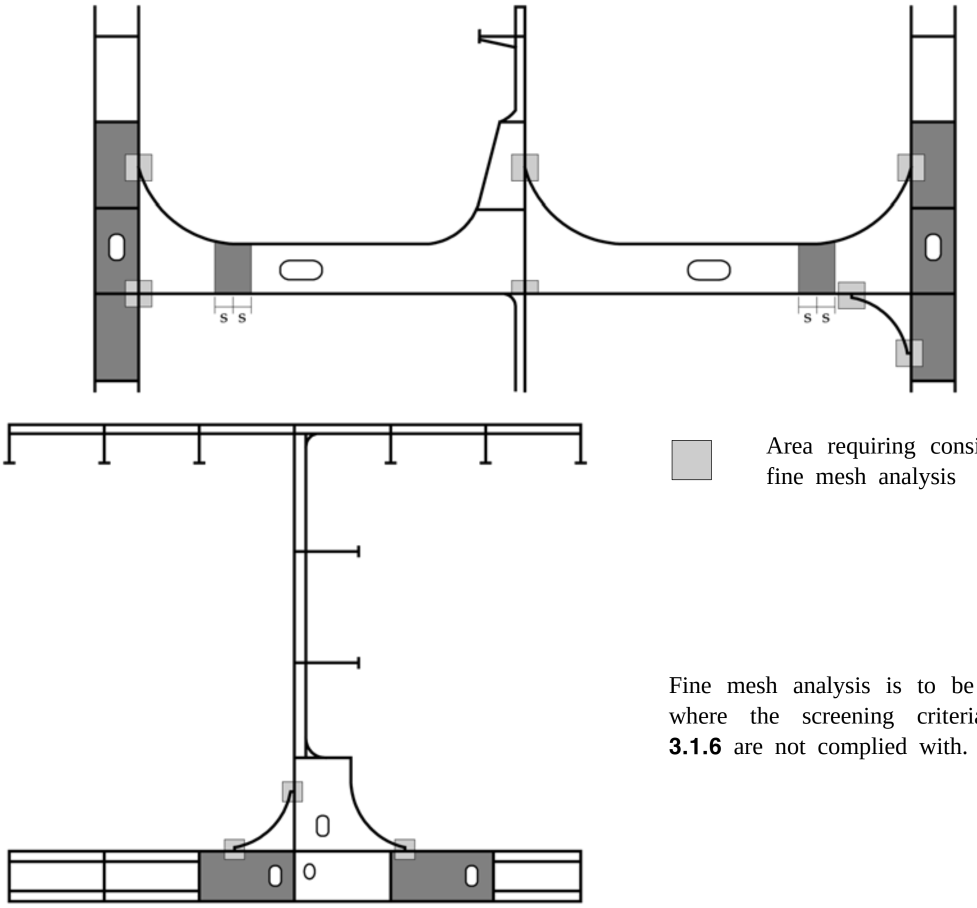
Fig B.3.1 (Continued)

Areas Requiring Consideration for Fine Mesh Analysis on a Typical Transverse Web Frame, Wash Bulkhead and Web Frame adjacent to Transverse Bulkhead



Upper hopper knuckle	Fine mesh analysis of upper hopper knuckle is required for cargo tank typical web frame, see **3.1.2**. Fine mesh analysis is not required for upper hopper knuckles on web frame adjacent to transverse bulkhead.
Bracket toes	Fine mesh analysis is to be carried out where the screening criteria given in **3.1.6** are not complied with
Openings (shaded regions)	Fine mesh analysis is to be carried out for all openings in shaded regions where the screening criteria given in **3.1.6** are not complied with
Openings (un-shaded regions)	Fine mesh analysis or evaluation based on screening criteria given in **3.1.6** is not required for openings in un-shaded regions if: • $h_o/h < 0.35$ and $g_o < 1.2$, and, • each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). where h_o, h and g_o are defined in **Table B.2.2** and b is the smallest of the length and breadth of the opening. Other openings in the un-shaded regions are subjected to fine mesh analysis where the screening criteria given in **3.1.6** are not complied with.

Fig B.3.2
Areas Requiring Consideration for Fine Mesh Analysis on Horizontal Stringer and Transverse Bulkhead to Double Bottom Connections



Area requiring consideration for fine mesh analysis

Fine mesh analysis is to be carried out where the screening criteria given in **3.1.6** are not complied with.

Bracket toes and heels	Fine mesh analysis is to be carried out where the screening criteria given in **3.1.6** are not complied with
Openings (shaded regions)	Fine mesh analysis is to be carried out for all openings in shaded regions where the screening criteria given in **3.1.6** are not complied with
Openings (un-shaded regions)	Fine mesh analysis or evaluation based on screening criteria given in **3.1.6** is not required for openings in un-shaded regions if: • $h_o/h < 0.35$ and $g_o < 1.2$, and, • each end of the opening forms a semi circle arc (i.e. radius of opening equal to $b/2$). where h_o, h and g_o are defined in **Table B.2.22** and b is the smallest of the length and breadth of the opening. Other openings in the un-shaded regions are subjected to fine mesh analysis where the screening criteria given in **3.1.6** are not complied with.

3.1.3 Transverse bulkhead stringers, buttress and adjacent web frame

3.1.3.1 Fine mesh analysis is to be carried out for the following locations where the screening criteria given in **3.1.6** are not complied with:

(a) main bracket toes, heels and openings on horizontal stringers of a transverse bulkhead specified in **Fig B.3.2.** The stringers of the forward and aft transverse bulkheads of the middle tank of the FE model which indicate highest von Mises stresses in way of the structural details from the cargo tank analysis is to be selected for the fine mesh analysis.

(b) main bracket toes and openings on transverse bulkhead to double bottom connection or buttress structure specified in **Fig B.3.2**. The double bottom connection/buttress structure in way of the forward and aft transverse bulkheads of the middle tank of the FE model which indicates highest von Mises stresses in way of the structural details from the cargo tank analysis is to be selected for the fine mesh analysis.

(c) main bracket toes and openings specified in **Fig B.3.1** on a web frame adjacent to the transverse bulkhead. Both web frames in way of the horizontal stringers of the forward and aft transverse bulkheads of the middle tank of the cargo tank FE model are to be considered. The web frame which indicates highest von Mises stresses in way of the structural details from the cargo tank analysis is to be selected for the fine mesh analysis.

3.1.3.2 Where the stress level at the heel connection of the transverse bulkhead horizontal stringer to the side horizontal girder exceeds the permissible criteria, it is recommended that a backing bracket be fitted in accordance with **Appendix C/2.5** to reduce the stresses.

3.1.4 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

3.1.4.1 End connections and attached web stiffeners of the following structural members are to be assessed:

(a) at least one pair of inner and outer bottom longitudinal stiffeners and adjoining vertical stiffener of transverse bulkhead

(b) at least one longitudinal stiffener on deck and adjoining vertical stiffener of transverse bulkhead

3.1.4.2 The selection of the longitudinal and vertical stiffeners to be analysed is to be based on the maximum relative deflection between supports, e.g. between floor and transverse bulkhead. Where there is a significant variation in end connection arrangement and scantlings between stiffeners, analysis of additional stiffeners may be required. **Fig B.3.3** shows the areas that require fine mesh analysis in way of deck, inner bottom and bottom longitudinal and transverse bulkhead vertical stiffeners.

3.1.5 Corrugated bulkheads

3.1.5.1 Where no shedder plate or shedder plate without a gusset plate is fitted to a corrugated transverse or longitudinal corrugated bulkhead, connection of corrugation and below supporting structure to lower stool shelf plate, as shown in **Fig B.3.4**, is to be evaluated by fine mesh analysis. Where no lower stool is fitted, connection of corrugation and below supporting structure to inner bottom plate is to be evaluated by fine mesh analysis.

3.1.5.2 Where shedder plate with a gusset plate is fitted to a corrugated transverse or longitudinal corrugated bulkhead, connection of the corrugation at the upper corner of the gusset plate is to be evaluated by fine mesh analysis.

3.1.5.3 The selection of the location of the corrugation unit for fine mesh analysis is to be based on the stress result from the cargo tank analysis. The location with the highest von Mises stress in way of the corrugation connection is to be selected for the analysis.

3.1.5.4 Where transverse and longitudinal corrugated bulkheads are of different arrangements or scantlings, the fine mesh analysis is to be carried out for both bulkheads.

3.1.5.5 Where the stress level at the connection of corrugation to the lower stool exceeds the permissible criteria, it is recommended that shedder plate and gusset plate be fitted in accordance with **Appendix C/2.5** to reducethe stresses. See **Sec 8/2.5.7.9** for required arrangement of supporting structure for corrugated bulkhead without a lower stool.

Fig B.3.3
Areas Requiring Fine Mesh Analysis on Deck, Inner and Outer Bottom Longitudinals

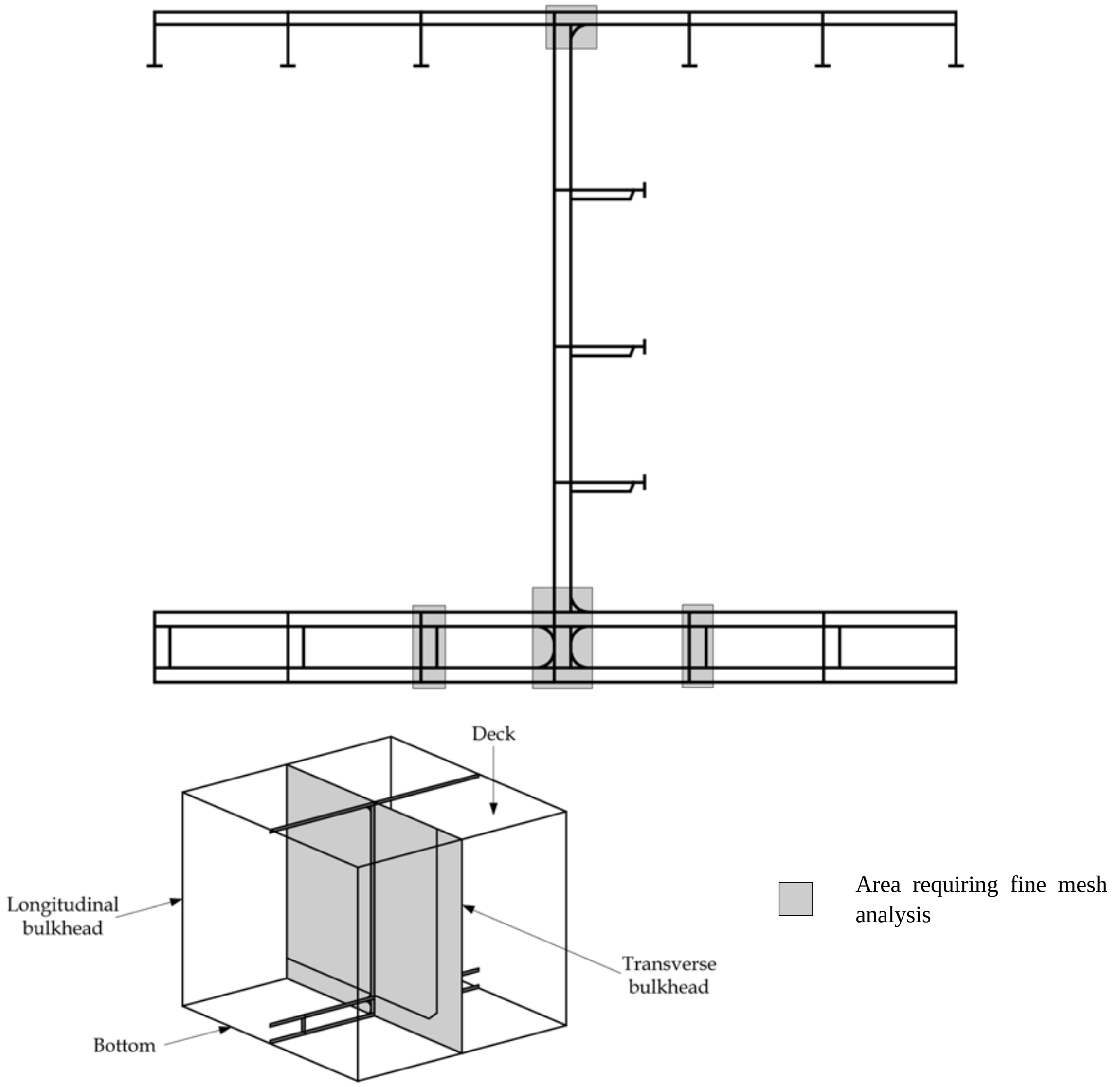
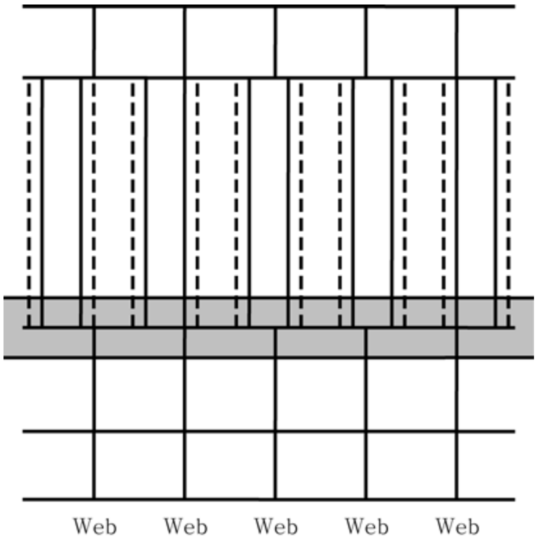


Fig B.3.4
Areas Requiring Fine Mesh Analysis at Connections of Corrugated Bulkhead to Bottom Stool



Note
Exact location of corrugation unit to be examined using fine mesh analysis is to be selected based on stress result from cargo tank analysis.

3.1.6 Screening criteria for Fine Mesh Analysis

3.1.6.1 The criteria given in this section are intended to identify areas that require to be investigated by means of fine mesh finite element analysis. These criteria apply to openings, bracket toes and heels of transverse web frames, vertical and transverse webs of wash bulkheads, horizontal stringers of transverse bulkhead and adjoining side horizontal girders, buttress and bottom girders.

3.1.6.2 Where the criteria given in this section for the structural detail are complied with, fine mesh finite element analysis of the structural detail may be waived with the exception of **3.1.6.3**. The compliance with these criteria is to be verified for all finite element load cases.

3.1.6.3 Large openings, for which their geometry is required to be represented in the cargo tank FE model in accordance with **Table B.2.2**, are to be investigated by fine mesh analysis.

Table B.3.1
Fine Mesh Analysis Screening Criteria for Openings in Primary Support Members

A fine mesh finite element analysis is to be carried out where:

λ_y > 1.7 (load combination S + D)

λ_y > 1.36 (load combination S)

Where:

λ_y	yield utilisation factor $= 0.85C_h\left(\left\|\sigma_x+\sigma_y\right\|+\left(2+\left(\dfrac{l_0}{2r}\right)^{0.74}+\left(\dfrac{h_0}{2r}\right)^{0.74}\right)\left\|\tau_{xy}\right\|\right)\dfrac{k}{235}$	
C_h	$=1.0-0.23\left(\dfrac{h_0}{h}\right)+2.12\left(\dfrac{h_0}{h}\right)^2$	for openings in vertical web and horizontal girder of wing ballast tank, double bottom floor and girder and horizontal stringer of transverse bulkhead
	= 1.0	for opening in web of main bracket and buttress (see figures below)
r	radius of opening, in mm	
h_0	height of opening parallel to depth of web, in mm	
l_0	length of opening parallel to girder web direction, in mm	
h	height of web of girder in way of opening, in mm	
σ_x	axial stress in element x direction determined from cargo tank FE analysis according to the coordinate system shown, in N/mm^2	
σ_y	axial stress in element y direction determined from cargo tank FE analysis according to the coordinate system shown, in N/mm^2	
τ_{xy}	element shear stress determined from cargo tank FE analysis, in N/mm^2,(2)	
k	higher strength steel factor, as defined in **Sec 6/1.1.4** but not to be taken as less than 0.78 for load combination S+D	

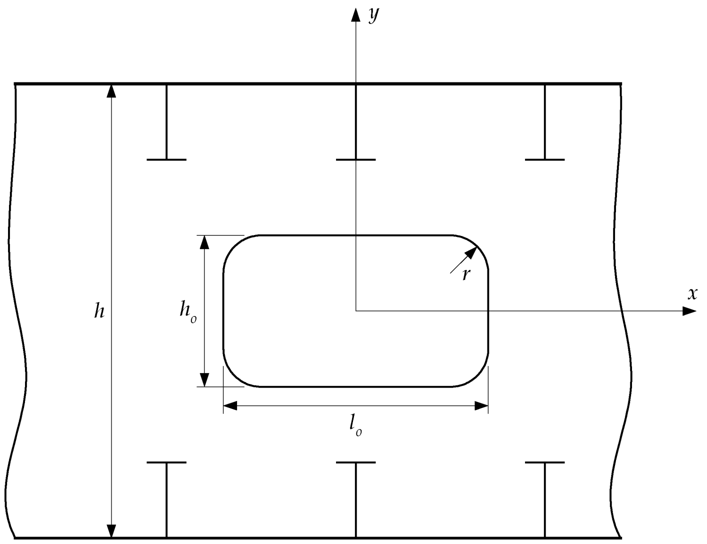
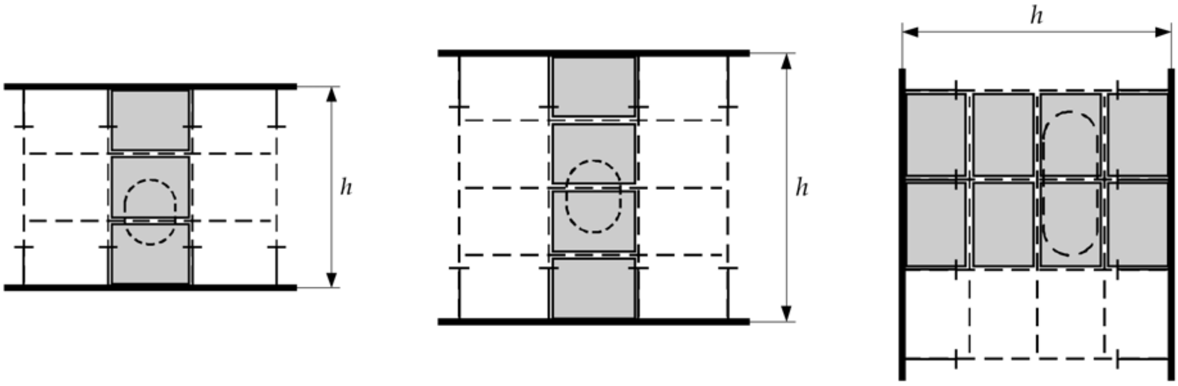
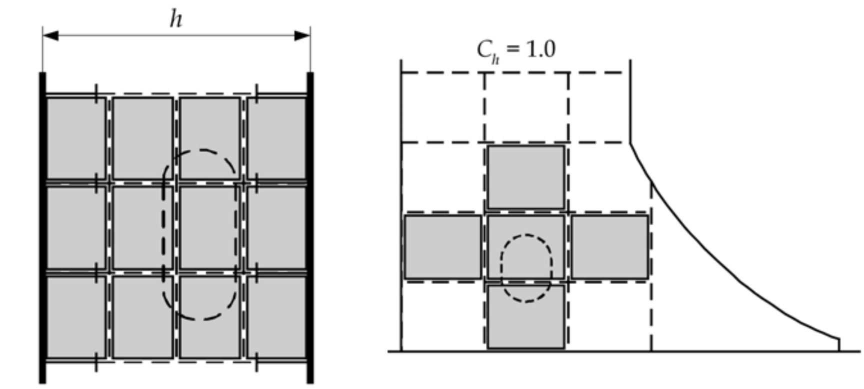


Table B.3.1 (Continued)
Fine Mesh Analysis Screening Criteria for Openings in Primary Support Members





Individual element in web to be verified against criteria

Notes

1. For opening where the modelled shear area in way of the opening is different from the actual net shear area the element shear stress is to be adjusted using the formula given in **B.2.7.2.4** prior to the evaluation of yield utilisation factor for verification against the screening criteria.
2. Where the geometry of the opening is required to be modelled in accordance with **Table B.2.2**, fine mesh FE analysis is to be carried out to determine the stress level. The screening criteria given in this table are not applicable.
3. Screening criteria is only valid if the cargo tank finite element analysis and the derivation of element stresses is carried out in accordance with **B/2**.

Table B.3.2
Fine Mesh Analysis Screening Criteria for Bracket Toes of Primary Support Members

A fine mesh finite element analysis is to be carried out where:

$\lambda_y > 1.5$ (load combination S + D)

$\lambda_y > 1.2$ (load combination S)

Where:

λ_y yield utilisation factor

$$= C_a \left(0.75 \left(\frac{b_2}{b_1} \right)^{0.5} |\sigma_{vm}| + 0.55 \left(\frac{A_{bar-net50}}{b_1 t_{net50}} \right)^{0.5} |\sigma_{bar}| \right) \frac{k}{235}$$

C_a $$= 1.0 - 0.2 \left(\frac{R_a}{1400} \right)^2$$

b_1, b_2 height of plate element in way of bracket toe in cargo tank FE model, in mm

$A_{bar-net50}$ sectional area of bar element in cargo tank FE model representing the face plate of bracket, in mm^2

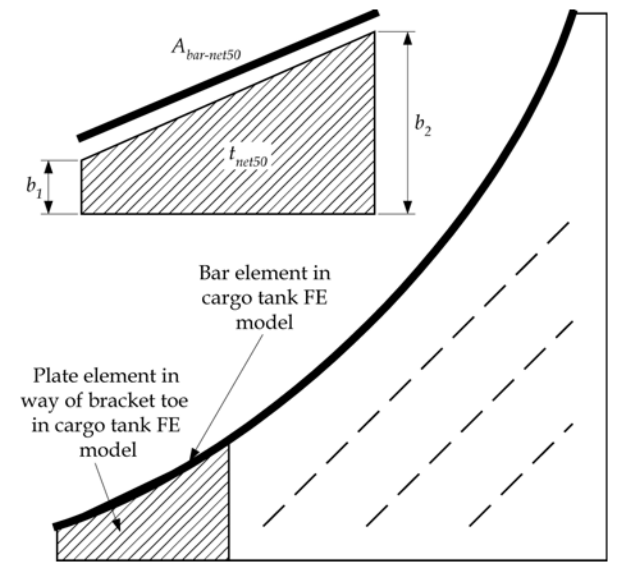
σ_{bar} bar element axial stress determined from cargo tank FE analysis, in N/mm^2

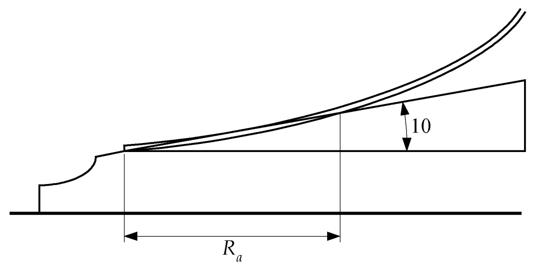
σ_{vm} von Mises stress of plate element in way of bracket toe determined from cargo tank FE analysis, in N/mm^2

t_{net50} thickness of plate element in way of bracket toe, in mm

R_a leg length distance in mm, not to be taken as greater than 1400 mm

k higher strength steel factor, as defined in **Sec 6/1.1.4**, but not to be taken as less than 0.78 for load combination S+D





Note

1. Screening criteria is only valid if the cargo tank finite element analysis and the derivation of element stresses is carried out in accordance with **B/2**.

Table B.3.3
Fine Mesh Analysis Screening Criteria for Heels of Transverse Bulkhead Horizontal Stringers

A fine mesh finite element analysis is to be carried out where:

$\lambda_y > 1.5$ (load combination S + D)

$\lambda_y > 1.2$ (load combination S)

Where:

λ_y yield utilisation factor

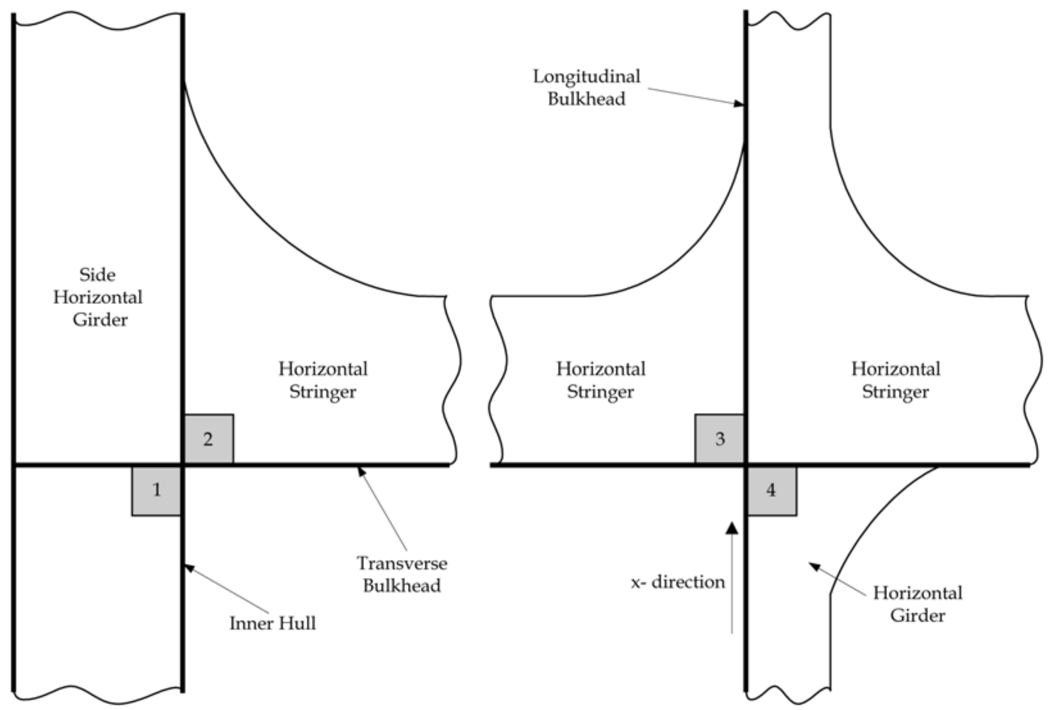
$= 3.0|\sigma_{vm}|\dfrac{k}{235}$ for heels at side horizontal girder and transverse bulkhead horizontal stringer, i.e. locations 1, 2 and 3 in figures.

$= 5.2|\sigma_x|\dfrac{k}{235}$ for heel at longitudinal bulkhead horizontal stringer, i.e. location 4.

σ_x axial stress in element x direction determined from cargo tank FE analysis in accordance with the co-ordinate system shown, in N/mm^2

σ_{vm} von Mises stress of plate element in way of heel determined from cargo tank FE analysis, in N/mm^2

k higher strength steel factor, as defined in **Sec 6/1.1.4**, but not to be taken as less than 0.78 for load combination S+D



Individual element in web to be verified against criteria

Note

1. Screening criteria is only valid if the cargo tank finite element analysis and the derivation of element stresses is carried out in accordance with **B/2**.

3.2 Structural Modelling

3.2.1 General

3.2.1.1 Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by means of separate local finite element model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo tank model. Alternatively, fine mesh zones incorporated into the cargo tank model may be used.

3.2.1.2 The extent of the local finite element model is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to coincide with primary support members, such as girders, stringers and floors, in the cargo tank model.

3.2.1.3 The mesh size in the fine mesh zones is not to be greater than 50 mm × 50 mm. In general, the extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation.

3.2.1.4 All plating within the fine mesh zone is to be represented by shell elements. A smooth transition of mesh density is to be maintained. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angle less than 60° or greater than 120°, are to be avoided. Stiffeners inside the fine mesh zone are to be modelled using shell elements. Stiffeners outside the fine mesh zones may be modelled using beam elements.

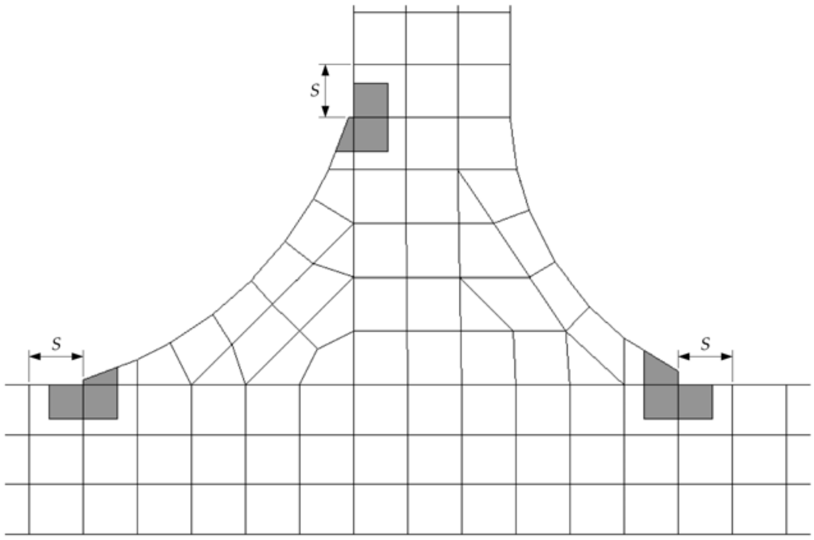
3.2.1.5 The element inside the fine mesh zone is to be modelled based on the net thickness, obtained by deducting the full corrosion addition, t_{corr}, from the gross thickness. The structure outside the fine mesh zone is to be modelled based on the net thickness obtained by deducting half the corrosion addition, $0.5\ t_{corr}$, from the gross thickness, as specified in **2.2.1.5**, for use in the cargo tank FE analysis.

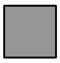
3.2.1.6 Where fine mesh analysis is required for main bracket end connections, the fine mesh zone is to be extended at least 10 elements in all directions from the area of interest, see **Fig B.3.5**. The modelling scantlings in the fine mesh zone are to be in accordance with **3.2.1.5.**

3.2.1.7 Where fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modelled with mesh size not greater than 50 mm × 50 mm, based on the net thickness with deduction of full corrosion addition, t_{corr},. The elements outside the first two layers are to be based on the net thickness with a deduction of corrosion addition, $0.5\ t_{corr}$, see **3.2.1.5.** A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modelled with plate elements. Web stiffeners close to an opening may be modelled using rod or beam elements located at a distance of at least 50 mm from the edge of the opening. Typical fine mesh zone around an opening is shown in **Fig B.3.6.**

3.2.1.8 Face plates of openings, primary support members and associated brackets are to be modelled with at least three elements across their width.

Fig B.3.5
Fine Mesh Zone Around Bracket Toes





Fine mesh zone
Element size ≤ 50 mm × 50 mm
Extent - at least 10 elements in all directions
Face plate modelled by plate elements

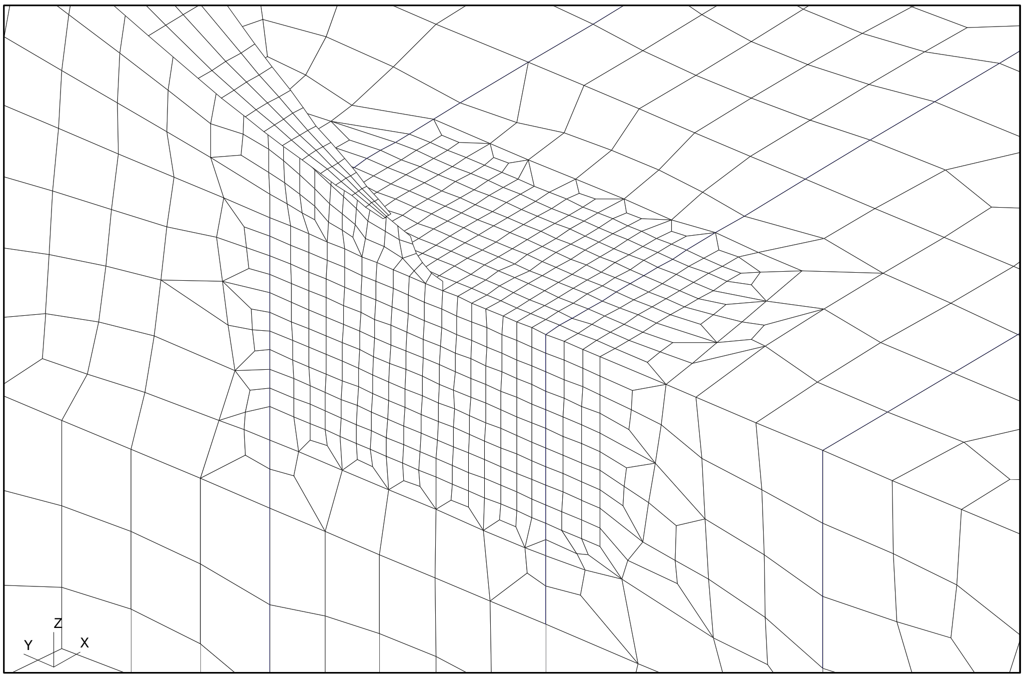
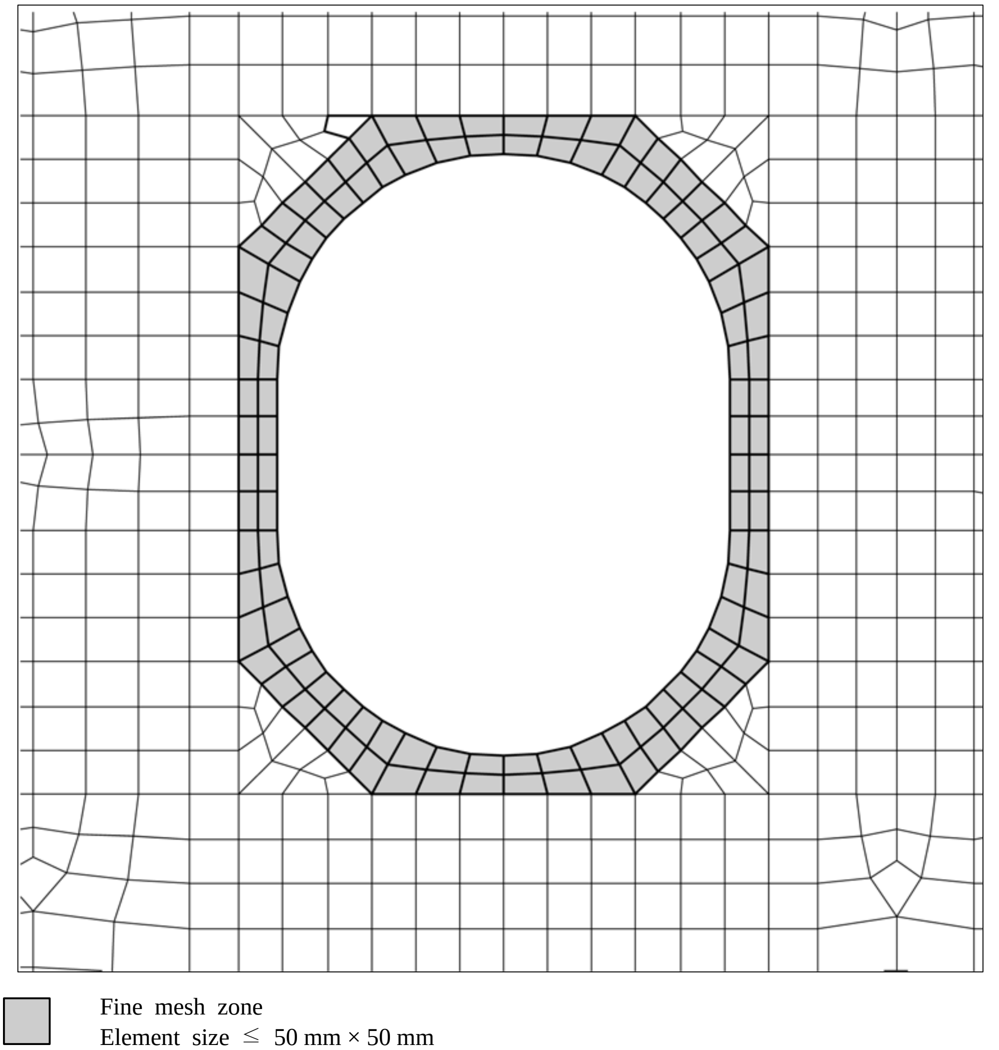


Fig B.3.6
Fine Mesh Zone Around an Opening



Fine mesh zone
Element size ≤ 50 mm × 50 mm

3.2.2 Transverse web frames

3.2.2.1 In addition to the requirements of **3.2.1**, the modelling requirements in this sub-section are applicable to the analysis of typical transverse web frame.

3.2.2.2 Where a FE sub model is used, the model is to have an extent of at least 1 + 1 web frame spaces, i.e. one web frame space extending either side of the transverse web frame under investigation. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub model.

3.2.2.3 The full depth and full breadth of the ship shall be modelled, see **Fig B.3.7.**

3.2.2.4 **Fig B.3.8** shows a close up view of the finite element mesh at the lower part of the vertical web and backing brackets.

Fig B.3.7
Extent of Sub-Model for Fine Mesh Analysis of Web Frame Bracket Connections and Openings

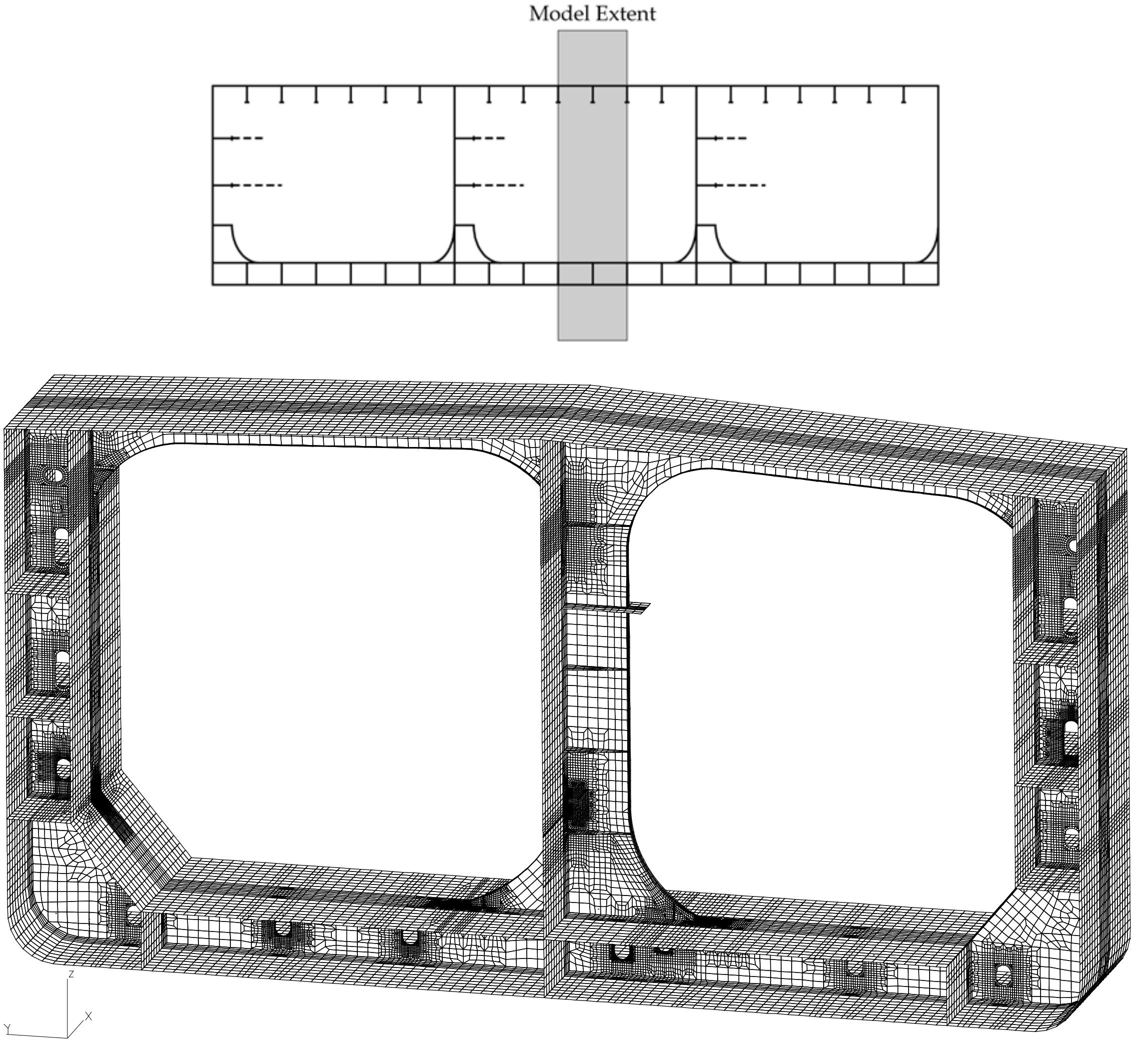
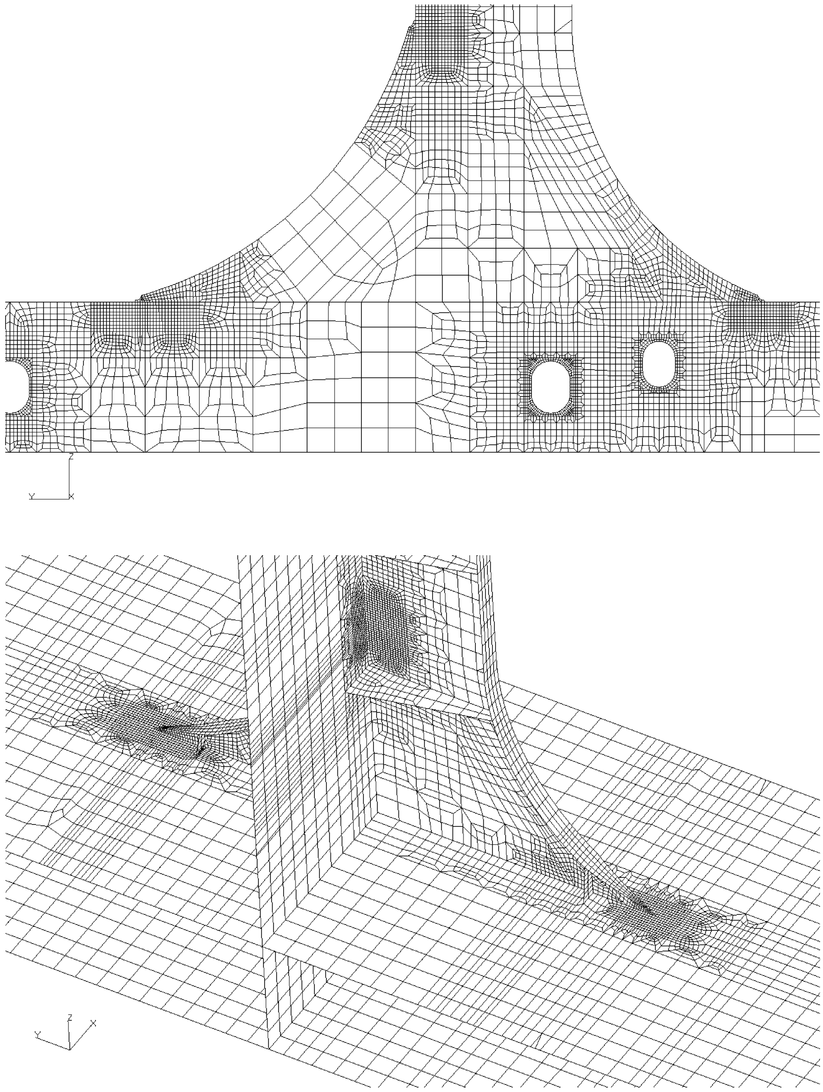


Fig B.3.8
Close-up View of Finite Element Mesh at the Lower Part of a Vertical Web Frame and Backing Brackets



3.2.3 Transverse bulkhead stringers, buttress and adjacent web frame

3.2.3.1 In addition to **3.2.1**, the modelling requirements in this sub-section are applicable to the analysis of transverse bulkhead and adjacent web frame as described in **3.1.3.**

3.2.3.2 Due to the structural interaction between the transverse bulkhead, horizontal stringers, web frames, deck and bottom, it is recommended that the FE sub-model represents a full section of the hull. Longitudinally, the ends of the model should at least be extended one web frame space beyond the areas that require investigation, see **Fig B.3.9**. The full breadth and depth of the ship should be modelled.

3.2.3.3 Alternatively, it is acceptable to use a number of sub-models, as shown in **Fig B.3.10**, to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship should be modelled. For the analysis of buttress structure, the sub-model width should be at least 4 + 4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

3.2.3.4 **Fig B.3.11** shows the finite element mesh on a **Fig B.3.12** shows the sub-model for the analysis of buttress connections to transverse bulkhead and double bottom structure, and openings.

Fig B.3.9
Extent of Sub-Model for Fine Mesh Analysis of Transverse Bulkhead and Adjacent Structure

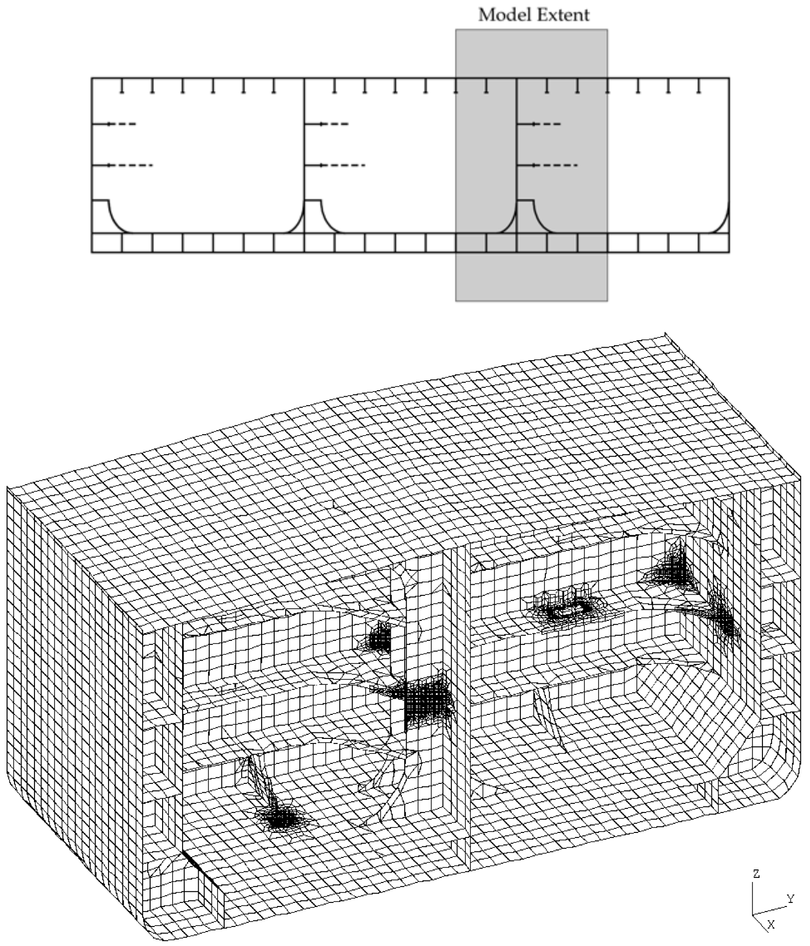


Fig B.3.10
Analysis of Transverse Bulkhead Structure Using Sub-Models

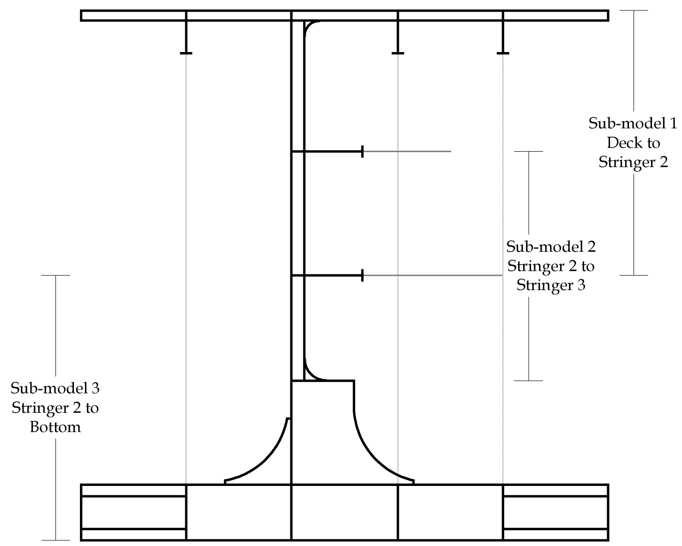


Fig B.3.11
Finite Element Mesh on Transverse Bulkhead Horizontal Stringer
(figure shows port side of model)

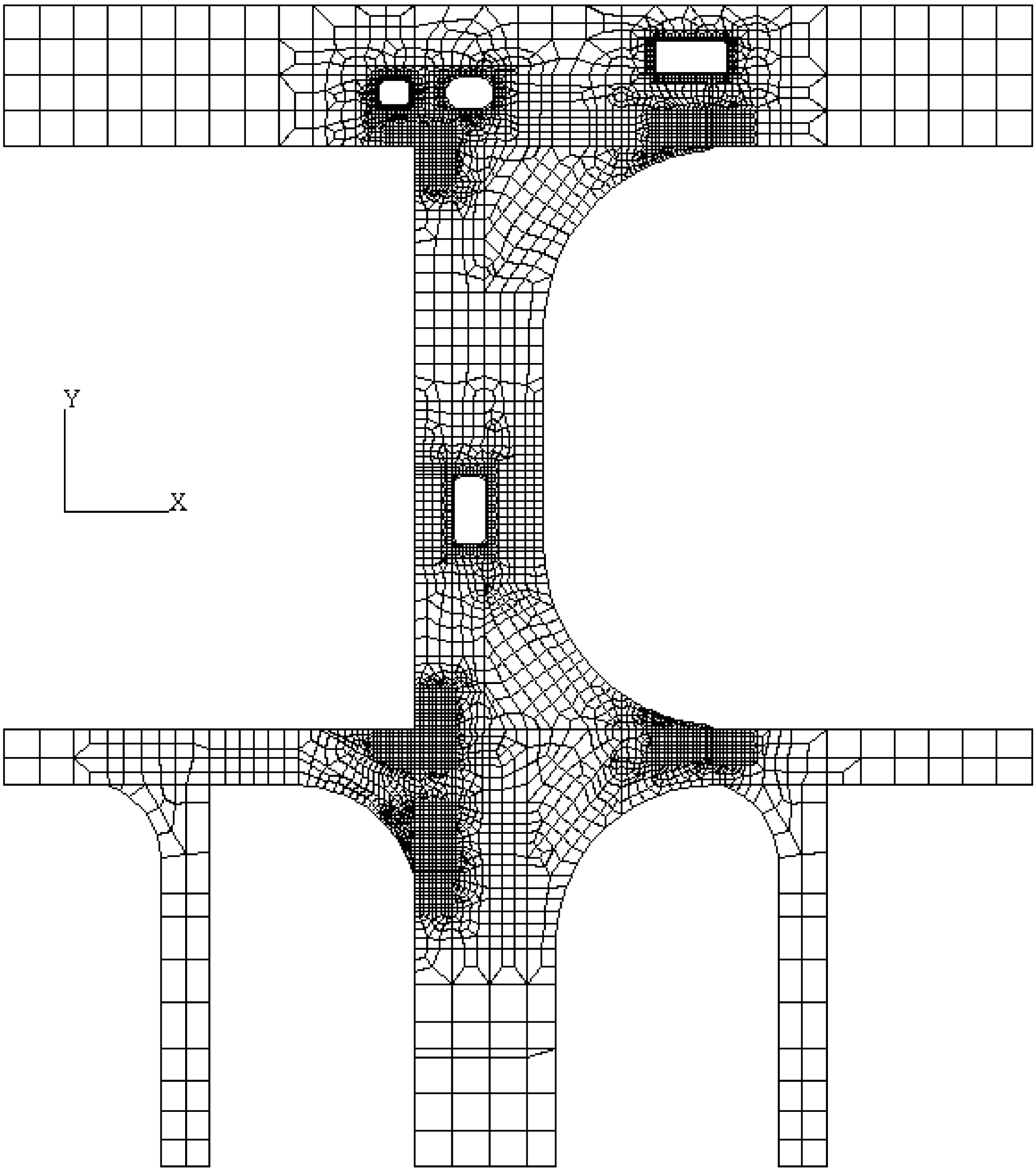
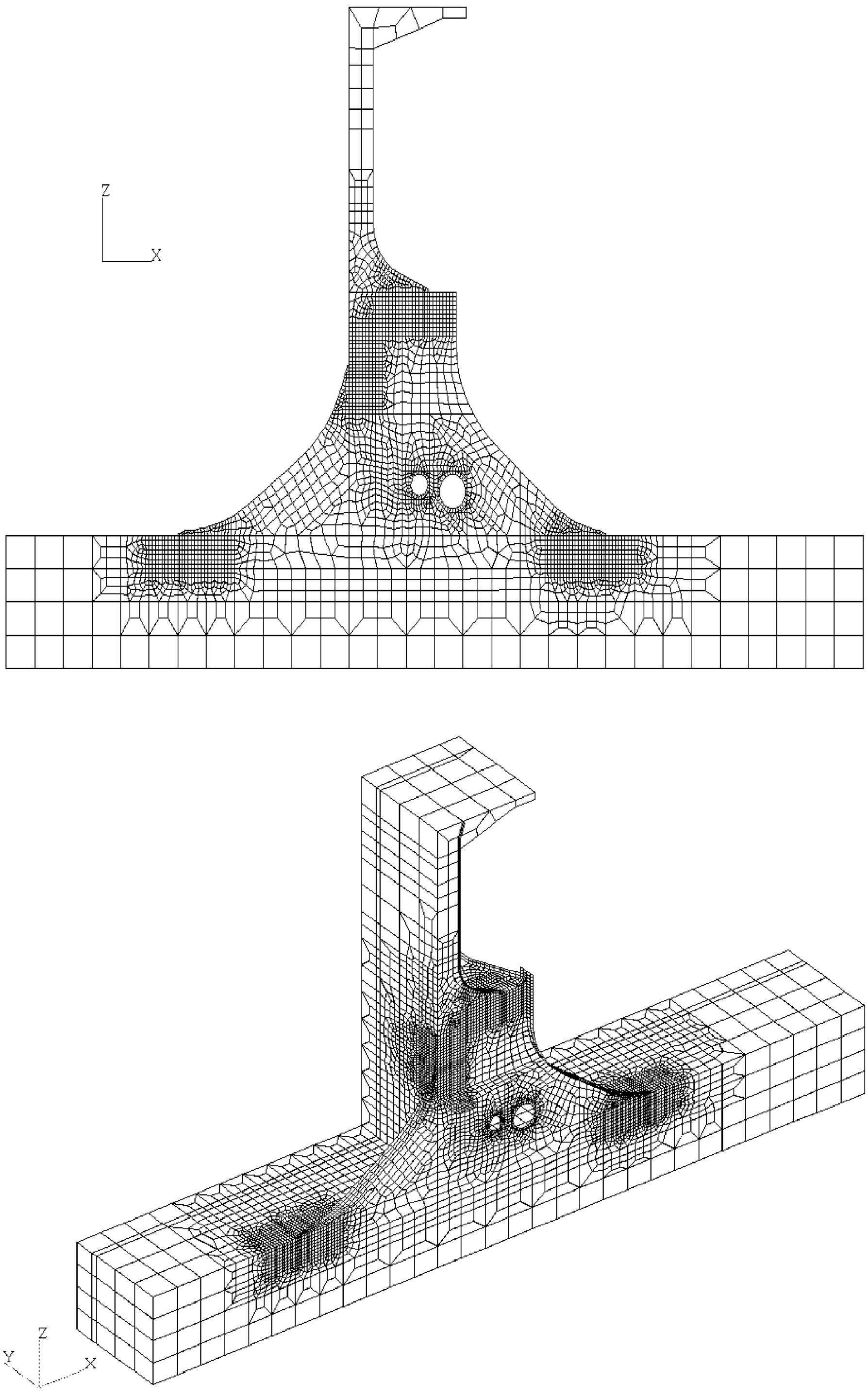


Fig B.3.12
Sub-Model for the Analysis of Buttress Connections to Bulkhead and Double Bottom Structure (figure shows port half of model)



3.2.4 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

3.2.4.1 The modelling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners as described in **3.1.4.**

3.2.4.2 Where a local FE model is used, each end of the model is to be extended longitudinally at least two web frame spaces from the areas under investigation. The model width is to be at least 2 + 2 longitudinal spaces. **Fig B.3.13** shows the longitudinal extent of the sub-model for the analysis of deck and double bottom longitudinal stiffeners and adjoining transverse bulkhead vertical stiffener.

3.2.4.3 The prescribed displacements or forces obtained from the cargo tank FE model should be applied to all boundary nodes which coincide with the cargo tank model.

3.2.4.4 The longitudinal and vertical stiffeners under investigation, including web, face plate, attached plating (within ½ + ½ longitudinal spaces) and associated brackets are to be modelled based on the gross thickness with deduction of the full corrosion addition t_{corr}. Other areas are to be based on gross thickness with deduction of half corrosion addition, 0.5 t_{corr}.

3.2.4.5 The web of the longitudinal stiffeners should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The face plate of the longitudinal stiffeners and brackets should be modelled with at least three elements across its width.

3.2.4.6 The mesh size and extent of the fine mesh zone is to be in accordance with **3.2.1.3**, see also **Fig B.3.13.**

Fig B.3.13
Sub-Model for Fine Mesh Analysis of End Connections and Web Stiffeners of Deck and Double Bottom Longitudinals

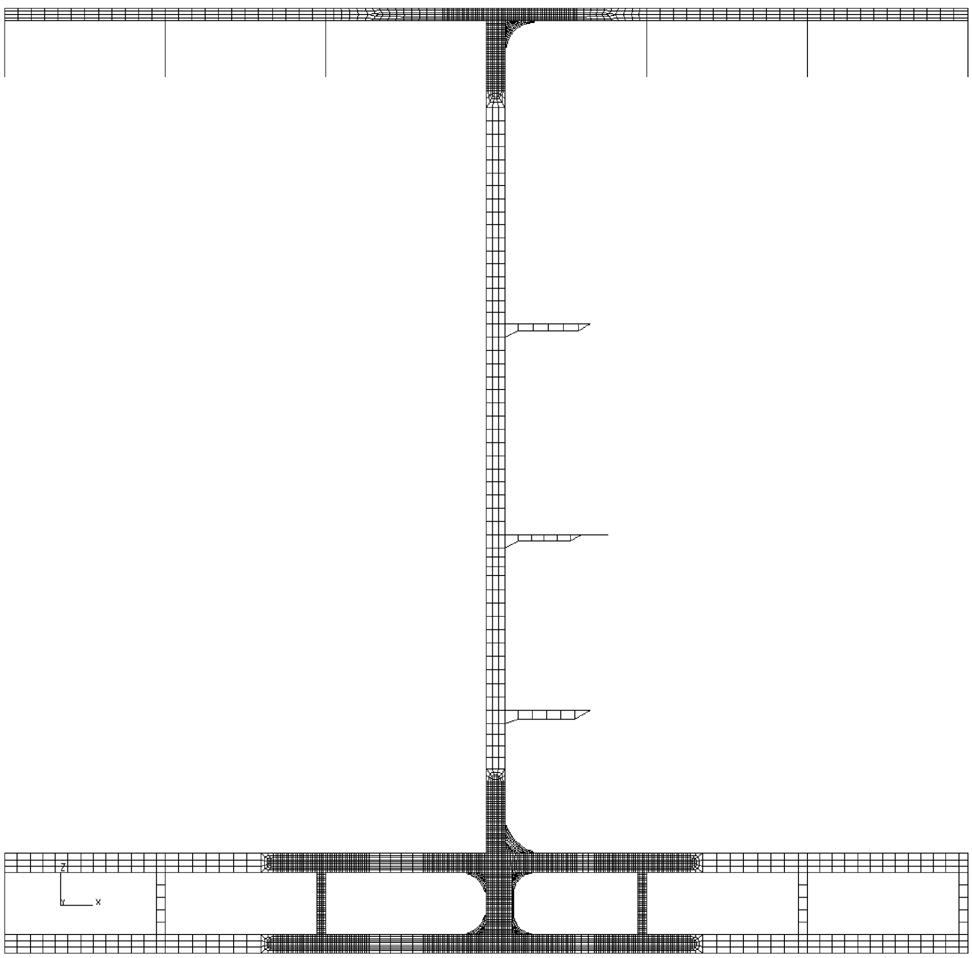
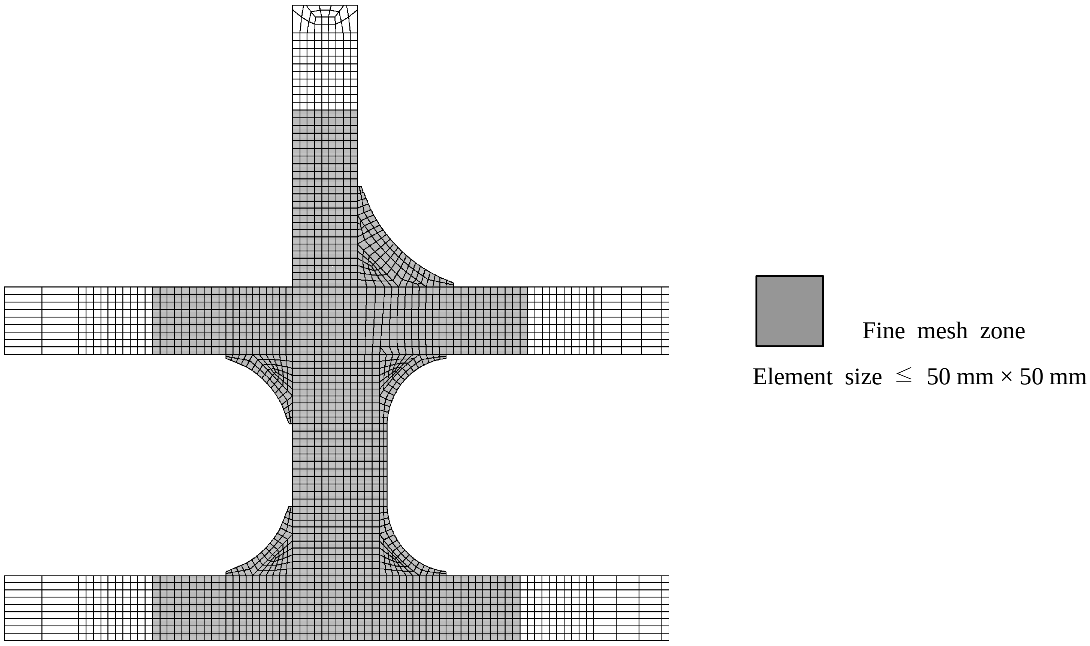
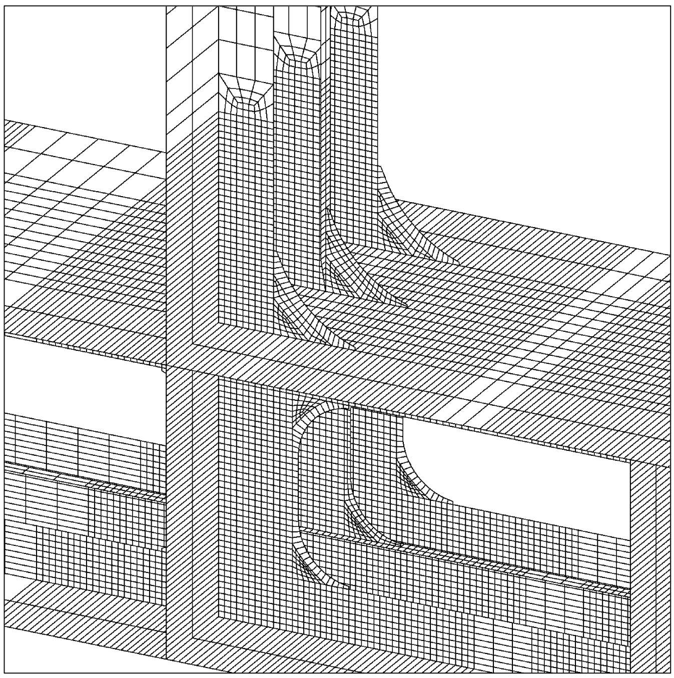


Fig B.3.13 (Continued)
Sub-Model for Fine Mesh Analysis of End Connections and Web Stiffeners of Deck and Double Bottom Longitudinals





3.2.5 Corrugated bulkheads

3.2.5.1 In addition to **3.2.1**, the modelling requirements in this sub-section are applicable to the analysis of connections of corrugated bulkheads to lower bulkhead stools as described in **3.1.5.**

3.2.5.2 The minimum extent of the sub-model is as follows, see also **Fig B.3.14**:

(a) vertically, from the bottom of the bottom bulkhead stool to a level at least 2 m above the connection of the corrugation to the upper part of the bulkhead stool. The upper boundary of the sub-model should be coincident with the horizontal mesh line of the cargo tank FE model

(b) for transverse corrugated bulkheads, the sub-model is to be extended transversely to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the sub-model covers two bulkhead stool transverse web spaces). The end diaphragms need not be modelled

(c) for longitudinal corrugated bulkheads, the sub-model is to be extended to the nearest web frame on each side of the fine mesh zone (i.e. the sub-model covers two frame spaces). The end web frames need not be modelled

(d) where the area under investigation is located close to the intersection of transverse and longitudinal corrugated bulkheads, the sub-model should cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever relevant. In addition the sub-model is to be extended at least one diaphragm/web frame outside the intersection of the stools.

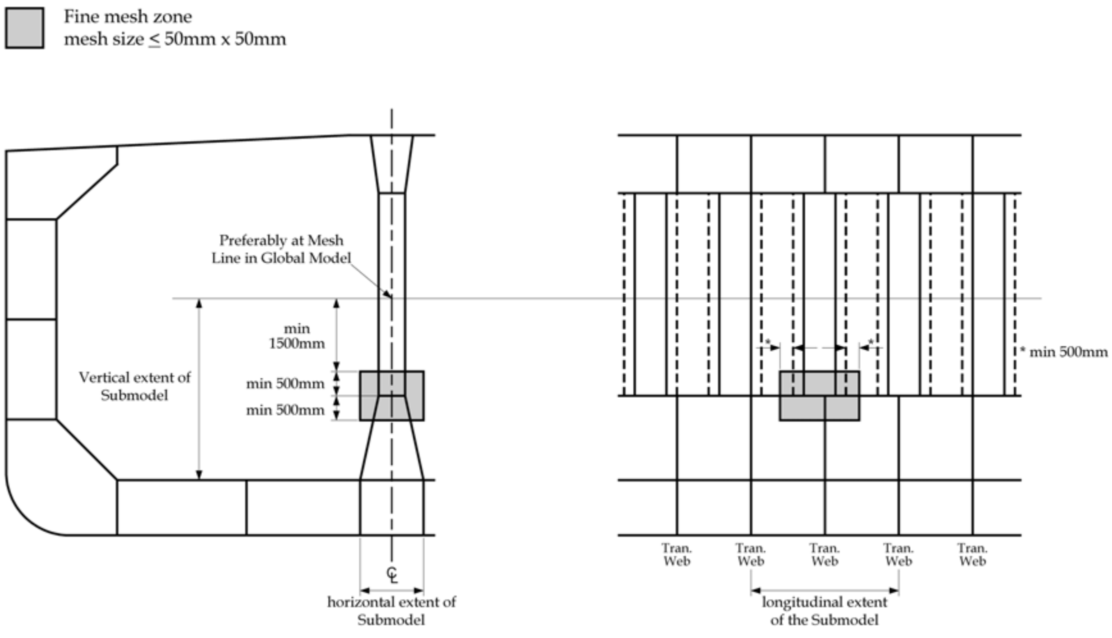
3.2.5.3 The fine mesh zone is to be extended at least 500 mm (10 elements) from the corrugation connection in a vertical direction, see **Fig B.3.1.4**. In a horizontal direction, the fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and a further extension of 500 mm from each end of the corrugation web (i.e. the fine mesh zone covers four corrugation knuckles), see **Fig B.3.14**. The mesh size within the fine mesh zone is not to be greater than 50 mm × 50 mm.

3.2.5.4 Diaphragm webs, brackets inside the lower stool and vertical stiffeners on the stool side plate are to be modelled at their actual positions within the extent of the sub-model. Shell elements are to be used for modelling of diaphragm, bracket and stiffener webs. Beam elements may be used to represent the flange of stiffeners and brackets.

3.2.5.5 Horizontal stiffeners on the lower stool side plate are to be represented by beam elements.

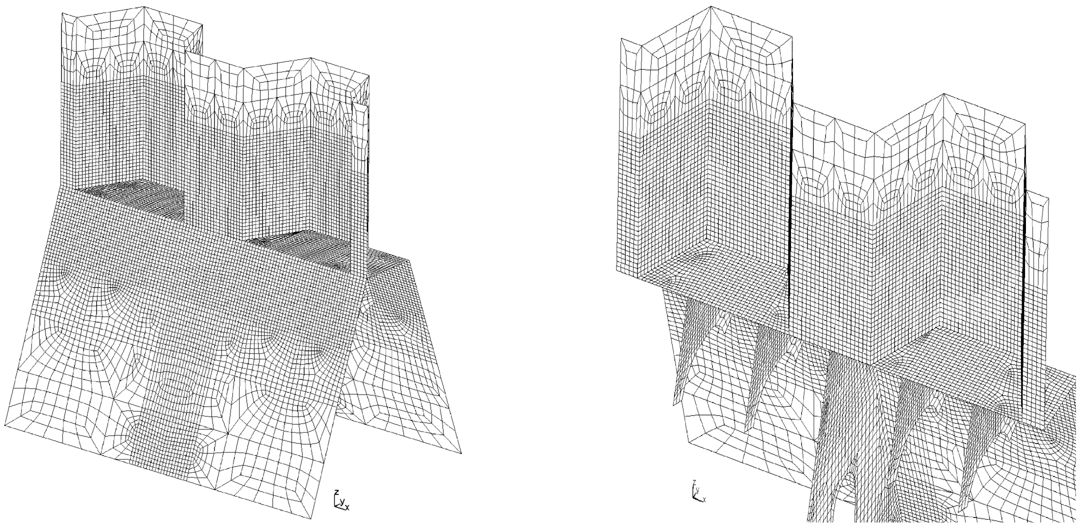
3.2.5.6 **Fig B.3.15** shows the finite element sub-model for the fine mesh analysis of longitudinal bulkhead to lower stool connection.

Fig B.3.14
Extent of Sub-Model and Fine Mesh Zone for the Analysis of Corrugated Bulkhead Connection to Lower Stool



Note
Above figures show extent of sub-model and fine mesh zone on longitudinal corrugated bulkhead connection to lower stool. Similar extent applies to transverse corrugated bulkhead.

Fig B.3.15
Sub-Model for the Analysis of Connection of Longitudinal Corrugated Bulkhead to Lower Stool



3.3 Loading Conditions

3.3.1 Stress analysis

3.3.1.1 The fine mesh detailed stress analysis is to be carried out for the standard load cases specified in **2.3.1**, and any other load cases specially considered as required by **Sec 9/2.2.3.**

3.4 Application of Loads and Boundary Conditions

3.4.1 General

3.4.1.1 Where a separate local finite element model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.

3.4.1.2 Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

3.4.1.3 All local loads, including any vertical loads applied for hull girder shear force correction, in way of the structure represented by the separate local finite element model are to be applied to the model.

3.5 Result Evaluation and Acceptance Criteria

3.5.1 Stress assessment

3.5.1.1 Stress assessment of the fine mesh analysis is to be carried out for the load cases specified in **3.3.1.**

3.5.1.2 The von Mises stress, σ_{vm}, is to be calculated based on the membrane direct axial and shear stresses of the plate element evaluated at the element centroid. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

3.5.1.3 The resulting von Mises stresses are not to exceed the permissible membrane values specified in **Sec 9/2.3.5**.

3.5.1.4 The maximum permissible stresses are based on the mesh size of 50 mm × 50 mm as specified in **3.2.1**. Where a smaller mesh size is used, an average von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area. The average stress is to be calculated based on stresses at element centroid; stress values obtained by interpolation and/or extrapolation are not to be used. Stress averaging is not to be carried across structural discontinuities and abutting structure.

4 Evaluation of Hot Spot Stress for Fatigue Analysis

4.1 Application

4.1.1 General

4.1.1.1 This Section describes the procedure to perform a finite element analysis using very fine meshes for the evaluation of geometric hot spot stresses for use in the determination of fatigue damage ratio in accordance with **Appendix C/2.**

4.1.1.2 The locations where a finite element analysis based fatigue assessment is to be carried out are specified in **Sec 9/3.3.**

4.2 Structural Modelling

4.2.1 General

4.2.1.1 Evaluation of hot spot stresses for fatigue assessment requires the use of very fine finite element meshes in way of areas of high stress concentration. This very fine mesh analysis can be carried out by means of separate local finite element models with very fine mesh zones in conjunction with the boundary conditions obtained from a cargo tank model. Alternatively, very fine mesh zones incorporated into the cargo tank model may be used.

4.2.1.2 All structural parts, within an extent of at least 500 mm in all directions leading up to the fatigue hot spot position, are to be modelled based on the net thickness, obtained by deducting half the corrosion addition (i.e. $0.5\,t_{corr}$) from the gross thickness.

4.2.1.3 The cargo tank finite element model for fatigue assessment is to be modelled in accordance with 2.2, but based on net thickness obtained by deducting a quarter of the corrosion addition (i.e. $0.25\,t_{corr}$) from the proposed thickness. Alternatively, if the cargo tank FE model for the strength assessment is used, which is based on a thickness deduction of $0.5\,t_{corr}$, the calculated stresses are to be corrected using the modelling reduction factor, f_{model}, given in **Appendix C/2.4.2.7.**

4.2.1.4 Where a separate local finite element model is used, the extent of the local model is to be such that the calculated stresses are not significantly affected by the imposed boundary conditions and application of loads. The boundary of the fine mesh model is to coincide with the primary support members, such as girders, stringers and floors, in the cargo tank model. The extent of the local finite element model of a hopper knuckle is described in **4.2.2.**

4.2.1.5 The evaluation of hot spot stress is to be based on shell element of mesh size $t_{net50} \times t_{net50}$, where t_{net50} is the net thickness of the plate where a potential fatigue crack is most likely to initiate. This mesh size is to be maintained within the very fine mesh zone, extending over at least 10 elements in all directions leading to the fatigue hot spot position. A uniform quadratic mesh is to be used within the very fine mesh zone. A smooth transition of mesh density leading up to the very fine mesh zone is to be maintained.

4.2.1.6 Four-node shell elements with bending and membrane properties are to be used inside the very fine mesh zone. The shell elements are to represent the mid plane of the plating and the bending properties of the plate. The geometry of the weld and structural misalignment is not required to be modelled.

4.2.1.7 Where stresses are to be evaluated on a free edge or corner welds, such as cut-outs for stiffener connections at web frames, butt welds on edge of plating and around hatch corners, a rod element of negligible cross-section area, e.g. $1\ mm^2$, is to be used to obtain the required stress value.

4.2.1.8 All structure in close proximity to the very fine mesh zones is to be modelled explicitly with shell elements. Triangular elements are to be avoided where possible. Use of extreme aspect ratio (e.g. aspect ratio greater than 3) and distorted elements (e.g. element's corner angle less than 60° or greater than 120°) are to be avoided.

4.2.2 Hopper knuckle connection

4.2.2.1 In addition to the general requirements in **4.2.1**, the modelling requirements in this sub-section are applicable to the modelling of welded hopper knuckle connections.

4.2.2.2 Fatigue assessment is to be carried out for the knuckle joint between inner bottom and hopper plate for at least one transverse frame in the midship cargo tank region, see **Sec 9/3.3.3**. The fatigue assessment is only required to be carried out on the structural detail at one side of the hull.

4.2.2.3 In general, the hopper knuckle connection at the mid position between transverse bulkheads is to be assessed. Where a wash bulkhead exists, the hopper knuckle connection at the mid position between the wash bulkhead and cargo tank end bulkhead is generally to be assessed. The results from the cargo tank FE analysis described in **2.2** should be examined for the highest transverse in-plane stress on the inner bottom plate adjacent to the lower hopper knuckle line to identify the exact frame position and the side of the hull where the fatigue assessment should be carried out.

4.2.2.4 Where a separate local finite element model is used, the minimum extent of the local model is as follows:

(a) longitudinally, the model is to cover two web frame spaces (i.e. one web frame space extending either side of the transverse web frame of interest). Transverse web frames at the end of the local model need not to be represented in the sub-model

(b) vertically, the model is to extend from the base line to the lower stringer in the double side water ballast tank. Where a fatigue assessment is also carried out for the upper knuckle connection, the model is to be extended to 4 longitudinal spaces above the lower stringer in the double side ballast tank

(c) transversely, the model is to extend from the ship side to 4 longitudinal spaces inboard of the double bottom side girder.

4.2.2.5 Mesh size in way of the knuckle connection is to be $t_{net50} \times t_{net50}$, where t_{net50} is the net thickness of the inner bottom plate in way of the connection obtained by deducting 0.5 t_{corr} from the gross thickness as specified in **4.2.1.2**. The minimum extent of the $t_{net50} \times t_{net50}$ mesh is to be (see also **Fig B.4.1**):

(a) inner bottom plate - 10 elements from knuckle in transverse direction, 10 elements forward and aft of the floor in the longitudinal direction

(b) scarfing bracket/inner bottom overhang - 10 elements from knuckle in transverse direction, 10 elements forward and aft of the floor in the longitudinal direction

(c) hopper sloping plate - 10 elements from knuckle in transverse direction, 10 elements forward and aft of the hopper web in the longitudinal direction

(d) girder - 10 elements from knuckle in vertical direction, 10 elements forward and aft of the floor/hopper web in the longitudinal direction

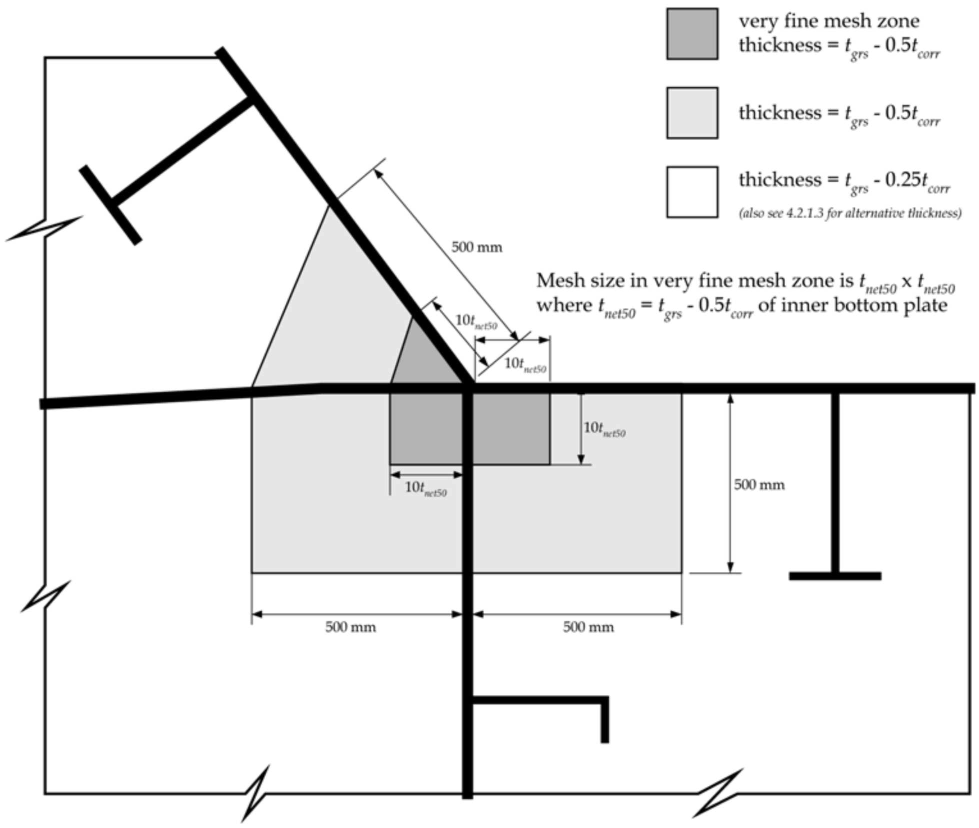
(e) floor/hopper web - 10 elements from the hopper knuckle in transverse and vertical directions respectively.

4.2.2.6 Any scarfing brackets on the web frame adjoining the inner bottom plating, the first longitudinal stiffeners away from the knuckle as well as any carlings and brackets offset from the main frames are to be modelled explicitly using shell elements. Longitudinal stiffeners further away from the knuckle may be modelled by beam elements. The inner bottom plate "overhang" outboard of the girder is to be modelled using shell elements up to the extent of the scarfing bracket. Away from the scarfing bracket, the inner bottom plate "overhang"may be modelled using line elements of equivalent area. Any perforations, such as cut-outs for cabling, pipes and access that are within one stiffener space from the knuckle point are to be modelled explicitly.

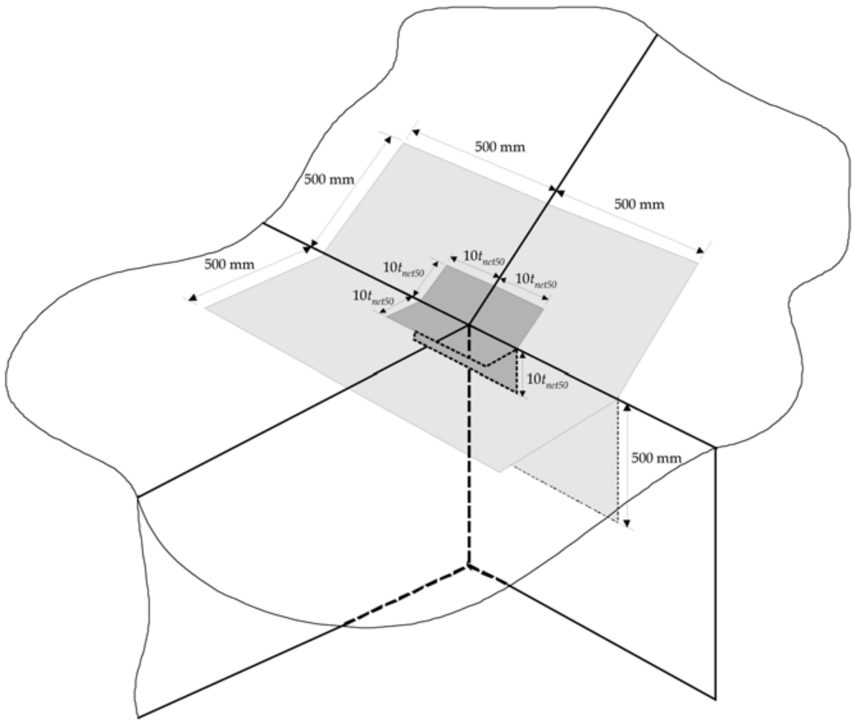
4.2.2.7 **Fig B.4.1** shows extent of the $t_{net50} \times t_{net50}$ mesh zone and extension of the areas of local thickness reduction.

4.2.2.8 **Fig B.4.2** to **B.4.4** show typical local finite element models of the hopper knuckle connection and close-up views of the $t_{net50} \times t_{net50}$ mesh zone.

Fig B.4.1
Minimum Extent of t_{net50} x t_{net50} Mesh Zone and Local Thickness Reduction Zone at Lower Hopper Joint



Floor and hopper web



Girder, inner bottom and hopper sloping plate

Fig B.4.2
Typical Local Finite Element Model of Hopper Knuckle Connection
t_{net50} x t_{net50} Mesh on Inner Bottom and Hopper Plate

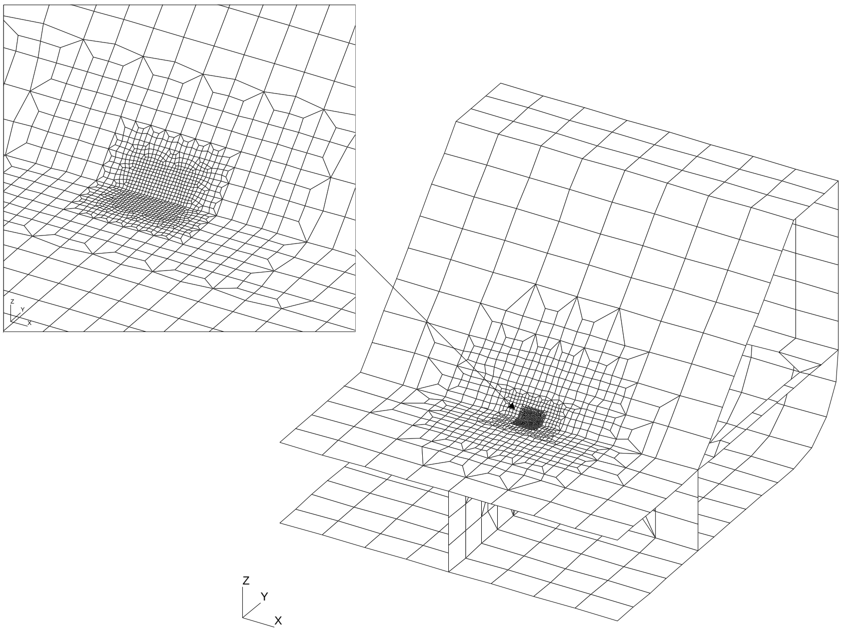
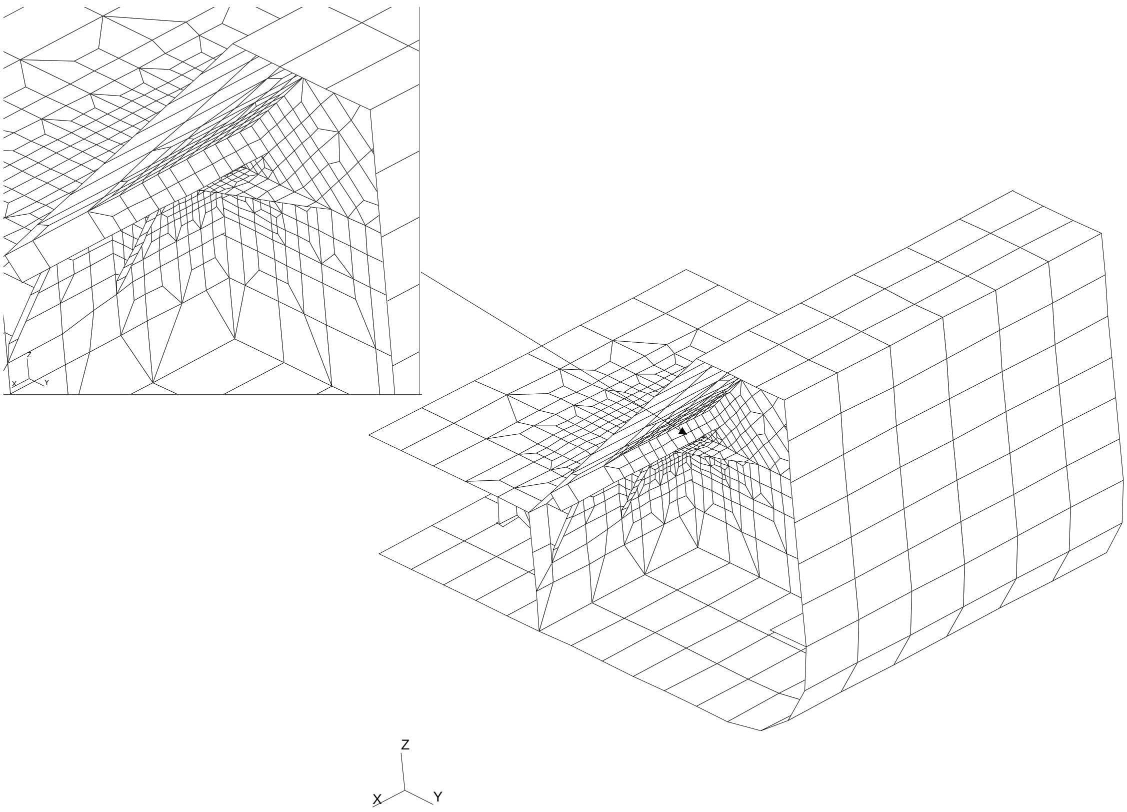


Fig B.4.3
Typical Local Finite Element Model of Hopper Knuckle Connection
t_{net50} x t_{net50} Mesh on Hopper Plate, Web Frame, Girder and Bracket in way



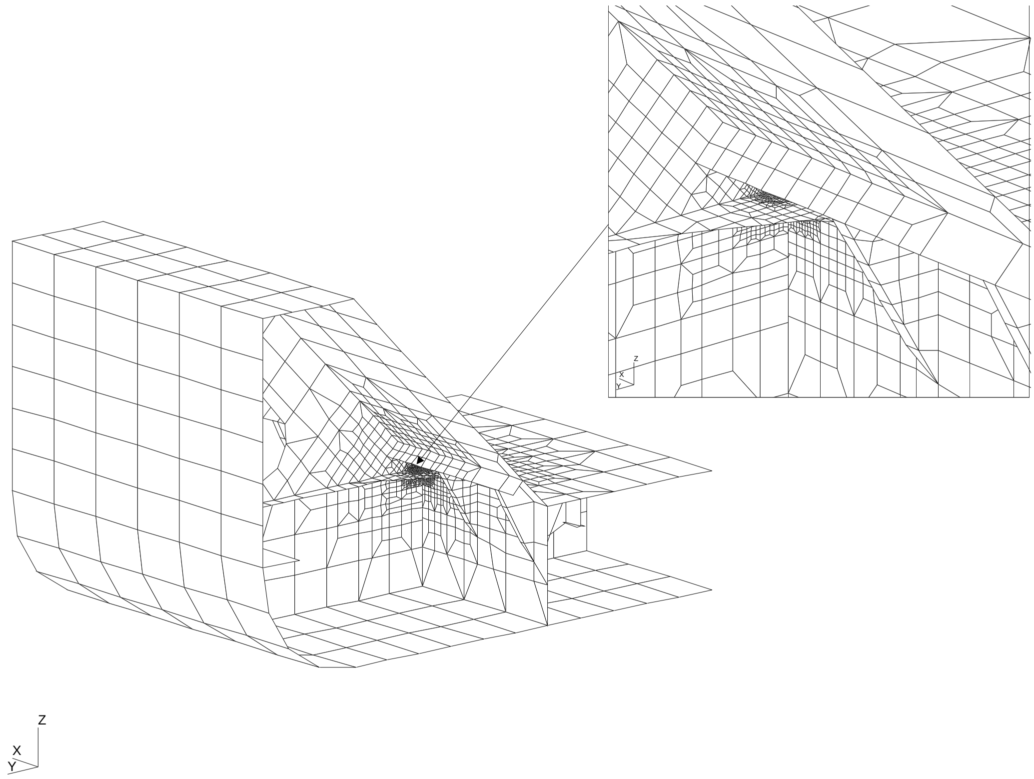
4.3 Loading Conditions

4.3.1 General

4.3.1.1 The ship loading conditions to be used to evaluate dynamic stress ranges for fatigue assessment are to be in accordance with **Appendix C/1.3.2.**

4.3.1.2 The cargo density to be used for the fatigue assessment is to be:
(a) longitudinal end connections - the greater of the cargo density specified for the homogeneous scantling draught condition and 0.9 t/m^3
(b) connection between inner bottom and hopper plate - 0.9 t/m^3

Fig B.4.4
Typical Local Finite Element Model of Hopper Knuckle Connection
t_{net50} x t_{net50} Mesh on Hopper Plate, Web Frame, Girder and Bracket in way



4.3.2 Finite element load cases for hopper knuckle connection

4.3.2.1 The requirements given in this sub-section are specifically applicable to the evaluation of hot spot stress range at hopper knuckle connection.

4.3.2.2 Only dynamic loads are considered for the evaluation of fatigue stress range. Static loads need not be included in the finite element analysis.

4.3.2.3 The load cases required to derive the component stress ranges for determining the combined stress ranges, see **Appendix C/2.4.2.7**, are given in **Table B.4.1.**

4.3.2.4 Stresses induced by vertical and horizontal hull girder bending moments are not to be included in the stress range for fatigue assessment. Stress caused by the bending effect of the hull girder is to be calculated and deduced from the fatigue stress range result in accordance with the procedure described in **4.5.2.**

Table B.4.1
Load Cases for the Evaluation of Component Stress Range for Hopper Knuckle Joint

Load case	Component stress	Applied load	Parameters for calculation of loads
Full load condition			
L1	s_{e1}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is analysed.	Ship draught = midship draught from departure homogeneous full load condition in the ship loading manual, see **Appendix C/1.3.2.** GM: see **Sec 7/3.1.3.4** $r_{roll-gyr}$: see **Sec 7/3.1.3.4** Cargo density = 0.9 t/m^3 (minimum, see **4.3.1.2**)
L2	s_{e2}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is not analysed.	
L3	s_{ix}	Dynamic tank pressure (full range) due to longitudinal acceleration.	
L4	s_{iy}	Dynamic tank pressure (full range) due to transverse accelerations.	
L5	s_{iz}	Dynamic tank pressure (full range) due to vertical acceleration.	
Ballast condition			
L6	s_{e1}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is analysed.	Ship draught = midship draught from departure normal ballast condition in the ship loading manual. If normal ballast condition is not defined, then the midship draught from light ballast condition is to be used, see **Appendix C/1.3.2**
L7	s_{e2}	Dynamic wave pressure (full range) applies only to the side of the hull where the hopper knuckle is not analysed.	
Load cases for bending moment correction			
C1	s_{VBM}	Unit vertical bending moment applies to ends of cargo tank model	No other loads are to be applied
C2	s_{HBM}	Unit horizontal bending moment applies to ends of cargo tank model	

Where:

$s_{e1}, s_{e2}, s_{ix}, s_{iy}, s_{iz}$ component stresses (with proper sign convention used) before correction for bending moment effect (5)
s_{VBM} stress response due to the application of unit vertical bending moment at ends of cargo tank model
s_{HBM} stress response due to the application of unit horizontal bending moment at ends of cargo tank models

Notes

1. For dynamic wave pressure load cases, the pressure distribution is to be calculated at mid-ship and this distribution is to be applied along the full length of the cargo tank FE model.
2. For dynamic tank pressure load cases, vertical, transverse and longitudinal accelerations are calculated at the centre of gravity position of the midship cargo tanks. The accelerations calculated for each tank are to be applied to all corresponding cargo tanks along the length of the FE model.
3. Longitudinal, transverse and vertical accelerations at tank centre of gravity position are to be calculated in accordance with **Sec 7/3.3**. The dynamic tank pressure amplitudes due to accelerations are to be calculated in accordance with **Sec 7/3.5.4.7**. The dynamic tank pressure (full range) is to be obtained as two times the dynamic tank pressure amplitude and distributed in accordance with **Fig 7.3.9**. Note that these pressure distributions are different from those used for strength analysis.
4. The dynamic wave pressure amplitude is to be calculated according to **Sec 7/3.5.2.3**. The dynamic wave pressure (full range) is to be obtained as two times the dynamic wave pressure amplitude. Note that the dynamic wave pressure and distribution is different from that used for strength analysis.
5. Component stresses (with proper sign convention used) calculated from load cases L1 to L7 are to be corrected to deduct the component due to vertical and horizontal bending moment effect, see **4.5.2.2**.

4.4 Boundary Conditions

4.4.1 Cargo tank model

4.4.1.1 The boundary conditions to be applied to the ends of the cargo tank model are to be in accordance with **2.6**. The application of unit vertical and horizontal bending moment at the model ends is to be in accordance with **2.5.4.5** or **2.5.4.6.**

4.4.2 Local finite element models

4.4.2.1 Where a separate local finite element model is used for evaluating the hot spot stress range, the nodal displacements or equivalent nodal forces from the cargo tank model are to be applied to the corresponding boundary nodes on the local model.

4.4.2.2 Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

4.4.2.3 All local loads in way of the structure represented by the separate local finite element model are to be applied to the model.

4.5 Result Evaluation

4.5.1 General

4.5.1.1 The fatigue damage calculation is to be based on the hot spot stress range evaluated close to the potential crack location in a direction perpendicular to the potential direction of the crack.

4.5.1.2 For welded structural details, the hot spot stress range is to be obtained as surface stress acting in a direction perpendicular to the weld at a distance of $0.5\,t_{net50}$ from the weld toe location, where t_{net50} is the net thickness of the plate where the fatigue crack is likely to initiate, see **Appendix C/2.4.2.6.**

4.5.1.3 For fatigue assessment of the free edge, a rod element is used to obtain stress at free edge. The stress range is to be based on the axial stress in the rod element.

4.5.1.4 For fatigue damage calculation of hopper knuckle connection, see **4.5.2.**

4.5.2 Hopper knuckle connection

4.5.2.1 Hot spot stress ranges for fatigue assessment of welded hopper knuckle joints are to be based on element direct stress along a direction perpendicular to intersection of the inner bottom plate and hopper plate. The stress ranges are to be evaluated on the upper surface of the hopper and inner bottom plate at a distance of $0.5\,t_{net50} + x_{wt}$ from the intersection line, where t_{net50} is the net thickness of the inner bottom plate and x_{wt} is weld toe distance, see **Fig C.2.1.** The stress at the required location can be obtained by linear interpolation based on the surface stresses evaluated at the centroid of the 1st and 2nd elements from the intersection of the hopper slope plate, and the inner bottom plate.

4.5.2.2 The component stress ranges are to be obtained by eliminating the stress induced by hull girder vertical and horizontal bending moments from the component stress determined from load cases L1 to L7 in **Table B.4.1** as follows:

$$S_{c\_i} = \left| s_{c\_i} - M_{V\_i}\, s_{VBM} - M_{H\_i}\, s_{HBM} \right|$$

Where:

S_{c_i} S_{e1}, S_{e2}, S_{ix}, S_{iy} or S_{iz}, component stress range after correction for bending moment effects

s_{c_i} s_{e1}, s_{e2}, s_{ix}, s_{iy} or s_{iz}, component stress (with proper sign convention used) including vertical and horizontal bending moment effects obtained from load cases L1 to L7, see **Table B.4.1**

M_{V_i} is the vertical hull girder bending moment due to loads applied to the cargo tank FE model obtained from load case L1, L2, L3, L4, L5, L6 or L7. The bending moment is to be calculated at the longitudinal position where the centroid of shell element under evaluation is located

M_{H_i} is the horizontal hull girder bending moment due to loads applied to the cargo tank FE model obtained from load case L1, L2, L3, L4, L5, L6 or L7. The bending moment is to be calculated at the longitudinal position where the centroid of shell element under evaluation is located

s_{VBM} stress due to unit vertical bending moment obtained from load case C1, see **Table B.4.1**

s_{HBM} stress due to unit horizontal bending moment obtained from load case C2, see **Table B.4.1**

4.5.2.3 The hull girder vertical and horizontal bending moments in **4.5.2.2** may be evaluated at the frame position where the hopper knuckle is under evaluation if the longitudinal distance from the element centroid to the frame position is less than 500 mm.

4.5.2.4 The component stress range, S_i, due to dynamic tank pressure resulting from longitudinal, transverse and vertical accelerations for the full load condition is given by:

$$S_i = 0.4|S_{ix}| + 0.9|S_{iy}| + 0.9|S_{iz}|$$

4.5.2.5 The combined hot spot stress ranges required for fatigue damage calculation are to be calculated in accordance with **Appendix C/2.4.2.7.**

4.5.2.6 Fatigue damage and fatigue life calculation is to be in accordance with **Appendix C/1.4.1.**

Appendix C

Fatigue Strength Assessment

1 Nominal Stress Approach

1.1 General

1.1.1 Applicability

1.1.1.1 This sub-section defines the procedure for a simplified fatigue assessment which is to be used to evaluate the fatigue strength of the ships structural details. The fatigue assessment uses a nominal stress approach based on beam theory.

1.1.1.2 The fatigue assessment is to be applied to welded connections where the steel has a minimum yield strength of less than 400 N/mm^2.

1.1.2 Assumptions

1.1.2.1 The following assumptions are made in the fatigue assessment:

(a) a linear cumulative damage model, i.e. Palmgren-Miner's Rule, has been used in connection with the S-N data in **1.4.5**

(b) for longitudinal stiffener end connections, nominal stresses obtained by empirical formulae, see **1.4.2** to **1.4.4**, and Rule based loads, see **1.3**, form the basis of the nominal stress based fatigue assessment

(c) the long term stress ranges of a structural detail can be characterized using a modified Weibull probability distribution parameter, ξ, as described in **1.4.1.5** and **1.4.1.6**

(d) structural details are idealised and classified in **1.5.**

1.1.2.2 The structural detail classification in **1.5** is based on typical joint geometry under simple loadings. When a structural detail is considered different from those shown in **1.5**, a suitable finite element (FE) analysis should be used to demonstrate the adequacy of the detail in terms of fatigue strength. See **2.1.1.3.**

1.1.2.3 Where the loading or geometry considered is too complex for a simple classification, a finite element (FE) analysis of the detail is to be carried out to determine the fatigue stress of that detail. **Sub-sec 2** defines the procedure for a finite element based assessment to determine hot spot stresses that is to be used for weld toe locations that are typically found at welded hopper knuckle connections in way of transverse primary support members. For bent type knuckle connections, recommendation is given in **2.1.1.2.**

1.2 Corrosion Model

1.2.1 Net thickness

1.2.1.1 The net thickness and corrosion additions, as indicated in **Sec 6/3** are to be incorporated into the representation of the structural capacity models.

1.3 Loads

1.3.1 General

1.3.1.1 Ship structures are subjected to various types of loads, which include:

(a) static loads including cargo and lightship weights

(b) wave induced loads

(c) impact loads, such as bottom slamming, bow flare impacts and sloshing in partially filled tanks

(d) cyclic loads resulting from main engine or propeller induced vibratory forces

(e) transient loads such as thermal loads

(f) residual stresses.

1.3.1.2 The fatigue strength analysis considers the following wave induced loads for calculation of the

long term distribution of stresses:
(a) hull girder loads (i.e. vertical and horizontal wave bending moments)
(b) dynamic wave pressures
(c) dynamic tank pressure loads resulting from ship motions.

1.3.2 Selection of loading conditions

1.3.2.1 Fatigue analyses are to be carried out for representative loading conditions according to the intended ship's operation. The following two loading conditions are to be examined:
(a) full load condition at design draught at departure, T_{full}, see **Sec 4/1.1.5.4**
(b) ballast condition at normal ballast draught at departure, T_{bal-n}, see **Sec 4/1.1.5.3**. If a normal ballast condition is not defined in the loading manual, minimum ballast draught, T_{bal}, see **Sec 4/1.1.5.2**, should be used.

1.3.3 Determination of loads

1.3.3.1 Loads applied to the structure are to be calculated in order to determine the stress ranges for the relevant loading conditions.

1.3.3.2 Combined stresses resulting from the action of global and local loads are to be calculated in accordance with **1.4.4**, with consideration given to the probability level of 10^{-4}.

1.3.4 Vertical wave bending moment

1.3.4.1 The vertical wave bending moment is to be calculated based on **Sec 7/3.4.1**. The pseudo amplitude (half range) values of the vertical wave bending moment, $M_{wv-v-amp}$, for full load and ballast condition are to be taken as:

$$M_{wv-v-amp} = 0.5(M_{wv-hog} - M_{wv-sag}) \quad \text{kNm}$$

Where:

M_{wv-hog} hogging vertical wave bending moment, in kNm

M_{wv-sag} sagging vertical wave bending moment, in kNm

1.3.5 Horizontal wave bending moment

1.3.5.1 The horizontal wave bending moment is to be calculated based on **Sec 7/3.4.2**. The pseudo amplitude (half range) values of the horizontal wave bending moment, $M_{wv-h-amp}$, for full load and ballast condition are to be taken as:

$$M_{wv-h-amp} = 0.5(M_{wv-h-pos} - M_{wv-h-neg}) \quad \text{kNm}$$

Where:

$M_{wv-h-pos}$ positive horizontal wave bending moment, in kNm
= M_{wv-h}

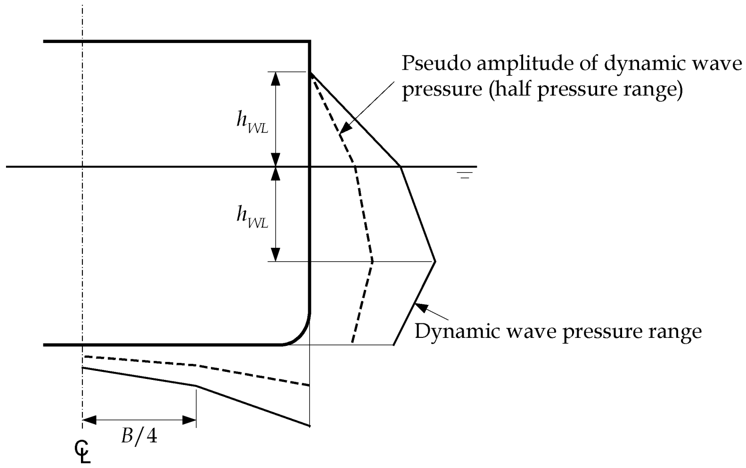
$M_{wv-h-neg}$ negative horizontal wave bending moment, in kNm
= $-M_{wv-h}$

1.3.6 Dynamic wave pressure

1.3.6.1 The dynamic wave pressure is to be calculated according to **Sec 7/3.5.2**.

1.3.6.2 Considering the stretching of the external pressure due to intermittent wet and dry area, a pseudo amplitude of external pressure (half pressure range), P_{ex-amp}, is defined in **Sec 7/3.5.2.3** in detail and illustrated in **Fig C.1.1.**

Fig C.1.1
Dynamic Pressure



1.3.7 Dynamic tank pressure

1.3.7.1 The dynamic tank pressure amplitude, $P_{in\text{-}amp\text{-}}$, is to be calculated according to **Sec 7/3.5.4.5** and **Sec 7/3.5.4.6**. No dynamic internal pressure is considered for the deck.

1.4 Fatigue Damage Calculation

1.4.1 Fatigue strength determination

1.4.1.1 The fatigue assessment of the structure is based on the application of the Palmgren-Miner cumulative damage rule given below. When the cumulative fatigue damage ratio, *DM*, is greater than 1, the fatigue capability of the structure is not acceptable. *DM* is to be taken as:

$$DM = \sum_{i=1}^{i=n_{tot}} \frac{n_i}{N_i}$$

Where:

n_i number of cycles of stress range S_i

N_i number of cycles to failure at stress range S_i

n_{tot} total number of stress range blocks

1.4.1.2 Assessment of the fatigue strength of welded structural members includes the following three phases:

(a) calculation of stress ranges

(b) selection of the design S-N curve

(c) calculation of the cumulative damage.

1.4.1.3 The cumulative fatigue damage ratio, *DM*, is to be less than 1 for the design life of the ship. The design life is not to be less than 25 years. Unless other wise specified the resultant cumulative damage is to be taken as:

$$DM = \sum_{i=1}^{2} DM_i$$

Where:

DM_i cumulative fatigue damage ratio for the applicable loading condition

i = 1 for full load condition

= 2 for normal ballast condition

1.4.1.4 Assuming the long term distribution of stress ranges fit a two-parameter Weibull probability distribution, the cumulative fatigue damage DM_i for each relevant condition is to be taken as:

$$DM_i = \frac{\alpha_i N_L}{K_2} \frac{S_{Ri}^m}{(lnN_R)^{m/\xi}} \mu_i \Gamma(1+\frac{m}{\xi})$$

Where:

N_L number of cycles for the expected design life. Unless stated otherwise, N_L to be taken as:

$$= \frac{f_0 U}{4logL}$$

The value is generally between 0.6×10^8 and 0.8×10^8 cycles for a design life of 25 years

f_0 0.85, factor taking into account non-sailing time for operations such as loading and unloading, repairs, etc.

U design life, in seconds

= 0.788×10^9 for a design life of 25 years

L rule length, in m, as defined in **Sec 4/1.1.1.1**

m S-N curve parameter as defined in **1.4.5.5**

K_2 S-N curve parameter as defined in **1.4.5.5**

α_i proportion of the ship's life:

α_1 = 0.5 for full load condition

α_2 = 0.5 for ballast condition

S_{Ri} stress range at the representative probability level of 10^{-4}, in N/mm^2

N_R 10,000, number of cycles corresponding to the probability level of 10^{-4}

ξ Weibull probability distribution parameter, as defined in **1.4.1.6**

Γ Gamma function

μ_i coefficient taking into account the change in slope of the S-N curve

$$\mu_i = 1 - \frac{\left\{ \gamma\left(1+\frac{m}{\xi}, \nu_i\right) - \nu_i^{-\Delta m/\xi} \gamma\left(1+\frac{m+\Delta m}{\xi}, \nu_i\right)\right\}}{\Gamma(1+\frac{m}{\xi})}$$

v_i $\left(\frac{S_q}{S_{Ri}}\right)^{\xi} lnN_R$

S_q stress range at the intersection of the two segments of the S-N curve, see **Table C.1.6**, in N/mm^2

Δm slope change of the upper-lower segment of the S-N curve

= 2

$\gamma(a,x)$ incomplete Gamma function, Legendre form

1.4.1.5 The probability density function of the long term distribution of stress ranges (hull girder + local bending) is to be represented by a two-parameter Weibull distribution. This assumption enables the use of a closed form equation for calculation of the fatigue life when the two parameters of the Weibull distribution are determined. The probability density function, *f(S)*, is to be taken as:

$$f(S) = \frac{\xi}{f_1}\left(\frac{S}{f_1}\right)^{\xi-1} exp\left(-\left(\frac{S}{f_1}\right)^{\xi}\right)$$

Where:

S stress range, in N/mm^2

ξ Weibull probability distribution parameter, as defined in **1.4.1.6**

f_1 scale parameter

$$= \frac{S_R}{(lnN_R)^{1/\xi}}$$

N_R number of cycles corresponding to the probability of exceedance of $1/N_R$

S_R stress range with probability of exceedance of $1/N_R$, in N/mm^2

1.4.1.6 For each structural detail considered, the Weibull shape parameter is to be selected with due consideration given to the load categories contributing to the cyclic stresses. ξ, is to be taken as:

$$\xi = f_{Weibull}(1.1 - 0.35\frac{L-100}{300})$$

Where:

L rule length, in m, as defined in **Sec 4/1.1.1.1**

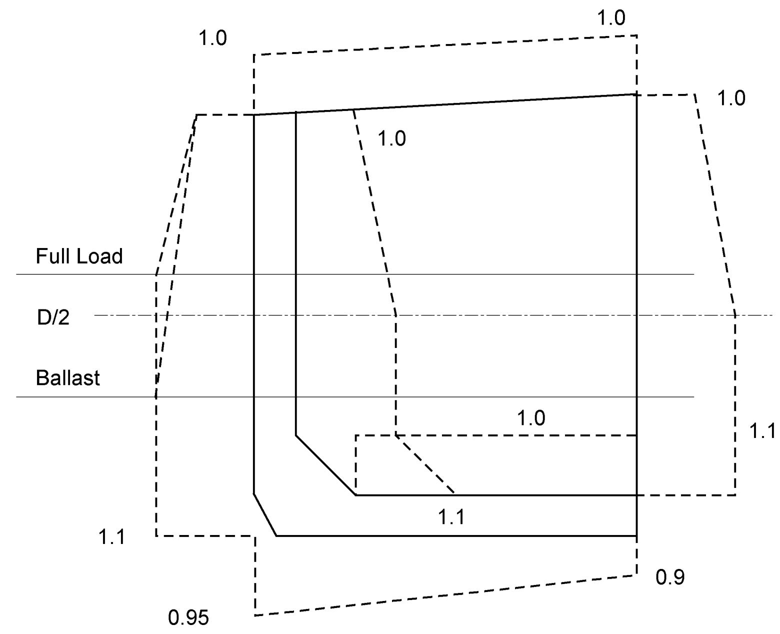
D moulded depth, in m, as defined in **Sec 4/1.1.4.1**

$f_{Weibull}$ area dependent modification factor, as given in **Table C.1.1** and **Fig C.1.2**

Table C.1.1
Distribution of $f_{Weibull}$ Factors

Plating area	$f_{Weibull}$ (see note)
Bottom	0.9 at centreline and 0.95 at side
Side and bilge	1.1 at up to draught T_{LC} and 1.0 at deck
Deck	1.0
Inner bottom	1.0
Inner hull longitudinal bulkhead	1.1 up to D/2 and 1.0 at deck
Inner longitudinal bulkhead	1.1 up to D/2 and 1.0 at deck
Centreline longitudinal bulkhead	1.1 up to D/2 and 1.0 at deck
Note: Intermediate values to be linearly interpolated	

Fig C.1.2
Distribution of $f_{Weibull}$ Factors



1.4.1.7 The cumulative fatigue damage ratio, *DM,* may be converted to a calculated fatigue life using the relationship given below. In this format, the calculated fatigue life is to be equal or greater than the design life of the ship.

$$Fatigue\ life = \frac{Design\ life}{DM} \quad \text{years}$$

1.4.2 Stresses to be used

1.4.2.1 The nominal stresses are to be determined taking into account the overall geometric changes of the detail. The effect of stress concentrations due to structural discontinuities, presence of attachments and the weld profile is not considered.

1.4.3 Nominal stress calculation

1.4.3.1 This Sub-Section outlines a simplified approach to determine the combination of global and local stress components of the stress response of the ship.

1.4.3.2 Stress responses are to be calculated with varying levels of detail. The following approach has been adopted in this simplified procedure:

(a) the hull girder is treated as a simple beam as a way of obtaining reasonable approximations to the nominal stress level in longitudinal hull girder elements. This is used for the evaluation of hull girder stress levels in way of critical details

(b) the structural member with effective attached plating is used in determining the nominal stress response of longitudinal and transverse frames due to dynamic wave pressure and dynamic tank pressure loads. The member end restraints and moments are considered.

1.4.4 Definition of stress components

1.4.4.1 Dynamic stress variations are referred to as either stress range, S, or stress amplitude, σ.

1.4.4.2 The global dynamic stress components (primary stresses) considered in fatigue analysis are vertical wave hull girder bending stress, σ_v, and horizontal wave hull girder bending stress, σ_h.

1.4.4.3 The local dynamic stress amplitudes considered are defined as the total local stress amplitude due to dynamic wave pressure loads or dynamic tank pressure loads, σ_{e-i}.

1.4.4.4 The local stress components are defined as secondary stress resulting from bending of girder systems, σ_2, stress amplitudeproducedbybendingofstiffenersbetweengirdersupports, σ_{2A}, and tertiary stress amplitude produced by bending of un-stiffened plate elements between longitudinals and transverse frames, σ_3. See **Fig C.1.3.**

1.4.4.5 The total local stress due to dynamic wave or dynamic tank pressure loads, σ_{e-i}, is to be taken as:

$$\sigma_{e-i} = \sigma_2 + \sigma_{2A} + \sigma_3 \qquad \mathrm{N/mm^2}$$

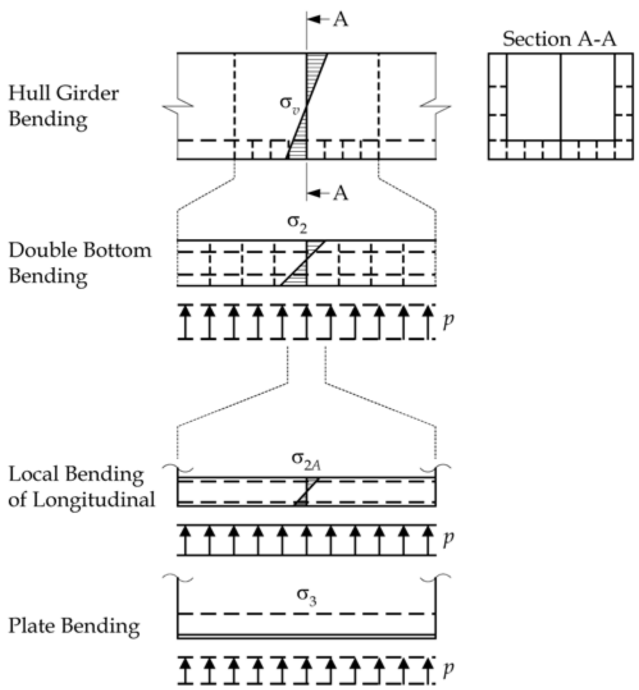
Where:

σ_2 local stress component, in $\mathrm{N/mm^2}$, as defined in **1.4.4.4**

σ_{2A} local stress component, in $\mathrm{N/mm^2}$, as defined in **1.4.4.4**

σ_3 local stress component, in $\mathrm{N/mm^2}$, as defined in **1.4.4.4**

Fig C.1.3
Definition of Local Stress Components



1.4.4.6 For the calculation of stress components, the vertical wave hull girder stress, σ_v, is given by:

$$\sigma_v = \frac{M_{wv-v-amp}}{Z_{v-net75}} 10^{-3} \qquad \mathrm{N/mm^2}$$

Where:

$M_{wv-v-amp}$ pseudo amplitude (half range), in kNm, as defined in **1.3.4**

$Z_{v-net75}$ $= \dfrac{I_{v-net75}}{|z - z_{NA-net75}|}$ $\mathrm{m^3}$ see **Sec 4/2.6.1**

$I_{v-net75}$ net vertical hull girder moment of inertia, of hull cross-section about transverse neutral axis, in $\mathrm{m^4}$

$I_{v-net75}$ is to be calculated based on gross thickness, minus the corrosion addition $0.25\, t_{corr}$ of all effective structural elements, see **Sec 4/2.6.1**

z distance from baseline to the critical location of the considered member, i.e. top of flange of longitudinal stiffener, in m

$z_{NA\text{-}net75}$ distance from baseline to horizontal neutral axis consistent with $I_{v\text{-}net75}$, in m

1.4.4.7 The corresponding stress range due to vertical wave bending moment, S_v, is to be taken as:

$$S_v = 2\sigma_v \quad \text{N/mm}^2$$

Where:

σ_v vertical wave hull girder stress, in N/mm^2, as defined in **1.4.4.6**

1.4.4.8 The horizontal wave hull girder stress, σ_h, is to be taken as:

$$\sigma_h = \frac{M_{wv-h-amp}}{Z_{h-net75}} 10^{-3} \quad \text{N/mm}^2$$

Where:

$M_{wv\text{-}h\text{-}amp}$ in kNm, as defined in **1.3.5**

$Z_{h\text{-}net75}$ $\dfrac{I_{h-net75}}{|y|}$ m^3 see **Sec 4/2.6.2**

y distance from vertical neutral axis of hull cross section to the critical location of the considered member, in m. i.e. top of face plate of longitudinal stiffener

$I_{h\text{-}net75}$ net horizontal hull girder moment of inertia, of the hull cross-section about the vertical neutral axis, in m^4.

$I_{h\text{-}net75}$ is to be calculated based on gross thickness, minus the corrosion addition $0.25\,t_{corr}$ for all effective structural elements, see **Sec 4/2.6.2**

1.4.4.9 The corresponding stress range due to horizontal wave bending moment, S_h, is to be taken as:

$$S_h = 2\sigma_h \quad \text{N/mm}^2$$

Where:

σ_h horizontal wave hull girder stress, in N/mm^2, as defined in **1.4.4.8**

1.4.4.10 The effect of secondary stress σ_2, as defined in **1.4.4.4**, is in general small for double hull tankers and is therefore not taken into consideration.

1.4.4.11 The stress amplitude produced by bending of stiffeners between girder supports (e.g. frames, bulkheads), σ_{2A}, is to be taken as:

$$\sigma_{2A} = K_n K_d \frac{M}{Z_{net50}} 10^3 \quad \text{N/mm}^2$$

Where:

K_n stress factor for unsymmetrical profiles, as defined in **1.4.4.15**

K_d stress factor for bending stress in longitudinal stiffeners caused by relative deformation between supports, may be determined by FE analysis of the cargo hold model where the actual relative deformation is taken into account or taken as follows:

1.0 at frame connections

1.15 for all longitudinals at transverse bulkhead connections including wash bulkheads except:

(a) in full load condition:

1.3 for side and bilge longitudinals at mid position between lowest side stringer and deck at side

1.15 for side and bilge longitudinals at lowest side stringer and deck at side to be linearly interpolated between these two positions

1.5 for bottom longitudinals at mid position between longitudinal bulkhead, bottom girders or buttress structure

1.15 for bottom longitudinals at longitudinal bulkhead, bottom girders or buttress structure

to be linearly interpolated between these two positions

See **Fig C.1.4**

(b) in ballast condition:

1.5 for bottom longitudinals in the mid position between longitudinal bulkhead, bottom girders or buttress structure

1.15 for bottom longitudinals at longitudinal bulkhead, bottom girders or buttress structure

to be linearly interpolated between these two positions

M moment at stiffener support adjusted to weld toe location at the stiffener (e.g. at bracket toe), in kNm:

$$= \frac{P s\, l_{bdg}^2 10^{-3}}{12} r_p$$

s stiffener spacing, in mm

l_{bdg} effective bending span, of longitudinal stiffener, as shown in **Fig C.1.5**, in m. See also **Fig 4.2.1** and **4.2.2** in **Sec 4** for soft toe brackets. Top stiffeners with a soft toe are to be treated the same as flat bars with a soft toe bracket. The span point is to be taken at the point where the depth of the end bracket, measured from the face of the member, is equal to half the depth of the member

Z_{-net50} section modulus of longitudinal stiffener with associated effective plate flange b_{eff}, in cm^3, calculated based on gross thickness minus the corrosion addition $0.5\, t_{corr}$.

b_{eff} as defined in **Sec 4/2.3.3**

r_p moment interpolation factor, for interpolation to weld toe location along the stiffener length:

$$= \left| 6\left(\frac{x}{l_{bdg}}\right)^2 - 6\left(\frac{x}{l_{bdg}}\right) + 1.0 \right| \quad \text{where} \quad 0 \le x \le l_{bdg}$$

where x is the distance to the hot spot, in m. See **Fig C.1.5.**

P lateral dynamic pressure amplitude at the mid-span between the frame considered and the neighbouring frame, in kN/m^2.

P_{in-amp} for dynamic tank pressure, is to be taken as defined in **1.3.7**

P_{ex-amp} for dynamic wave pressure, is to be taken as defined in **1.3.6**

Fig C.1.4
Variation of Bulkhead Factor K_d in Full Load Condition for a Vessel with Two Longitudinal Bulkheads

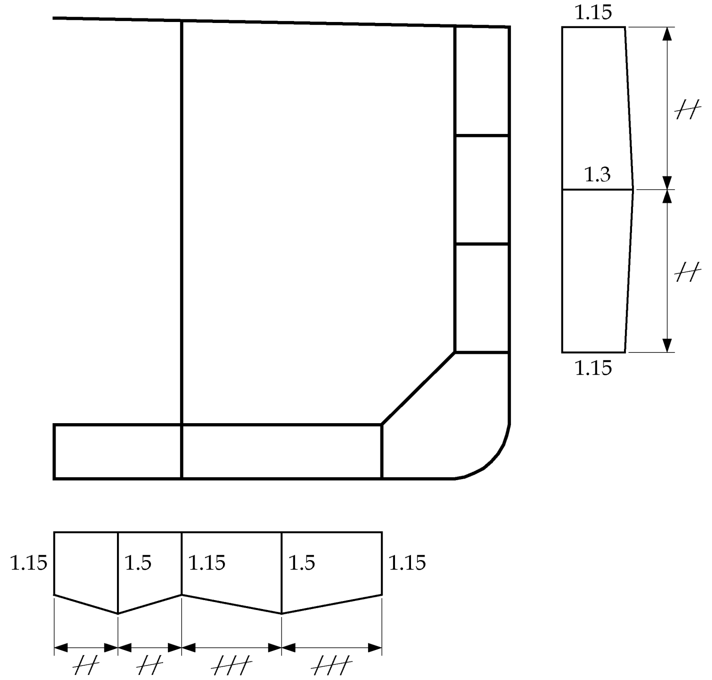
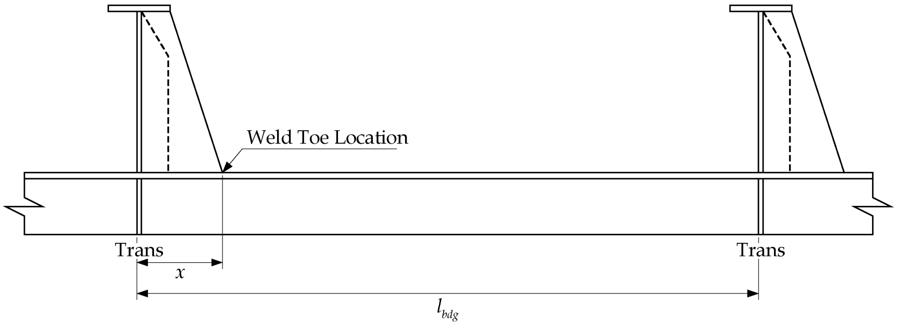
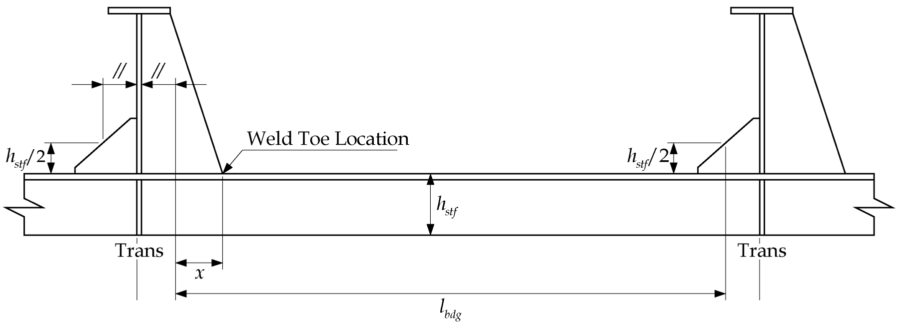


Fig C.1.5
Definition of Effective Span Lengths

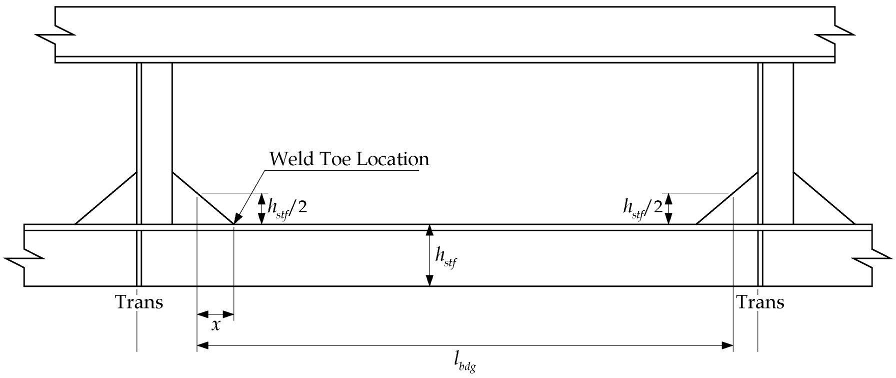


Supported by free flange transverses (1)



Supported by free flange transverses (2)

Supported by double skin / transverse bulkheads (1)



Supported by double skin / transverse bulkheads (2)

1.4.4.12 The stress range due to external wave or internal tank pressure, S_e or S_i, is to be determined as:

$S_e = 2\sigma_{2Ae}$ N/mm²

$S_i = 2\sigma_{2Ai}$ N/mm²

Where:

σ_{2Ae} stress amplitude, in N/mm², as defined in **1.4.4.11** when $P_{ex\text{-}amp}$ is used

σ_{2Ai} stress amplitude, in N/mm², as defined in **1.4.4.11** when $P_{in\text{-}amp}$ is used

1.4.4.13 Longitudinal local tertiary plate bending stress amplitude in the weld at the plate, transverse frame or bulkhead intersection, σ_3, is not relevant to the critical locations being considered and is to be neglected.

1.4.4.14 The effective breadth of plate flanges of stiffeners (longitudinals) in bending (due to the shear lag effect), exposed to uniform lateral load for bending at ends, is defined in **Sec 4/2.3.3.**

1.4.4.15 The stress concentration factors at the flange of un-symmetrical stiffeners on laterally loaded panels, K_{n1} and K_{n2}, as shown in **Fig C.1.6**, are to be taken as:

$K_{n1} = \dfrac{1+\lambda\beta}{1+\lambda\beta^2\psi_z}$ at the flange edge

$K_{n2} = \dfrac{1+\lambda\beta^2}{1+\lambda\beta^2\psi_z}$ at the web

K_{n2} is typically used in the fatigue analysis of longitudinal end connections

Where:

β $1-\dfrac{2b_g}{b_f}$ for built-up profiles

$1-\dfrac{t_{w-net50}}{b_f}$ for rolled angle profiles

b_g breadth of flange from web centreline, in mm, see **Fig C.1.7**

$t_{w\text{-}net50}$ net web thickness, in mm

d_w depth of stiffener web, see **Fig C.1.7**, in mm

λ factor, as defined in **1.4.4.17**

ψ_z ratio between section modulus of the stiffener web with plate flange, as calculated at the flange and the section modulus of the complete panel stiffener

$\dfrac{d_w^2\, t_{w-net50}}{4Z_{net50}10^3}$ may be used as an approximate value

Z_{net50} section modulus of stiffener including the full width of the attached plate, s, with respect to a neutral axis normal to the stiffener web, in cm³. It is to be calculated based on the gross thickness minus the corrosion addition 0.5 t_{corr}

Fig C.1.6
Bending Stress in Symmetrical and Un-symmetrical Panel Stiffener with Same Web and Flange Areas

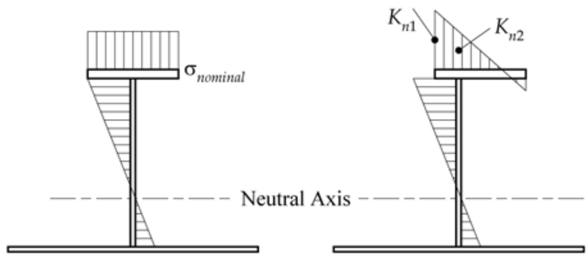
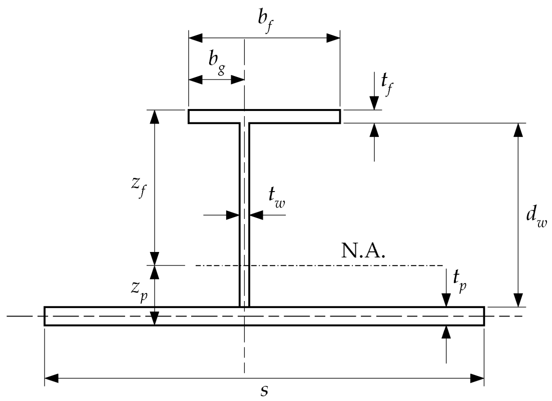


Fig C.1.7
Stiffener Geometry



1.4.4.16 The formulations are not directly applicable for bulb profiles. For these, the equivalent built-up profile is to be considered, see **Fig C.1.8**. The assumed built-up flange is to have the same properties as the bulb flange for cross-sectional area and moment of inertia about the vertical axis and neutral axis position. For HP bulb profiles, the equivalent built up profile dimensions are to be determined. Several examples are tabulated in **Table C.1.2.**

1.4.4.17 For continuous stiffeners (fixed ends) the λ-factor at supports is to be taken as:

$$\lambda = \frac{3(1+\frac{\eta}{280})}{1+\frac{\eta}{40}}$$

Where:

$$\eta = \frac{l_{bdg}^4 \, 10^{12}}{b_f^3 \, t_{f-net50} \, h_{stf}^2 \left(\frac{4 h_{stf}}{t_{w-net50}^3} + \frac{s}{t_{p-net50}^3} \right)}$$

l_{bdg} effective bending span, of longitudinal stiffener, in m

bf breadth of flange, in mm

$tf\text{-}net50$ net flange thickness, in mm

h_{stf} stiffener height, including face plate, in mm

$tw\text{-}net50$ net web thickness, in mm

$t_{p\text{-}net50}$ net plate thickness, in mm

s plate width between stiffeners, in mm

Fig C.1.8
Bulb Profile and Equivalent Built-up Flange

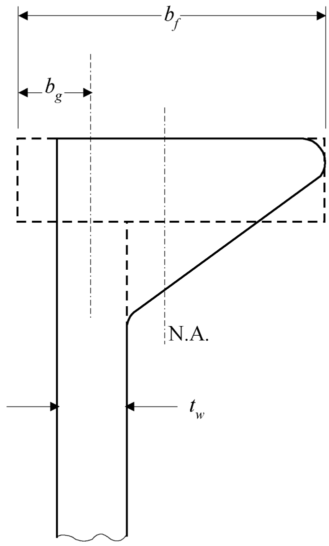


Table C.1.2
HP Equivalent Built-up Profile Dimensions

HP-bulb		Equivalent built-up flange		
Height (mm)	Web thickness t_w (mm)	b_f (mm)	t_f (mm)	b_g (mm)
200	9 − 13	t_w + 24.5	22.9	$(t_w$ + 0.9)/2
220	9 − 13	t_w + 27.6	25.4	$(t_w$ + 1.0)/2
240	10 − 14	t_w + 30.3	28.0	$(t_w$ + 1.1)/2
260	10 − 14	t_w + 33.0	30.6	$(t_w$ + 1.3)/2
280	10 − 14	t_w + 35.4	33.3	$(t_w$ + 1.4)/2
300	11 − 16	t_w + 38.4	35.9	$(t_w$ + 1.5)/2
320	11 − 16	t_w + 41.0	38.5	$(t_w$ + 1.6)/2
340	12 − 17	t_w + 43.3	41.3	$(t_w$ + 1.7)/2
370	13 − 19	t_w + 47.5	45.2	$(t_w$ + 1.9)/2
400	14 − 19	t_w + 51.7	49.1	$(t_w$ + 2.1)/2
430	15 − 21	t_w + 55.8	53.1	$(t_w$ + 2.3)/2

1.4.4.18 For each loading condition, combined local stress components due to simultaneous dynamic tank and dynamic wave pressure loads are to be combined with global stress components induced by hull girder wave bending.

1.4.4.19 Total combined stress range, S, is given by:

$$S = f_{SN} \left| f_1 S_v + f_2 S_h + f_3 S_e + f_4 S_i \right| \quad \text{N/mm}^2$$

Where:

f1, f2, f3and f4 stress range combination factors, representing the phase correlation between total stress range and each stress range component which is between 1.0 and -1.0, as defined in **Tables C.1.3** to **C.1.5**. Where the factor is greater than 1.0 it is to be taken as 1.0. Where the factor is less than -1.0 it is to be taken as -1.0

f_{SN} 1.06, factor to account for joints in combined protected and unprotected environment.

S_v corresponding stress range due to vertical bending moment, in N/mm^2, as defined in **1.4.4.7**

S_h corresponding stress range due to horizontal bending moment, in N/mm^2, as defined in **1.4.4.9**

S_e stress range due to external wave or internal tank pressure, in N/mm^2, as defined in **1.4.4.12**

S_i stress range due to external wave or internal tank pressure, in N/mm^2, as defined in **1.4.4.12**

1.4.4.20 The stress range combination factors, f_1, f_2, f_3 and f_4, which are to be applied to the following zones, are given in **Tables C.1.2** to **C.1.4**:

(a) Zone M: Midship region. This zone extends over the full length of all tanks where the tank LCG lies between 0.35 L and 0.8 L from AP.

(b) Zone A: Aft region. This zone starts at the middle of the tank immediately aft of Zone M and extends aftwards to include all the aftmost tanks.

(c) Zone F: Forward region. This zone starts at the middle of the tank immediately forward of Zone M and extends forwards to include all the foremost tanks.

(d) Zone AT: Aft transition region between Zone M and Zone A. The stress range combination factors are to be calculated by linear interpolation between the stress range combination factors for Zones M and A.

(e) Zone FT: Forward transition region between Zone M and Zone F. The stress range combination factors are to be calculated by linear interpolation between the stress range combination factors for Zones M and F.

Note

Where ballast tanks, centre and wing cargo tanks do not have the same lengths e.g. if slop tank is present, the middle position is to be taken at the middle of the longer tank.

Table C.1.3
Stress Range Combination Factors for Zone M

	Stiffener location		f_1	f_2	f_3	f_4	f_i
Ballast	Bottom shell	a_i	-0.49	0.49	-1.04	-0.13	$a_i(\lvert y \rvert/B)+b_i$
		b_i	0.97	0.17	0.87	0.56	
	Side shell and bilge below D/2	a_i	-1.48	0.50	-0.64	0.72	$a_i(z/D)+b_i$
		b_i	0.94	0.40	0.72	0.04	
	Side shell above D/2	a_i	1.70	-1.00	-1.10	-0.60	$a_i(z/D)+b_i$
		b_i	-0.65	1.15	0.95	0.70	
	Inner bottom and lower stool	a_i	-0.18	0.34	0.00	-0.30	$a_i(\lvert y \rvert/B)+b_i$
		b_i	0.90	0.22	0.00	0.74	
	Inner hull below D/2 (including hopper plate)	a_i	-1.70	-0.90	0.00	1.04	$a_i(z/D)+b_i$
		b_i	1.15	0.70	0.00	0.45	
	Inner hull above D/2	a_i	1.40	0.50	0.00	-1.94	$a_i(z/D)+b_i$
		b_i	-0.40	0.00	0.00	1.94	
	Deck and Upper stool	a_i	-0.15	1.05	0.00	0.00	$a_i(\lvert y \rvert/B)+b_i$
		b_i	1.02	-0.27	0.00	0.00	
	Centreline longitudinal bulkhead below D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	
	Centreline longitudinal bulkhead above D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	
	Longitudinal bulkhead below D/2	a_i	-0.20	1.30	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.10	0.00	0.00	
	Longitudinal bulkhead above D/2	a_i	0.20	-1.30	0.00	0.00	$a_i(z/D)+b_i$
		b_i	0.80	1.40	0.00	0.00	
Loaded	Bottom shell	a_i	-0.43	0.78	-0.77	0.00	$a_i(\lvert y \rvert/B)+b_i$
		b_i	0.98	0.13	0.75	0.00	
	Side shell and bilge below D/2	a_i	-0.29	-0.47	0.14	0.00	$a_i(z/D)+b_i$
		b_i	0.19	0.78	0.92	0.00	
	Side shell above D/2	a_i	1.77	-0.05	-1.20	0.00	$a_i(z/D)+b_i$
		b_i	-0.84	0.57	1.59	0.00	
	Inner bottom and Lower stool	a_i	-0.71	1.13	0.00	0.55	$a_i(\lvert y \rvert/B)+b_i$
		b_i	1.03	0.18	0.00	-0.18	
	Inner hull below D/2 (including hopper plate)	a_i	-0.80	-1.70	0.00	2.60	$a_i(z/D)+b_i$
		b_i	0.55	1.20	0.00	-0.35	
	Inner hull above D/2	a_i	1.90	0.30	0.00	-1.70	$a_i(z/D)+b_i$
		b_i	-0.80	0.20	0.00	1.80	
	Deck and upper stool	a_i	-0.26	1.40	0.00	0.00	$a_i(\lvert y \rvert/B)+b_i$
		b_i	1.02	-0.16	0.00	0.00	
	Centreline longitudinal bulkhead below D/2	a_i	-1.40	0.00	0.00	1.00	$a_i(z/D)+b_i$
		b_i	0.75	0.00	0.00	0.60	
	Centreline longitudinal bulkhead above D/2	a_i	1.70	0.00	0.00	-1.20	$a_i(z/D)+b_i$
		b_i	-0.80	0.00	0.00	1.70	
	Longitudinal bulkhead below D/2	a_i	-0.60	0.40	0.00	1.10	$a_i(z/D)+b_i$
		b_i	1.00	0.40	0.00	0.05	
	Longitudinal bulkhead above D/2	a_i	0.60	-0.84	0.00	-0.84	$a_i(z/D)+b_i$
		b_i	0.40	1.02	0.00	1.02	

Table C.1.4
Stress Range Combination Factors for Zone A

	Stiffener location		f_1	f_2	f_3	f_4	f_i
Ballast	Bottom shell	a_i	-0.20	-0.80	1.20	1.50	$a_i(\lvert y\rvert/B)+b_i$
		b_i	0.00	0.50	-0.25	1.07	
	Side shell and bilge below D/2	a_i	-1.00	1.20	-0.80	2.00	$a_i(z/D)+b_i$
		b_i	0.20	0.00	0.60	-0.40	
	Side shell above D/2	a_i	3.40	-1.20	-2.80	0.80	$a_i(z/D)+b_i$
		b_i	-2.00	1.20	1.60	0.20	
	Inner bottom and lower stool	a_i	-0.50	-1.90	0.00	0.30	$a_i(\lvert y\rvert/B)+b_i$
		b_i	-0.05	0.60	0.00	0.85	
	Inner hull below D/2	a_i	8.20	-2.80	0.00	0.20	$a_i(z/D)+b_i$
		b_i	-3.50	1.00	0.00	0.90	
	Inner hull above D/2	a_i	0.60	2.80	0.00	-0.50	$a_i(z/D)+b_i$
		b_i	0.30	-1.80	0.00	1.25	
	Deck and upper stool	a_i	0.00	0.70	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	0.00	0.00	0.00	
	Inner longitudinal bulkhead below D/2	a_i	-1.20	2.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.10	0.00	0.00	0.00	
	Inner longitudinal bulkhead above D/2	a_i	1.50	-2.70	0.00	0.00	$a_i(z/D)+b_i$
		b_i	-0.25	2.35	0.00	0.00	
	Centreline longitudinal bulkhead below D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
	Centreline longitudinal bulkhead above D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
Loaded	Bottom shell	a_i	-2.20	1.50	2.60	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.20	-0.15	-0.30	0.00	
	Side shell and bilge below D/2	a_i	-1.20	-1.20	0.60	0.00	$a_i(z/D)+b_i$
		b_i	0.30	0.80	0.70	0.00	
	Side shell above D/2	a_i	3.00	-0.30	-0.50	0.00	$a_i(z/D)+b_i$
		b_i	-1.80	0.35	1.25	0.00	
	Inner bottom and lower stool	a_i	-1.00	2.30	0.00	-0.20	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	-0.10	0.00	0.00	
	Inner hull below D/2	a_i	-0.80	1.00	0.00	1.00	$a_i(z/D)+b_i$
		b_i	0.20	0.00	0.00	0.50	
	Inner hull above D/2	a_i	3.20	-1.00	0.00	-0.80	$a_i(z/D)+b_i$
		b_i	-1.80	1.00	0.00	1.40	
	Deck and upper stool	a_i	-0.10	1.50	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	-0.15	0.00	0.00	
	Inner longitudinal bulkhead below D/2	a_i	-0.80	0.30	0.00	1.00	$a_i(z/D)+b_i$
		b_i	1.00	0.50	0.00	0.30	
	Inner longitudinal bulkhead above D/2	a_i	0.20	-0.90	0.00	-0.08	$a_i(z/D)+b_i$
		b_i	0.50	1.10	0.00	0.84	
	Centreline longitudinal bulkhead below D/2	a_i	-1.10	0.00	0.00	0.44	$a_i(z/D)+b_i$
		b_i	0.60	0.00	0.00	0.80	$a_i(z/D)+b_i$
	Centreline longitudinal bulkhead above D/2	a_i	1.30	0.00	0.00	-0.56	$a_i(z/D)+b_i$
		b_i	-0.60	0.00	0.00	1.30	$a_i(z/D)+b_i$

Table C.1.5
Stress Range Combination Factors for Zone F

	Stiffener location		f_1	f_2	f_3	f_4	f_i
Ballast	Bottom shell	a_i	-0.90	1.00	2.40	-1.20	$a_i(\lvert y\rvert/B)+b_i$
		b_i	0.85	-0.10	-1.00	1.10	
	Side shell and bilge below D/2	a_i	-0.60	-0.40	1.00	-1.80	$a_i(z/D)+b_i$
		b_i	0.00	0.50	-0.15	0.90	
	Side shell above D/2	a_i	0.60	-0.90	-2.70	3.00	$a_i(z/D)+b_i$
		b_i	-0.60	0.75	1.70	-1.50	
	Inner bottom and ower stool	a_i	-0.30	-1.00	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	0.90	0.25	0.00	1.00	
	Inner hull below D/2	a_i	-12.00	-2.40	0.00	1.20	$a_i(z/D)+b_i$
		b_i	5.00	1.00	0.00	0.50	
	Inner hull above D/2	a_i	3.00	1.40	0.00	-0.90	$a_i(z/D)+b_i$
		b_i	-2.50	-0.90	0.00	1.55	
	Deck and upper stool	a_i	0.00	1.00	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	-0.10	0.00	0.00	
	Inner longitudinal bulkhead below D/2	a_i	-1.80	1.90	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.30	0.00	0.00	0.00	
	Inner longitudinal bulkhead above D/2	a_i	1.80	-2.50	0.00	0.00	$a_i(z/D)+b_i$
		b_i	-0.50	2.20	0.00	0.00	
	Centreline longitudinal bulkhead below D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
	Centreline longitudinal bulkhead above D/2	a_i	0.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.00	0.00	0.00	$a_i(z/D)+b_i$
Loaded	Bottom shell	a_i	-0.60	-0.15	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	-0.45	0.05	1.00	0.00	
	Side shell and bilge below D/2	a_i	-1.20	0.18	0.00	0.00	$a_i(z/D)+b_i$
		b_i	0.00	-0.03	1.00	0.00	
	Side shell above D/2	a_i	4.00	0.02	0.00	0.00	$a_i(z/D)+b_i$
		b_i	-2.60	0.05	1.00	0.00	
	Inner bottom and lower stool	a_i	2.80	2.20	0.00	-1.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	-0.80	-0.30	0.00	1.10	
	Inner hull below D/2	a_i	10.20	1.60	0.00	0.00	$a_i(z/D)+b_i$
		b_i	-4.50	-0.60	0.00	1.00	
	Inner hull above D/2	a_i	-0.80	-0.90	0.00	0.00	$a_i(z/D)+b_i$
		b_i	1.00	0.65	0.00	1.00	
	Deck and upper stool	a_i	-0.24	1.80	0.00	0.00	$a_i(\lvert y\rvert/B)+b_i$
		b_i	1.00	0.00	0.00	0.00	
	Inner longitudinal bulkhead below D/2	a_i	-2.10	-1.00	0.00	1.50	$a_i(z/D)+b_i$
		b_i	1.15	0.60	0.00	0.35	
	Inner longitudinal bulkhead above D/2	a_i	0.40	-0.30	0.00	-0.40	$a_i(z/D)+b_i$
		b_i	-0.10	0.25	0.00	1.30	
	Centreline longitudinal bulkhead below D/2	a_i	-0.60	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	0.25	0.00	0.00	1.00	$a_i(z/D)+b_i$
	Centreline longitudinal bulkhead above D/2	a_i	0.20	0.00	0.00	0.00	$a_i(z/D)+b_i$
		b_i	-0.15	0.00	0.00	1.00	$a_i(z/D)+b_i$

1.4.5 Selection of S-N curves

1.4.5.1 The capacity of welded steel joints with respect to fatigue strength is characterized by S-N curves which give the relationship between the stress ranges applied to a given detail and the number of constant amplitude load cycles to failure.

1.4.5.2 For ship structural details, S-N curves are represented by:

$S^m N = K_2$

Where:

S stress range, in N/mm^2, as defined in **1.4.4.19**

N predicted number of cycles to failure under stress range S

m constant depending on material and weld type, type of loading, geometrical configuration and environmental conditions (air or sea water), as defined in **1.4.5.5.**

K_2 constant depending on material and weld type, type of loading, geometrical configuration and environmental conditions (air or sea water), as defined in **1.4.5.5.**

1.4.5.3 Experimental S-N curves are defined by their mean fatigue life and standard deviation. The mean S-N curve gives the stress level S at which the structural detail will fail with a probability level of 50 percent after N loading cycles. S-N curves considered in the present Rules are based upon a statistical analysis of appropriate experimental data and represent two standard deviations below the mean lines.

1.4.5.4 Unless direct experimental measurements are available, the S-N curves described in **1.4.5.5** to **1.4.5.16** are to be used for assessment of the fatigue strength of structural details.

1.4.5.5 As shown in **Fig C.1.9**, the basic design curves consist of linear relationships between $\log(S)$ and $\log(N)$, which are to be expressed as follows. The S-N curves have a change of inverse slope from m to $m+2$ at $N = 10^7$ cycles (which corresponds to stress range S_q).

$\log(N) = \log(K_2) - m\log(S)$

Where:

$\log(K_2) = \log(K_1) - 2\delta$

N predicted number of cycles to failure under stress range S

K_1 constant relating to the mean S-N curve, as given in **Table C.1.6**

δ standard deviation of $\log(N)$

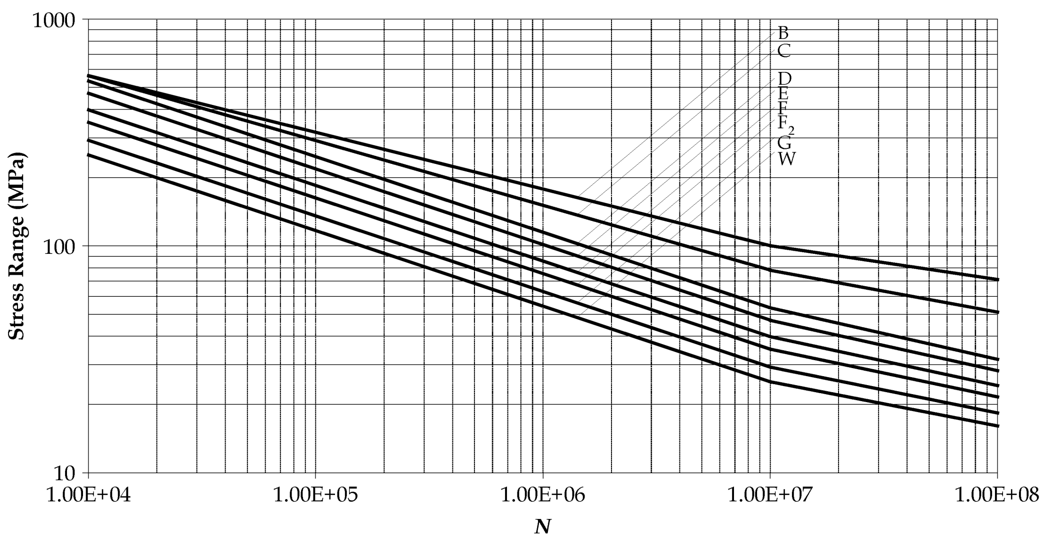
m inverse slope of the S-N curve, as given in **Table C.1.6**

S_q Stress range corresponding to 10^7 cycles of the S-N curve, in N/mm^2, as given in **Table C.1.6**

Table C.1.6
Basic S-N Curve Data, In-Air

Class	K_1			m	Standard Deviation		K_2	S_q N/mm^2
		$\log_{10}$	$\log_e$		$\log_{10}$	$\log_e$		
B	2.343 E15	15.3697	35.3900	4.0	0.1821	0.4194	1.01 E15	100.2
C	1.082 E14	14.0342	32.3153	3.5	0.2041	0.4700	4.23 E13	78.2
D	3.988 E12	12.6007	29.0144	3.0	0.2095	0.4824	1.52 E12	53.4
E	3.289 E12	12.5169	28.8216	3.0	0.2509	0.5777	1.04 E12	47.0
F	1.726 E12	12.2370	28.1770	3.0	0.2183	0.5027	0.63 E12	39.8
F2	1.231 E12	12.0900	27.8387	3.0	0.2279	0.5248	0.43 E12	35.0
G	0.566 E12	11.7525	27.0614	3.0	0.1793	0.4129	0.25 E12	29.2
W	0.368 E12	11.5662	26.6324	3.0	0.1846	0.4251	0.16 E12	25.2

Fig C.1.9
Basic Design S-N Curves, In-Air



1.4.5.6 The class of S-N curve selected for determination of the cumulative fatigue damage, *DM*, is to be consistent with the fatigue assessment methods used and the type of detail to be analyzed.

1.4.5.7 Experimental S-N curves give the relationship between the nominal stress range and the number of cycles to failure. Therefore, when using these S-N curves, the calculated stresses are to correspond to the nominal stresses used in creating these curves.

1.4.5.8 The basic S-N curves to be used in this Appendix for fatigue assessment of longitudinal stiffener end connections are given in **1.4.5.5**, with the S-N curve parameters given in **Table C.1.6.**

1.4.5.9 Generally, adjustments to the S-N curves to take into account the following can be made:
(a) effect of mean stresses
(b) effect of plate thickness
(c) weld improvement
(d) influence of the environment.

1.4.5.10 The stress range may be reduced depending on whether the mean stress is tensile or compressive. In the event that it can be demonstrated that a compressive stress exists and can be quantified, the effect of mean stress may be considered by assuming a stress range equal to the tensile component plus 60 % of the compressive component. The actual still water bending moment (SWBM) and the applicable static sea and tank pressures for the full load condition or ballast condition as appropriate are to be used in determining the mean stress level.

1.4.5.11 The total stress range considering the mean stress effect is to be taken as follows:

$S_{Ri} = \sigma_{tensile} - 0.6\,\sigma_{compressive}$ if $\sigma_{compressive} < 0$ and $\sigma_{tensile} > 0$

$S_{Ri} = S$ if $\sigma_{compressive} \geq 0$

$S_{Ri} = 0.6\,S$ if $\sigma_{tensile} \leq 0$

Where:

$\sigma_{tensile}$ mean stress plus half stress range, in N/mm^2

$= \sigma_{mean} + S/2$

$\sigma_{compressive}$ mean stress minus half stress range, in N/mm^2

$= \sigma_{mean} - S/2$

σ_{mean} mean stress due to static load components in the full load condition or ballast condition as appropriate, in N/mm^2, see **1.3.2**

For the nominal stress approach, S and σ_{mean} are to be calculated as follows:

S total combined stress range, in N/mm^2, as defined in **1.4.4.19**

$= \sigma_{tensile} - \sigma_{compressive}$

$\sigma_{mean} = \sigma_{hg} + \sigma_{ex} + \sigma_{in}$

σ_{hg} mean stress due to hull girder bending, to be derived using σ_v from **1.4.4.6** with $M_{wv\text{-}v\text{-}amp}$ taken as the actual SWBM for the full load condition or ballast condition as appropriate, see **1.3.2.**

σ_{ex} mean local bending stress due to external static sea pressure, if applicable. σ_{ex} is to be derived using σ_{2A} from **1.4.4.11** with P calculated based on the actual draught for the full load condition or ballast condition as appropriate, see **1.3.2**, where $P = P_{hys}$, see **Sec 7/2.2.2.1.**

σ_{in} mean local bending stress due to internal static tank pressure, if applicable. σ_{in} is to be derived using σ_{2A} from **1.4.4.11** with P calculated based on the head to the top of tank and the tank contents for the full load condition or ballast condition as appropriate, see **1.3.2**, where $P = P_{in\text{-}tk}$, see **Sec 7/2.2.3.1.**

Notes

1 P is to be taken as negative when the pressure is acting on the plate side and positive when acting on the stiffener side. This gives compressive stress with a negative sign

2 Where the stiffener is on the boundary between two cargo tanks, then the mean stress is to be taken as the net stress acting on the stiffener.

3 It is to be assumed that water ballast and cargo tanks are 100 % full. The fluid density is to be taken in accordance with **Sec 7/2.2.3.1**, where cargo density is not to be less than 0.9 tonnes/m^3

For the hot spot stress approach in **Sub Sec 2**, the mean stress, σ_{mean}, is to be calculated by applying the applicable static loads to the FE model for the full load condition or ballast condition as appropriate. Alternatively, in lieu of applying the static loads to the FE model, the total stress range is to be calculated in accordance with **2.4.2.8.**

1.4.5.12 The fatigue performance of a structural detail depends on member thickness. For the same stress range the joint's fatigue resistance may decrease as the member thickness increases. This effect (also called the ‘scale effect’) is caused by the local geometry of the weld toe in relation to the thickness of the adjoining plates and the stress gradient over the thickness. The basic design S-N curves are applicable to thicknesses that do not exceed the reference thickness of 22 mm. For members with thickness greater than 22 mm, the S-N curve for a joint member, with net thickness, t_{net50}, in mm, is to be taken as:

$$\log(N) = \log(K_2) - m\log\left(\frac{S_{Ri}}{(22/t_{net50})^{0.25}}\right)$$

Where:

$\log(K_2) = \log(K_1) - 2\delta$

N the predicted number of cycles to failure under stress range S

K_1 constant relating to the mean S-N curve, as given in **Table C.1.6**

δ standard deviation of $\log(N)$

m inverse slope of the S-N curve, as given in **Table C.1.6**

S_{Ri} stress range, as defined in **1.4.5.11**, in $\mathrm{N/mm^2}$

1.4.5.13 Where the longitudinal stiffeners are flat bars or bulb plates, the thickness effect described in **1.4.5.12** is not applicable.

1.4.5.14 The benefits of weld toe grinding should not be taken into consideration at the design stage. However, an exception may be made for the weld connection between the hopper plate and inner bottom if the calculated fatigue life is greater than one half of the design fatigue life or minimum 17 years excluding the grinding effects, whichever is greater. Where grinding is applied, full details of the grinding standard including the extent, smoothness particulars, final weld profile, and grinding workmanship and quality acceptance criteria are to be clearly shown on the applicable drawings and submitted for review together with supporting calculations indicating the proposed factor on the calculated fatigue life. Grinding is preferably to be carried out by rotary burr and to extend below the plate surface in order to remove toe defects and the ground area is to have effective corrosion protection. The treatment is to produce a smooth concave profile at the weld toe with the depth of the depression penetrating into the plate surface to at least 0.5 mm below the bottom of any visible undercut. The depth of groove produced is to be kept to a minimum, and, in general, kept to a maximum of 1mm. In no circumstances is the grinding depth to exceed 2 mm or 7 % of the plate gross thickness, whichever is smaller. Grinding has to extend to areas well outside the highest stress region. Provided these recommendations are followed, an improvement in fatigue life up to the design fatigue life will be granted.

1.4.5.15 The basic design S-N curves, as shown in **Fig C.1.9**, are valid for joints located in air or details exposed to sea water but adequately protected from corrosion by effective coating. For unprotected joints in sea water, the basic S-N curves are to be reduced by a factor of 2 on fatigue life.

1.4.5.16 The basic design S-N curves, as shown in **Fig C.1.9**, are used in this Appendix. To account for the fact that the joint will spend part of the time in a protected environment and part of time in an unprotected environment, a factor f_{SN}, has been introduced into the total nominal stress range calculation.

1.5 Classification of Structural Details

1.5.1 General

1.5.1.1 The joint classification of structural details is to be made using **Table C.1.7** where the design of soft toes and backing brackets corresponds to those shown in **Fig C.1.10**. When alternative designs are proposed, the adequacy in terms of fatigue strength is to be demonstrated using a suitable finite element analysis. See **2.1.1.3.**

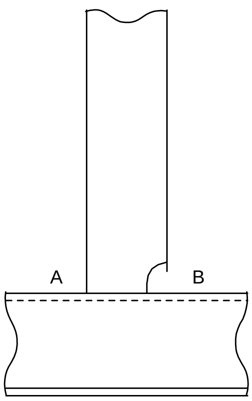
1.5.1.2 Where the primary support member web stiffeners are omitted or not connected to the longitudinals in way of bottom, side and inner hull, see Note 6 of **Table C.1.7.**

Table C.1.7
Classification of Structural Details

Notes

1. Where the attachment length is less than or equal to 150 mm, the S-N curve may be upgraded one class from those specified in the table. For example, if the class shown in the table is F2, upgrade to F. Attachment length is defined as the length of the weld attachment on the longitudinal stiffener face plate without deduction of scallop.
2. Where the longitudinal stiffener is a flat bar and there is a stiffener/bracket welded to the face, the S-N curve is to be downgraded by one class from those specified in the table. For example, if the class shown in the table is F, downgrade to F2; if the class shown in the table is F2, downgrade to G. This also applies to unsymmetrical profiles where there is less than 8 mm clearance between the edge of the stiffener flange and the face of the attachment, e.g. bulb or angle profiles where the stated clearance cannot be achieved.
3. Lapped connections (attachments welded to the web of the longitudinals) should not be adopted and therefore these are not covered by the table.
4. For connections fitted with a soft heel, class F may be used if it is predominantly subjected to axial loading. Stiffeners fitted on deck and within 0.1 D below deck at side are considered to satisfy this condition.
5. For connections fitted with a collar around the face plate (i.e., connection type ID25 through 30) or full collar (i.e., connection type ID31), class F may be used if subjected to axial loading. Stiffeners fitted on deck and within 0.1 D below deck at side are considered to satisfy this condition
6. ID31 and 32 show details where web stiffeners are omitted or are not connected to the longitudinal stiffener face plate. A full collar (i.e. connection type ID31) or alternatively a detail design for cut-outs as shown in **Fig C.1.11** or equivalent is required in way of:
   - Side below the highest point of the wave wetted zone or below 0.1 D from the deck at side, whichever is lower.
   - Bottom
   - Inner hull longitudinal bulkhead below 0.1 D from the deck at side
   - Hopper
   - Inner bottom

   The highest point of the wave wetted zone is defined as the full load draft plus h_{wl} as shown in **Fig C.1.1.** Equivalence to **Fig C.1.11** is to be demonstrated through a satisfactory fatigue assessment by using comparative FEM based hot spot stress of the cut-out in the primary support member and the collar.
7. For connection type ID32 having no collar welded to the face plate, class F is to be used in way of longitudinals in the strength deck irrespective of slot configuration. In other areas class E may be used irrespective of slot configuration.

ID	Connection type	Critical locations notes (1), (2), (3)	
		A	B
1		F2	F2

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Classification of Structural Details

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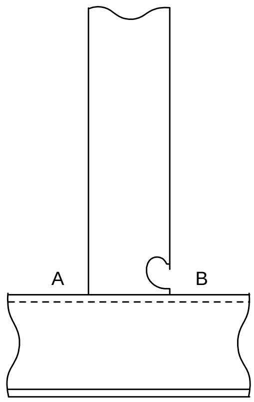
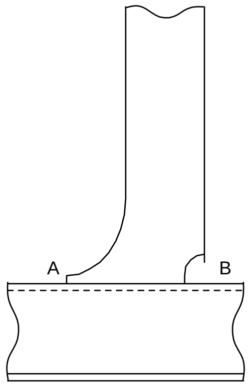
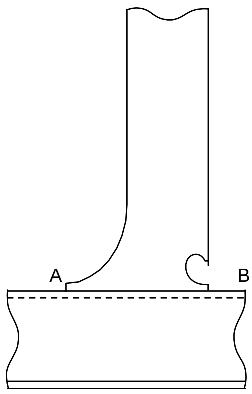
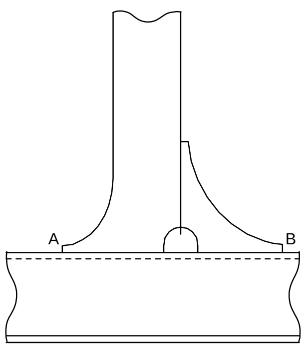
2		F2	F2(4)
3		F	F2
4		F	F2(4)
5		F	F

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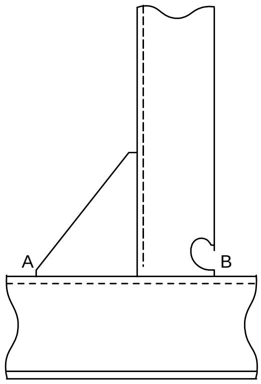
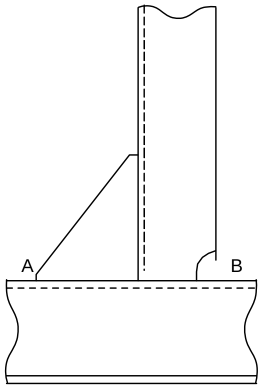
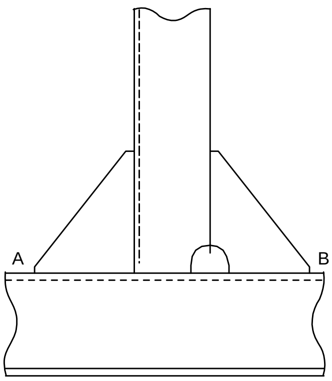
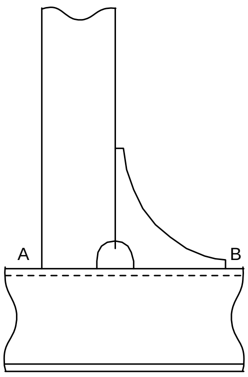
6		F2	F2(4)
7		F2	F2
8		F2	F2
9		F2	F

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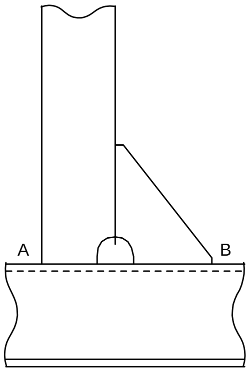
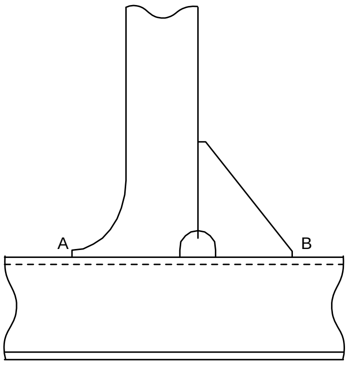
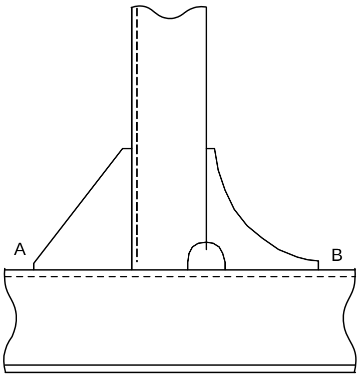
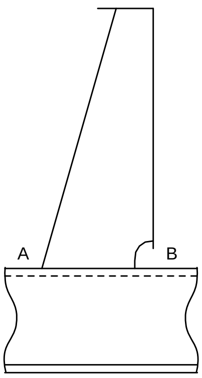
10		F2	F2
11		F	F2
12		F2	F
13		F2	F2

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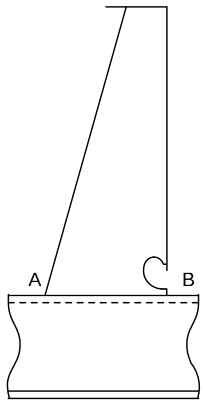
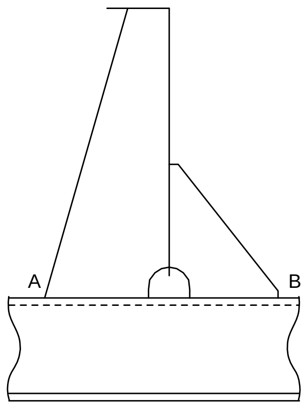
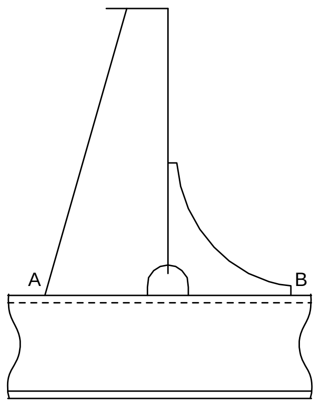
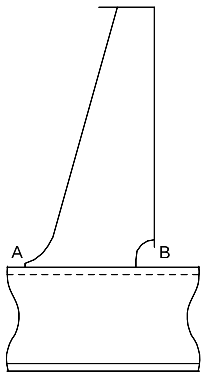
14		F2	F2(4)
15		F2	F2
16		F2	F
17		F	F2

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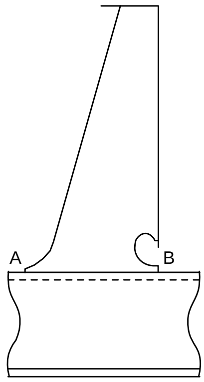
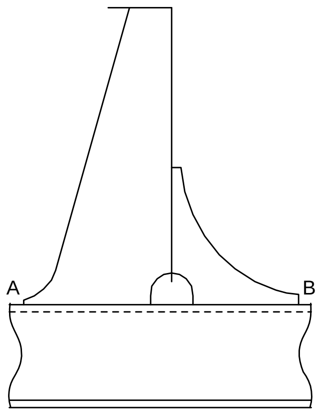
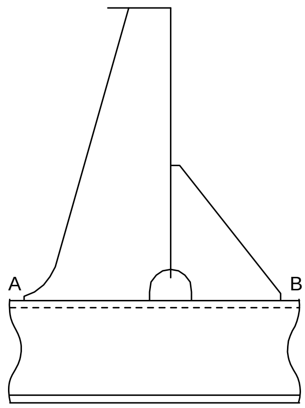
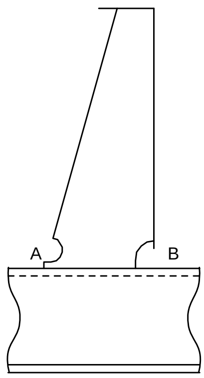
18		F	F2(4)
19		F	F
20		F	F2
21		F	F2

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Classification of Structural Details

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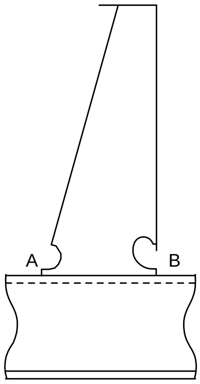
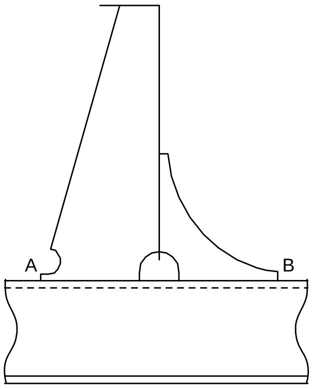
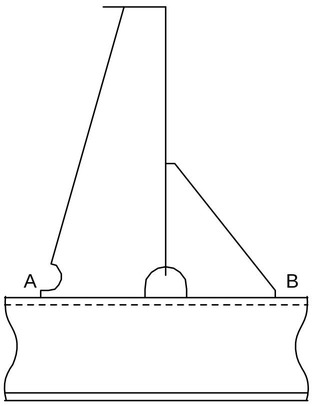
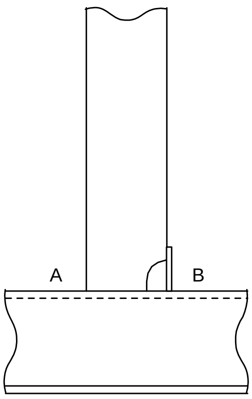
22		F	F2(4)
23		F	F
24		F	F2
25		F2	F2(5 only)

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Classification of Structural Details

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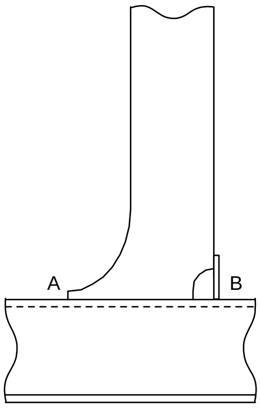
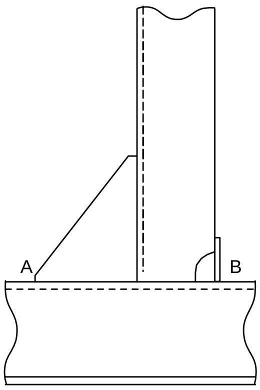
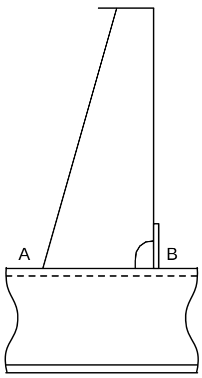
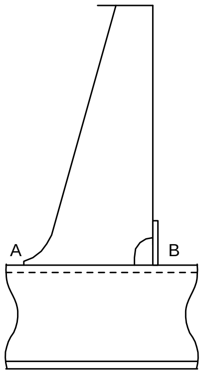
26		F	F2(5 only)
27		F2	F2(5 only)
28		F2	F2(5 only)
29		F	F2(5 only)

Table C.1.7 (Continued)
Classification of Structural Details

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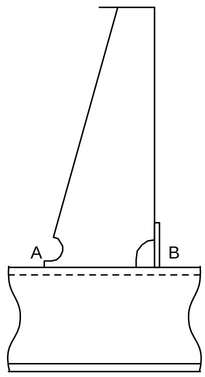
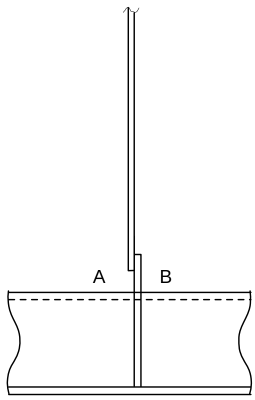
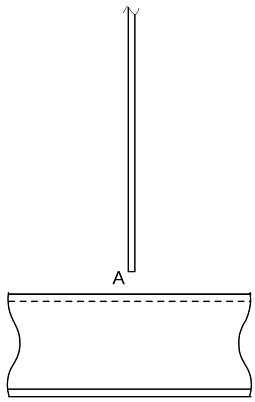
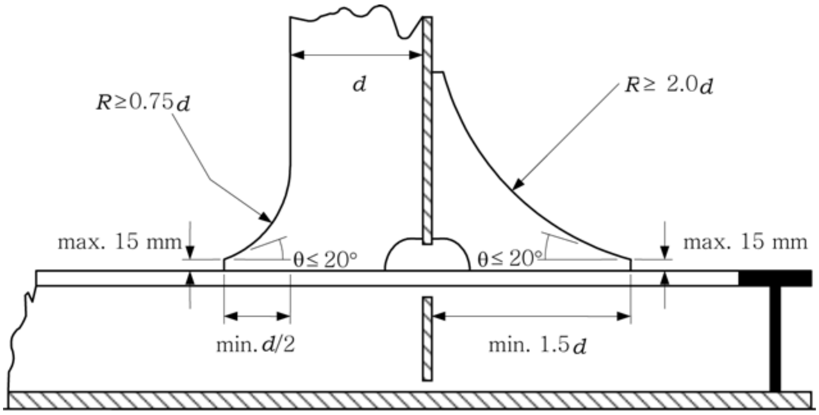
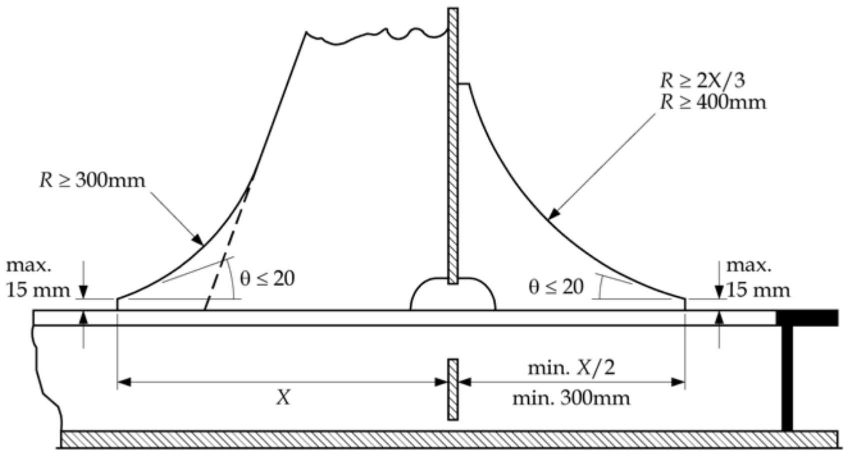
30		F	F2(5 only)
31		F2(5, 6 only)	F2(5, 6 only)
32		F(6, 7 only)	N/A

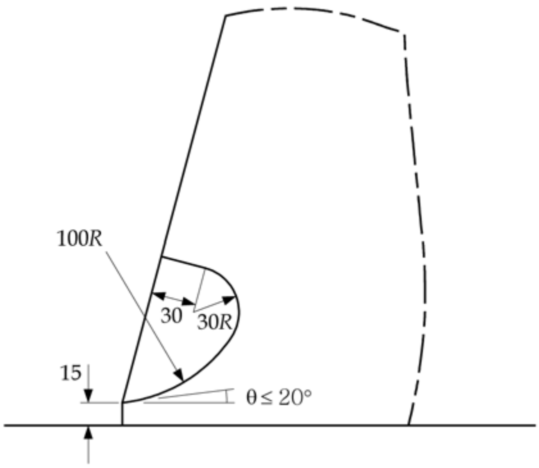
Fig C.1.10
Detail Design for Soft Toes and Backing Brackets



Recommended Design of Soft Toes and Backing Bracket of Pillar Stiffeners



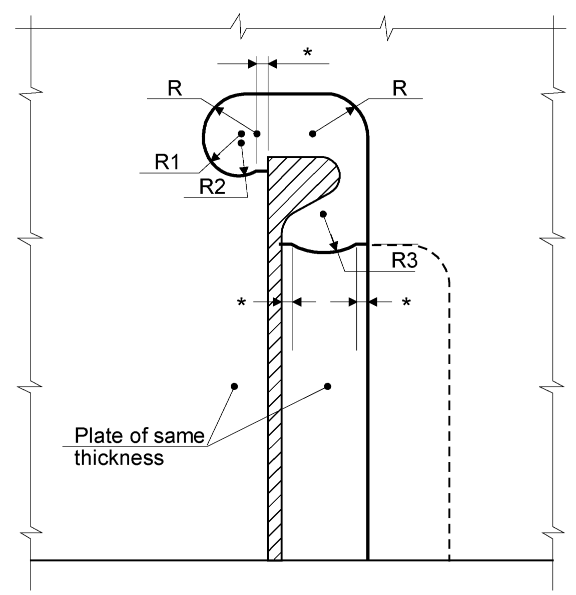
Recommended Design of Soft Toes and Backing Bracket of Tripping Brackets



Recommended Alternative Design of Soft Toes of Tripping Brackets

Fig C.1.11
Design for Cut Outs in cases where Web Stiffeners are Omitted

1



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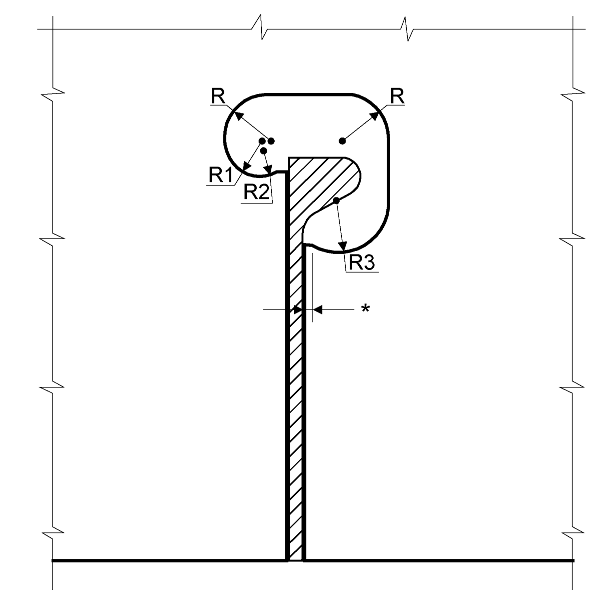

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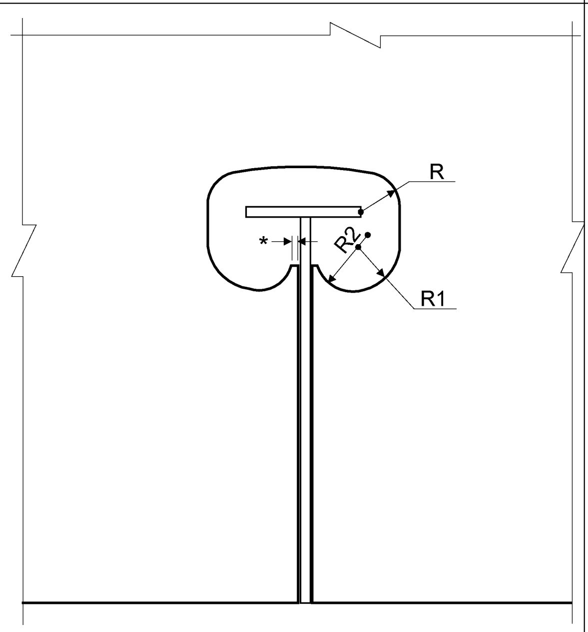

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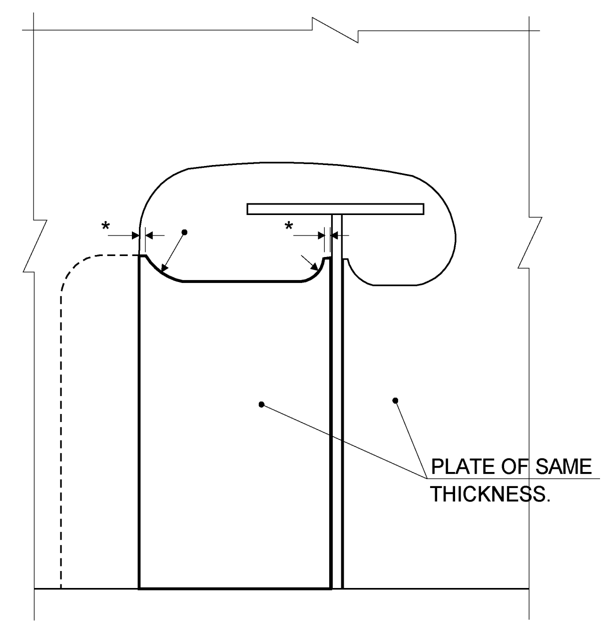


Notes

1. Soft toes marked “*” are to be dimensioned to suit the weld leg length such that smooth transition from the weld to the radiused part can be achieved. Max. 15 mm.
2. Configurations 1 and 4 indicate acceptable lapped lug plate connections, alternatively, butted lug plates with similar shape may be adopted.
3. Designs that are different than shown in the above sketches are acceptable subject to a satisfactory fatigue assessment by using comparative FEM based hot spot stress.

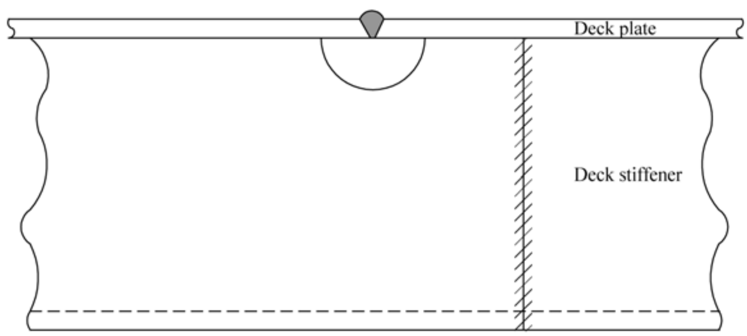
1.6 Other Details

1.6.1 Scallops in way of block joints

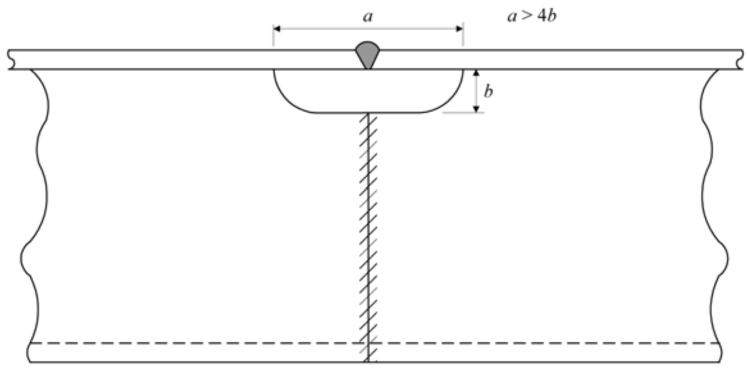
1.6.1.1 Scallops in way of block joints in the cargo tank region, located on the strength deck, and down to 0.1*D* from the deck at side are to be designed according to **Fig C.1.12** unless the specification in **Sec 8/1.5.1.3** for class F2 is satisfied.

Fig C.1.12
Welding of Deck Stiffeners in way of Block Joints

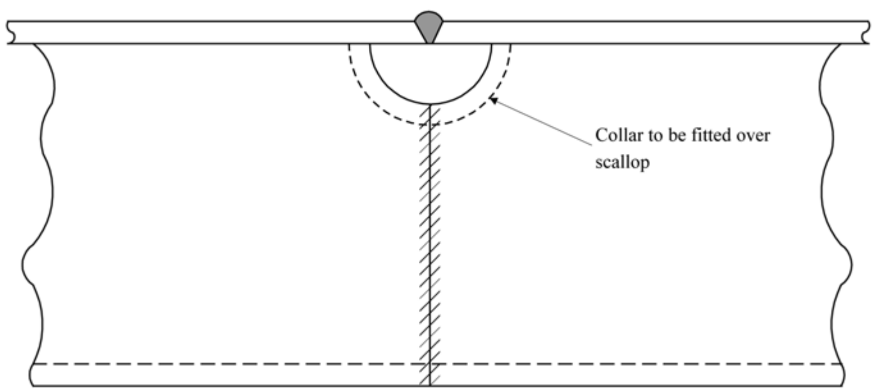
(I) Offset butt on stiffener



(II) Elongated scallop on stiffener



(III) Closing scallop with collar



Notes

Alternative scallop geometry to that shown in option II may be accepted subject to demonstration of satisfactory fatigue life based on hull girder loads taking into account additional stress concentration factor in way of weld, determined using fine mesh FEM and applying class D S-N curve.

2 Hot Spot Stress (FE Based) Approach

2.1 General

2.1.1 Applicability

2.1.1.1 The procedure in this section applies to welded knuckles between inner bottom and hopper plate fatigue analysis using a finite element (FE) based hot spot stress approach. A similar application method as described in **Sub-Sec 1** for the nominal stress approach is used except where indicated in the following sections.

2.1.1.2 Where the hopper knuckle between inner bottom and hopper plate is of the bent type, hot spot stress fatigue assessment is not a requirement provided the detail design standard described in **2.5.1.2** is followed. When alternative design is proposed, a suitable finite element (FE) analysis should be used to demonstrate the equivalency of the detail in terms of fatigue strength.

2.1.1.3 Where the hot spot stress approach is considered necessary for demonstration of the adequacy of longitudinal stiffener end connection in lieu of the nominal stress approach, the procedure described in **Sub-Sec 1** is generally to be followed with the exception that S_v, S_h, S_i and S_e are to be determined directly from the finite element analysis using the surface hot spot stress component perpendicular to the weld obtained by linear extrapolation to the centre-line of the attachment, and then to the weld toe position. The S-N curve according to **2.4.3** is applicable.

2.1.2 Assumptions

2.1.2.1 The assumptions made are given in **1.1.2.**

2.2 Corrosion Model

2.2.1 Net thickness

2.2.1.1 The net thickness and corrosion additions given in **Sec 6/3** are to be incorporated into the representation of the FE structural capacity models as described in **Appendix B/4.**

2.3 Loads

2.3.1 General

2.3.1.1 Dynamic wave and tank pressures are to be considered for the FE based fatigue analysis of knuckles between inner bottom and hopper plates, see **1.3.6** and **1.3.7.**

2.4 Fatigue Damage Calculation

2.4.1 Fatigue strength determination

2.4.1.1 The procedure outlined in **1.4** is to be applied.

2.4.1.2 The Weibull probability distribution parameter applicable to welded knuckles between inner bottom and hopper plate, ξ, is to be taken as:

$$\xi = 1.1 - 0.35\frac{L-100}{300}$$

Where:

L rule length, in m, as defined in **Sec 4/1.1.1.1**

2.4.2 Stresses to be used

2.4.2.1 To determine hot spot stresses, local 2D or 3D very fine mesh stress analyses, in conjunction with a 3D coarse mesh analysis are to be used. In highly stressed areas, in particular in the vicinity of structural discontinuities, the level of stresses depends on the size of elements because of the high stress gradient. If the stress field is more complex than a uniaxial field, the stresses adjacent to the potential crack location are to be used. A uniform mesh is to be used with smooth transition and avoidance of abrupt changes in mesh size.

2.4.2.2 The following defines a general basis for the modelling of local structures:

(a) hot spot stresses are to be calculated using an idealized welded joint with no misalignments. The finite element mesh is to be fine enough near the hot spot such that stresses and stress gradients can be determined with sufficient accuracy

(b) plating, webs and face plates of primary and secondary members are modelled by 4-node thin shell elements. In cases of steep stress gradients, 8-node thin shell elements are to be used.

(c) when thin shell elements are used, the structure is to be modelled at the mid face of the plates. For practical purposes, adjoining plates of different thickness may be assumed to be median line aligned, i.e., no staggering in way of thickness change is required.

(d) the aspect ratio of elements is not to be greater than three in the vicinity of the hot spot.

(e) the size of elements located in the vicinity of the hot spot is to be comparative to the net thickness of the structural member

(f) stresses are to be calculated at the surface of the plate with a view to taking into account the plate bending moment, where relevant.

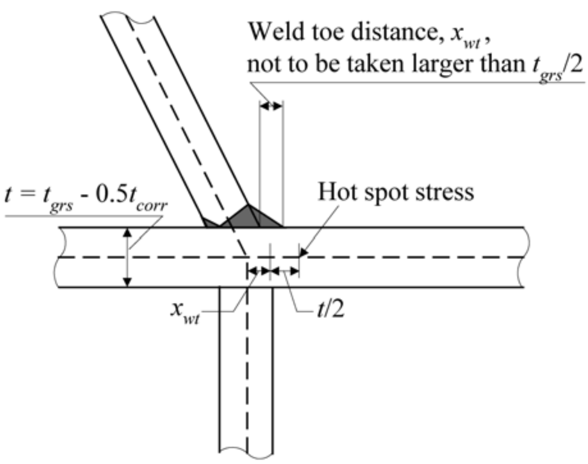
2.4.2.3 A detailed description of hot spot stress calculation using finite element modelling is given by **Appendix B/4.**

2.4.2.4 Generally, the element stresses are derived at the Gaussian integration points. Depending on the element type, it may be necessary to perform several interpolations in order to determine the actual stress at the considered hot spot location.

2.4.2.5 For critical structural details, hot spot stresses are generally highly dependent on the finite element model used for representation of the structure. Alternative procedures to those described here, for the derivation of the hot spot stress, are to be confirmed or documented by reference to available fatigue test results for similar structural details.

2.4.2.6 The hot spot stress is defined as the surface stress at $0.5\,t$ away from the weld toe location, as shown in **Fig C.2.1.** The hot spot stress is to be obtained by linear interpolation in the ship's transverse direction using the respective stress at the 1^{st} and 2^{nd} element from the structure intersection.

Fig C.2.1
Hot Spot Stress



2.4.2.7 Stress range components along the direction perpendicular to the weld, due to the loads defined in **2.3**, are to be calculated based on **Appendix B/4**. The total combined stress range, S, is to be taken as:

$S = f_{model}\left| 0.85(S_{e1} + 0.25S_{e2}) - 0.3S_i \right|$ for full load condition

$S = f_{model}\left| 0.85(S_{e1} - 0.2S_{e2}) \right|$ for ballast load condition

Where:

S_{e1} stress range due to dynamic wave pressure applied to FE-model on the side where the hopper knuckle is to be investigated, in N/mm^2, see **Table B.4.1**

S_{e2} stress range due to dynamic wave pressure applied to FE-model on the side of the hull where the hopper knuckle is not analysed, in N/mm^2, see **Table B.4.1**

S_i stress range due to dynamic tank pressure applied to FE-model, in N/mm^2, see **Appendix B/4.5.2.4** and **Table B.4.1**

f_{model} 1.0 if the FE model is made according to net thickness for fatigue, i.e. using corrosion addition of 0.25 t_{corr} for the FE model except in way of critical location (in way of a knuckle and within 500 mm in all directions), which uses corrosion addition of 0.5 t_{corr}
0.95 if the FE model for strength assessment is used. FE model for strength assessment applies a corrosion addition of 0.5 t_{corr} for the whole model including structure in way of critical location

2.4.2.8 To account for the mean stress effect, in lieu of applying the static loads to the FE model, the total stress range may be taken as:

$S_{Ri} = 1.0S$ for full load condition

$S_{Ri} = 0.6S$ for ballast load condition

Where:

S total combined stress range, in N/mm^2, as defined in **2.4.2.7**

2.4.3 Selection of S-N curves

2.4.3.1 The fatigue analysis is to be carried out applying the Class D S-N curve for welded details if the hot spot stress is calculated according to **2.4.2.8.** The thickness effect according to **1.4.5.12** will be applicable.

2.5 Detail Design Standard

2.5.1 Hopper knuckles

2.5.1.1 Design details for the welded knuckle between hopper plating and inner bottom plating are to be as shown in **Fig C.2.2.**

Guidance Note:

Fig C.2.3 may be used as an option to increase fatigue strength at the hopper connection.

2.5.1.2 Design details for the bent knuckle between hopper plating and inner bottom plating are to be as shown in **Fig C.2.4.**

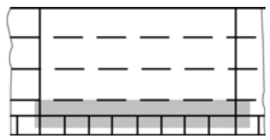
2.5.2 Transverse Bulkhead Horizontal Stringer Heel

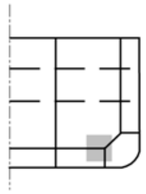
2.5.2.1 Detail design improvement given in **Fig C.2.5** is recommended for reducing the stress level and increasing fatigue strength at the horizontal stringer heel location between transverse oil-tight and wash bulkhead plating and inner hull longitudinal bulkhead plating. This recommendation should be considered in association with fine mesh FE analysis as required in **Appendix B/3.1.3.**

Fig C.2.2
Hopper Knuckle Connection Detail, Without Bracket

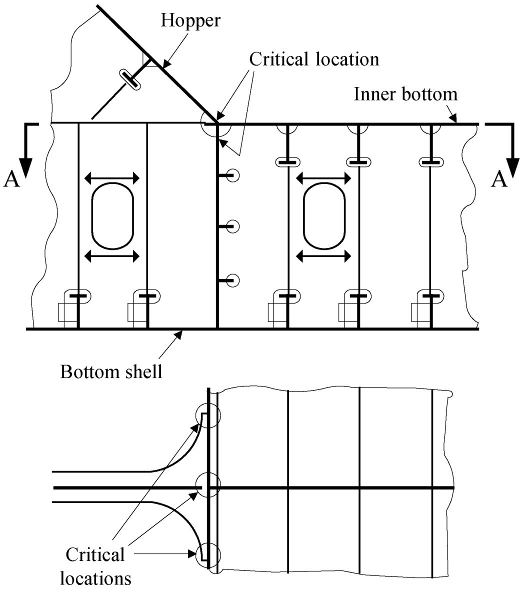
Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating

Critical areas



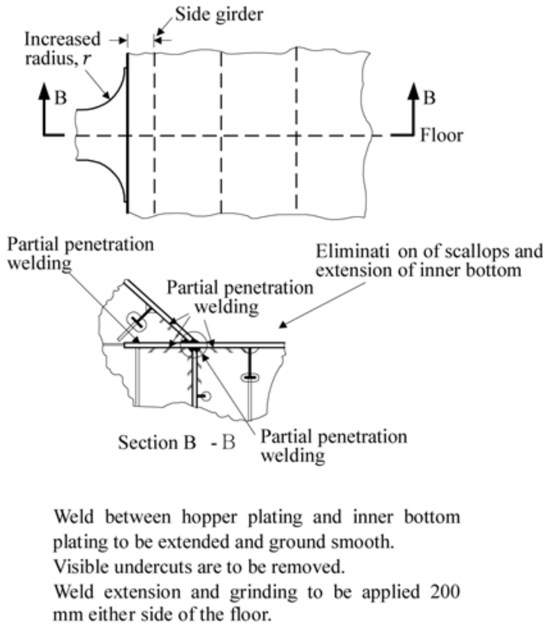


Critical locations



Section A-A

Detail design standard A

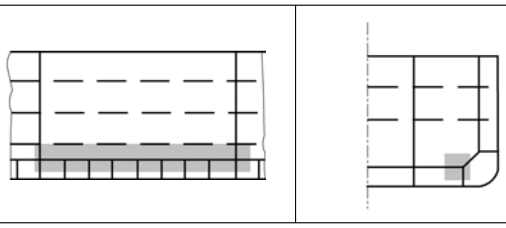
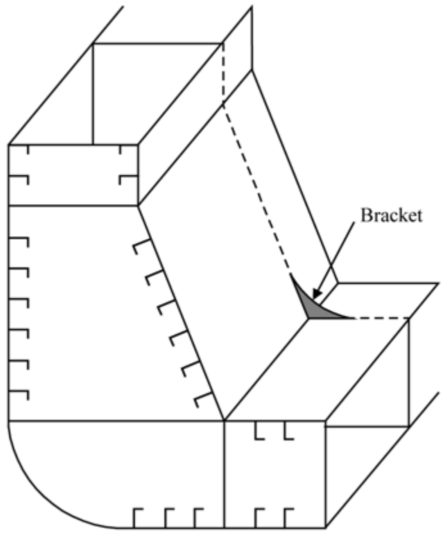


Note:
1. A root face with a maximum of 1/3 of the abutting plate thickness is acceptable for the partial penetration welding, see **Sec 6/5.3.4.**
2. Grinding need not be applied in the No.1 tank in which floor spans are reduced due to shape.
3. Grinding need not be applied for the knuckle joints at transverse bulkhead positions, or at the floor adjacent to the transverse bulkhead.

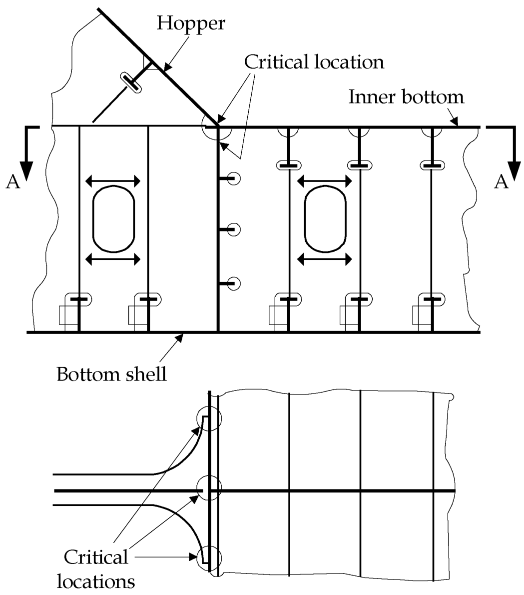
Minimum requirement	As a minimum, detail design standard A or B is to be fitted. Further consideration will be given where the hopper angle exceeds 50 degrees. The ground surface is to be protected by a stripe coat, of suitable paint composition, where the lower hopper knuckle region of cargo tanks is not coated.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girders in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness is to be close to that of the inner bottom in way of knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of the girder with an allowable tolerance of t/3 or 5 mm, whichever is less, where t is the inner bottom thickness. The allowable tolerance is to be measured parallel to the inner bottom.
Welding requirements	Partial penetration welding (hopper sloping plating to inner bottom plating). Partial penetration weld (connection of floors to inner bottom plating and to side girders, connection of hopper transverse webs to sloping plating, to inner bottom plating, and to side girders in way of hopper corners).

Fig C.2.3
Option: Hopper Knuckle Connection Detail, With Bracket

Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing welded inner bottom and hopper sloping plating

Critical areas	Detail design standards B
	

Critical locations



Section A-A

Note:
1. Bracket to be fitted inside cargo tank
2. Bracket to extend approximately to the first longitudinal
3. The bracket toes are to have a soft nose design
4. Full penetration welding at bracket toes
5. Bracket material to be same as that of inner bottom
6. Buckling of bracket to be checked:

$$\frac{d}{t_{bkt}} < 21\sqrt{235/\sigma_{yd}}$$

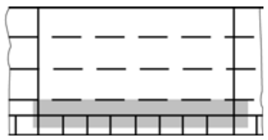
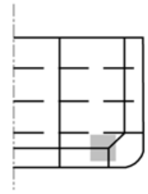
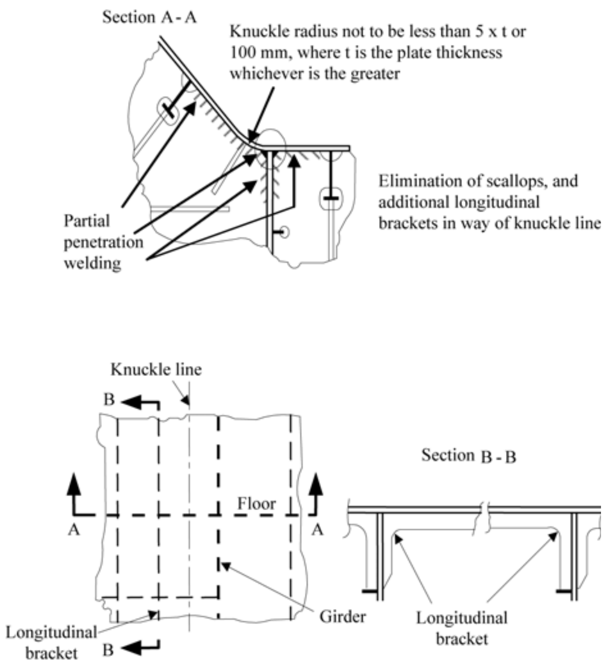
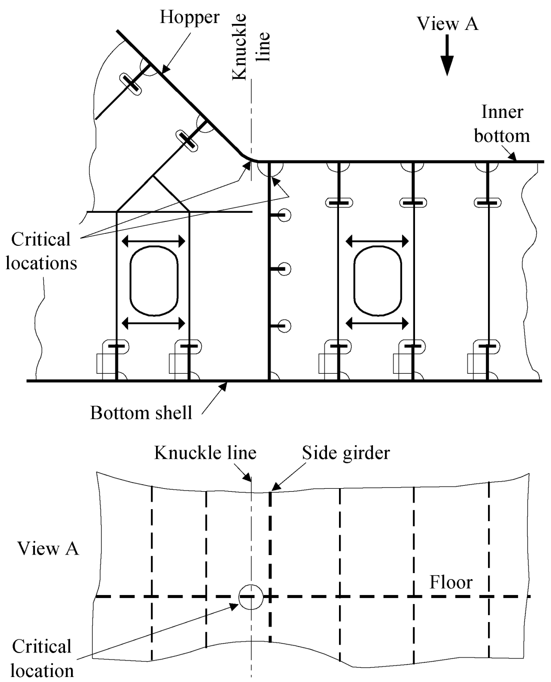
where:

d = bracket max depth, as defined in **Table 10.2.3**
t_{bkt} = bracket thickness
σ_{yd} = specified minimum yield stress of material

Minimum requirement	As a minimum, detail design standard A or B is to be fitted. Further consideration will be given where hopper angle exceeds 50 degrees.
Critical location	Hopper sloping plating connections to inner bottom plating in way of floors. Floor connections to inner bottom plating and side girders in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners, extension of inner bottom plating to reduce level of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure and hull girder loads. Scarfing bracket thickness to be close to that of the inner bottom in way of knuckle.
Building tolerances	Median line of hopper sloping plate is to be in line with the median line of girder with an allowable tolerance of t/3 or 5 mm, whichever is less, where t is the inner bottom thickness.
Welding requirements	Partial penetration welding (hopper sloping plating to inner bottom plating). Partial penetration weld (connection of floors to inner bottom plating and to side girders, connection of hopper transverse webs to sloping plating, to inner bottom plating, and to side girders in way of hopper corners).

Fig C.2.4
Hopper Knuckle Connection Detail, Bent Type

Connections of floors in double bottom tanks to hopper tanks
Hopper corner connections employing bent knuckle inner bottom and hopper sloping plating

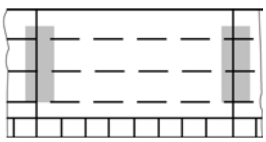
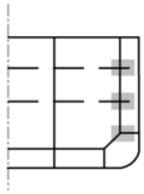
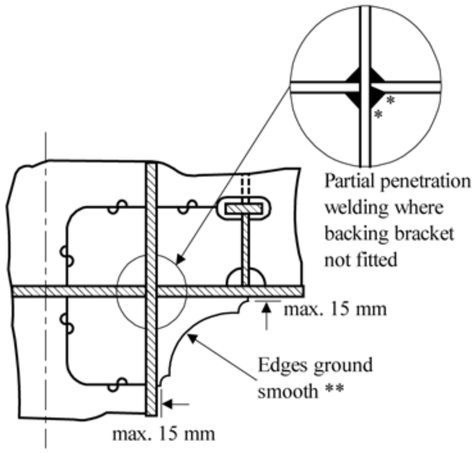
Critical areas	Detail design standard C
 	
Critical locations	
	

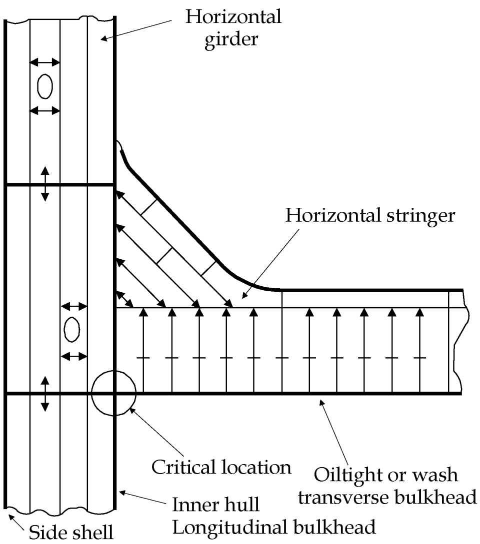
Note:
Longitudinal brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line.

Minimum requirement	As a minimum, the detail design standard C is to be fitted.
Critical location	Side girder connections to inner bottom plating in way of floors. Floor and hopper transverse web connections to inner bottom plating and to side girders in way of hopper corners.
Detail design standard	Elimination of scallops in way of hopper corners and additional longitudinal brackets to reduce peak and range of resultant stresses arising from cyclic external hydrodynamic pressure, cargo inertia pressure, and hull girder global loading.
Building tolerances	Enhanced alignment standard. The nominal distance between the centres of thickness of the two abutting members (e.g. floor and hopper web plate and additional supporting brackets) should not exceed 1/3 of the table member thickness.
Welding requirements	Partial penetration welding with a maximum root face of 1/3 of the abutting plate thickness (Connection of side girders to inner bottom plating. Connection of floors to inner bottom plating and to side girders. Connection of hopper transverse webs to sloped inner bottom plating and to side girders in way of hopper corners).

Fig C.2.5
Option: Transverse Bulkhead Horizontal Stringer Heel

Connections of horizontal girder in double side tanks to transverse bulkheads
Connection of horizontal stringer on plane oiltight transverse or wash bulkheads to inner hull longitudinal bulkhead

<table>
<tr><th colspan="2">Critical areas</th><th>Detail design improvement</th></tr>
<tr><td></td><td></td><td rowspan="3">

Note:
* Weld toe to be ground smooth, visible undercuts to be removed where brackets not fitted.
** Where a face plate is considered necessary, it is recommended that design features be adopted to reduce the stress concentration at the face plate termination (e.g., taper and soft nose).</td></tr>
<tr><td colspan="2">Critical locations</td></tr>
<tr><td colspan="2">
</td></tr>
</table>

Critical location	Intersections of webs of transverse bulkhead horizontal stringer and double side tank horizontal girder forming square corners.
Detail design improvement	Elimination of scallops in way of cruciform joint and fitting a localized ‘D’ grade steel insert plate, with minimum thickness of 7 mm in addition to the Rule required thickness, to reduce the peak and range of resultant stresses arising from cyclic cargo inertia pressure and hull girder global loading. In addition, a soft toed backing bracket of suitable dimension is to be fitted. The following bracket sizes are recommended: • VLCC: 800 × 800 × 30 R600 with soft toe as shown in Figure • Suezmax and Aframax tankers: 800 × 600 × 25 R550 with soft toe as shown in Figure, where the longer arm length is in way of the inner skin. The actual bracket design is to be verified by fine mesh finite element analysis in accordance with **Appendix B/3.1.3.**
Building tolerances	Enhanced alignment standard. The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the table member thickness.
Welding requirements	Fillet welding having minimum weld factor of 0.44, where backing bracket is fitted or partial penetration welding where backing bracket is not fitted. The extent of partial penetration should be of the order of longitudinal spacing. A small scallop of suitable shape, which is to be closed by welding after completion of the continuous welding of bulkhead, should be provided where scallop is eliminated.

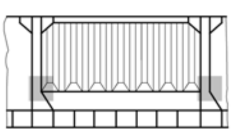
2.5.3 Transverse and longitudinal corrugated bulkhead connection to lower stool

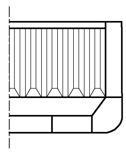
2.5.3.1 Detail design improvement given in **Fig C.2.6** is recommended for reducing the stress level at the connection of transverse and longitudinal corrugated bulkhead to lower stool. This recommendation should be considered in association with fine mesh FE analysis as required in **Appendix B/3.1.5.**

Fig C.2.6
Transverse and Longitudinal Bulkhead Connection to Lower Stool

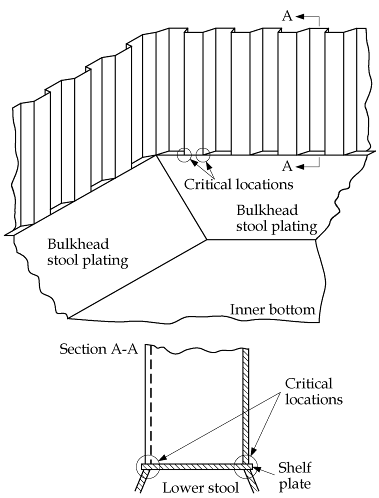
Connections of side stringers in double side tanks to transverse bulkheads
Higher tensile stringers to horizontal girders on plane oiltight transverse or wash bulkheads

Critical areas

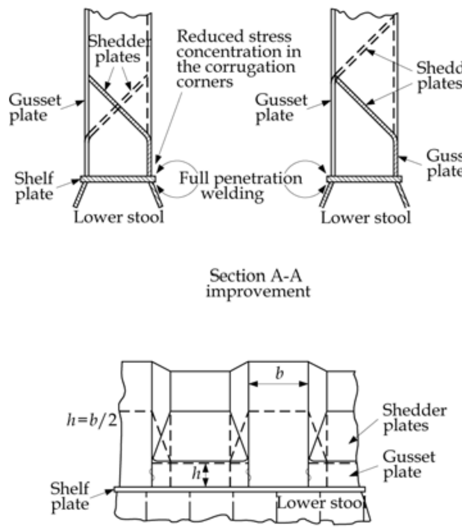




Critical locations



Detail design improvement



Note:
* Full penetration weld is to be applied at the connection of the corrugated bulkhead and stool plate to the shelf plate of the lower stool.
** Where adjacent shedder plates cross, a bracket stiffener is to be provided at the crossing point.

Critical location	1. Connections of corrugated bulkhead to lower stool and shelf plate 2. Connections of corrugated bulkhead to shedder plate if fitted without a gusset plate
Detail design improvement	1. Gusset plate should be fitted to the shelf plate in line with the face of the corrugation to reduce stress concentrations at the corrugated corners. The minimum height of the gusset plate should be taken as half the corrugated bulkhead flange width. 2. To reduce stress concentration at the crossing of the shedder plates, shedder plates may be arranged in an alternate configuration as shown in figure. Alternatively, bracketed stiffener may be fitted at the crossing points underneath the shedder plates.
Building tolerances	Ensure good alignment between lower stool sloping plates and corrugation faces as far as possible. The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the table member thickness.
Welding requirements	Full penetration welding should be used at the connections of the bulkhead corrugations, gusset plates and the lower stool sloping plates to the lower stool shelf plate (Grade Z steel is recommended). Start and stop of welding should be as far away as practicable from the corners of the corrugations.

Appendix D

Buckling Strength Assessment

1 Advanced Buckling Analysis

1.1 General

1.1.1 Scope

1.1.1.1 This appendix describes the advanced buckling analysis method and its application as required by the Rules. The advanced buckling analysis method is to be based on nonlinear analysis techniques, or equivalent, which predict the complex behaviour of stiffened and un-stiffened panels.

1.1.2 Alternative procedures

1.1.2.1 While this appendix describes the general purpose or direct calculation techniques to be employed, alternative advanced buckling and ultimate strength analysis procedures may be used provided they give comparable and consistent results to those obtained using the reference advanced buckling procedure given in the Background to **Appendix D** which is the basis for the permissible buckling utilisation factors in **Sec 9/Table 9.2.2.** See also **1.1.2.3.**

1.1.2.2 Where an alternative advanced procedure is used, documentation of the alternative advanced buckling analysis methodologies and detailed comparison of its results with those of the reference advanced buckling procedure given in Background to **Appendix D** and software tools are to be supplied for review and acceptance.

1.1.2.3 Use of alternative buckling procedures to the reference advanced buckling procedure is acceptable provided that the alternative procedure is verified against the test cases specified in the *Background to* **Appendix D** and where the permissible utilisation buckling factor for the alternative method, $\eta_{all-alt}$t, complies with:

$$\eta_{all-alt} \leq \eta_{all} \cdot \left(\frac{\eta_{alt-i}}{\eta_{reft-i}} \right)_{\min}$$

Where:

η_{all} permissible utilisation factor against buckling for plate and stiffened panels as specified in **Sec 9/Table 9.2.2**

η_{ref-i} utilisation factor for reference advanced buckling procedure for test case i specified in Background to **Appendix D**

η_{alt-i} utilisation factor for alternative buckling procedure for test case i specified in Background to **Appendix D**

1.1.3 Definitions

1.1.3.1 "Buckling" is used as a generic term to describe the strength of structures, generally under in-plane compressions and/or shear. The buckling strength or capacity can take into account the internal redistribution of loads depending on the situation.

1.1.3.2 Buckling capacity accepting local elastic plate buckling with load redistribution is referred to as Method 1. The buckling capacity is the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel. Buckling capacity based on this principle gives a lower bound estimate of ultimate capacity, or the maximum load the panel can carry without suffering major permanent set. Method 1 buckling capacity assessment utilizes the positive elastic post-buckling effect for plates and accounts for load redistribution between the structural components, such as between plating and stiffeners. For slender structures the capacity calculated using this method is typically higher than the ideal elastic buckling stress (minimum Eigen-value). Accepting elastic buckling of structural components in slender stiffened panels implies that large elastic deflections and reduced in-plane stiffness will occur at higher buckling utilization levels.

1.1.3.3 Method 2 buckling capacity does not accept load redistribution between structural components and refers to the minimum of value of the ideal elastic buckling stress and the Method 1 buckling capacity. Method 2 buckling capacity normally equals the same strength as Method 1 for stocky panels, while it is the ideal elastic buckling stress (minimum Eigen-value cut-off) for slender panels. By applying the ideal elastic buckling stress limitation, large elastic deflections and reduced in-plane stiffness will be avoided at higher buckling utilization levels.

1.1.3.4 A “buckling failure mode” refers to a specific pattern of buckling failure. Typical failure modes of stiffened panels with open profiles are:

(a) plate buckling

(b) torsional stiffener buckling

(c) stiffener web plate buckling

(d) lateral stiffener buckling.

2 Advanced Buckling Analysis Method

2.1 General

2.1.1 Effects to consider

2.1.1.1 The advanced buckling assessment method is to be capable of considering the following effects:
(a) non linear geometrical behaviour
(b) inelastic material behaviour
(c) initial deflections - geometrical imperfections/out-of flatness
(d) welding residual stresses
(e) interactions between buckling modes and structural elements; plates, stiffeners, girders etc.
(f) simultaneous acting loads; bi-axial compression/tension, shear and lateral pressure
(g) boundary conditions.

2.1.1.2 Detailed requirements for items listed in **2.1.1.1** are given in **2.1.2** to **2.1.8.** Additional requirements applicable to non-linear finite element models are given in **2.1.9** and **2.1.10.**

2.1.2 Non linear geometrical behaviour

2.1.2.1 The buckling method is to be based on non-linear large deflection plate theory or equivalent. Second order membrane strains due to geometrical non-linearity are to be accounted for.

2.1.2.2 Non-linear plate theory according to von Karman and Marguerre is acceptable for assessing the strength beyond the ideal elastic buckling level.

2.1.3 Material behaviour and properties

2.1.3.1 Inelastic material behaviour is to be considered. If the buckling method is not capable of handling non linear material and spread of plasticity, then the redistributed stress fields due to non-linear geometrical behaviour and geometrical imperfections are to be limited to below the von Mises yield criterion.

2.1.3.2 Alternatively, if the buckling method is capable of handling non linear material, then a bi-linear material model is to be used with a conservative strain-hardening coefficient in the plastic region.

2.1.3.3 The material property assumptions are to use the characteristic values of yield strength and Young’s Modulus. Where appropriate, a bi-linear isotropic elasto-plastic material model excluding strain rate effects is to be used or the Tangent Modulus is to be taken as a conservative value. A plastic tangent modulus of 1000 Mpa is acceptable for normal and higher strength steel.

2.1.4 Initial deflections - geometrical imperfections/out-of-flatness

2.1.4.1 Initial deflections are to be included in the buckling assessment.

2.1.4.2 For the deterministic strength assessment the geometrical imperfections are to be transformed to a regular model pattern.

2.1.4.3 The imperfections may be divided into local imperfections (plate out-of-flatness and stiffener sideways out-of-straightness), and global imperfections of the stiffeners (stiffener lateral/vertical out-of-straightness).

2.1.4.4 The shape of the initial deflections is to be such that the most critical failure modes are represented and triggered by the analysis. In general, a combination of the lowest buckling Eigen-modes will be appropriate. Consideration is to be given in the case of plates with high slenderness and in the case of simultaneously acting loads, where the critical failure mode may be different from the lowest Eigen-modes.

2.1.4.5 The default maximum values of the imperfections are to be taken to be consistent with the

IACS Shipbuilding and Quality Repair Standard. However, regular model imperfection amplitudes may generally be taken less than the maximum tolerance specified. The regular model imperfections may typically be case dependant (load ratio dependant) and are also to cover imperfections due to welding. The actual level of model imperfections will depend on the method of analysis, extension of model, etc. and is to be approved by the individual Classification Society.

2.1.5 Welding induced residual stress

2.1.5.1 Residual stresses are not required to be explicitly included in the buckling assessment, see **2.1.4.5.**

2.1.6 Interactions between buckling modes and structural elements

2.1.6.1 The advanced buckling analysis method is to accurately model the interactions between the various structural components and hence between the different buckling modes.

2.1.6.2 All the critical initial imperfection shapes are to be included, see **2.1.4.**

2.1.7 Simultaneous acting loads

2.1.7.1 The method is to be able to model any combination of biaxial in-plane compressive and shear membrane loads and lateral pressure.

2.1.7.2 Any lateral pressure is to be applied first, in order to generate the deformed shape. The lateral pressure is then to be kept constant.

2.1.7.3 The effect of lateral pressure enforcing deflections in different patterns than in-plane loads is to be included in such a way that the most critical buckling mode is developed.

2.1.8 Boundary conditions

2.1.8.1 The boundary conditions are to represent the actual response of the plate or stiffened panel. In-plane and out-of-plane boundary conditions are to be considered.

2.1.8.2 Where a panel is an integral part of a larger continuous area of stiffened plating, such as bottom or side panels, the edges may be taken as free to move in-plane, but forced to remain straight. Where a panel is not supported in-plane by adjacent structure, such as a stringer web panel or bottom girder web, then the edges are to be considered as completely free.

2.1.8.3 Rotational restraint on the plate from the stiffeners is to be accounted for by direct analysis of the plate and stiffener interaction. Prescribed boundary conditions are, in general, not acceptable.

2.1.8.4 The panels can be taken as supported in the lateral/vertical direction at the primary support members. The stiffeners may be taken as horizontally supported at the crossing of primary support members (preventing tilting at crossings). Geometrical rotational restraint of the plate from the primary support members is to be neglected.

2.1.9 Model extent

2.1.9.1 The extent of the model used in the buckling assessment is to be sufficient to account for the structure that is surrounding the panel of interest, and to reduce the uncertainties introduced through the boundary conditions.

2.1.9.2 In general, the model is to include more than one stiffener span in the stiffener direction and the portion between two primary support members in the direction normal to the stiffeners.

2.1.10 Element size for non-linear finite element models

2.1.10.1 The element size is to be small enough to describe the buckling deflections accurately.

2.1.10.2 The mesh size will depend on the complexity of the geometry and loads and the type of element used, but a minimum of five elements across a half-buckling wave length is generally required.

3 Application and Structural Modelling Principles

3.1 General

3.1.1 Scope

3.1.1.1 The following specifies the standard assumptions to be applied for the application of the advanced buckling method. These assumptions may be refined when the advanced buckling method is capable of more accurate representation of the structure.

3.1.2 Boundary conditions

3.1.2.1 The boundary conditions are to accurately account for the in-plane and rotational constraints imposed by the adjacent structures (such as stiffeners, primary support members and adjacent plates). The assumptions defined in **3.1.2.3** to **3.1.2.4** are to be applied.

3.1.2.2 The boundary conditions are divided into two main groups being representative for “free edge plating” and “continuous plating”. The latter group represents large stiffened panels such as deck plating, bottom plating, ship sides, etc., while the other represents girders, floors, stringers, etc.

3.1.2.3 The continuous plating condition is representative for elements having in-plane support conditions by the surrounding structure. The boundary conditions for stiffened panels are to be taken as:

(a) panel edges perpendicular to stiffeners are to be considered simply supported

(b) panel edges parallel to stiffeners are to be considered as having rotational support equivalent to that provided by stiffeners within the panel

(c) the ends of stiffeners are to be considered as part of a continuous panel and supported sideways by the primary support members

(d) all edges of the panel are to be constrained to remain straight but are free to displace inwards.

3.1.2.4 Free edge plating conditions are representative for elements having weak in-plane support along one or more edges, e.g. vertically stiffened double bottom floors. The boundary conditions for stiffened panels are to be taken as:

(a) panel edges perpendicular to stiffeners are to be considered simply supported

(b) panel edges parallel to stiffeners are to be considered as having rotational support equivalent to that provided by stiffeners within the panel

(c) the ends of stiffeners are to be considered as supported sideways when attached directly to adjacent structure, otherwise they are to be assumed simply supported

(d) all free edges of the panel are free to displace inwards. Rotational restraints of the edge reinforcements on the free edges may be considered.

3.1.2.5 The boundary conditions for un-stiffened panels are to be taken as:

(a) panel edges are to be considered simply supported unless otherwise stated

(b) free edges of the panel, if any, are free to displace inwards. The continuous edges are to be constrained to remain straight.

3.1.3 Structural idealisation

3.1.3.1 The structural modelling and buckling assessment method applicable for free edge plating is to be taken as:

(a) parallel to the stiffener direction: one frame bay is normally sufficient for structures having significant stress gradients. For uniformly compressed elements with the free edges parallel to the stiffener direction, such as longitudinal girders, multi-bay models are to be considered

(b) normal to the stiffener direction: between primary support members, but may be limited to six stiffener spacings

(c) assessment method: Method 2 - buckling capacity with no allowance for redistribution of load unless otherwise specified.

3.1.3.2 The structural modelling and buckling assessment method applicable for continuous plating is to be taken as:

(a) parallel to the stiffener direction: at least two frame bays, in order to model imperfections between adjacent panels

(b) normal to the stiffener direction: between primary support members, but may be limited to six stiffener spacings

(c) assessment method: Method 1 - buckling capacity with allowance for redistribution of load unless otherwise specified.

4 Assessment Criteria

4.1 General

4.1.1 Buckling strength assessment methods

4.1.1.1 The buckling capacity value is to be based on one of the following assessment methods:

(a) Buckling Capacity with allowance for redistribution of load

(b) Buckling Capacity with no allowance for redistribution of load

The application of which assessment method to use is given in **3.1.3**

4.1.2 Method 1: Buckling capacity with allowance for redistribution of load

4.1.2.1 The buckling capacity value is to be taken as the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel. This includes the redistribution of load as indicated in **1.1.3.2.** In particular the following locations are to be checked for von Mises stresses equivalent to yield:

(a) at the edges of the plate

(b) along the line of intersection of the plate and stiffeners, especially at the ends of the stiffener and at the stiffener mid point

(c) along the flanges of the stiffeners, especially at the ends of the stiffener and at the stiffener mid point.

4.1.3 Method 2: Buckling capacity with no allowance for redistribution of load

4.1.3.1 The buckling capacity value or the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel, see **1.1.3.3.**

4.2 Utilisation Factors

4.2.1 General

4.2.1.1 The utilisation factor, η, is used as a measure of safety margin against buckling strength failure. The utilisation factor is defined as the ratio between the applied loads and the corresponding ultimate capacity or buckling strength.

4.2.1.2 A structure is considered to have an acceptable buckling strength if it satisfies the following criteria:

$\eta_{act} \leq \eta_{allow}$

Where:

η_{allow} allowable buckling utilisation factor, as defined in **Sec 9/2.2.5**

η_{act} actual buckling utilisation factor based on the applied design loads

4.2.1.3 For combined loads, the utilisation factor, η, is to be taken as the ratio between the applied equivalent load and the corresponding buckling capacity, see **Fig D.4.1**, and is to be taken as:

$$\eta = \frac{W_{act}}{W_u}$$

Where:

W_{act} applied equivalent load due to the combined membrane loads

$$= \sqrt{\sigma_{dx}^2 + \sigma_{dy}^2 + \tau_d^2} \quad \text{N/mm}^2$$

W_u equivalent load due to the combined membrane loads which results in the buckling capacity point, see **Fig D.4.1**

$$= \sqrt{\sigma_{cx}^2 + \sigma_{cy}^2 + \tau_{cr}^2} \quad \text{N/mm}^2$$

Where the combined loads are all factored by the same ratio and the applied pressure load is to be kept constant

σ_{dx} applied axial stress in x direction, in N/mm^2

σ_{dy} applied axial stress in y direction, in N/mm^2

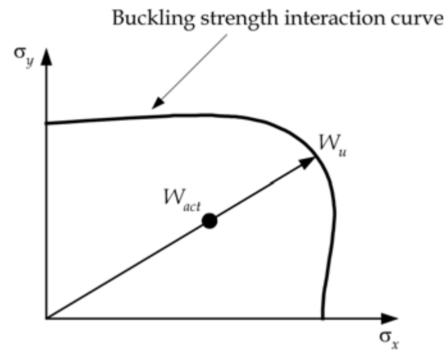
τ_d applied shear stress, in N/mm^2

σ_{cx} buckling strength due to compression in x direction, in N/mm^2

σ_{cy} buckling strength due to compression in y direction, in N/mm^2

τ_{cr} buckling strength in shear, in N/mm^2

Fig D.4.1
Definition of Utilisation Factor Example Showing a Bi-Axial Loading Pattern



5 Strength Assessment (FEM) - Buckling Procedure

5.1 General

5.1.1 Scope

5.1.1.1 The following procedure is to be used for the assessment of the buckling requirements for the Strength Assessment (FEM) as part of the Design Verification procedure, see **Sec 9/2.**

5.1.1.2 All structural elements in the finite element analysis are to be assessed individually. Each stiffener with attached plate and all un-stiffened panels are to be assessed.

5.1.1.3 The buckling performance of each member is considered acceptable if it satisfies the following criterion:

$\eta_{act} \leq \eta_{allow}$

Where

η_{allow} allowable buckling utilisation factor, as defined in **Sec 9/2.2.5**

η_{act} actual buckling utilisation factor based on the applied design loads, see **4.2.1**

5.2 Structural Modelling and Capacity Assessment Method

5.2.1 General

5.2.1.1 The longitudinally effective structure of the hull girder is to be modelled as stiffened panels or un-stiffened panels as specified in **Table D.5.1** and **Fig D.5.1.** These provide the standard assumptions to be used for the buckling capacity assessment method.

5.2.1.2 The structural models are to be based on the net thickness obtained by deducting the full corrosion addition, i.e. -1.0 t_{corr}, and any owner's extras from the proposed thickness. This thickness reduction applies to the plating and the stiffener web and face plate.

5.2.2 Stiffened panels

5.2.2.1 Each stiffener with attached plate is to be represented as a stiffened panel of the extent defined in **Table D.5.1** and hence is assumed to be part of a larger structural entity to correctly model the overall buckling behaviour.

5.2.2.2 In general, the assessment method is to model changes in plate thickness, stiffener size and spacing. However where the advanced buckling method is unable to correctly model these changes, the calculations are to be performed separately for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel. If the plate thickness, stiffener properties and stiffener spacing varies within the stiffened panel, the calculations are to be performed for all configurations of the panel. Where the panel between stiffeners consists of several plate thickness the weighted average thickness may by used for the thickness of the plating for assessment of the corresponding stiffener/plating combination. Calculation of weighted average is to be in accordance with **5.2.3.3.** See **Fig D.5.6.**

5.2.3 Un-stiffened panels

5.2.3.1 The assessment method is to model changes in plate thickness and panel geometry.

5.2.3.2 In way of web frames, stringers and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. Where the advanced buckling method is unable to correctly model the panel geometry, then an equivalent rectangular panel is to be defined as shown in **Fig D.5.5.** Where web stiffeners are not connected to the intersecting stiffeners, then the panel may be defined as shown in **Fig D.5.6.** The FE analysis is to represent the actual structure in order to derive realistic stress values for application to the equivalent rectangular panel. The stresses of all elements whose centroids are within the equivalent plate panel are to be considered for stress average in accordance with **5.3.2.1.**

5.2.3.3 Where the advanced buckling method is unable to correctly model changes in net plate thickness across a panel, and the panel consists of a number of finite plate elements, then the average thickness is to be taken as:

$$t_{avr} = \frac{\sum A_j t_j}{\sum A_j}$$

Where:

A_j area of the j^{th} plate element making up the panel

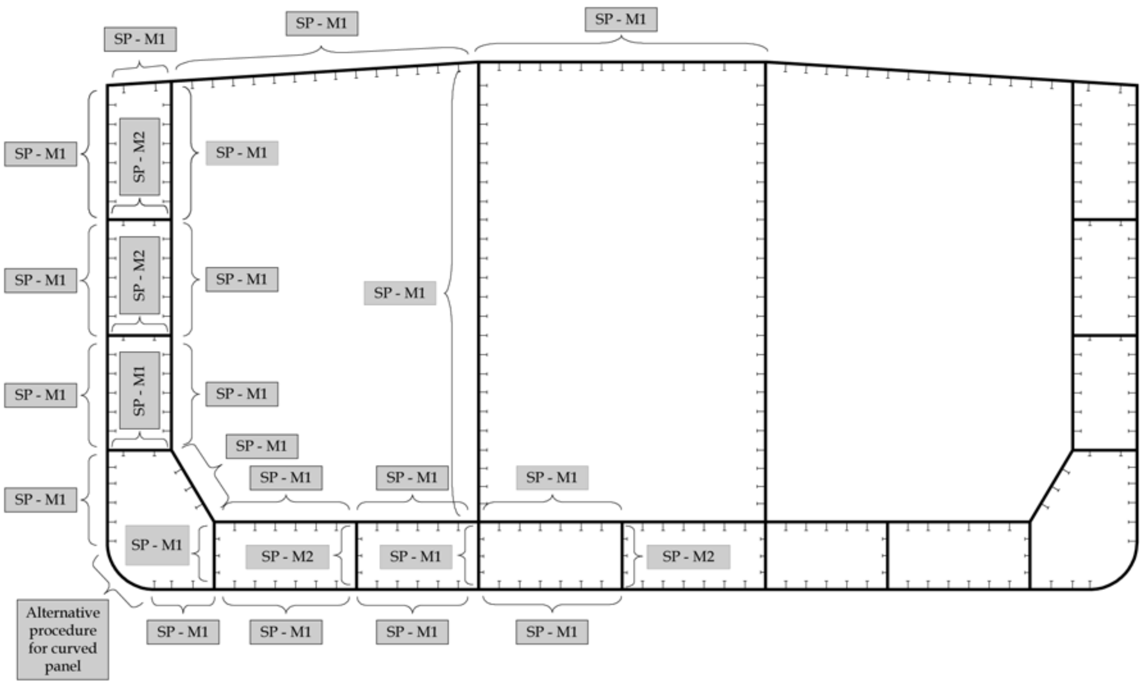
t_j net thickness of the j^{th} plate element making up the panel

Table D.5.1
Structural Elements for the Strength Assessment (FEM)

Structural elements	Idealisation	Assessment method[1]	Normal panel definition[2]
Longitudinal structure, see **Fig D.5.1**			
Longitudinally stiffened panels Shell envelope Deck Inner hull Hopper tank side Longitudinal bulkheads Centreline bulkheads	Stiffened panel	Method 1	Length: between web frames Width: between primary support members (PSM)[2]
Double bottom longitudinal girders in line with longitudinal bulkhead or connected to hopper tank side	Stiffened panel	Method 1	Length: between web frames Width: full web depth
Web of horizontal girders in double side tank connected to hopper tank side	Stiffened panel	Method 1	Length: between web frames Width: full web depth
Web of double bottom longitudinal girders not in line with longitudinal bulkhead or not connected to hopper tank side	Stiffened panel	Method 2	Length: between web frames Width: full web depth
Web of horizontal girders in double side tank not connected to hopper tank side	Stiffened panel	Method 2	Length: between web frames Width: full web depth
Web of single skin longitudinal girders	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM
Transverse structure, see **Fig D.5.2**			
Web of transverse deck girders including brackets	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM
Vertical web in double side tank	Stiffened panel	Method 2	Length: full web depth Width: between primary support members
All irregularly stiffened panels, e.g. Web panels in way of hopper tank and bilge	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM
Double bottom floors	Stiffened panel	Method 2	Length: full web depth Width: between primary support members
Vertical web frame including brackets	Un-stiffened panel	Method 2	Between vertical web stiffeners/face plate/PSM
Cross tie web plate	Un-stiffened panel	Method 2	Between vertical web stiffeners/face plate/PSM
Transverse oil-tight and watertight bulkheads, see **Fig D.5.3** and transverse wash bulkheads, see **Fig D.5.4**			
All regularly stiffened bulkhead panels	Stiffened panel	Method 1	Length: between primary support members Width: between primary support members
Regularly stiffened bulkhead with secondary buckling stiffeners perpendicular to regular stiffeners[3]	Stiffened panel	Method 1	Length: between primary support members Width: between primary support members
All irregularly stiffened bulkhead panels, e.g. web panels in way of hopper tank and bilge	Un-stiffened panel	Method 2	Between local stiffeners/face plate
Web plate of bulkhead stringers including brackets	Un-stiffened panel	Method 2	Between web stiffeners/face plate
Transverse corrugated bulkheads			
Upper/lower stool including stiffeners	Stiffened panel	Method 1	Length: between internal web diaphragms Width: length of stool side
Stool internal web diaphragm	Un-stiffened panel	Method 2	Between local stiffeners/face plate/PSM

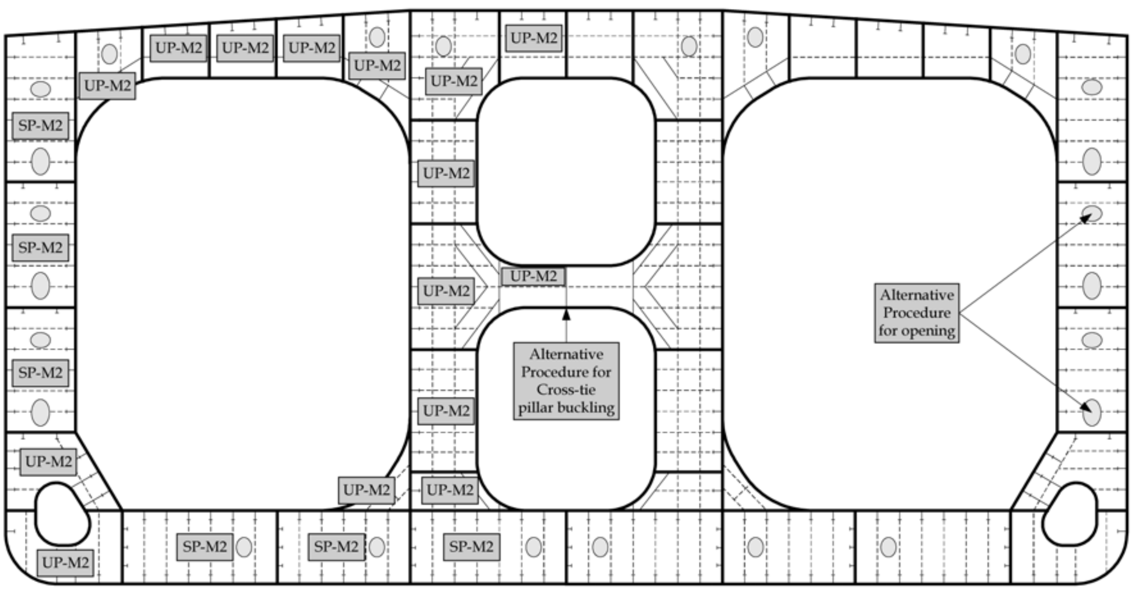
Note
1. The assessment method specifies which buckling strength assessment method is to be used, see **4.1**
2. See structural idealisation, **3.1.3.**
3. The secondary stiffener can be modelled as “sniped” or “continuous”. The stiffener is considered “sniped” unless rotational end supports are provided at both ends
   An area stiffened by irregular buckling stiffeners only should be assessed by considering each plate in the panel as Unstiffened panel using Method 2.

Fig D.5.1
Advanced Buckling Assessment for longitudinal strength



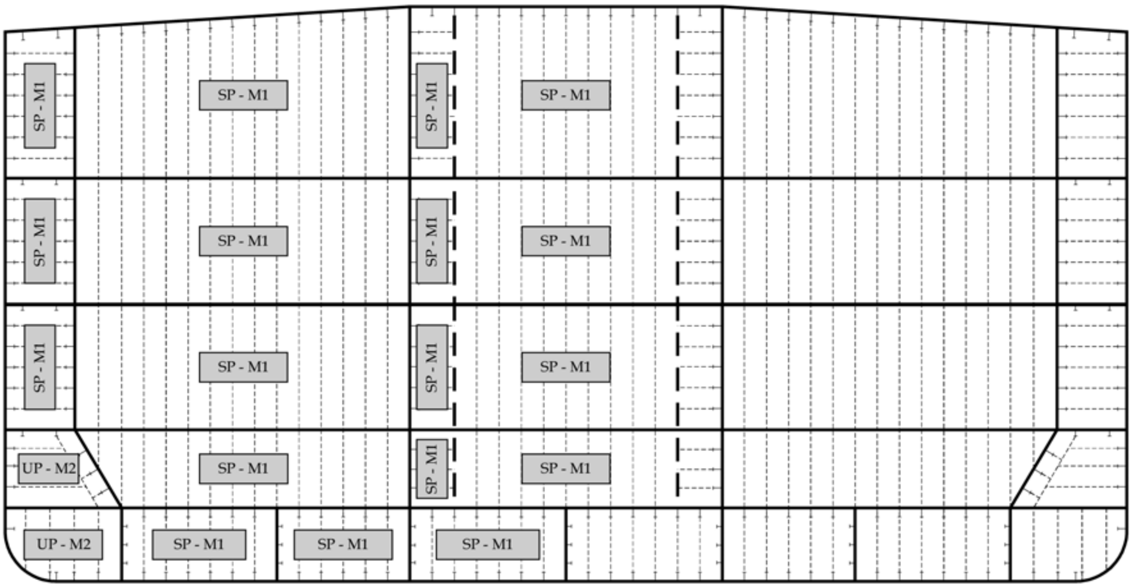
Notes
1. SP - M1 denotes stiffened panel - buckling strength assessed using Method 1
2. SP - M2 denotes stiffened panel - buckling strength assessed using Method 2

Fig D.5.2
Transverse Web Frames



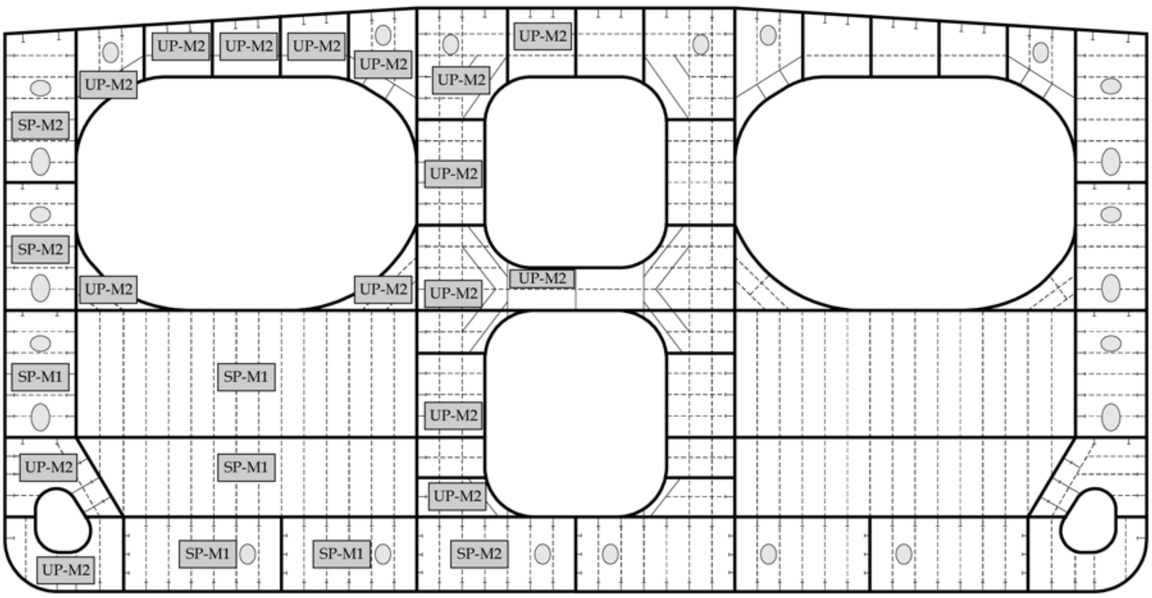
Notes
SP - M1 denotes Stiffened Panel - buckling strength assessed using Method 1
UP - M2 denotes Un-stiffened Panel - buckling strength assessed using Method 2
SP - M2 denotes Stiffened Panel - buckling strength assessed using Method 2

Fig D.5.3
Transverse Bulkhead



Notes
SP - M1 denotes Stiffened Panel - buckling strength assessed using Method 1.
UP - M2 denotes Un-stiffened Panel - buckling strength assessed using Method 2

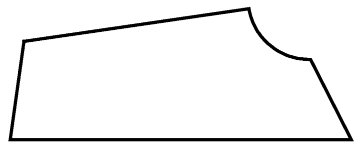
Fig D.5.4
Cross Tie



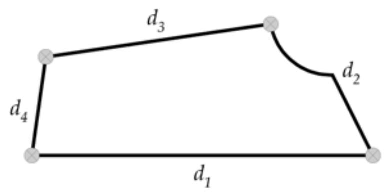
Notes
SP - M1 denotes Stiffened Panel - buckling strength assessed using Method 1
UP - M2 denotes Un-stiffened Panel - buckling strength assessed using Method 2
SP - M2 denotes Stiffened Panel - buckling strength assessed using Method 2

Fig D.5.5
Modelling of an Un-stiffened Panel with Irregular Geometry

(a) The four corners closest to a right angle, 90 degrees, in the bounding polygon for the plate are identified

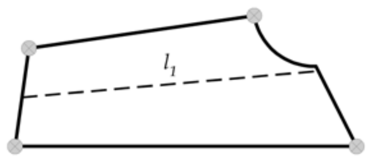


(b) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight line segments between the end points



(c) The pair of opposite edges with the smallest total length is identified, i.e. minimum of d_1+d_3 and d_2+d_4

(d) A line is joined between the middle points of the chosen opposite edges (i.e. a mid point is defined as the point at half the distance from one end). This line defines the longitudinal direction, x_1, for the capacity model. The length of the line defines the length of the capacity model, l_1 or d_2 measured from one end point.

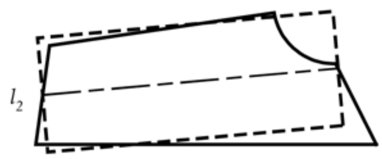


(e) The width of the model, l_2, is to be taken as:

$l_2 = A_{pl} / l_1$

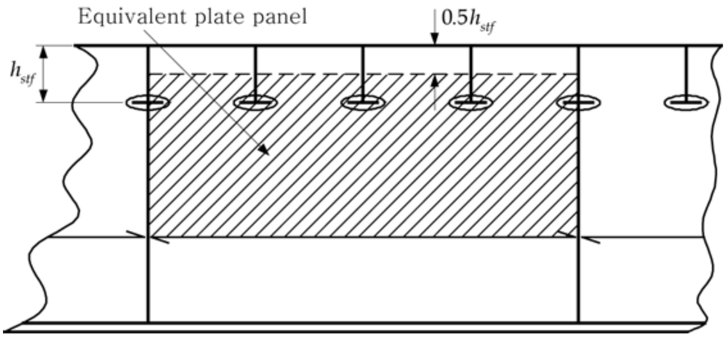
Where:

A_{pl} area of the plate



(f) The stresses from the FE analysis are to be resolved into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

Fig D.5.6
Capacity Model for Web Plate



Note
The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

5.3 Load Application

5.3.1 General

5.3.1.1 The ultimate capacity or buckling strength is to be assessed for the effects of the combined bi-axial and shear membrane stresses acting on the structural panel.

5.3.1.2 The axial compressive and shear stress distribution is to be taken from the FE analysis and applied to the buckling model. The stresses from the FE analysis are not to be adjusted for the required change in thickness for buckling, i.e. -0.5 t_{corr} used in the FE analysis and 1.0 t_{corr} used for the buckling assessment.

5.3.1.3 The lateral pressure applied to the FE analysis is also to be applied to the buckling assessment.

5.3.1.4 The stresses may be applied by means of enforced displacements obtained from the finite element analysis to the panel edges or by loads applied to the panel edges.

5.3.1.5 Where the advanced buckling method is unable to correctly model changes in axial or shear stress across a panel, then the stresses and pressures may be averaged as defined in **5.3.2** and **5.3.3.**

5.3.2 Average membrane stresses

5.3.2.1 When the plate panel consists of a number of finite plate elements, the average membrane stress is to be calculated using a weighted average approach, as given by:

$$\sigma_{xm} = \frac{\sum_1^n A_i \sigma_{xmi}}{\sum_1^n A_i} \quad \text{N/mm}^2$$

$$\sigma_{ym} = \frac{\sum_1^n A_i \sigma_{ymi}}{\sum_1^n A_i} \quad \text{N/mm}^2$$

$$\tau_{xym} = \frac{\sum_1^n A_i \tau_{xymi}}{\sum_1^n A_i} \quad \text{N/mm}^2$$

Where:

σ_{xmi} membrane stress in x-direction at the centroid of the i^{th} plate element of the panel, in N/mm^2

σ_{ymi} membrane stress in y-direction at the centroid of the i^{th} plate element of the panel, in N/mm^2

τ_{xymi} membrane shear stress at the centroid of the i^{th} plate element of the panel, in N/mm^2

A_i area of the $i$thplateelementmakingupthepanel, in mm^2

n number of elements in the panel

When σ_{xmi} or σ_{ymi} are in tension, then the respective value is to be taken as zero.

5.3.3 Average lateral pressure

5.3.3.1 Where the plate panel consists of a number of finite elements, the average pressure, P_{avr}, is to be calculated using a weighted average approach, as given by:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i} \quad kN/m^2$$

Where:

P_i pressure acting on the i^{th} plate element making up the panel, in kN/m^2

A_i area of the i^{th} plate element making up the panel, in mm^2

n number of elements in the panel

5.4 Limitations of the Advanced Buckling Assessment Method

5.4.1 General

5.4.1.1 In the absence of a suitable advanced buckling method, then the following structural elements can be assessed according to **Table D.5.2.**

Table D.5.2
Requirements for Structures Where There is no Advanced Buckling Method Available

Structural elements	Buckling mode	Rule reference
bilge plate	transverse elastic buckling	**Sec 8/2.2.3**
primary support members	global (overall) buckling and torsional buckling	**Sec 10/2.3**
web plate of primary support members in way of openings	buckling of web plate	**Sec 10/3.4**
cross ties	global (overall) buckling	**Sec 10/3.5**
corrugated bulkheads	flange panel buckling	**Sec 10/3.2**
	global (overall) buckling	**Sec 10/3.5**

6 Ultimate Hull Girder Strength Assessment

6.1 General

6.1.1 Scope

6.1.1.1 This procedure is required for the assessment of the ultimate hull girder strength assessment as part of the Design Verification procedure, see **Sec 9/1.**

6.1.1.2 All structural elements of the strength deck are to be assessed individually.

6.2 Load Application

6.2.1 General

6.2.1.1 The uni-axial compressive stress used for the ultimate capacity assessment of longitudinally stiffened deck panels is to be calculated at the stiffener/plate intersection point.

6.2.1.2 The hull girder stresses are based on the section modulus properties using a deduction of half the corrosion addition, i.e. -0.5 t_{corr}, and owner's extra from the proposed thickness.

6.2.1.3 Lateral pressure is not to be included in the buckling assessment for hull girder ultimate strength.

6.3 Structural Modelling and Buckling Assessment

6.3.1 General

6.3.1.1 The longitudinally effective structure of the strength deck is to be modelled as stiffened panels using Method 1 to derive the ultimate capacity.

6.3.1.2 Each deck stiffener with attached plate is to be represented as a stiffened panel with the transverse extent being between two adjacent primary support members.

6.3.1.3 The buckling capacity models are to be based on the net thickness obtained by deducting half the corrosion addition, i.e. -0.5 t_{corr}, and any owner's extras from the proposed thickness. This thickness reduction applies to the plating and the stiffener web and face plate.

6.3.1.4 In general, the assessment method is to correctly model changes in plate thickness, stiffener size and spacing. However where the advanced buckling method is unable to correctly model these changes, the calculations are to be performed separately for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel. If the plate thickness, stiffener properties and stiffener spacing varies within the stiffened panel, the calculations are to be performed for all configurations of the panel.

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